Contrast and font affect reading speeds of adolescents with and without a need for language-based learning support

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This pre-study investigates the effects of the font type and the contrast between the colour of the text and the colour of the background on the reading speed of readers a) with different age groups and b) with a different need for language-based learning support using state-of-the art eye-tracking technology. We determine no significant difference between participants who were or were not receiving learning support (special support with a specialist teacher) due to language-based reading disabilities when reading the font type Open Dyslexic. This suggests that this font increases the reading speed of participants who receive learning support for language-based learning disabilities. Comparison of the reading speed for different passages of text displayed in different colour combinations indicates that a contrast of light text on a dark background may improve reading ability and reading performance. Both of these findings have significant implications for foreign-language teaching.

KEYWORDS: *eye-tracking, font type, colour contrast, reading speed, reading comprehension, learning support, language-based learning disabilities*

1. INTRODUCTION

Reading is a key linguistic competency that is required to obtain information and participate in cultural life (Perfetti, 2013). All educational processes are based on reading and being able to decode information encoded in text independently. The ability to read as a linguistic competency must be explicitly taught and practised to a great extent, as there is only limited evidence to suggest that humans are biologically predisposed to become literate (Böttger, 2016, p. 139-140). Reading ability plays a particularly significant role in success in school for learners with dyslexia, which has a negative effect on the literacy acquisition in learners of average intelligence (Gallego et al., 2011). Around 5% of school pupils are affected by dyslexia (Snowling, 2000; Shaywitz, 2003). Zorzi et al. (2012) for example, referencing Cunningham and Stanovich (1998), note that children with dyslexia read as many words in a year as children without dyslexia do in two days. They go on to state that is it

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incredibly important to get children with dyslexia to read more in a shorter period of time in conditions of EBD (Emotional Behavioural Disorder) in order to ensure that they are able to access information. Reading speed is less dependent on the type or genre of text and more on the difficulty of the content and the complexity of the surface structure (e.g. syntax) (Eysel, 2011, p. 355). In a school context, learners who require linguistic support are therefore given special support in the form of specific programmes and measures to compensate for disadvantages – not only in their native language. They also require support to promote their ability to read and understand English texts in a foreign language teaching context, since proficiency in the *lingua franca* of English is crucial in many situations, such as in order to read scientific publications.

One aspect of reading ability is the connection between reading speed and reading comprehension. This can be promoted through targeted educational measures, such as providing individual learning support, but could hypothetically also be facilitated by altering teaching and learning materials, a method that has not yet been thoroughly researched (Zorzi et al., 2012, p. 11455). Two areas that are of interest to research in this context – but have received little attention to date – are the relationship between reading speed and font type, and the relationship between reading speed and colour contrast. In our literature review, we identified only a small number of studies that investigated reading in the context of learning rather than in the field of marketing. In the latter context, Frey et al. (2013), for example, focused on targeted information seeking during the reading of texts with the aim of co-registering eye tracking measurements and EEG (Electroencephalography) signals. Zhao et al. (2014) studied reading strategies for understanding combinations of text and images and show that texts are very important for pupils in order to construct mental models (Zhao et al., 2014, p. 46).

In the context of dyslexia, various recommendations exist for a preferred font. The British Dyslexia Association has developed a comprehensive style guide that recommends the use of fonts such as Arial, Comic Sans, or Verdana (www. bdadyslexia.org.uk). What all of the recommended fonts have in common is that they are sans-serif, which suggests that the British Dyslexia Association considers serifs a potential hindrance to the reading process. Wilkins et al. (2007) suggest that the additional lines of the serifs increase the visual stress created by the vertical and horizontal lines that make up a letter.

