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Influence of increased letter spacing and font type on the reading ability of dyslexic children

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Abstract
Recent research studies have shown that increased letter spacing has a positive effect on the reading ability of dyslexic individuals. This study aims to investigate the effect of spacing on the readability of different fonts for children with and without dyslexia. Results did not support the hypothesis of better performance among children with dyslexia when reading text in Dyslexie than in other fonts. They, however, revealed that only spacing plays a role in enhancing dyslexic individuals' reading performance because Dyslexie and the Times New Roman interspaced font have no difference. Furthermore, the negative effect of the unfriendly fonts Times New Roman Italic and Curlz MT was eliminated through increased interletter spacing.

Keywords Dyslexia · Dyslexie · Font · Letter spacing · Reading

Introduction

Reading is a unique cognitive skill that is important in modern society; unfortunately, about 5–10% of children experience learning difficulties. They suffer from a disorder called dyslexia (Gabrieli, 2009; Shaywitz & Shaywitz, 2005). Dyslexia is a condition related to poor reading ability among children and adults who have age-appropriate intelligence, education, and reading instruction. The difficulties are manifested in accurate and/or fluent word recognition and by poor spelling and decoding abilities (Lyon, Shaywitz, & Shaywitz, 2003).

The dominant view on dyslexia is explained by the phonological deficit hypothesis, that is, deficits on how words are sounded out. This approach has resulted from the substantial evidence that shows that, from the early literacy learning stage to adulthood, dyslexics have experience difficulties in phonological processing (see Beaton, McDougall, & Singleton, 1997; Bruck, 1993; Snowling, 2000; Stanovich, 1988) and have specific impairments in the

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representation, storage, and/or retrieval of speech sounds (Ramus, 2003; Snowling, 2001). The phonological deficit hypothesis has predominantly explained this phenomenon in the past two decades, but it is only just one of the several competing theories that try to explain the probable possible cause of dyslexia.

Letter reversals and misordering of letters are more frequently observed among dyslexics than among normal readers (Terepocki, Kruk, & Willows, 2002). The phonological deficit hypothesis, however, does not explain the prevalence of such errors. Difficulties in ascertaining the sequence of letters in words among dyslexics cannot be easily explained by the presence of phonological deficits (Vidyasagar & Pammer, 2009). Recently, interest in visual deficit in dyslexia, which is described to include difficulties in processing words on a page of text, has been increasing. Its possible causes are unstable binocular fixations or poor vergence (Ramus et al., 2003), and one of its effects is "crowding."

Crowding is "the negative effect of surrounding visual elements on the recognition of a central target" (Spinelli, de Luca, Judica, & Zoccolotti, 2002, p. 179). The degree of crowding depends on the characteristics of the stimulus, such as distance between visual elements and eccentricity in the visual field (Kooi et al., 1994; Huckauf, Heller, & Nazir, 1999). Different studies have reported crowding-related deficits in dyslexics (see Hawelka & Wimmer, 2005; Martelli, Di Filippo, Spinelli, & Zoccolotti, 2009; Spinelli, de Luca, Judica, & Zoccolotti, 2002). Indeed, Spinelli et al. (2002) have suggested that "visual crowding may be a factor contributing to the genesis of dyslexia" (p. 197).

Increased spacing has been shown to reduce crowding and improve the reading performance of dyslexics (Legge & Bigelow, 2011; O'Brien, Mansfield, & Legge, 2005; Perea, Panadero, Moret-Tatay, & Gómez, 2012; Spinelli et al., 2002; Zorzi et al., 2012). Studies of words presented with increased interletter spacing or with the default settings were conducted in Spanish (Perea et al., 2012), Italian (Spinelli et al., 2002; Zorzi et al., 2012), French (Zorzi et al., 2012), and English (Sjoblom, Eaton, & Stagg, 2016). Dyslexics made significantly fewer errors and read largely spaced text faster than normally spaced text. For English, however, the results showed that letter spacing improves the reading speed in general but has no specific effect on dyslexics. However, letter spacing improved the reading accuracy. These results are expected from the perspective of the orthographic depth hypothesis (see Katz & Frost, 1992) and based on the meaning of reading accuracy in English orthography, which provides higher chances for reading errors to be made because of the relatively high degree of inconsistency (Ziegler et al., 2003).

