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LONG PAPER

Affording inclusive dyslexia-friendly online text reading

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Abstract To date, guidelines for designing inclusive dyslexia-friendly online learning environments, which take into consideration both learners with and without dyslexia, are still scarce. As web text is one of the extensively used elements in online learning, this study aims to derive practical guidelines on this aspect by exploring the experience of learners with dyslexia and learners without dyslexia when using different online reading affordances. The study employed a within-subjects qualitative study and key patterns that emerged from the data collected via observations and interviews were interpreted based on two important aspects of learning experience, which were perceived learning and engagement. The study reveals that (1) the direct application of Printed Text on the web should be carefully considered, (2) existing web accessibility guidelines (limit to guidelines examined in this study) are appropriate and (3) the use of a Screen Reader for online reading should not be made compulsory and be available as an option instead. The comparison between the experience of learners with and without dyslexia in this study has yielded insights into affordances that are perceived positively by both groups of learners. As learners with dyslexia form a significant minority of the online learning population, the inclusive dyslexia-friendly guidelines derived from this study would better inform the future implementation of online reading affordances that acknowledge differences and similarities between online learners.

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1 Introduction

Dyslexia is a language-based learning disability in which individuals experience difficulty in performing language-related tasks such as word recognition or reading, writing, spelling, reading comprehension and sometimes speaking [82]. It is estimated that as many as 15–20% of the school population in the USA exhibit some symptoms of dyslexia [87].

The pervasive use of online learning at all levels of education nowadays calls for the crucial need to create inclusive online learning environments. Inclusive learning acknowledges differences between learners and aims to nurture an atmosphere where all learners actively and comfortably engage in their learning. As persons with dyslexia form a significant minority in the online population, their online learning needs and expectations should not be ignored. McCarthy and Swierenga [55], who have carried out a research review on dyslexia and web accessibility, report a number of web accessibility guidelines for dyslexia and other disabled users. However, many of these guidelines are meant to accommodate all visual disabilities and not specifically meant to meet the needs of persons with dyslexia [23, 55]. On the other hand, guidelines by the International Organization for Standardization [44], Nielsen [60] and the US Department of Health and Human Services [90] are among the many available web design guidelines for typical users. Little is known, however, of the effort to create inclusive dyslexia-friendly web design guidelines, particularly for online learning purposes.

As web text is one of the most extensively used elements in online learning, this study attempts to explore the experience of both learners with dyslexia and learners without dyslexia when using different online reading affordances. Previous studies on people without dyslexia have shown the effects of different online text layout on reading speed [18, 29], comprehension [18, 30], satisfaction as well as ease of reading [17–20]. Other studies on persons with dyslexia have shown the effects of such layout on readability [74] and comprehension [74, 75]. Most studies examined the effects of text layout on people with and without dyslexia separately.

This study, thus took the initiative to explore the learning experiences of both learners with and without dyslexia in a single study to derive practical guidelines for inclusive dyslexia-friendly online text reading. As the Screen Reader is acknowledged as an assistive learning technology for persons with dyslexia [56], this study also examined the experience of using this reader among learners with dyslexia and compared it with the experience of learners without dyslexia.

2 Method

The present study used a within-subjects qualitative approach. Twelve secondary school students with dyslexia (7 female, 5 male) as well as 12 typical secondary school students without dyslexia (8 female, 4 male), with ages ranging from 14 to 18 years old, were involved. The researcher identified all students with dyslexia via the Education Department of Sarawak, Malaysia, and all these students were diagnosed by medical doctors.

The study employed a qualitative approach to discover these students' learning experience for each online reading affordance. Qualitative approach via observations and structured individual interviews allows a more in-depth examination into this experience. A structured guide with questions was applied to address the different online reading affordances in a consistent way. The researcher served as the interactant with the participants during the evaluation sessions. In addition, a research assistant was assigned to jot down relevant observations during each participant's interaction with the three reading affordances as well as during individual interview sessions.

2.1 Online reading affordances

The study involved the use of three types of online reading affordances, known as Printed Text mode, Standard Guidelines mode and Screen Reader mode. Each mode consisted of an online reading passage with contents related to GIMP, an open source image editing tool. Although the contents for each mode were different, they were all on a similar topic, i.e., on how to use different GIMP functions, and of similar level of difficulty. In addition, the length of the passage for each mode was almost equivalent.

Table 1 shows the tasks given to the participants for each mode. The Printed Text mode was developed based on the layout and typefaces of a conventional printed book, the Standard Guidelines mode adopted some dyslexia-friendly text guidelines as suggested by The British Dyslexia Association [16], and the Screen Reader mode was similar to the Standard Guidelines mode but with the addition of a Screen Reader. Figures 1, 2 and 3 show the excerpts of the three modes.

2.2 Instruments

The study examined the participants' perceived learning and engagement with the three affordances. To ensure the validity of these two constructs, related literature was reviewed to derive questions for the interview guide which was used to elicit data in the study.

Table 1 Tasks for Printed Text, Standard Guidelines and Screen Reader modes

Printed Text	Read the passage with black text on white background, in single column paragraph form, justified alignment, single spacing, serif font type and font size (12–14 point)
Standard Guidelines	Read the passage with black text on beige background, in bulleted points, left justified, 1.5 line spacing, sans serif font type, font size (16–18 point)
Screen Reader	Read the passage with black text on beige background, in bulleted points, left justified, 1.5 line spacing, sans serif font type, font size (16–18 point) using a Screen Reader (Natural Reader)

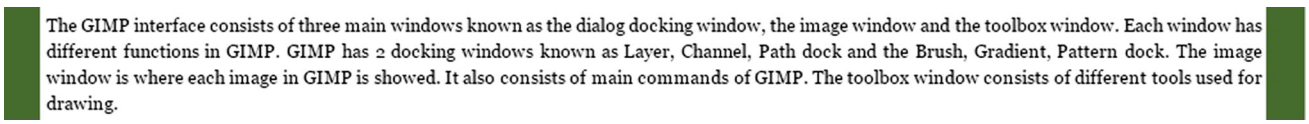
The GIMP interface consists of three main windows known as the dialog docking window, the image window and the toolbox window. Each window has different functions in GIMP. GIMP has 2 docking windows known as Layer, Channel, Path dock and the Brush, Gradient, Pattern dock. The image window is where each image in GIMP is showed. It also consists of main commands of GIMP. The toolbox window consists of different tools used for drawing.