Furthermore, studies by Cornelissen et al. (1991) and O'Brien et al. (2005) show that people with dyslexia have problems recognising individual letters when the distance between them is too small. Increasing the distance between letters

therefore leads to improved reading accuracy and faster reading speed among these readers (Zorzi et al., 2012, p. 11457). Beymer et al. (2008) investigated how font size and font type affect reading performance when reading text from a computer screen. They obtained remarkable results for the serif font Georgia in comparison to sans-serif font types. The participants in their study read Georgia almost 8% faster than the sans-serif font (Helvetica). However, overall this result was not statistically significant. The authors state that the versions with and without serifs are visually very similar, so the non-significant result is unsurprising (Beymer et al., 2008, p. 17). They do not provide any further interpretations of the result. However, in the discussion they note that the result could be due to differences in the native languages of the study participants, as significantly longer fixations and shorter saccades were measured for participants who did not state English as their native language compared to those who did. Rello and Baeza-Yates (2013) were unable to determine any significant difference in the reading speed of people diagnosed with dyslexia for serif and sans-serif fonts. They summarise that the font has an effect on overall readability, but they do not specify how strong this effect is. In their study, they determined a significantly faster reading speed for texts in sans-serif, non-italic, mono-spaced fonts in comparison to texts in serif, italic, proportional fonts. Although Arial is often recommended, for example by Evett and Brown (2005), Rello and Baeza-Yates (2013), studies are unable to confirm its suitability. They deduce from their results that people with dyslexia are able to read Courier and Helvetica faster. Their results support those of a study by De Leeuw (2010), who did not identify any effects on readability when the font Open Dyslexic is used. Furthermore, the participants with reading difficulties in the study by Rello and Baeza-Yates (2013) stated that they preferred Verdana or Helvetica over Open Dyslexic, a font that was designed especially for people with reading difficulties.

The statement that a larger font size may increase reading speed is contradicted by various recommendations including Wilkins et al. (2007) and Rello et al. (2012). With regard to colour contrast, Gregor and Newell (2000) emphasise that this is particularly significant for people with dyslexia. For example, coloured transparent overlays that can be placed over black text printed on white paper are available for people with dyslexia. It is generally suggested that the combination of black text on a white background should also be avoided on websites. In addition, the study by Rello et al. (2012), in which people with dyslexia were presented with different combinations of text and background colour, shows no beneficial effect on reading when grey backgrounds are used. The most successful colour combination was cream-coloured text on a black background.

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2. MATERIALS AND METHODS

2.1 Testing instruments

The aim of the pre-study was firstly to determine the effects of the font type on the reading speed of readers (a) with different age groups and (b) with different need for language based learning support and in a second step to determine the effects of the contrast between the colour of the text and of the background on the reading speed of readers (a) with different age groups and (b) with different need for language-based learning support.

The data used for the study were collected between December 2016 and January 2017 through field research carried out under laboratory conditions at the Franconian International School in Erlangen, Germany, and at the English Didactics department at the Catholic University of Eichstätt-Ingolstadt.

The technical equipment used consisted of the high-performance MangoldVision Software Package© with an eye tracker, eye tracking project manager, and accompanying data analysis software.

We selected excerpts from the novel Robin Hood as the basic texts for our study. We adapted selected passages on the archery competition for pupils from different grades who were assigned to three different proficiency levels. The excerpts that we used were taken from the textbook *The New Green Line 5* and from the version of the novel by Gina Clemens. Our changes were focused not on potential linguistic barriers (cf. pupils' years of experience learning the language) but on adapting the syntactic structure and the number of words. As the learners in 12th grade were being taught at level C1/ C2 of the Common European Framework of Reference for Languages and higher, they were assigned to the same group as university students and adults.

The three versions of the text (for 6th grade pupils, 8th grade pupils and 12th grade students/adults) consisted of four paragraphs of almost identical length (± 3 words). Each of these paragraphs was written in a different font: one each in Times New Roman, Arial, Courier, and Open Dyslexic. The fonts were chosen on the basis of the studies described above, as well as the fact that the frequency of their use is high. When selecting the fonts we also took care to include both serif and sans-serif fonts in addition to Open Dyslexic, a font that was designed especially for people with dyslexia.

To randomise the study, we created two different versions of each text in which the order of the fonts varied. As this was a pre-study with a small sample, we decided not to create further randomised versions in order to avoid decreasing the number of participants who read each different version even further.