All previous studies used standard fonts with increased letter spacing. Recently, Marinus et al. (2016) used Dyslexie, a special font developed to help improve the reading ability of dyslexics. This font has special letter shapes that look different with the base of the letters looking "heavier" to prevent them from turning around, because dyslexics tend to rotate or reverse letters (Boer, 2016). This font also has relatively large spacing settings compared with standard fonts. Marinus et al. (2016) noted that poor readers performed better when reading text in the Dyslexie than in the standardly spaced Arial font. However, when the within-word and between-word spacing of Arial was matched with that of Dyslexie, the difference in reading speed was no longer significant. The researchers concluded that the efficacy of the Dyslexie is not due to its especially designed letter shapes but its large spacing. Increasing the reading efficiency of poor readers has been argued to be possible by simply changing the font's spacing settings, without the need to alter the shape of the letters. To investigate this argument, in the present study, we used different fonts with increased interletter spacing and analyzed the reading efficiency of dyslexics. The standard font, Dyslexie, and fonts that are not recommended for dyslexics, such as italic and fancy fonts (British Dyslexia Association, 2012; Lockley, 2002; Rello & Baeza-Yates, 2013) were used. The aim of the present study was to investigate the effect of spacing on the readability of different fonts for children with and without dyslexia. Therefore, we developed an experiment to investigate whether increased letter spacing independent of font type improves the reading performance of dyslexics, a research area that has not been investigated before.

We replicated the procedures used in the study conducted by Zorzi et al. (2012) so that we could compare our results with those of other studies conducted for shallow orthographies. We extended their work through research not only on interletter spacing but also on different fonts. We also considered chronological age, not only RL, so that we could follow the process in normally achieving children too and possibly analyze the deficit characteristics, that is, whether this phenomenon is a result of fundamental deficits or a consequence of lack of reading (Goswami, 2003). Times New Roman (TNR) was used, not Arial as Marinus et al. (2016) did, because, generally, the majority of books are printed in a serif font (Moret-Tatay & Perea, 2011), and it is the most used font in Bosnian books.

Therefore, this study aims to replicate the study conducted by Marinus et al. (2016) and investigate whether dyslexics perform better when reading text in Dyslexie than in TNR. If only spacing plays a role in improving our participants' reading performance, the Dyslexie and the TNR interspaced font will have no difference, and dyslexics will read faster in the Dyslexie than in the TNR font with the default interletter spacing. Furthermore, by replicating and extending the study conducted by Zorzi et al. (2012), we examined whether TNR Italic and Curlz MT are unfriendly fonts even in interspaced text. If TNR Italic and Curlz MT are unfriendly fonts, we would predict that the dyslexics read significantly faster and more accurately in the Dyslexie than in the TNR Italic and Curlz MT interspaced fonts. However, for the chronological-age and reading-level groups, we would not find a difference between the aforementioned conditions.

Method

Participants

A total of 69 children (23 dyslexics, mean age = 10.77 years; 23 chronological-age control participants, mean age = 10.44 years; and 23 reading-level control participants, mean age = 7.59 years), participated in the study. All the children were recruited from regular primary schools in Bosnia and Herzegovina. They were all native Bosnian speakers. No child had been introduced to the Dyslexie before or trained to read largely spaced text. The Ministry of Education of the Tuzla Canton approved all the study procedures. The children's parents gave written permission for their children to participate in the research.

According to the criteria in the International Classification of Diseases (ICD-10, version: 2016) (World Health Organization, 2016), children who score at or below the 10th percentile in reading tasks are considered dyslexic if the nonverbal intelligence test yields an average or above-average IQ. All the children's nonverbal IQs were evaluated using Raven's Progressive Matrices (Raven, 1963). None of the participants reported a history of neurological diseases, psychiatric disorders, spoken language impairment, inadequate schooling, or vision or hearing problems. The children who scored above the 25th percentile in reading tasks and had an average or above-average IQ were included in the control groups.

Participants with dyslexia Children were assessed by individually administering the subtest of the Dyslexia Screening Test (Duranovic, 2013) and the standardized Bosnian test. Accuracy and speed in word and nonword reading were measured. Children were considered dyslexic if they had at least two attainment scores in the reading tasks (errors and/or speed) at or below the 10th percentile. The means and SDs for all the tests are presented in Table 1.