Fig. 1 Excerpt of the Printed Text mode

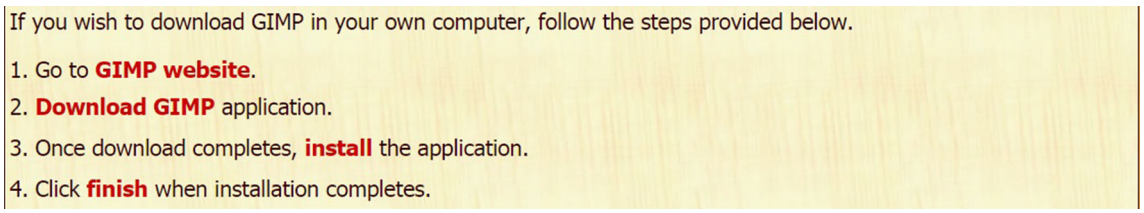

Fig. 2 Excerpt of the Standard Guidelines mode

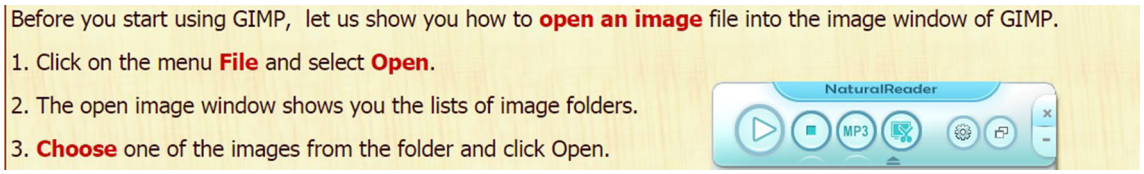

Fig. 3 Excerpt of the Screen Reader mode

Table 2 Perceived learning questions in the interview guide

Did you find it easy to read the passage?
Did you find it easy to remember the content of the passage?
What knowledge have you gained?
Did you think the passage broadened your knowledge?
Did you think the quality of your learning had improved?
Did you think the passage was useful to your learning?

Table 3 Engagement questions in the interview guide

Cognitive engagement (CE)
Did you pay much attention to the passage?
Did you check whether you understand the passage?
Did you have the tendency to stop half way while reading the passage?
Did you put your best effort to read through the passage to gain a better understanding?
Affective engagement (AE)
Did you think learning was fun because you gained more knowledge through the passage?
Did you enjoy reading the passage?
Did you think reading the passage is a waste of time?
Behavioral engagement (BE)
Would you recommend the use of [each reading affordance] to your friend for online reading?
Are you looking forward to using [each reading affordance] for reading a passage in your future studies?

Perceived learning or self-reports of learning is the amount of knowledge that students think they are gaining [93]. Perceived learning is considered as a valid measurement of learning as opposed to learning measured by grades or test results [62, 93]. Learning is perceived to occur when learning difficulties are compensated or abilities are harnessed [48, 68], when new knowledge is built [12, 27, 49] and when there is positive learning experience [13, 94]. Based on this literature, related questions on perceived learning were derived (as shown in Table 2).

Engagement reflects a person's active involvement in a task or activity [70] and specifically refers to attitudes, interest and self-efficacy in a particular learning situation [69]. According to Fredericks, Blumenfeld and Paris [36] and Jimerson et al. [46], there are three types of engagement: cognitive (investment in learning, self-regulation) affective (positive feelings, interest, belonging, valuing) and behavioral (positive conduct, participation). Cognitive engagement (CE) is defined as a psychological state in which students put in ample effort to understand a subject matter and show persistence in studying over a long period of time [78]. When students are willing to pay attention to their learning content, double check their work, perform their best in the tasks given, they are cognitively engaged with their work [76]. Affective engagement (AE) describes the degree to which students internalize class information and experiences in making them relevant to their lives [43]. It emphasizes the feeling of connection to their learning by having a sense of belonging in the learning environment [3, 36]. Behavioral engagement (BE) is defined by 41 as a particular motivational process that underpins a particular set of behaviors. The participation and commitment put forth by a student can be seen when the student wishes to be actively involved in the learning environment [76]. Based on the above, related questions on engagement were derived (as shown in Table 3).

2.3 Procedure

Each participant was involved in three separate evaluation sessions. All sessions were video-recorded. In the first evaluation, the participant was required to read a passage presented in the Printed Text mode. In the second evaluation, the participant was required to read another passage

presented in the Standard Guidelines mode and, subsequently, another passage in the Screen Reader mode during the third evaluation session. Thus, this study did not employ counterbalanced design to control for order effects that may elicit false responses.

An interview based on the questions in Tables 2 and 3 was conducted after each participant had completed the three reading tasks. During the interview session, the three modes were continuously shown to the participant to aid them in recalling their reading experience when answering the interview questions. The researchers also took note of all pertinent observations.

3 Findings

The following subsections explain the findings based on the analysis of the data elicited via interviews, observations and cross-checked with video recordings for both perceived learning and engagement. The present study employed the iterative qualitative data analysis model as proposed by Gay and Airasian [37]. This process employs the following steps: (1) familiarize with the data and identify potential themes, (2) provide detailed descriptions, (3) code and categorize data into themes and (4) interpret and synthesize data into written conclusions.

