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MASTER THESIS

Reading performance of dyslexics with a special font and a colored background

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Does reading performance of dyslexics improve with a special font and/or a colored background?

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Abstract

This research examined if the reading performance of dyslexics and non-dyslexics was positively affected by the adaptation of background color and font. Using a light yellow background could have a positive influence on reading performance in comparison with a white background. Also, the font Dyslexie was compared with the font Arial. According to the magnocellular theory the adaptation of these visual elements can improve the reading performance of dyslexics and non-dyslexics. Measurements of reading performance were speed and accuracy. Twenty-two dyslexics and forty-two non-dyslexics with a lower and higher reading level participated in this study. Every child read four different texts with the following color-font combination: Yellow-Dyslexie, White-Dyslexie, Yellow-Arial and White-Arial.

For reading accuracy an interaction was found of the color yellow and the font Dyslexie for dyslexics with a lower reading level. Findings also showed a positive main effect of the font Dyslexie with the reading accuracy for the total group of dyslexics and for dyslexics with a lower reading level. Further research is needed to fully explore the role of background color and level of prior knowledge between dyslexics with a lower and higher reading level and the influence on reading performance. Practical implication could be the implementation of the color yellow and the font Dyslexie for dyslexics with a lower reading level.

Samenvatting

Dit onderzoek analyseerde of de leesprestatie van kinderen met en zonder dyslexie positief zou worden beïnvloed door de aanpassing van achtergrondkleur en lettertype. Het gebruik van een lichtgele achtergrond zou een positieve invloed kunnen hebben op de leesprestatie in vergelijking met een witte achtergrond. Het lettertype Dyslexie werd vergeleken met het lettertype Arial. Volgens de magnocellulaire theorie kan de aanpassing van deze visuele elementen de leesprestatie van dyslecten en niet-dyslecten verbeteren. Metingen van de leesprestatie waren leessnelheid en de accuratesse. Tweeëntwintig dyslecten en tweeënveertig niet-dyslecten met een lager en hoger leesniveau hebben deelgenomen aan dit onderzoek. Elk kind heeft vier verschillende teksten gelezen met de volgende kleurlettertype combinatie: Geel-Dyslexie, Wit-Dyslexie, Geel-Arial en Wit-Arial.

Voor accuratesse is een interactie gevonden van de kleur geel en het lettertype Dyslexie voor dyslecten met een lager leesniveau. De bevindingen lieten ook een positief hoofdeffect zien van het lettertype Dyslexie bij de accuratesse voor de totale groep dyslecten en voor dyslecten met een lager leesniveau. Verder onderzoek is nodig om volledig te onderzoeken wat de rol van achtergrondkleur en het niveau van voorkennis is tussen dyslecten met een lager en hoger leesniveau en de invloed hiervan op de leesprestatie. Praktische implicatie kan de implementatie zijn van de kleur geel en het lettertype Dyslexie voor dyslecten met een lager leesniveau.

Introduction

One of the most common learning disorders in children is developmental dyslexia. The prevalence of developmental dyslexia has been estimated at 4 – 10 % (Castles, Mclean & Mcarthur, 2010) and also at 5 – 17.5 % (Démonet, Taylor & Chaix, 2004). In the Netherlands the commission Dyslexia Health Council estimates the percentage of pupils with severe dyslexia around 3%. In addition, there is a larger percentage with less severe dyslexia (Braams, 2002).

There are different definitions of developmental dyslexia. For example, the definition of the Diagnostic and Statistical Manual of Mental Disorders [DSM] IV (DSM IV, 1994 in Essential Learning Institute, 2012) is as follows: 'Reading achievement is substantially below that expected given the person's chronological age, measured intelligence and age-appropriate education. The disturbance significantly interferes with academic achievement or activities of daily living that require reading skills. If a sensory deficit is present, the reading difficulties are in excess of those usually associated with it.' The definition used by the International Dyslexia Association [IDA] (Lyon, Shaywitz & Shaywitz, 2003) is: 'Dyslexia is a specific learning disability that is neurobiological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge.'

