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SHORT REPORT

WILEY

Increasing inter-word spacing reduces migration errors and improves reading comprehension in students with dyslexia

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We report a small study in which we explored the effects of manipulating narrative text on levels of comprehension for students with and without dyslexia. Using two pieces of standardised narrative text deemed to be of similar difficulty and length, we manipulated the texts such that we could present two texts to each participant, one in each condition. The first condition was text using standard inter-word spacing; the second condition used increased inter-word spacing. Scores on standardised comprehension questions were significantly improved for participants with dyslexia. Additionally, given that there is evidence of delayed visual attention disengagement in individuals with specific forms of dyslexia, we hypothesised that the phenomena of migration of letters and words for some readers might be mitigated by increasing inter-word spacing. We did indeed find that incidence of migration was significantly reduced in this condition for all participants.

KEYWORDS

inter-word spacing, letter migration, reading comprehension, reading errors, reading fluency, word migration

Practitioner Points

- Simple modification of text that makes reading easier for dyslexic students.

- A means to reduce migration when reading for dyslexic students.
- A means to improve reading comprehension for dyslexic students.
- A means to improve motivation to read to dyslexic students.
- A means to reduce errors when reading for dyslexic students.

1 | INTRODUCTION

The aim of reading text is of course to understand what has been written and its intended message, and so it is important that this should be fluent for all readers. Dyslexic readers often find fluent reading and comprehension problematic. We present this paper from a 'what is observed' rather than a 'what causes' perspective; our aim is to explore a novel text-manipulation intervention rather than focus on the origins of reading difficulties (Elliott & Grigorenko, 2014). We take a brief look at other research that has utilised text manipulation regarding visual attention and migration of letters and/or words. We define migration as occurring when letters from one word intrude into another word (inter-word migration, e.g., 'curled toes' becomes 'turled coes'), where letters within words appear to change position (intra-word migration, e.g., 'cloud' becomes 'could') or where whole words may exchange position (Saffran, 1996).

There appears to be evidence that the historic phonological link with reading difficulties may to some extent be attributable to the greater quantity of research carried out in English speaking countries where phonological errors tend to be more frequent than visual errors compared to other languages (Giannouli & Pavlidis, 2014). In Chinese dyslexic children, for example, recent research suggests that visual-orthographic sensitivity is more important than phonological sensitivity (McBride et al., 2018). Thus, we look to research into visual errors.

Research into visual errors has in the past focussed on crowding and the effects of font size, letter spacing and line spacing (Gregor et al., 2003; Katzir et al., 2013; Rello & Baeza-Yates, 2017). The reported effects of visual crowding suggest that manipulation of, for example, letter spacing, would affect reading ability. However, a recent study analysing the impact of increased inter-letter spacing on reading performance accuracy and comprehension, and using eye-tracking technology, found a decrease in the duration of fixations in readers with dyslexia, but no effect on reading accuracy or comprehension (Łuniewska et al., 2022).

Other research has explored the impact of different kinds of fonts with mixed findings. Wery and Diliberto (2017) found no improvements from a specially designed font, whereas Bachmann and Mengheri (2018) found significant improvements from another specially designed font, although they conclude that the effect may have been the result of increased inter-line and/or inter-word spacing. There is some evidence that larger between-letter spacing improves text reading performance and it has been presumed that this is because of crowding effects (Zorzi et al., 2012). There is some evidence that inter-word spacing rather than between-letter spacing, has a greater positive impact on children with dyslexia (Bai et al., 2013; Marinus et al., 2016). Bai et al. (2013) found that children with dyslexia read target words in Chinese more quickly in an increased word spacing condition. Marinus et al. (2016) found that children benefitted when the spaces between words were relatively larger than the spacing within words. They speculate that this makes it easier for the reader to delineate between words.