We also developed comprehension questions on the text for each group that could not be answered on the basis of general knowledge of *Robin Hood* alone. The purpose of this was to allow us to contrast the reading speed with reading comprehension.

In addition, for each group and for each font we created two further passages of text in two different contrast combinations: yellow text on a black background and black text on a cream-coloured background. We chose these colour combinations as they were identified most frequently in the study by Rello et al. (2012).

Here we also created different variations of the text passages in which different parts of the text for each age group were shown in different contrast combinations for the purposes of randomisation. We decided not to create additional colour combinations due to nature of the pre-study design with its small sample. We also developed a set of comprehension questions on these passages according the same principle as above. These were used to create several questionnaires for each group in which the order of the questions varied.

Finally, we uploaded all of the files that we had created to the Mangold Project Manager©. Here we marked the passages in different fonts as one stimulus and the passages with different contrasts as another stimulus.

2.2 Participants

The sample consisted of 47 participants. Of these, 16 were pupils in the 6th grade, 12 were pupils in the 8th grade, and 19 were pupils in the 12th grade (students or adults).

Originally 50 people were recruited for the experiment, but as it was not possible to calibrate the equipment properly for three participants, data was only obtained for 47.

The composition of the different age groups included in this pre-study was as follows.

The native language of the majority of the pupils who participated in the experiment was German (N=19). A further eight were bilingual, while five participants had English as their native language. The pupils who had learned English as a second or foreign language had been learning the language for an average of 7.41 years (*SD – standard deviation* – 1.32) in the 6th grade group, 8.75 years (SD 1.09) in the 8th grade group, and 10.5 years (SD 0) in the 12th grade group. Because the learners were attending an international school where classes were taught in English, and due to the number of years that they stated they had been learning the language for, it can be assumed that the L2 learners in each age cohort had native-speaker level English proficiency.

Differentiating the participants by their learning

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support status results in the following groups: Nine of the pupils were receiving learning support from the school and were classified as having reading difficulties/dyslexia (6th grade *N*=3, 8th grade *N*=1, 12th grade *N*=5). This means that these learners were participating in a special support programme at the school that aimed to improve their reading abilities. All learners were officially tested for their need for learning support in order to officially be given this status by the school.

The remaining 15 participants were students of English from the university and teachers from the school, and had an average age of 41.33 years (SD 10.86). Seven of the adults stated that they had learned English as a native language either monolingually or bilingually. The students and teachers with English as a second or foreign language had been learning English for an average of 16 years (SD 7.29). The number of years that those with English as an L2 had been learning the language means that it can also be assumed that the participants in the adult/ student group all had a comparable level of proficiency.

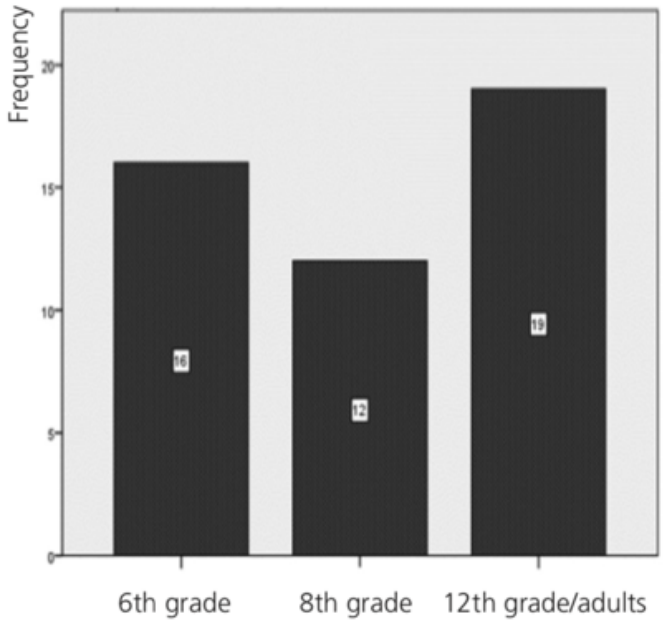

Figure 1. Participants by age group

2.3 Experimental procedure

After the participant had provided consent to participate in the experiment (with parental consent in the case of the pupils), the Mangold Player© was started on a laptop, with the desktop also displayed on an additional screen for the participant. The participant was then allocated an ID. The Mangold Eye Tracker©, which was