Chronological-age control children (CA) This group was formed by using the method of equivalent pairs—equal across gender and chronological age with the group of dyslexics.

Reading-level control children (RL) All children exhibited the reading level expected for their age. This group matched those with dyslexia for reading ability. The children were matched for reading speed, not for reading accuracy. Reading accuracy in transparent languages reaches the ceiling by the end of grade 1 (Seymour, Aro, & Erskine, 2003). Since Bosnian is a language with transparent orthography, we could not find children who would be able to decode sentences in the experimental task and who would make errors. All the children showed accuracy, but they were matched with the children with dyslexia according to their reading speed.

Materials and procedure

Text was prepared as a black print on a piece of white A4 paper in random order. The task included 100 meaningful short sentences, 20 per condition. The sentences were made up of high-frequency Bosnian words extracted from the Oslo Corpus of Bosnian Texts (1997, http://www.Tekstlab.uio.no/Bosnian/Corpus.html#cont). Sixty-eight words were used per condition. The extracted unrelated words were constructed into meaningless sentences to avoid any contextual cues in reading (e.g., "Her name is Lina. This is solution."). The sentences were made for five different conditions perfectly matched in number of words, syllables, word frequency, and grammatical class (see Table 2).

Table 1 Test scores and ages for participants with dyslexia, chronological age, and reading level control children

Variable	Dyslexic group		Chronological age control		Reading level control	
	Mean	SD	Mean	SD	Mean	SD
One-minute reading[a]	27.13	11.96	71.65**	14.44	32.00	10.21
Real word reading						
Errors[a]	8.48	5.66	0.17**	0.39	2.17**	2.67
Reading time (s)[a]	119.26	83.77	28.13**	7.93	88.22	69.60
Nonword reading						
Errors[a]	12.52	5.85	1.48**	1.62	6.83**	5.90
Reading time (s)[a]	187.04	153.32	46.22**	14.78	120.65	72.86
IQ[b]	29.61	4.15	31.39	3.10	27.22	4.29

[a] Subtests of the Dyslexia Screening Test (Duranovic, 2013)

[b] IQ, average of individual intelligence quotients according to the Standard Progressive Matrices Test

** $p < 0.01$

Table 2 Characteristics of sentences for the five conditions

	Condition 1	Condition 2	Condition 3	Condition 4	Condition 5	*F*	*p*
Number of words in sentence	3.40 (0.68)	3.40 (0.68)	3.40 (0.68)	3.40 (0.68)	3.40 (0.68)	0.00 (4.00)	1.00
Number of syllables in sentence	6.50 (1.43)	6.50 (1.70)	6.30 (1.66)	6.50 (1.67)	6.40 (1.96)	0.06 (4.16)	0.994
Length of words in sentence	4.13 (1.52)	4.16 (1.66)	4.18 (1.357)	4.07 (1.72)	4.16 (1.98)	0.04 (4.12)	0.997
Word frequency in sentence	6561.87 (16,127.66)	4742.44 (10,466.60)	5239.12 (12,695.11)	8265.53 (16,657.98)	8347.60 (16,425.86)	0.88 (4.19)	0.478

The sentences appeared in five different conditions. The text with increased letter spacing was printed in condition 1, Dyslexie; condition 2, TNR interspaced; condition 3, TNR Italic interspaced; and condition 4, Curlz MT interspaced font. In condition 5, the sentences were presented in 14-point TNR with the default interletter spacing. The internal consistency for the sample was 0.88.

In condition 1, the Dyslexie was presented in 11-point with a larger font size and between-word to within-word spacing ratio compared with other fonts, 1.3 points between words and 1.0 point between letters within words (Marinus et al., 2016). Therefore, to match conditions 2–4 with the Dyslexie, the font size was increased to 14 points, between-word spacing by 1.3 points, and interletter spacing by 1.0 point for conditions 2–3 and by 1.3 points for condition 4. The interline spacing was doubled to replicate the study conducted by Zorzi et al. (2012). In condition 5, the sentences presented in TNR had normal within-word and between-word spacing.

In keeping with the guidelines from the British Dyslexia Association (2012) for creating “dyslexia friendly” written material, we followed print size recommendations and used a 14-point print size for all the sentence presentation conditions, except for the Dyslexie font. Recommendations for layout and writing style were also followed. We used left-justified alignment with ragged right edge; avoided starting a sentence at the end of a line so that every sentence started in a new line; used short, simple sentences in a direct style; avoided double negatives; and constructed concise sentences.