Theories of crowding do not fully explain migration and so we turn to theories of visual attention that may provide clues to letter and word migrations that typically occur with dyslexia. There is evidence to support the theory of sluggish attentional capture and subsequent sluggish disengagement of visual attention (Hari & Renvall, 2001; Liu et al., 2016; Liu et al., 2018). Chinese dyslexic children had no trouble engaging their attention at a particular location but appeared to be slow to disengage that attention (Fu et al., 2019). Friedmann and Rahamim (2014), cite their earlier work (in Hebrew) in which they found reduced within-word and between-word migrations as a consequence of increased word spacing for some individuals with letter-position dyslexia (intra-word letter migration). For individuals with attentional dyslexia, letters appear to 'migrate' from one word to another (Friedmann & Gvion, 2001). Research has also demonstrated that reading words separately using a word-sized virtual window almost completely eliminated migrations (Friedmann et al., 2010). Other research has suggested that letter-migration errors result from orthographic information being 'pooled' from multiple words and from flexibility in letter-position coding (Grainger et al., 2014; Vandendaele et al., 2019).

The present study set out to investigate the effect of increased inter-word spacing in a short passage of narrative text. Since the ultimate objective of reading is comprehension, we sought to discover the effect of adjusting the text on levels of comprehension. In addition, we sought to analyse the types and frequency of errors that readers made and if the adjusted text influenced the typical errors found in readers. We further sought to investigate any effect of adjusting the text for both dyslexic and a control group of non-dyslexic readers to ascertain any differences and any advantages to either or both groups.

Here, we address two questions, firstly, does greater between-word spacing lead to improved comprehension during the reading of narrative text and secondly, does greater between-word spacing reduce errors during the reading of narrative text. Although we have mainly considered research into letter/word migration in the introduction, we will also be looking for errors that are typically highlighted during reading assessments, including mispronunciation, omission, insertion, substitution, repetition and correction.

We carried out preliminary exploratory trials to compare inter-word spacing and inter-line spacing, in various combinations. We found no effect of increased line spacing. We found little effect from doubling (two spaces) the inter-word spacing, and negative effects from inter-word spacing greater than three spaces. We found the optimum inter-word spacing in our trial sample to be three spaces instead of one, which replicates similar previous findings (Paterson & Jordan, 2010).

2 | METHOD

2.1 | The current study

The study was a simple comparison design. Two comparisons were made. Firstly, we compared two conditions with the whole sample of participants. Condition 1 with standard between-word spacing and condition 2 with increased inter-word spacing equivalent to three spaces. Secondly, the sample was divided into two groups for comparison: students with dyslexia and non-dyslexic students. We used two different texts of similar difficulty taken from a standardised test for reading comprehension. Both texts were printed in both conditions so that it was possible to randomise the order of presentation of each condition to participants. This was easily achieved by alternating between using text A (unaltered) followed by B (altered), then for the next participant using C (altered) followed by D (unaltered) and so on.

2.2 | Participants

Participants were student volunteers from a UK university. Students were offered £10 vouchers to participate. Participants recruited were not typically used to reading extended narrative text. Forty-six participants ($\alpha = 0.50$, power $= 0.70$) were recruited for face-to-face assessments (male $n = 27$; female $n = 19$). Online participation was trialled, but it was not possible to control for variability in display technology on participants' devices. There were two groups: non-dyslexic ($n = 22$) and dyslexic ($n = 24$). Of the dyslexic students, 14 had been diagnosed through the university student support service, six had been diagnosed at primary school either by the SENCo or an educational psychologist, two had been diagnosed through a private dyslexia centre and two had self-diagnosed.

2.3 | Measures

The reading materials were taken from the York Assessment of Reading for Comprehension (YARC) which has been standardised (Snowling et al., 2009). Texts used: Form A Level 6: Pirates and Form B Level 6: Shoes, taken from the YARC, and the prescribed administration protocols were followed. The texts were standardised for school-aged children and were composed to be of similar difficulty levels. This made it possible to manipulate the texts such that we could present two texts to each participant, one in each condition, and randomly reverse the order to reduce the effects of learning or weariness during the session. Both texts were presented printed on paper, using the Tahoma font 12-point size. The inter-word space manipulation was made by replacing single spaces with three spaces.