These definitions show that children with dyslexia have difficulty with reading. Children with dyslexia make more reading errors and they need more time to read something than children without dyslexia. As a result, they often experience less pleasure in reading (Braams, 2002). The current study investigates the effect of a colored background and a special font to achieve a better reading performance. To understand and deal with this it is important to look at the underlying theories about the potential causes of dyslexia.

Theoretical background

Phonological deficit theory. At an early age children learn phonological or non-lexical reading skills, this is the knowledge of the sounds of letters (Mayer, 2008). Children need these skills for reading new and unfamiliar words. The acquisition of these skills in children

with dyslexia is affected by phonological deficits. A phonological deficit is a lack of the ability to represent, store or retrieve speech sounds. This makes it difficult for children to learn associate sounds with their corresponding letters when learning to read in an alphabetic system (Castles et al., 2010).

Auditory processing deficit theory. Connected to phonological deficits is the auditory processing deficit theory. This theory suggest that children with developmental dyslexia are born with an impaired ability to process non-speech and speech sounds. According to Castles et al. (2010) this causes atypical neural representations of phonemes which impairs the acquisition of non-lexical reading skills. According to this theory phonological problems are secondary to the auditory deficits (Heim et al., 2008). Besides theories about phonological and auditory processing several researchers claim that dyslexia is due to a visual processing deficit of the magnocellular system.

Magnocellular deficit theory. The magnocellular deficit theory assumes an impairment of the visual transient system in dyslexics. This leads to impaired sensitivity for low contrast (Lovegrove, Bowling, Badcock & Blackwood, 1980 cited in De Jong et al., 2009) or coherent visual motion (Stein & Walsh, 1997). The magnocellular system is responsible for determining the location of objects, the 'where' stream (Ray, Fowler & Stein, 2005; Stein, 2003; Talcott, Hansen, Willis-Owen, McKinnell, Richardson & Stein, 1998).

Research of Boets, Wouters, Van Wieringen, De Smedt and Ghesquière (2008) showed that visual processing is related to orthographic skills. Orthographic or lexical skills are the ability to recognize words as whole units. These skills are necessary for reading fluency (Castles et al., 2010). The magnocellular system plays an important role in the development of orthographic skills. This role probably exists of a steady direction of visual attention and eye fixations on words (Stein, 2003). So an important function of the magnocellular system is to help control eye movements (Stein, 2003; Stein & Walsh, 1997). With dyslexics this function is impaired and might cause problems with fixation. Letters might then appear to move around and this in turn causes visual confusion (Stein, 2003; Stein & Walsh, 1997). Especially with reading small letters their vision is unstable. Visual reading errors are made less when dyslexics are given larger letters. Also less visual reading errors are made when one eye is occluded. Reading with one eye ensures less confusion from independently moving images (Stein, 2003; Stein & Walsh, 1997). A common visual reading error of dyslexics are reversals (Stein & Walsh, 1997; Terepocki, Kruk & Willows, 2002).

This study focuses on this theory in how the adaptation of visual elements can help to improve the reading performance of dyslexics. In several studies reading performance tends to be better with the use of color.

Use of color with reading

Since it is known that the magnocellular pathway is the visual system for text perception many research has focused on the use of color and its influence on reading performance. Results from several studies show that the use of colored filters or overlays improves reading (Chase, Ashourzadeh, Kelly, Monfette & Kinsey, 2003; O'Connor, Sofo, Kendall & Olsen, 1990; Ray et al., 2005; Smith & Wilkins, 2007; Stein, 2003; Waldie & Wilkins, 2004). Research of Ray et al. (2005) and Stein (2003) shows that children with reading difficulties who had worn a yellow filter improved in accommodation and convergence. Also their motion sensitivity was lowered and their contrast improved. In addition to the use of filters the use of overlays or transparencies is tested. Using a colored overlay ensures that children's reading speed improves. To achieve this Waldie and Wilkins (2004) found that the overlay has to cover the entire text. According to Chase et al. (2003) and O'Connor et al. (1990) the use of colored transparencies also improves reading accuracy and comprehension.