attached to a bracket under the participant's screen, was subsequently adjusted exactly to complete the calibration. Through calibration the eye tracker was set to the position of the participant's eyes/ pupils while he or she looked at specified points on the screen. It was necessary to recalibrate the eye tracker in some cases, sometimes multiple times. Once suitable values, which were displayed in a green area in the Mangold Player©, had been reached, the data collection was initiated. First the participant was shown written information on the test design. Then the part of the test using different fonts began (independent variables: age, learning support status/dependent variable: text versions). The participant's task was to read the text once and give the experimenter a signal once he or she had read the text in full. While the participant was reading the Mangold Eye Tracker© recorded the eye movements.

As soon as the participant had finished reading the text once, he or she was asked the comprehension questions that he or she had been told to expect. The participant was then asked to rank the different fonts according to which was the most pleasant to read.

After this the part of the test using the different colour contrasts began. The font that was rated as the most pleasant before was the font in which the subsequent two passages with different colour contrasts were shown. As this was a pre-study, no other fonts were presented in different contrasts.

The participant was then asked further comprehension questions. Finally, the participant's demographic data were recorded.

3. STUDY AND RESULTS

3.1 Software and samples

As the Mangold Vision Player© had divided the screen into sections using an x/y coordinate system while data was being collected and transferred the position of the participant's pupils that was determined during calibration to all other movements, we were able to use the Mangold Vision Analyzer© to analyse the data for each time unit. In order to obtain exact information on how long a participant spent looking at a particular point on the screen, it was necessary to define areas of interest (AOIs). We placed an area of interest (AOI) over each line of text in the Mangold Vision Analyzer© to allow us to determine the amount of time each participant spent looking at the line. The Analyzer calculates the amount of time that the gaze is directed at the AOIs that have been determined. When creating the AOIs, we ensured that each AOI was identical in size by copying and pasting the marking over the text each time. This allowed us to determine the amount of time participants spent reading each individual line. We then calculated the means for each font type and each colour contrast using the

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statistics program SPSS, Version 24 (SPSS Inc., Chicago, USA). We used this data as the basis for further statistical analysis. Due to the small sample in this pre-study, we used mean values as the basis for our data analysis because the conditions for multivariate analysis methods were not sufficiently fulfilled; however, MANOVA and multiple regression analysis point to the same relationships/differences.

3.2 Font types

3.2.1 Calculations

In order to determine the effects of font on reading speed, in this pre-study we made calculations on the basis of age group. The results show that Open Dyslexic font was read significantly faster than the others. The participants spent an average of only 3.2 seconds reading this area of text. By contrast, they required 6 seconds for both Arial and Courier. They required the longest amount of time to read Times New Roman, with an average of 7 seconds. This indicates that although the same amount of text was shown in each font, the participants processed the text displayed in Open Dyslexic significantly faster. They required twice as long for the fonts Courier and Times New Roman as they did for Open Dyslexic, which indicates a clear and significant difference in reading speed.