The researcher transcribed the recorded interviews and cross-checked the transcript with video recordings in order to add pertinent nonverbal information. The data for each mode were analyzed based on the two learning experience aspects, i.e., perceived learning and engagement. For each reading mode, significant statements on each learning experience aspect were coded with a label and corresponding statements were coded with the same label. These labels were categorized into the two aspects of learning experience. Then, the researcher chose an appropriate theme for the labels for each aspect or category to summarize statements within a mode. Peer examination data were used to increase the consistency of the findings [6]. Three researchers independently coded the set of data and the codes were later merged after reaching agreement among the researchers. This organization of data into different modes and learning experience aspects has allowed a more effective comparison of the three online reading affordances.

3.1 Perceived learning

Table 4 displays the responses of participants with dyslexia toward the various reading modes in terms of their perceived learning. The data are divided into two main categories, unfavorable responses and favorable responses. It was rather apparent that the responses were mostly unfavorable for the Printed Text mode. As for the Standard Guidelines mode, it was also quite obvious to note that the participants had provided more positive responses. A mixture of unfavorable and favorable responses was observed for the Screen Reader mode with more participants providing favorable rather than unfavorable responses. Table 5 that shows the responses of participants without dyslexia toward the various reading modes reveals a similar pattern.

The following summarizes the main findings of the participants' perceived learning.

3.1.1 Printed Text mode: low learning quality

The findings show that all participants with dyslexia perceived the amount of knowledge that they managed to gain via the Printed Text mode was little and of lower quality and least useful as compared to the two other modes. The experience with this mode did not contribute positively to their learning experience as they faced difficulty to comprehend and remember the passage. Seven participants with dyslexia (D1, D2, D4, D5, D7, D8, D11) mentioned how the long sentences in a paragraph, overcrowding of

Table 4 Perceived learning of participants with dyslexia on the reading modes

Mode	Perceived learning							
	Unfavorable responses (%)				Favorable responses (%)			
	Low learning quality	Little knowledge gained	Difficult	Not useful	High learning quality	Much knowledge gained	Easy	Highly useful
Printed Text	**9 (75%)**	**9 (75%)**	11 (91.7%)	**9 (75%)**	–	–	–	–
Standard Guidelines	–	–	–	–	**8 (66.7%)**	**8 (66.7%)**	**10 (83.4%)**	**8 (66.7%)**
Screen Reader	2 (16.7%)	–	–	4 (33.3%)	**4 (33.3%)**	**4 (33.3%)**	**6 (50.0%)**	**7 (58.3%)**

Bold values indicates ≥50% responses

Table 5 Perceived learning of participants without dyslexia on the reading modes

Mode	Perceived learning							
	Unfavorable responses (%)				Favorable responses (%)			
	Low learning quality	Little knowledge gained	Difficult	Not useful	High learning quality	Much knowledge gained	Easy	Highly useful
Printed Text	**9 (75%)**	**9 (75%)**	**1 (83.30%)**	**9 (75%)**	–	–	–	–
Standard Guidelines	–	–	–	–	**7 (58.3%)**	**8 (66.7%)**	**11 (91.6%)**	**8 (66.7%)**
Screen Reader	3 (25%)	–	–	2 (16.7%)	**8 (66.7%)**	**8 (66.7%)**	**10 (83.3%)**	**8 (66.7%)**

Bold values indicates ≥50% responses

words, high contrast of black font on white background caused them much discomfort and difficulties in reading and remembering the passage. Three participants (D2, D7, D12) commented on the small font size and two participants (D4, D11) specifically mentioned that they were unable to identify the main points of the passage which caused them to have poor understanding of the passage at the end of the reading task.

Participants without dyslexia did not regard their perceived amount of knowledge that they gained from the Printed Text mode as little although they did perceive that the knowledge gained from this mode was the least compared to the other two modes. In addition, compared to participants with dyslexia, there were fewer participants without dyslexia who reported difficulties in remembering the content of the passage. Five of them (T1, T2, T3, T7, T12) reported such difficulties as due to lengthy sentences and small font size.

Most participants with dyslexia did not think the font size was inappropriate as fonts of 12–14 points were still legible. This is in line with the font size recommendation by Al-Wabil et al. [1] and British Dyslexia Association [16]. However, three participants with dyslexia (D2, D7, D12) expressed their problems with the font size. Unexpectedly, more participants without dyslexia, five of them, thought the font was rather small. Although such font size did not cause serious problems such as causing reading mistakes or creating pronunciation problem among these participants, they reported reading discomfort with such font size.

3.1.2 Standard Guidelines mode: high learning quality

Findings from the analysis show that all participants with and without dyslexia responded positively to this mode. They reported their ability to understand the passage and remember the content more easily as compared to the Printed Text mode. Six participants with dyslexia (D2, D5, D6, D10, D11, D12) and seven participants without dyslexia (T1, T2, T6, T7, T9, T11, T12) attributed their high learning quality to the clear text presentation which encompassed enlarged font size, bulleted points and highlighted keywords, increased line spacing as well as better choice of colors.

According to Dixon [25], Kurniawan and Conroy [50] and McCarthy and Swierenga [55], the application of web accessibility practices is beneficial to almost everyone as the dyslexic-accessible practices help to alleviate difficulties faced by other Internet users including those of other disabilities. It is known that one of the most applicable dyslexic-accessible practices that have benefited most Internet users is the use of larger font size when designing web sites [11].