Research has also focused on the use of color while reading from computer screens. Buchner, Mayr and Brandt (2009) say that reading text from computer screens is better when text is printed in dark letters on a light background. Their research shows that text is more readable when the overall display luminance is high. Scharff, Ahumada and Hill (1999) used black letters on different background colors at two intensities to test reading speed. They found that text on a light yellow background read faster than text on a light gray or light blue background. Wu and Yuan (2003) also studied the effect of color on reading speed. To improve reading speed the foreground, the text, should be darker and the background should be lighter. Best results were black on green and black on yellow (Wu & Yuan, 2003). It is striking that the worst results came from black on white while this is used in everyday life.

Less research has been done about the use of colored paper such as colored texts or backgrounds. One suggestion about the use of color is to print difficult letters in color (Altschuler, Altschuler, Altschuler, Samber & Ramachandran, 2007). Printing the difficult letters in color could make it easier to read these letters and therefore reading speed could increase. Several studies indicate that when using colors on paper the background color must be a light shade. For example Tinker and Paterson (1963, in Bloodsworth, 1993) found that

contrast of brightness between print and paper is important. Therefore dark ink on lightly tinted paper is the best legible combination when using colors. This was also found by Bix, Lockhart, Cardoso and Selke (2003). They examined different color combinations to be most legible. The best reading results was black letters on a white background. The next best result was with blue letters on a yellow background. These colors had the highest contrast of colors and luminance level.

Fonts

Another way of improving reading performance is by adjustments in the font. Several researchers say that a font affects the reading performance. An important difference in fonts is whether or not they have serifs (Coronel-Beltrán & Alvarez-Borrego, 2010). A serif is a horizontal line at the end stroke of a letter (Bernard, Chaparro, Mills & Halcomb, 2003; Lockhead & Crist, 1980). See Figure 1 for serif and sans serif letters. A well-known serif font is Times New Roman and a well-known sans serif font is Arial.

Figure 1. Letters with serif and sans serif

It is said that the use of serifs is not only ornamental but also functional. Serifs could help distinguish letters and therefore can help reading (Arditi & Cho, 2005; Bernard et al., 2003). Research into the effects of serif and sans serif fonts shows different outcomes. Arditi and Cho (2005) found that reading with their own made serif font had stronger effects on the legibility of the text than reading without serifs. The same results were found in studies of Bernard et al. (2003) and Lockhead and Crist (1980), they found that reading without serifs was slower. While performance was worse, the overall preference of the participants was for the use of sans serif font (Bernard, Chaparro, Mills & Halcomb, 2002; Bernard et al., 2003; Ling & Van Schaik, 2006). The researchers explain that the use of serifs and narrow space could affect the perceived readability (Bernard et al., 2003).

Other researchers have found positive results for reading performance with sans serif font. Wilkins and others found that reading was slightly faster with the sans serif font (Wilkins, Cleave, Grayson & Wilson, 2009; Wilkins et al., 2007). An explanation for this result was that the sans serif font has less 'stripy' words. Similarity between letters in a word can cause a striped appearance of the word (Wilkins et al. 2007). According to Jainta, Jaschinski and Wilkins (2010) this striped appearance affects the reading speed because both eyes have to take longer time to recognize the letters and the word. Research from Moret-Tatay and Perea (2011) confirms this statement. They found that a sans serif font leads to faster word identification. The use of serifs does not facilitate visual-word identification. A possible explanation is that without serifs there is more space between the letters. Research has shown that a small increase in inter-letter spacing produces faster word identification and faster reading times (Perea & Gomez, 2012; Perea, Moret-Tatay & Gómez, 2011; Perea, Panadero, Moret-Tatay & Gómez, 2012; Spinelli, De Luca, Judica & Zoccolotti, 2002). The position of the letters is clearer, so there is less crowding and less perceptual uncertainty (Perea et al., 2012). Besides an increase in inter-letter spacing, increasing interline spacing also produces faster reading times (Van Overschelde & Healy, 2005). It improves letter - and word identification. This is probably due to the reduced amount of information in the visual field (Van Overschelde & Healy, 2005). Hartley (1978) describes that the interline spacing is best when the minimum line space is increased with the amount of word-spacing. In this way the interline space will not appear less than the word-space. The word-space should be large enough to clearly distinguish the words (Hartley, 1978).