2.4 | Procedure and design

Text manipulations were presented across both texts. Randomisation was achieved by alternating which text was presented first to successive participants, to avoid possible text bias were the texts not to be fully equivalent for this analysis. The second author tested all participants individually at the university, withholding information as to whether students had a diagnosis of dyslexia until after the analyses had been completed by the first author to reduce researcher bias. Participants were presented with two texts, one in each condition. They were asked to read one text aloud and then answer eight questions about the text, and then read aloud the second text and answer a further eight questions about the second text. In addition, participants were asked to indicate if they had found either text easier to read. This was voice recorded, taking approximately 20 mins per participant. The voice recordings were subsequently analysed for fluency and errors, and scores were allocated for answers as per the YARC protocol. The questions designed by Snowling et al. (2009) measure comprehension, with a particular focus on inference generation. For the purposes of this research, scores were simply recorded as the number of correct responses (raw scores). Fluency (reading speed) was measured as words per second (the total amount of time taken to read the text divided by the number of words presented within the text). The total number of errors were calculated and broken down as mispronunciations, omissions, insertions, substitutions, repetitions, corrections and migrations (between letters and words).

Error types analysed: Omissions were defined as whole words or suffixes omitted; mispronunciations were clear attempts at speaking the correct words, but not following established rules of pronunciation; substitutions were completely different words that would make sense in the context; repetitions were simply repeating the same word over; corrections were going back to a previously incorrect word and changing it and migrations were defined as letters or words seeming to move into different positions similar to the effect of spoonerisms. Examples of migrations from the sample are shown in Table 1.

TABLE 1 Examples of migration of letters and/or words from the sample.

Participant number	Transcript of recording	Original text
7	Draw *dripping* strap	Draw*string* strap
11	Bold as *many* men	Bold as *any* men
11	Modern day *sneakers or trainers*	Modern day *trainers or sneakers*
12	Long *turled coes*	Long *curled toes*
13	*Rubbersised* soul	*Rubberised* soul
9	*Commanded* to hang	*Condemned* to hang
20	With *curled long* toes	With *long curled* toes
25	On in legends *today*	On *today* in legends
30	The *unofficial* uniform	The *official* uniform

3 | RESULTS

Our first research question, to look at the impact of greater word spacing on comprehension was addressed using eight standardised questions for each text in each condition. Correct responses to these questions require inference generation from the text and therefore give a good indication of comprehension. Our second research question was to look at the effect that greater word spacing may have on the number and type of errors that might have an impact on comprehension and fluency.

Step one: An analysis of the whole of our student sample. Results are shown in Table 2. A straightforward comparison of raw scores for comprehension showed a difference in mean scores (normal text $M = 5.43$; adjusted text $M = 6.09$, $t(44) = -1.843$, $p = 0.034$, $d = 0.38$) that was statistically significant and showed a moderate effect size. Given that previous studies have found the increased speed with increased inter-word spacing (Marinus et al., 2016), we anticipated a similar finding, however, we found no differences in mean speed (normal text $M = 2.22$, adjusted text $M = 2.20$, $t(44) = 0.136$, $p = 0.445$, $d = 0.03$). There was only one category of error, migrations, that showed a statistically significant difference and moderate to large effect size (normal text $M = 0.59$, adjusted text $M = 0.22$, $t(44) = 2.564$, $p = 0.005$, $d = 0.54$). Of the remaining errors, there was clearly a considerable difference in the number of omissions, for which the numbers were close to significance and showed a moderate effect size (normal text $M = 2.17$, adjusted text $M = 0.96$, $t(44) = 1.644$, $p = 0.051$, $d = 0.36$).