As a matter of fact, a handful of the participants mentioned that although the font size used in the Printed Text mode was somewhat acceptable for short readings, the larger text size used in the Standard Guidelines mode made reading and understanding the content much easier. For example, participant T9 commented, "If it was a short passage, still okay but for long passages, better to read with bigger words." As for the participants with dyslexia, most of them agreed that the large text size used in the Standard Guidelines mode has improved their reading as well as understanding tremendously. Some of the related comments from the participants include, "The big font size makes it easy to read and understand the passage (D7); The bigger font size and colors made it easy for me to see what I am reading so I can learn better (D12); This passage was more readable than the first one. At least the fonts are bigger which really helped in making reading easier (D1)." These comments echo the findings of Rello et al. [74] who, based on their empirical study on dyslexic-friendly Wikipedia, have recommended the use of 18-point font size when designing web text for readers with dyslexia. In another study on the accessibility of web text for those with dyslexia, Rello et al. [73] found that even bigger font size

(22–26 points) was preferred by users with dyslexia. Despite the difference in the suggested size, it clearly reinforces the role of bigger font size in increasing text readability.

Many dyslexia-friendly practices have mentioned the benefits of employing bulleted points and also in bolding or highlighting key words when presenting text regardless of websites or printed materials [15, 91, 95]. The Dyslexia Association of Ireland [28] suggests that using bulleted points or numbers and keeping sentences short and to the point are practices that can help readers with dyslexia in text navigation and comprehension. The participants from both groups expressed that the highlighted words presented in bulleted points was most helpful to their understanding as they were able to identify the main points of the passage easily. Some of the related comments from the participants include, "I liked the bulleted points. It has helped me to understand the main points of the passage" (D11); "I think the shorter sentences made it easy to identify the main point of the passage" (D9); "I can see the main points easily. It is not so tiring to read compared to the first method" (T6); "Not only the color helped me to identify the main points of the passage, but it also helped me to remember the things I have read" (T9).

The use of bulleted points seems to aid the participants' reading. This is in line with one of Sloan's [81] accessibility guidelines, which recommends the breaking of text into lists or short paragraphs. A few of the participants reported that they paused in between reading to check their understanding. The use of bulleted points most probably had guided the read-pause pattern of these participants. A participant commented "I read and stop." Such pausing is most probably guided by the way the information was presented and assisted in understanding instead of the paragraph form presented in the Printed Text mode. This further strengthens the benefit of using bulleted points in aiding comprehension. As pointed out by Freire et al. [37], the third most frequent problem faced by web users with dyslexia is their difficulty to scan a page for specific items due to the lack of structural or visual aids that would highlight these items. Moreover, the findings show that most of the participants without dyslexia found the bulleted points beneficial to both their reading and learning process. Bevan [9] and Nielsen [60] were among others who recommend the use of bulleted points to improve web text scan ability and support a more interactive learning experience for web users. This is supported by Atkinson and Mayer [4] who point out that a screen full of text overloads the mind's visual channel. In reading with the Standard Guidelines mode, both bulleted points and highlighted keywords would serve as such aids to avoid overloading the mind's visual channel. This is also in line with recommendations by Beacham [7] who highlights the need to communicate key points in his proposed guidelines for developing dyslexia-friendly learning materials as well as Nielsen [60] who recommends similar web text guideline for typical users.

Participants were also able to pay attention to the passage when reading with the bulleted points. An eye-tracking study by Schneps et al. [80] demonstrated that short lines, as with the use of bulleted points in oppose to lengthy paragraph form, facilitate reading for those with dyslexia by guiding their visual attention to the uncrowded span. Schneps et al. [80] found that those with dyslexia tend to read faster by up to 27% when reading in short text lines of about 16–18 characters per line, compared to 60–65 characters per line as recommended in the traditional print book typography. It was further emphasized that these lines should be ragged-right as justified text would likely nullify the beneficial effects and even decrease reading speed because of the large, variable and unpredictable word spaces that are resulted by the justification of short lines.

McCarthy and Swierenga [55] stated that poor colored text is one of the main problems faced by persons with dyslexia when reading from the web. Previous studies have showed that specific text and background colors could be beneficial for people with dyslexia when reading on a digital device's screen [39, 73]. Furthermore, Bradford [14], British Dyslexia Association [15] and Pedley [64] discovered that when readers with dyslexia were given the option to customize text color, lower brightness and color contrast between text and background were commonly selected and preferred compared to other average readers.

This is well in line with the responses given by the participants with dyslexia as they expressed that it was more comfortable to read the passage in the Standard Guidelines mode than the Printed Text mode. For example, participants D10 commented, "It is easier to read with this color. It is not so glaring anymore when I look at the screen." It has been found that generally people with dyslexia were able to read faster when color pairs are of lower contrast; for example, black text on yellow and dark blue on light blue were among the most preferred color pairs [33, 71]. The study by Gregor and Newell [39] shows that subjects with dyslexia generally preferred low color contrast between text and background such as brown on muddy green. Although a number of studies revealed different preferences of color combination between text and background colors (i.e., black on yellow, dark blue on light blue, brown on muddy green) among those with dyslexia, it is noticeable that these combinations are of lower color contrast which is able to alleviate reading difficulties and discomfort among them.

Four participants without dyslexia who reported this Standard Guidelines mode as the most useful attributed

their preference to the text layout used in this mode as well as the unavailability of narration which was regarded as a distraction. When examining the effects of different media combinations on learning by persons with dyslexia, Beacham and Alty [8] reported the highest increase in learning when text only presentation was used. This is in line with the perception of improved learning quality by all participants for this Standard Guidelines mode, as only text is presented in this mode. According to Beacham and Alty [8], the use of a single text modality reduces the possibility of split attention [86] and consequently reduces the switching of code modalities and cognitive load. The unavailability of redundant information also allows learners to keep pace of their reading.