Sheedy, Subbaram, Zimmerman and Hayes (2005) studied the difference of legibility between upper case and lower case letters and words with different serif and sans serif font types. They found that sans serif fonts Verdana and Arial had the best legibility.

Another difference that affects reading performance is the size of a font (Rudnicky & Kolers, 1984). Several researches showed that children benefit from a larger font point size (Bernard et al., 2003; Hughes & Wilkins, 2000; Wilkins et al., 2009) and that they also prefer a larger font point size (Bernard et al., 2002). According to Bernard et al. (2002) the larger 14-point size was reported as more legible and faster to read than the 12-point size. Sheedy et al. (2005) found similar results, namely that 14-point size generally had the highest legibility. Wilkins et al. (2009) found that a larger font size increased the reading speed which was accompanied by an increase in accuracy. So the reading speed was not due to a greater tolerance of inaccuracy. Hughes and Wilkins (2000) found that children made more errors

with the smaller text than the larger texts and that reading speed could increase with a larger point size.

The appearance of fonts is affected by the x-height, the height of the body of a letter (Bernard et al., 2002; Wilkins et al. 2009). This height differs in fonts and makes it look smaller or larger. For example the x-height of Arial is larger than Times New Roman in the same point size. A larger x-height gives the letters a bigger body and this may help in discriminating letters but it reduces the ascenders and descenders of letters (Bernard et al., 2002; Bernard et al. 2003). Ascenders are the strokes of letters above the x-height and descenders are the strokes below the x-height. Therefore a medium to large x-height should be optimal (Bernard et al., 2002).

Besides a larger x-height and no serifs more can be done to distinguish letters. For example, Lockhead and Crist (1980) made letters distinctive with dots and slashes. They compared the readability of these letters with normal letters. Results showed that children with and without reading disabilities and adults were more accurate and faster (Lockhead & Crist, 1980). Sometimes letters are made italic or bold to ease reading. According to Sheedy et al. (2005) the use of italics decreases the legibility of letters and words. The use of bold letters could increase legibility but the strokes must not be too width (Sheedy et al., 2005). More recent are the adjustments of a font done by Boer. He made several adjustments and this created a special font named Dyslexie.

Font Dyslexie

The font Dyslexie is especially designed for people with dyslexia (Boer, 2011). The specific characteristics in the font are designed to make it easier to distinguish letters. This should reduce the effort it takes for dyslexics to read a text which enhances the reading speed and the font should reduce reading errors. Figure 2 shows the letters of the font Dyslexie.

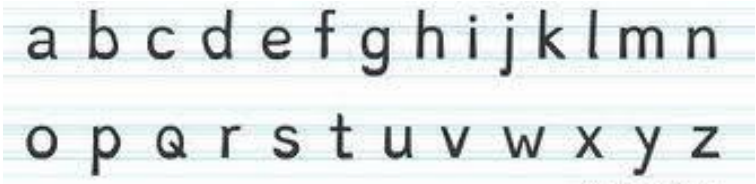

Figure 2. Letters font Dyslexie

Several adjustments have been made to make the letters more distinguished. The bottom part of each letter is made heavier which prevents the letter from turning upside down. The openings of the letters are enlarged so they look less alike and have a clearer shape. Some

letters and tails are put slightly italic which reduces the similarity and avoids mirror image and rotation (Boer, 2011). The ascenders and descenders of several letters are longer and so is the x-height. Similar letters are made more distinctive by differences in height and by using deeper inlets. Now each letter has its own features which make them clearer to read. Also the spacing between letters and words is increased. In addition capitals and punctuation marks are made bold. With these changes it should be easier to read each sentence (Boer, 2011). Figure 3 shows some examples of the changes.