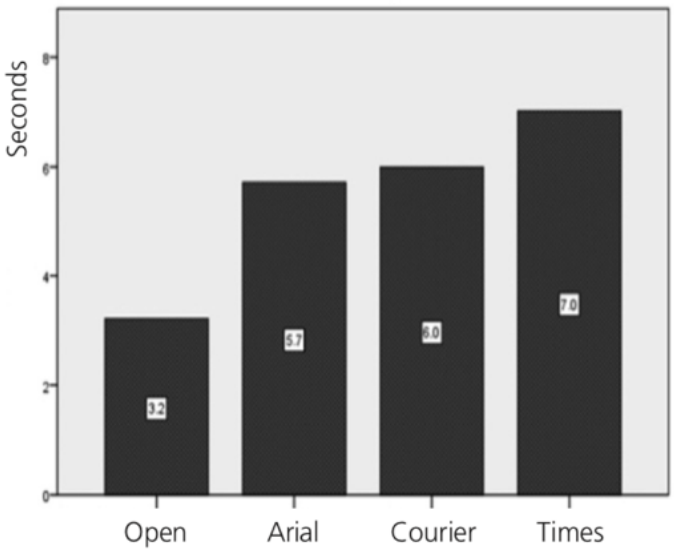

Figure 2. Average reading speed by font

If Open Dyslexic allows to understand the same amount of content while doubling reading speed in comparison to when Times New Roman and Courier – two quite common fonts – are used, it may be more suitable in teaching contexts, such as in textbooks, than the current standard fonts.

3.2.2 Reading speed according to font and age group

To examine these assumptions more closely, we analysed our results on the basis of age group. The following figure shows that Open Dyslexic was read the fastest by all age groups. On average, the font that the participants in the 6th grade group and the 8th grade group required the longest amount of time to read was Times New Roman, while the group of 12th grade pupils and adults appeared to have the most difficulty processing Courier.

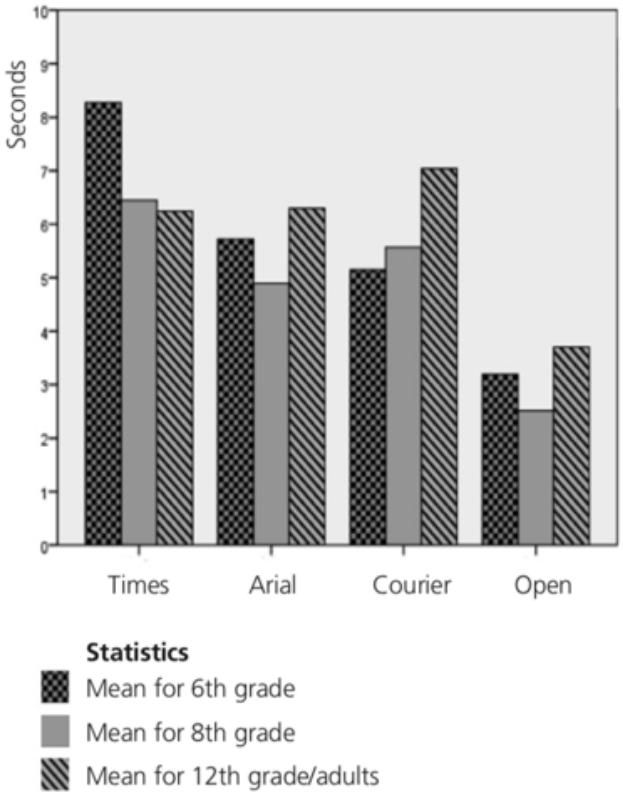

Figure 3. Average reading speed by font

The 6th grade group was the slowest at reading Times New Roman (>8 seconds). The group of 12th grade pupils and adults was the slowest for Arial (>6 seconds) as well as Courier.

These participants were also the slowest at reading Open Dyslexic. It is striking that the oldest group was only the fastest for Times New Roman and was the slowest on average for all other fonts. This is surprising, as the 12th grade pupils and adults are the most experienced readers. A possible explanation could be the higher difficulty level of the texts, despite the fact that they were designed for this age group.