3.1.3 Screen Reader mode: mixed excellent and moderate learning quality

Four participants with dyslexia (D2, D5, D8, D9) and eight participants without dyslexia (T1, T2, T3, T4, T5, T7, T8, T10) showed very strong preference toward the Screen Reader mode although they reported the Standard Guidelines mode to be acceptable to them. These participants believed that the availability of a Screen Reader helped greatly in improving their reading, comprehension, retention and pronunciation. They also found this reading affordance to be most useful to their learning. Thus, these participants were categorized as having excellent learning quality with this mode.

Participants (D2, D5, D8, D9, T2, T3, T5, T7, T8, T10) agreed that the Screen Reader helped them in understanding the passage content better. In addition, five participants (T1, T3, T4, T8, T10) mentioned that they were able to rely more on their listening skills when the Screen Reader read the passage aloud, which helped them in both reading and comprehension. Participants T1 and T4 even commented that the Screen Reader acted like a guide in their reading which they felt comfortable and enjoyable.

Three participants with dyslexia (D1, D4, D5) perceived their learning to have improved only when they were given the control of the Screen Reader. These participants were categorized as having moderate learning quality with this mode. Participants without dyslexia, on the other hand, did not report on the needs to adjust the reading speed of the reader. The default speed was acceptable to all of them.

The remaining participants who perceived best learning using the Standard Guidelines mode were also categorized as having moderate learning quality because they all preferred the Screen Reader mode to the Printed Text mode. The reasons for their preference toward the Standard Guidelines mode include the following: (1) the audio produced by the Screen Reader was distracting and posed challenge for simultaneous reading and listening (D7, D10, D12, T6, T9, T11, T12), (2) the default screen reading speed used in this study was too fast (D7, D10) and (3) personal preference toward the Standard Guidelines mode although the Screen Reader mode was also acceptable (D1, D3, D4, D6, D7, D10, D11, D12, T6, T9, T11, T12).

Text-to-speech technology or more commonly known a Screen Reader holds promise as a compensatory tool for adolescents with learning disabilities in accessing grade-level expository text [57]. Since its introduction to the world of technology, the Screen Reader has enabled digital text to be read aloud by computer-generated speech that resembles the natural voice while highlighting words as words are spoken [2, 5, 52]. It also allows users to learn the correct pronunciation of multisyllabic words which is a common struggle for people with dyslexia [24].

Despite the many benefits that a Screen Reader offers, seven participants found it difficult to cope with reading using it. Participants faced difficulty to manage listening and reading the passage simultaneously, with many describing the Screen Reader as "distracting" and "disturbing." For example, participant D10 reported that "The Screen Reader is quite distracting in my opinion. It makes it hard for me to follow and to focus when it is reading out loud." Apparently, a few of the participants without dyslexia also thought likewise regarding the Screen Reader. For example participant T6 commented: "I did feel a little confused with the Screen Reader as I find the audio interrupting my thoughts when I try to understand the passage." The distraction faced by these participants had caused them to have a poor understanding toward the passage content that hindered them from positively improving their learning and engagement level. This is consistent with the findings from Elkin et al. [32] which report that some of the 14% of their study participants who showed lower comprehension scores when using a computer reader had difficulty attending both audio and visual presentations simultaneously. In addition, Sorrell et al. [83] also discovered that readers with difficulties integrating auditory and visual information are those who read faster than conversational speech (i.e., 176 words per minute [wpm]) and also those who had reasonably good comprehension degraded their reading performance when using a computerized reading program, Kurzweil 3000. The participants without dyslexia who found the Screen Reader as "distracting" may be fast readers with good comprehension, which is why they were perceived as not able to improve their reading performance when the Screen Reader was provided.

The distraction caused by the Screen Reader can be associated with Dual Coding Theory [63] and Cognitive Load Theory [85]. Generally, Dual Coding Theory posits that there are two independent information processing channels; the verbal channel processes information such as

Table 6 Comparison of perceived learning between modes

	Printed Text		Standard Guidelines		Screen Reader	
	Dyslexia	Without dyslexia	Dyslexia	Without dyslexia	Dyslexia	Without dyslexia
Knowledge	Little	Somewhat	Much	Much	A great deal for some; somewhat for others	A great deal for many; somewhat for others
Ease of reading and knowledge retention	Difficult	Somewhat	Easy	Easy	Very easy for some; difficult for others	Very easy for many; difficult for others
Usefulness	Little	Little	Much	Much	A great deal for some; somewhat for others	A great deal for many; somewhat for others

Table 7 Engagement of participants with dyslexia toward the reading modes

Mode	Engagement								
	Unfavorable responses (%)			Favorable responses (%)					
	Low CE	Low AE	Poor BE	Moderate/high CE		Moderate/high AE		Moderate/high BE	
Printed Text	**10** (**83.3**%)	**9** (**75**%)	–	–	–	–	–	**10** (**83.3**%)	–
Standard Guidelines	–	–	–	–	**8** (**66.7**%)	**6** (**50.0**%)	5 (41.7%)	4 (33.3%)	4 (33.3%)
Screen Reader	2 (16.7%)	2 (16.7%)	–	4 (33.3%)	8 (66.7%)	2 (16.7%)	**8** (**66.7**%)	–	**8** (**66.7**%)

Bold values indicates ≥50% responses

text and audio, and the visual channel processes information such as image and animations. The use of the verbal channel to process both text reading and listening to the Screen Reader may have overloaded this particular channel. The participants may also experience split attention between these two modalities [86]. In addition, the impairment in phonological processing [47, 51, 67] and deficit in visuo-spatial attention [92] as well as weaknesses in their short-term memory [51, 54, 65, 89] limit the number of verbal items that persons with dyslexia can retain in memory. Thus, this may explain the distraction experienced by some of the participants with dyslexia when using the Screen Reader.