Step two: A comparison of the two groups. Results are shown in Table 3 for the two subsets of the sample. For non-dyslexic readers, there was only a statistically significant difference for the migrations error (normal test $M = 0.40$, adjusted text $M = 0.09$, $t(20) = 1.886$, $p = 0.033$, $d = 0.88$) which occurred with greater frequency in the normal text. For the dyslexic readers, there was a statistically significant difference between the two texts for comprehension, and a moderate effect size (normal text $M = 4.92$, adjusted text $M = 6.40$, $t(22) = -1.691$, $p = 0.048$, $d = 0.48$). Again, there was a statistically significant difference only for the migrations error (normal text $M = 0.75$, adjusted text $M = 0.33$, $t(22) = 1.855$, $p = 0.034$, $d = 0.54$). It is also worth noting that the difference in omissions was close to significance and showed a moderate effect size (normal text $M = 3.46$, adjusted text $M = 1.46$, $t(22) = 1.691$, $p = 0.056$, $d = 0.46$).

When comparing the two groups on comprehension scores for the normal text, the group difference was found to be statistically significant: $t(44) = 1.975$, $p = 0.027$, whereas there was no significant difference for the adjusted text: $t(44) = 1.468$, $p = 0.074$, suggesting that the adjusted text reduced the group differences, and validating the difference between the two groups.

TABLE 2 Mean scores for normal text and adjusted text for student sample.

	Normal text mean (SD)	Adjusted text mean (SD)	*p* value	Cohen's *d*
Comprehension	5.43 (1.91)	6.09 (1.47)	**0.034**	0.38
Speed (words per second)	2.22 (0.52)	2.20 (0.48)	0.445	0.03
Total errors	9.65 (9.19)	7.26 (6.58)	0.079	0.29
Mispronunciations	1.24 (1.82)	0.91 (1.89)	0.201	0.17
Omissions	2.17 (4.35)	0.96 (1.65)	0.051	0.36
Insertions	0.54 (0.91)	0.72 (0.83)	0.171	0.20
Substitutions	2.26 (2.87)	1.67 (2.07)	0.132	0.23
Repetitions	2.13 (1.90)	1.89 (1.55)	0.255	0.13
Corrections	0.93 (1.23)	0.96 (1.33)	0.467	0.02
Migrations (letters and words)	0.59 (0.85)	0.22 (0.46)	**0.005**	0.54

Note: $n = 46$. The bold emphasis indicates statistically significant results.

TABLE 3 Mean scores for normal text and adjusted text in each group (non-dyslexic and dyslexic).

	Non-dyslexic				Dyslexic			
	Normal text mean (SD)	Adjusted text mean (SD)	*p* value	Cohen's d	Normal text mean (SD)	Adjusted text mean (SD)	*p* value	Cohen's d
Comprehension	6.0 (1.74)	6.40 (1.18)	0.183	0.27	4.92 (1.95)	5.79 (1.61)	**0.048**	0.48
Speed (words per second)	2.48 (0.39)	2.42 (0.33)	0.289	0.16	1.97 (0.51)	2.0 (0.51)	0.423	0.05
Total errors	5.5 (4.14)	4.5 (3.11)	0.185	0.27	13.43 (10.87)	9.79 (7.87)	0.096	0.38
Mispronunciations	0.72 (1.63)	0.40 (0.90)	0.215	0.24	1.71 (1.89)	1.38 (2.41)	0.298	0.15
Omissions	0.77 (1.19)	0.40 (0.66)	0.109	0.38	3.46 (5.67)	1.46 (2.10)	0.056	0.46
Insertions	0.36 (0.84)	0.59 (0.66)	0.164	0.30	0.71 (0.95)	0.85 (0.96)	0.326	0.12
Substitutions	1.09 (1.97)	0.86 (1.42)	0.331	0.00	3.33 (3.18)	2.42 (2.32)	0.130	0.32
Repetitions	1.81 (1.59)	1.72 (1.45)	0.422	0.05	2.42 (2.14)	2.04 (1.65)	0.250	0.19
Corrections	0.54 (0.85)	0.45 (0.67)	0.348	0.11	1.29 (1.42)	1.42 (1.61)	0.388	0.08
Migrations (letters and words)	0.40 (0.73)	0.09 (0.29)	**0.033**	0.88	0.75 (0.94)	0.33 (0.56)	**0.034**	0.54

Note: Non-dyslexic $n = 22$; Dyslexic $n = 24$. The bold emphasis indicates statistically significant results.