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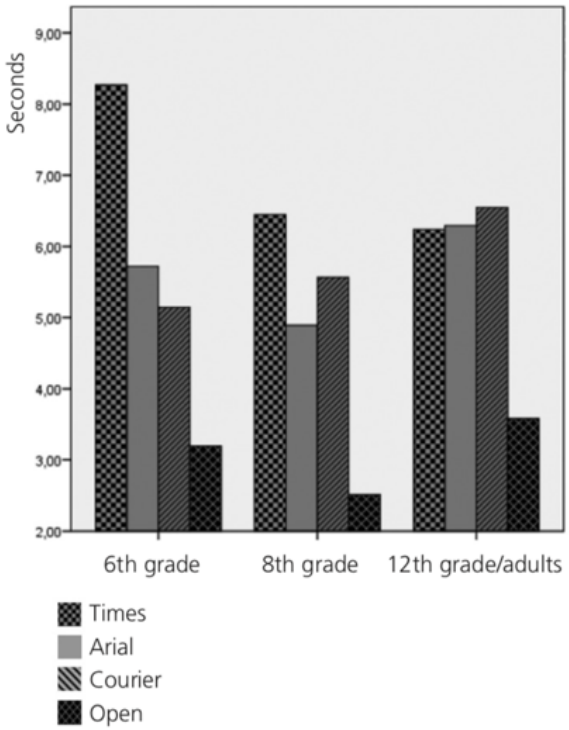

Figure 4. Average reading speed by age group

The figure above shows that Open Dyslexic was read the fastest by all age groups by a considerable margin. Participants required an average of between 2.5 and 3.5 seconds to read Open Dyslexic, while it took them between 6 and 8.2 seconds to read Times New Roman. In the group of 12th grade pupils and adults there was almost no difference in reading speed between the commonly used fonts Courier, Times New Roman, and Arial, but a highly significant difference for Open Dyslexic. The younger the children, the larger the differences in average reading speed between different fonts.

This suggests that people become accustomed to commonly used fonts during their time at school and there is therefore no statistically demonstrable relationship between font and reading speed for the 'standard' fonts. The diagram shows that the reading speeds for different fonts become increasingly similar as pupils progress through the grades. The uncommon font Open Dyslexic is a significant exception here as it is processed twice as quickly.

3.2.3 Reading speed according to font and need for learning support

Our sample can also be broken down into participants who require learning support and participants who do not.

Open Dyslexia was designed specifically for people who require learning support in

reading, and our analysis indicates that the difference in reading speed between people who do and do not require learning support is smallest for this font. As the following figure shows, the participants who required learning support were slower than those who did not when reading all four fonts:

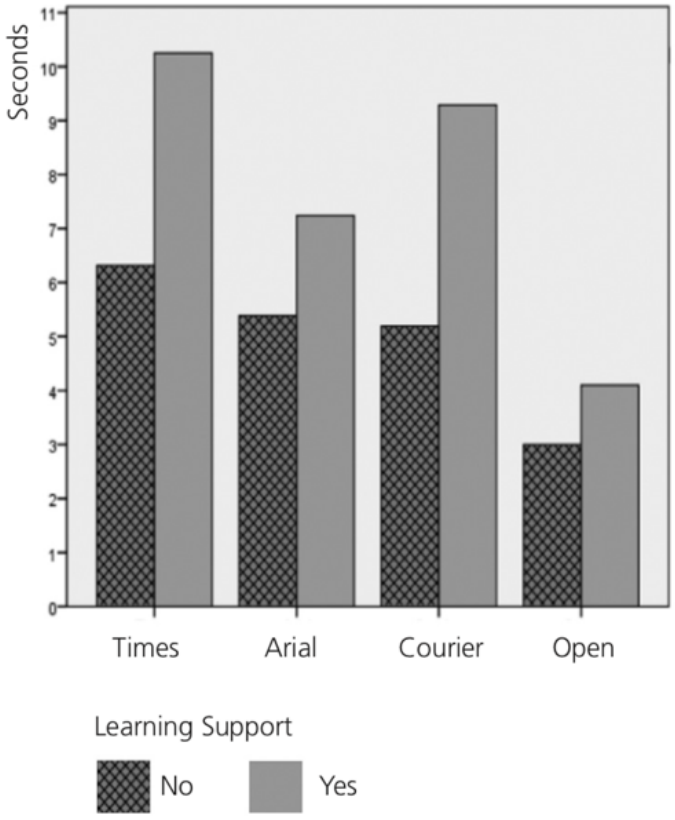

Figure 5. Average reading speed by font and need for learning support

The difference in the average amount of time taken to process the text is 4 seconds for Times New Roman and Courier and 2 seconds for Arial, while for Open Dyslexic it is only one second.