Besides the issue with distraction, some of the participants who did not favor the Screen Reader mode expressed that they are not auditory learners and that they preferred to read by themselves. By practicing self-reading, the participants mentioned that they were able to understand and remember the passage content more clearly. This is in line with some of the recommendations proposed by Gupta [42] who stated that students should be able to develop skills to learn faster and remember better through self-reading. Some of the comments made by the participants include: "I would prefer to read by myself. It gives me some time to understand and remember what am I reading" (D6) "…I didn't progress much in my learning. I felt that after listening to the Screen Reader, I forgot almost everything I just heard" (T9), "…I did find the Screen Reader a little distracting. Maybe I am used to reading by myself and I am able to understand better if I read it quietly" (T12)." This echoes the findings of Elkin et al. [32] as some participants of their study felt that the computerized reading system was reading for them and reducing their opportunity to improve their independent reading skills. Others also commented that it was unnecessary, since they felt that they could read well by themselves [32].

Table 6 summarizes how participants perceived their learning using each of these modes.

3.2 Engagement

Table 7 summarizes the responses of participants with dyslexia toward the various reading modes in terms of their engagement. The data are divided into two main categories, namely unfavorable responses and favorable responses. It was rather apparent that the responses were mostly unfavorable for the Printed Text mode. As for the Standard Guidelines mode, it was also quite obvious to note that the participants had provided more positive responses. A mixture of unfavorable and favorable responses was observed for the Screen Reader mode with more participants providing favorable than unfavorable responses. The summary of the responses for participants without dyslexia toward the various reading modes (as shown in Table 8) seems to reveal a similar pattern.

The following summarizes the main findings of the participants' engagement with the three reading modes.

Table 8 Engagement of participants without dyslexia toward the reading modes

Mode	Engagement								
	Unfavorable responses (%)			Favorable responses (%)					
	Low CE	Low AE	Poor BE	Moderate/high CE		Moderate/high AE		Moderate/high BE	
Printed Text	**10** (**83.3**%)	**10** (**83.3**%)	–	–	–	–	–	**9** (**75.0** %)	–
Standard Guidelines	–	–	–		**12** (**100.0**%)	–	**12** (**100.0**%)		**9** (**75.0**%)
Screen Reader	2 (16.7%)	2 (16.7%)	–	4 (33.3%)	**8** (**66.7**%)	2 (16.7%)	**8** (**66.7**%)		**9** (**75.0**%)

Bold values indicates ≥50% responses

3.2.1 Printed Text mode: moderate BE

Ten participants with dyslexia (D1, D2, D3, D4, D5, D6, D7, D8, D9, D11) and nine participants without dyslexia (T1, T2, T3, T5, T6, T7, T9, T10, T11) were classified as having moderate behavioral engagement while reading with this mode. They were not able to fully commit in their reading mainly due to the poor text presentation and were also not interested in introducing this Printed Text mode to their friends due to their reading discomfort experience. Nevertheless, the observations made during the study revealed that all participants, both those with and without dyslexia, read the passage attentively with some of them read out the passage softly. All of them self-reported that they put their best effort to understand the passage.

3.2.2 Printed Text mode: low CE

Ten participants with dyslexia (D1, D2, D3, D4, D5, D6, D7, D9, D10, D11) and ten participants without dyslexia (T1, T3, T4, T5, T6, T7, T8, T9, T11, T12) were classified as having low cognitive engagement when reading the passage in the Printed Text mode. Based on their comments, they were found to be unable to pay attention, encountered hiccups in their reading as well as read without understanding when attempting the reading task in this mode. Overcrowded and unappealing paragraphs with small font size were recognized as the major causes. Participants also self-reported that they checked their understanding of the passage by reading it repeatedly and/or paused frequently while reading. According to Beacham [8], persons with dyslexia tend to re-read computer-based textual learning materials to allow context to aid decoding and therefore to increase understanding [34]. As for learners without dyslexia, web text is preferred to be short and direct to the point [59].

Participants with dyslexia also commented on the high-contrast background. This is consistent with the study by Freire et al. [37] in which many web users with dyslexia in their study encountered problems with black writing on white background as the text forms "visual patterns" or "dancing around." The impaired development of the magnocellular component of the visual system among many persons with dyslexia, which is crucial in controlling eye movements, explains this unsteady vision [84]. Gregor et al. [40] report similar findings in which black on white setting caused their study participants to experience visual stress and lost. Using the combination of black on white produces high contrast and is not recommended for persons with dyslexia [7, 73] as some of them are sensitive to color and brightness [45]. This phenomenon distracts attention.

3.2.3 Printed Text mode: low AE (confusing and boring)

Nine participants with dyslexia (D1, D2, D3, D4, D5, D6, D8, D10, D12) and ten participants without dyslexia (T1, T2, T3, T4, T5, T7, T8, T9, T10, T11) were classified as having low affective engagement while reading in the Printed Text mode. Generally, participants reported the Printed Text mode as confusing though the severity of confusion among participants without dyslexia is lesser. Passages presented in such format did not seem to aid understanding, and repeated reading of long paragraphs were considered as wasting their time and required a lot of patience. Although most participants did think reading using a computer was fun, the Printed Text mode was viewed as uninteresting and boring.

3.2.4 Standard Guidelines mode: moderate to high BE

Four participants with dyslexia (D2, D3, D4 and D5) were classified as having moderate behavioral engagement because they felt this mode was better than the Printed Text mode though would not introduce it to their friends as they favored the assistance of the Screen Reader. Four participants with dyslexia (D6, D7, D10 and D12) and nine without dyslexia (T1, T2, T4, T5, T6, T8, T9, T11, T12) were classified as having high behavioral engagement as they were able to be committed in their reading as they felt the reading was comfortable and it was also easy to concentrate. They would introduce this mode to their friends as well. Similar to the Printed Text mode, all participants

were also observed to read the passage attentively with almost half of them uttering the passage softly. All of them were observed as well and self-reported that they did not have the tendency to stop halfway while reading the passage and put their best effort to understand the passage.