To avoid repeated administration effects (test-retest effects) (see Bruno-Golden, 2013), we used the same paradigm employed by Marinus et al. (2016). Every child read all the sentences for the five different conditions. The texts for the five different conditions were presented in a controlled, randomized order. Every sentence appeared in every condition for all the children to avoid confounding the sentences with the font/spacing conditions. The counterbalancing procedures used in the study conducted by Marinus et al. (2016) were replicated. Latin square matrices (ABCDE, BCEAD, CEDBA, DABEC, and EDACB, as well as 12345, 24513, 31452, 45231, and 53124) were used to define the order and condition of the sentences. This resulted in 25 (5 × 5) different sentence and condition combinations. For example, child 1 got the code B2C4E5A1D3, it means that the child read the sentences in the BCEAD order, with sentences B in the TNR interspaced font, sentences C in the Curlz MT interspaced font, sentences E in the TNR font with default spacing, sentences A in the Dyslexie, and sentences D in the TNR Italic interspaced font.

The children were tested in a quiet room at school. Reading accuracy (number of errors) and speed (number of words per second) were analyzed according to the five conditions. Multiple accuracy errors could be counted within the same word (e.g., if a one word had two syllables, then a child could read both syllables incorrectly, leading to two errors in a single word). The errors were mostly omissions (e.g., "vata" instead of "vrata") (30%), substitutions (e.g., "kalta" instead of "karta") (52%), and insertions (e.g., "plas" instead of "pas") (18%). An independent observer was tasked to ensure the reliability of the correct scores. First, the author scored the children's reading errors. The observer who was trained to score the reading errors double-checked all the scores. If the observer found different results, the error would be reviewed by the author and the observer, and they would agree on the presence of the error.

Digital recording devices were used to record the children's reading. The participants were instructed to start reading aloud as soon as they got the hand signal. Their reading speed and errors were determined using the recording, and their speed was timed the moment they started reading out loud until they finished reading the text for the condition.

Results

The mean scores assigned for the dyslexics and the scores achieved by the control groups for every condition are shown in Table 3. The results showed the smallest mean for number of reading errors and the reading time among dyslexics for the Dyslexie and the highest number of errors for the TNR default interspaced font. The smallest number of reading errors for the CA was recorded for the TNR default interspaced font, while for the RL, the TNR interspaced font. The CA had the best reading speed for the TNR interspaced font. The RL had the smallest mean for reading time for the Dyslexie font.

Reading accuracy (number of errors) and speed (number of words per second) were analyzed using a repeated measures ANOVA with conditions being a within subject factor. To protect against Type I error, we used Bonferroni procedure for each ANOVA. There were separate ANOVAs for the dyslexic and normally developing readers.

First, ANOVAs have been done for dyslexic group. For reading accuracy, the main effect of font condition was significant, $F(4.88) = 5.28$, $p < 0.001$. Pairwise comparisons indicated significant difference between Dyslexie and TNR default interspaced font ($p = .006$) and between TNR interspaced and TNR default interspaced fonts ($p = .047$). Difference was not

Table 3 Mean scores, standard deviations of reading accuracy (number of errors), and speed (number of words per second) for each font condition

Variable	Dyslexic group				Chronological age control				Reading level control			
	Reading accuracy		Reading speed		Reading accuracy		Reading speed		Reading accuracy		Reading speed	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Dyslexie font	14.39	10.29	2.04	1.93	1.30	2.03	0.57	0.31	6.91	14.12	1.44	1.00
Times New Roman interspaced font	16.57	11.21	2.27	1.76	1.39	2.33	0.53	0.17	4.96	7.30	1.51	0.96
Times New Roman Italic interspaced font	22.91	18.76	2.45	1.90	2.17	4.99	0.59	0.36	6.52	8.57	1.60	1.05
Curlz MT interspaced font	21.22	21.48	2.44	2.00	1.39	2.73	0.68	0.47	8.52	11.86	1.62	1.03
Times New Roman with the default inter-letter spacing	26.22	19.41	2.47	2.08	0.91	2.21	0.55	0.29	7.30	11.15	1.53	1.07

found between Dyslexie and TNR interspaced font ($p = 1.00$). Pairwise difference was not significant between Dyslexie and TNR Italic ($p = .096$) and Dyslexie and Curlz MT interspaced fonts ($p = .494$) (Fig. 1).