When students were asked which of the passages of text they found easier to read, 59% of the non-dyslexic students preferred the adjusted text and 79% of the dyslexic students preferred the adjusted text; the remaining participants expressed no preference.

4 | DISCUSSION

The main aim of our study was to explore the impact of increased inter-word spacing on comprehension, fluency (speed) and errors including letter/word migration, on a sample population of students. Our first analysis of the whole sample elicited two statistically significant differences in outcomes between the two texts. Results showed significantly higher scores for comprehension of the adjusted text. There were also significantly fewer migration errors in the adjusted text for the whole sample. Omission errors were also considerably reduced although the numbers did not reach significance. These reduced errors may have contributed to the improved comprehension scores in the sample. In terms of fluency, measured as words per second, the outcomes do not indicate any differences. This was unexpected given the results of our pilot trials and those found in the literature (Marinus et al., 2016), and may be due to the length of the narrative passages to be read—longer passages may have revealed greater differences.

In our second analysis of the two groups, there was no longer a significant difference between the texts for the non-dyslexic students for the passage reading comprehension, but this remained for the dyslexic students. Both groups showed significantly fewer migrations in the adjusted text. These results accord with the findings of Friedmann et al. (2010) showed reduced migrations when words were separated using a word-sized window. The omissions were considerably reduced, although not achieving significance, for the dyslexic group.

Interestingly, the adjusted text appeared to increase the number of insertions in both groups, but more so for the non-dyslexic students. One could speculate that increasing the word spacing for more skilled readers may interfere with their predictive reading skills by inducing the insertion of semantically plausible additional words.

In the whole sample and both subsets, we found lower numbers of mispronunciations and substitutions in the adjusted text, although this was not significant. Fewer corrections were made by the non-dyslexic subset in the adjusted text, but interestingly the reverse was found for the dyslexic students. One could speculate that the increased word spacing allowed the dyslexic participants the opportunity to become aware of their errors; this could possibly have reduced their speed (words per second) but have contributed to greater understanding. It is of course possible that benefits only apply to a subset of dyslexic students.

When asked which text they found easier to read, the majority of the whole sample chose the adjusted text, with more of the dyslexic group expressing this preference. The combination of an easier read and better comprehension using the adjusted text for students with dyslexia, we feel is an important finding.

In conclusion, we found that for this sample of dyslexic students, the adjusted text led to a reduction in errors and improved comprehension. It is not within the scope of this small exploratory study to determine why the increased inter-word spacing reduced migration and other errors and improved comprehension. One possibility is that the increased inter-word spacing makes it easier to delineate words as suggested by Marinus et al. (2016). Another possibility is that it allows time to disengage visual attention for readers with 'sluggish' disengagement of visual attention (Fu et al., 2019; Liu et al., 2018). It may be that research using eye-tracking technology could shed light on the impact of increased inter-word spacing. However, the fact that these effects were observed may nonetheless have implications for researchers and teachers, and potentially also for exam boards and publishers. In practical terms, this inter-word spacing adjustment is very simple to achieve and could have real benefits to many readers.

We emphasise the preliminary nature of this work which is based on a relatively small sample size, for this short report of early results. We acknowledge that as a small sample any conclusions must be treated with caution. It is also important to acknowledge that our sample of students, and, in particular, those with dyslexia, may well have well-developed compensatory strategies for reading aloud that, for example, a sample of dyslexic primary children would not yet have. Nevertheless, we feel that the results from this small exploratory study would justify a largerscale study in the future and hope that this study will encourage further work to investigate the suggested possible visual aspect of dyslexia further.

CONFLICT OF INTEREST STATEMENT

No conflict of interest.

DATA AVAILABILITY STATEMENT

Author elects to not share data. Research data are not shared.

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