3.2.5 Standard Guidelines mode: high CE

All participants were able to pay attention to the passage. Several participants with dyslexia attributed that their ability to pay attention was due to the use of bulleted points as they reported that they paused in between reading to check their understanding. The use of bulleted points most probably guided the read-pause pattern of these participants. An eye-tracking study by Schneps et al. [80] demonstrated that short lines, as with the use of bulleted points as opposed to lengthy paragraph forms, facilitate reading for persons with dyslexia by guiding visual attention to the uncrowded space. Participants, both with and without dyslexia, also put an effort to check their understanding by reading the passage repeatedly. Repeated reading is a simple rehearsal strategy that helps to improve comprehension [26, 61].

3.2.6 Standard Guidelines mode: high AE (satisfying and comfortable)

None of the participants reported negative emotion after experiencing the Standard Guidelines mode. Some sample comments include "I feel comfortable using this…," "Enjoy reading this passage…I like reading quietly" and "Learning is fun because I can remember what I read." Generally, they were satisfied with this experience and found it to be comfortable and enjoyable.

3.2.7 Screen Reader mode: moderate BE

As with the Printed Text and Standard Guidelines mode, all participants were also observed to listen and read the passage attentively with almost half of them read out the passage softly. All of them were observed as well and self-reported that they did not have the tendency to stop halfway while reading the passage and put their best effort to understand the passage. Eight participants with dyslexia (D1, D2, D3, D4, D5, D8, D9, D11) and nine without dyslexia (T1, T2, T3, T4, T5, T6, T7, T8, T10) agreed that they were more committed to reading using this mode and would be happy to use it again in the future. Participants D1, D8 and D9 also mentioned that this is a good tool for poor readers as they were able to learn the correct pronunciation and also to overcome the fear of reading. Nevertheless, the rest of the participants (four with and three without dyslexia) provided negative feedback as they found the audio to be distracting. Thus, this Screen Reader mode is interpreted as yielding moderate behavioral engagement among participants.

3.2.8 Screen Reader mode: mixed high and moderate CE

Most participants were able to pay attention to this reading mode. Eight participants with dyslexia (D1, D2, D3, D4, D5, D8, D9, D11) and nine without dyslexia (T1, T2, T3, T4, T5, T6, T7, T8, T10) were classified as having high cognitive engagement, as they reported easiness to stay focused at their reading with the presence of the Screen Reader, and great improvement in understanding and listening to the passage read aloud was very helpful to them. These participants were observed to repeat the audio to ensure their understanding. A participant with dyslexia commented "Screen Reader acts as a person reading for me…this makes it more attractive and easier to concentrate" whereas a participant without dyslexia commented "This is similar to teacher talking while doing my own reading." Thus, this mode is viewed as able to yield high cognitive engagement. Four participants with dyslexia and three without dyslexia reported that the use of audio or Screen Reader distracted their reading. Nevertheless, they still preferred this Screen Reader mode to the Printed Text mode. This finding echoes the study by Elkind et al. [32], which reports that 14% of their study participants showed lower comprehension scores when using computer reader to aid their reading although majority of their participants benefited from this reader. These participants were classified as having moderate cognitive engagement.

Learning styles seem to play an important role in justifying participants' preferences. Advocates of learning style models [21, 22] postulate that students learn in different ways. As shown by Beacham and Alty [8] in their study, different media combinations yield different learning effects for learners of different learning styles. The VARK model [35] defines learning style as an individual's preferred way of gathering, organizing and thinking about information and focuses on perceptual modes. The acronym VARK stands for Visual (V), Aural (A), Read/Write (R) and Kinesthetic (K). Those who prefer the Screen Reader mode are most probably auditory learners who learn best through listening [31]. Since these participants mentioned that they would prefer to self-read than listen, it suggests that they belong to the read/write group of learners. Fleming [35] highlighted that read/write learners enjoy printed handouts, essays, textbooks, manuals, web pages and taking notes, which explains why they preferred the Standard Guidelines mode.

The distraction caused by the Screen Reader can be associated with Dual Coding Theory [63] and Cognitive Load Theory [85]. Generally, the Dual Coding Theory

Table 9 Comparison of engagement (BE, CE, AE) between modes

	Printed Text		Standard Guidelines		Screen Reader	
	Dyslexia	Without dyslexia	Dyslexia	Without dyslexia	Dyslexia	Without dyslexia
BE						
Observation	Read attentively	Read attentively	Read attentively	Read attentively	Read attentively	Read attentively
Tendency to stop halfway	Yes for some	No	No	No	No	No
Put best effort	Yes	Yes	Yes	Yes	Yes	Yes
CE						
Pay much attention	Yes, white background posed problem for some	Yes	Yes	Yes	Yes, audio was distracting for some	Yes, audio was distracting for some
Check understanding	Read repeatedly	Read repeatedly	Paused in reading, read repeatedly	Read repeatedly	Listen to audio repeatedly	Listen to audio repeatedly
AE	Confused and bored	Confused and bored	Satisfied and comfortable	Satisfied and comfortable	Excited, confident, worried, lost	Excited, confident, confused

posits that there are two independent information processing channels; the verbal channel processes information such as text and audio, and the visual channel processes information such as image and animations. The use of the verbal channel to process both text reading and listening to the Screen Reader may have overloaded this particular channel. The participants may also experience split attention between these two modalities [86]. In addition, the impairment in phonological processing among persons with dyslexia [51] and deficit in visuo-spatial attention [92] as well as weaknesses in their short-term memory [51, 89] limit the number of verbal items that persons with dyslexia can retain in memory. Thus, this may explain the reported distraction experienced by some participants when using the Screen Reader.