It must be taken into consideration that the passages of text were relatively short; for a text of this length, a difference of 4 seconds is statistically relevant.

To reinforce the results in spite of the small sample size, we examined the reading speeds for each font in more detail according to the age of the participants and whether or not they require learning support, and determined that those who require learning support achieved significantly slower reading speeds. The younger the participants, the larger the difference is for all four fonts. With increasing age, the difference becomes

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smaller. In light of this, Open Dyslexic stands out because from the 8th grade onwards participants who require learning support were in fact faster at reading this font than those who do not.

This supports the assumption that using Open Dyslexic in inclusive settings promotes the performance of pupils who do and do not require learning support.

These findings are based on the following statistics (Table 1):

Table 1

Average reading speed by font and need for learning support

INCLUSION	GRADE			TIMES	ARIAL	COURIER	OPEN
No	6	N	Valid	13	13	13	13
			Missing	0	0	0	0
		Mean		7.0481	5.5173	4.7415	2.5713
		Median		5.9300	5.3800	4.6050	2.5600
	8	N	Valid	11	11	11	11
			Missing	0	0	0	0
		Mean		6.1891	4.9245	5.5773	2.5755
		Median		5.6200	4.6450	5.4400	2.4600
	12	N	Valid	13	13	13	13
			Missing	1	1	1	1
		Mean		5.6969	5.6477	5.3233	3.7892
		Median		6.1700	5.2100	4.6300	3.6400
Yes	6	N	Valid	3	3	3	3
			Missing	0	0	0	0
		Mean		13.5767	6.6050	6.8883	5.8883
		Median		13.8500	6.7000	7.3850	6.7750
	8	N	Valid	1	1	1	1
			Missing	0	0	0	0
		Mean		9.2800	4.5500	5.4550	1.8250
		Median		9.2800	4.5500	5.4550	1.8250
	12	N	Valid	4	4	5	5
			Missing	1	1	0	0
		Mean		8.0012	8.3900	11.4950	3.4830
		Median		8.2500	8.4750	12.8800	3.1400

The findings on the next page are based on these statistics (Table 2):

Table 2

Average reading speed by contrast and need for learning support

INCLUSION	GRADE			CONTRAST 1	CONTRAST 2
No	6	N	Valid	13	13
			Missing	0	0
		Mean		2.2328	2.2902
		Median		2.0270	2.1400
		Standard deviation		.76817	.80989
	8	N	Valid	11	11
			Missing	0	0
		Mean		1.6321	1.6269
		Median		1.6020	1.5180
		Standard deviation		.31172	.57596
	12	N	Valid	12	12
			Missing	2	2
		Mean		2.5183	2.1703
		Median		2.6688	2.1163
		Standard deviation		.98990	1.37334
Yes	6	N	Valid	3	3
			Missing	0	0
		Mean		2.9143	3.5300
		Median		2.8170	3.5300
		Standard deviation		.94377	.42700
	8	N	Valid	1	1
			Missing	0	0
		Mean		1.8750	1.4730
		Median		1.8750	1.4730
	12	N	Valid	5	5
			Missing	0	0
		Mean		3.0112	2.9748
		Median		3.2540	2.7000
		Standard deviation		.46246	.97693

3.3 Contrast

In this study we use the term 'contrast' to refer to the difference between the colour of text and the colour of background, whereby one is light and the other is dark.

We created two additional passages of text for each group and for each font in the following contrast combinations: black text on a cream-coloured background (Contrast 1) and yellow text on a black background (Contrast 2) (cf. 1.2).

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The results for reading speed according to contrast and age showed that the normal contrast, Contrast 1 (dark text on a light background), was only processed faster than Contrast 2 (light text on a dark background) by the 6th grade pupils. The other age groups processed Contrast 2 faster. This applied to both participants who required learning support and those who did not. We did not identify any other trends.