For reading speed, the main effect of font condition was significant for dyslexics, $F(4.88) = 6.26$, $p < 0.001$. Pairwise comparisons indicated difference between Dyslexie and TNR default interspaced font ($p = .003$). Difference was not found between TNR interspaced and TNR default interspaced fonts ($p = 1.00$). Pairwise comparisons indicated that the difference of Dyslexie with TNR Italic interspaced font was significant ($p = .012$). For Dyslexie and Curlz MT interspaced fonts, comparison indicated that pairwise difference was not significant ($p = .078$).

The RL and CA groups seem to show floor effects for accuracy (means are very low and SDs are higher than means). Therefore, accuracy data was not analyzed for these groups. A repeated measures ANOVA with font condition as a within-subjects variable with five levels have been done for the CA and RL groups. For CA, there was no significant within-subject effect for reading speed ($p = 0.08$) and no significant main effect for pairwise comparison between the five conditions. For the RL, the main effect was significant for reading speed $F(4.96) = 3.04$, $p = 0.021$. Pairwise comparisons indicated that the difference of Dyslexie with Curlz MT interspaced fonts was significant ($p = 0.012$). Difference was not found for all other conditions.

Discussion

The positive impact of increased spacing and font type on reading was examined among typical readers and dyslexics for Bosnian, a language with a transparent orthography. Evidence showing the influence of spacing on both reading accuracy and reading speed was found among dyslexics. The obtained results support the findings of previous researchers (Zorzi et al., 2012; Perea et al., 2012; Spinelli et al., 2002), who noted that dyslexics read texts faster and make significantly fewer errors when the spacing is increased. This effect is a characteristic of both shallow and opaque orthographies. This effect has been obtained in Spanish (Perea et al., 2012), Italian (Zorzi et al., 2012), and Bosnian (this study), three languages with a shallow writing systems. The same effect was observed in French (Zorzi et al., 2012) and English (Marinus et al., 2016), two languages with more opaque writing systems.

The present study employed five different conditions, four with largely spaced text and one with normally spaced text. The results showed that dyslexics commit the highest

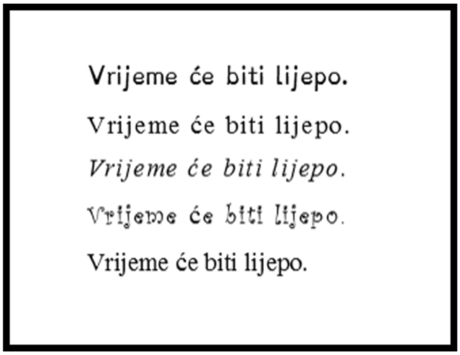

Fig. 1 Font conditions

number of errors and have the slowest speed when reading normally spaced text. The perception of a given letter is impaired when other letters are nearby due to lateral masking between the neighboring letters (Bouma, 1970). A slight increase in interletter spacing relative to the default settings may reduce the detrimental effects of crowding without affecting the whole word's integrity (Perea & Lupker, 2003, 2004). The theory of the influence of increased letter spacing on reading accuracy is further supported by the fact that dyslexics read less accurately and more slowly in normally spaced sentences in TNR than largely spaced sentences in italic and Curlz MT fonts that are not recommended for dyslexic readers (British Dyslexia Association, 2012; Lockley, 2002; Rello & Baeza-Yates, 2013).

Perea et al. (2012) and Zorzi et al. (2012) showed that increased letter spacing improves the reading performance of dyslexics without any training. The participants of other studies were dyslexics who were recruited from tutorial centers (Marinus et al., 2016; Zorzi et al., 2012). Attending such centers could give them opportunity to be introduced to Dyslexie or interletter spacing text. In the present study, we examined Bosnian dyslexics who were first diagnosed with dyslexia during this research. They did not attend remedial reading programs or use Dyslexie or any other font with increased spacing before this research. The results of the present study gave us information about the positive effects of wider letter spacing on the fly and proof that increased crowding is a fundamental deficit in dyslexics that can be specifically improved by increasing the interletter spacing (Zorzi et al., 2012). These results did not support the hypothesis that dyslexics perform better when reading text in Dyslexie than in other fonts. Only spacing was noted to play a role in improving their reading performance because no difference was observed between the Dyslexie and the TNR interspaced font. Higher reading accuracy and faster speed when the Dyslexie is used instead of the TNR default font could be explained by the wider interletter spacing but not by the shape of the letters. This finding is consistent with the argument of Marinus et al. (2016), who noted that we do not need to alter the shape of the letters to improve the reading ability of poor readers. Changing the font's spacing settings is enough.