3.2.9 Screen Reader mode: mixed high (interesting, confident), moderate (frustrated—without dyslexia) and low (worried, lost—dyslexia) AE

All participants reported the Screen Reader mode as interesting, exciting and fun. This mode also gave more confidence to some of them. Some of the comments include: "Most fun…will introduce to my friends as I think they will also like this because they are lazy to read," "It also gave more confidence and I will use it in the future," "I felt relieved because computer reads for me," "I do not feel so lonely when reading with the Screen Reader." Nevertheless, some participants with dyslexia felt worried and lost when they were not given the option to control the reading speed and play/pause function. Examples of the comments include: "The computer reads too fast…I am lost" and "Screen Reader promotes better learning when suitable speed is used. If speed is too slow, the audio becomes a disturbance." These participants are classified as having low AE, and this finding points to the importance of providing adequate control to the learner with dyslexia when using a Screen Reader. Two participants without dyslexia, classified as having moderate AE, did not feel lost or worried though reported some frustration over the difficulty to understand passage due to distracting audio.

Table 9 summarizes participants' behavioral engagement (BE), cognitive engagement (CE) as well as affective engagement (AE) when experiencing each of these modes.

3.3 Summary of findings

Table 10 summarizes the key patterns derived from each reading affordance. The findings of this study revealed that the online reading modes explored by participants with and without dyslexia resulted in different perceptions of learning and level of engagement. It was apparent that the Printed Text mode was the least preferred mode of reading, while the Standard Guidelines mode was well received by all participants. Although the Screen Reader mode received a mixture of positive and negative responses by the participants, it is apparent to note that a majority of them expressed having excellent learning experience when reading with such assistive technology.

4 Implications

The following section discusses the implications of the findings from this study.

Table 10 Key patterns for Printed Text, standard guidelines and Screen Reader modes

	Printed Text		Standard Guidelines		Screen Reader	
	Dyslexia	Without dyslexia	Dyslexia	Without dyslexia	Dyslexia	Without dyslexia
Perceived learning	Low	Low	High	High	Excellent and moderate	Excellent and moderate
Behavioral engagement	Moderate	Moderate	Moderate and high	High	Moderate	Moderate
Cognitive engagement	Low	Low	High	High	High and moderate	High and moderate
Affective engagement	Low	Low	High	High	High and low	High and moderate

4.1 Careful consideration on the direct display of Printed Text on the web

The Printed Text mode yielded a perception of poor learning improvement, low satisfaction as well as low engagement level among the participants during the reading task. The participants emphasized the inappropriateness of using small font size, lengthy paragraph and black font on white background when presenting text on web. This not only adds to the reading difficulties commonly experienced by readers with dyslexia but has also led to reading discomfort among the readers without dyslexia. This implies the inappropriateness of employing text layout used in the conventional printed book for web text reading. Web designers and academic instructors, especially those in tertiary education who normally incorporate online learning courses in their teaching practice, should be made aware of the risk of direct application of standard used in Printed Text for web text. Findings of this study suggest that learners often feel unexcited, lazy and easily bored with such presentation of text on the computer screen.

4.2 Empirical evidence for existing guidelines

McCarthy and Swierenga [55] have compiled many existing dyslexia-friendly web accessibility guidelines. The perception of improved learning quality, high engagement toward the Standard Guidelines mode has provided additional evidence on the appropriateness of the existing guidelines employed in this particular mode. These guidelines include the use of bulleted points, left justified, 1.5 line spacing, sans serif font type, font size (16–18 point) and black font on beige background.

The participants expressed that reading with the Standard Guidelines mode made them feel comfortable, pleasant and enjoyable, which has increased their confidence in reading and understanding of the passage. Therefore, the acceptance showed by the participants without dyslexia toward the dyslexia-friendly existing guidelines through their positive learning experience indicated that these guidelines are appropriate to be employed when presenting text for an online course. On the other hand, since this study involved persons with dyslexia from an eastern country, findings from this study also provide evidence on the relevance of the existing guidelines that were derived in western countries, to be used in this part of the world.

4.3 Screen Reader is an excellent aid for some but not all

Existing literature such as [5, 10, 23, 31, 77] have highlighted the benefits a person with dyslexia can gain from the use of the Screen Reader. The findings of the present study revealed that a majority of participants with dyslexia has indeed yielded the perception of excellent learning quality and high engagement during the reading task which implied that the Screen Reader did serve as a great reading aid. The participants with dyslexia appreciated the opportunity to listen and read simultaneously which has increased their understanding. In addition, positive learning experience among some participants without dyslexia also indicates the potential to harness the benefits of Screen Readers among normal learners even though Screen Readers are often only recommended for those with dyslexia.

However, there were also those who perceived the Screen Reader as distracting, which made their reading less engaging and/or less preferred to be used. Hence, this suggests that the Screen Reader may not be useful for all learners with dyslexia. Therefore, making Screen Readers as an optional aid for reading web text is another inclusive guideline, as this assistive technology greatly benefits most of the participants with dyslexia and some of the participants without dyslexia though not others.

4.4 Inclusive dyslexia-friendly online text reading guidelines

In summary, this study recommends that (1) the direct application of Printed Text on the web should be carefully

considered, (2) existing web accessibility guidelines (those employed in the Standard Guidelines mode) are appropriate for all learners and (3) the use of a Screen Reader for online reading should not be made compulsory and be available as an option instead.

5 Conclusion

The comparison between the experience of learners with and without dyslexia has yielded insights into the affordances that are perceived positively by both groups of learners. As learners with dyslexia form a significant minority of the online learning population, the inclusive dyslexia-friendly guidelines derived from the present study would better inform the future implementation of online reading affordances acknowledging differences and similarities between online learners.

Future studies may look into affordances for other elements of online learning such as web writing, information organization, collaborative activities and multimedia presentation. The study may also be extended by increasing the sample size to enable triangulation of data via both quantitative and qualitative approaches.

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