Our results indicate that with increasing age a non-standard contrast of light text on a dark background (Contrast 2) leads to improved reading speed.

The 12th grade participants who do not require learning support required an average of 2.5 seconds to read a passage of text in Contrast 1, while they only required 2.1 seconds for a passage in Contrast 2.

The differences in speeds are significantly smaller in the lower grades. Participants who required learning support found it easier to read Contrast 1 in the lower grades, while Contrast 2 appeared to be easier for those who required learning support with increasing age.

The 6th grade participants required an average of 2.9 seconds for the passage in Contrast 1 and 3.5 seconds for the passage in Contrast 2. In comparison, the 12th grade participants required almost the same amount of time for Contrast 1 (3 seconds) as for Contrast 2 (2.9 seconds). The majority of participants stated that their preferred contrast was the familiar contrast (dark text on a light background).

4. DISCUSSION

4.1 Font types

The data obtained in this pre-study allow us to identify various tendencies that require further verification for individual variables in a study with a larger number of participants.

The results show that differences in reading performance can be reduced, at least to some extent, by using the font Open Dyslexic, as participants who required learning support found it much easier to read this font than the common fonts Times New Roman, Courier, and Arial. Participants who required learning support processed Open Dyslexic three times faster than Times New Roman. In this regard, their performance was almost identical to that of participants who did not require learning support. This means that using this font could promote equal opportunities in inclusive settings.

However, Open Dyslexic appears to be advantageous not only for people who require specific learning support but also for those who do not. The participants without a language-based learning disability were also able to read this font

much quicker with the same level of comprehension. What is surprising here is that, unaware of this data and the increase in their reading speed, the participants who did not require learning support did not respond well to this font. It ranked last in the list of their preferred fonts. By contrast, the participants who required learning support were strongly in favour of this font, ranking it among their preferred fonts.

As the experiment shows, a familiarisation effect occurs with the commonly used fonts, leading to the reading speed for each font becoming increasingly similar over time and resulting in the font in which a text is displayed being of almost no relevance any longer.

The very small sample size as mentioned before, which is weakened further by the randomisation, should be considered critically. In further studies the sample should be increased in size and ideally tested in series.

Furthermore, it could be suggested that although the participants were able to read the text faster, they may have understood or internalised it to a lesser extent. For this reason, we asked the participants questions on the individual passages of text. To ensure that the reading speed did not affect comprehension, we only included data for a passage if the participant had answered the questions correctly. In addition, we ensured that none of the fonts were associated more frequently with more difficult passages than others by randomising the experiment.

Our evaluation of participants' comprehension showed no significant differences between the different fonts, providing further evidence to suggest that Open Dyslexic can indeed be read faster with the same level of retention and comprehension.

4.2 Contrast

These data from our pre-study also indicate tendencies that require verification in another study. Our analysis of the data for the different contrasts showed no empirically significant differences in reading speed. The differences described above may be due to chance. This is mainly due to the very small sample size — for example, only one pupil who was receiving learning support in the 8th grade — and the very short text, which consisted of only a few lines. Due to the length of the text, the differences here are in the range of mere milliseconds (1.632 compared with 1.626 seconds). The sample size and the length of the passage of text would have to be increased considerably in order to obtain more meaningful and statistically relevant results.

5. CONCLUSION

Although Open Dyslexic was unfamiliar to and unpopular with the majority of the participants,

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our findings regarding the reading speeds for this font were remarkable (up to three times faster than for others). It appears to be especially advantageous for students who require language-based learning support. Further investigation into the possibility of using it systematically and consistently in the context of education is therefore required. We may suggest on the basis of our findings that a contrast of light text on a dark background could improve reading ability and reading performance. Indeed, this combination is already used in certain situations, such as in the presenter view in Microsoft PowerPoint and increasingly in the design of the slides themselves. Our data provide support for a shift in this direction. While it would be necessary to repeat the experiment with a much larger number of participants in order to draw empirical conclusions, our findings provide initial indications that are of significance for educational contexts.

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