Bachmann and Mengheri (2018) compared EasyReading™, another special font for dyslexics, with TNR and found that the performance of dyslexics improved in terms of both fluency and accuracy for all the stimuli presented in EasyReading™. But the authors did not used a version of TNR with expanded spacing and could not confirm whether the efficacy of EasyReading™ depended on the specific font, or the spacing. In this study, dyslexics also performed better in the Dyslexie font than in the TNR. But the Dyslexie did not show any advantage over the TNR interspaced font. The results are consistent with those of the study conducted by Kuster, van Weerdenburg, Gompel, and Bosman (2018), who found that children with and without dyslexia did not perform better when they read text in Dyslexie than in TNR.

We also examined whether TNR Italic and Curlz MT are unfriendly fonts even in interspaced conditions. The results showed that the dyslexics read the text faster but not more accurately in the Dyslexie than in the TNR Italic interspaced font. No difference was found between the Dyslexie and the Curlz MT interspaced font. We did not find any difference between these conditions for the CA. For the RL, we found a difference only between the Dyslexie and the Curlz MT interspaced font. The results suggest that the negative effect of the unfriendly fonts was eliminated by increasing the interletter spacing. Only the TNR Italic font had a negative influence on the reading speed of dyslexics, and Curlz MT should be avoided by younger children.

The results of the present study indicate that dyslexics may benefit from the increased letter spacing in text. Previous research has noted that crowding influences reading speed (Yu, Cheung, Legge, & Chung, 2007; Pelli et al., 2007) and accuracy (Whitney & Levi, 2011), especially in dyslexics. These findings were supported by this study. Our results showed the different influences of crowding on dyslexics and normally achieving readers. Only dyslexics benefited from increased letter spacing, whereas no significant effect was observed in typical readers. The null effect of interletter spacing on total reading times is in line with the previous silent reading experiments with adults (i.e., Perea, Giner, Marcet, & Gomez, 2016), and reading larger interletter spacing is not helpful for normally achieving children. This could be explained with a well-functioning attention orienting system and magnocellular-dorsal stream (Perea et al., 2012; Zorzi et al., 2012) which are impaired in dyslexics (see Gori & Facoetti, 2014).

This study adds to a growing body of evidence that supports the positive effects of increased letter spacing (e.g., Perea et al., 2012; Zorzi et al., 2012) but not those of the Dyslexie font on dyslexics. One of the strengths of this study is its use of different fonts, which allowed us to assess the influence of interletter spacing in relation to dyslexia-friendly and nonfriendly fonts and have a clear picture of the importance of increased letter spacing in improving reading accuracy and speed independent of font type. Well-chosen spacing settings may be more beneficial to the dyslexics and should be used in addition to providing proper remediation of reading problems but not as replacement.

Further studies are required to determine whether increased spacing would be effective for dyslexics during reading text which do not include the recommendations of the British Dyslexia Association (2012) for creating “dyslexia-friendly” written material. Previous studies used larger fonts (18-point font, Marinus et al., 2016; 14-point font, Perea et al., 2012; Zorzi et al., 2012), avoided text in block capitals, used left-justified alignment with ragged right edge, and employed simple, short sentences. It would be of great interest to use standard chapters from the basal readers of elementary school children with characteristic sentences usually provided for a particular grade and with a 12-point or smaller font, as it is usually used in children’s books. Its only difference from regular chapters is its increased letter spacing or usage of Dyslexie instead of the standard font. The results of such study would give us information about the real benefits of increased letter spacing and the Dyslexie font in a typical reading situation that is a characteristic of a particular grade. If we find a positive effect, it will have huge practical implications in improving the reading performance of dyslexics without formal training, just by increasing the letter spacing in books.

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