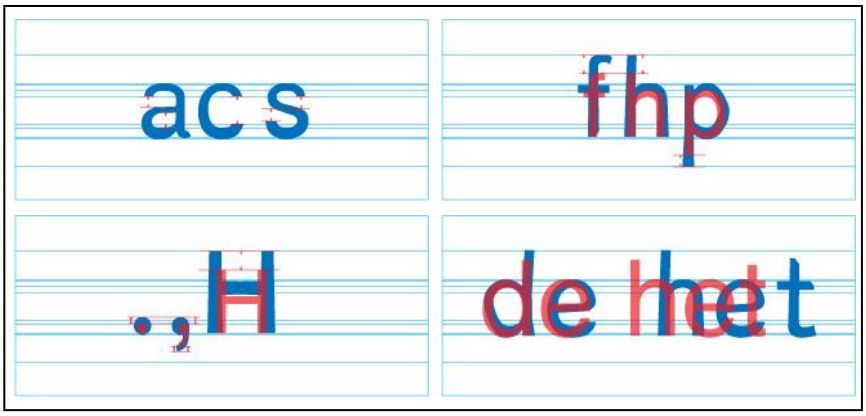

Figure 3. Examples of changes of the font Dyslexie. Letters of the font Dyslexie are in blue, normal sans serif letters are in red.

Reading with the special font Dyslexie could increase the reading performance of dyslexics because of the adjustments of the letters. Several researches have been conducted to the effect of the font Dyslexie. Research from De Leeuw (2010) shows that reading speed did not improve among dyslexic and non-dyslexic students while reading on word level. However the dyslexic students made fewer errors while reading with the font Dyslexie in comparison with the normal readers. In addition the dyslexic students preferred the font Dyslexie rather than the font Arial (De Leeuw, 2010). Research from Kuster, Braams and Bosman (2012) shows no support for the font Dyslexie. They found no significant results on reading speed and accuracy with the font Dyslexie in comparison with the font Arial. Unlike research from Kuster et al. Ossen (2012) found positive results supporting the font Dyslexie. The reading speed and accuracy of children with dyslexia improved. Besides the children reported having more ease reading the text in the font Dyslexie than in the font Arial (Ossen, 2012).

Reading level dyslexics

Children with dyslexia differ in their reading level. This difference in reading level could be influenced by the level of prior knowledge. Research from Taft and Leslie (1985) with average readers showed that children with low prior knowledge made more errors with oral reading than children with high prior knowledge. As a consequence the reading accuracy of the children with low prior knowledge was worse (Taft & Leslie, 1985). Research from Priebe, Keenan and Miller (2010) supports this finding. The level of prior knowledge affected word identification skills. Children with low prior knowledge relied more on graphic cues where children with high prior knowledge relied more on semantic cues (Priebe et al., 2010; Taft & Leslie, 1985). Research showed that this also accounts for below average readers, they rely more on graphic cues (Leslie, 1980).

Research from Badian (1997) also showed that children with dyslexia can be divided into more and less impaired readers. These children did not differ in verbal IQ (Badian, 1997). More impaired readers were more likely to have problems with phonological, naming-speed and orthographic skills. These children have more difficulty with reading because they have less compensatory skills to fall back on (Badian, 1997). As a consequence the more impaired dyslexics had a lower reading level than the less impaired dyslexics.

In view of these findings dyslexics in this study will be distinguished between a lower reading level and a higher reading level given the expectation in difference of performance. The adaptation of the visual elements color and font could serve as compensator for the lack of prior knowledge or reading skills like naming-speed and orthographic skills. With these visual adaptations the graphic outlay changes. This leads to the expectation that dyslexics with a lower reading level will benefit more from the visual adaptations because they rely more on graphic cues than dyslexics with a higher reading level.

Hypotheses and design

Hypotheses. Based on the literature the question arises whether or not dyslexics will have a better reading performance when the color yellow is used as background color and when the font Dyslexie is used. In addition, the expectation is that dyslexics with a lower reading level benefit more from these visual adaptations than dyslexics with a higher reading level.

In this study the reading performance will be compared with the reading performance on a yellow and white paper and the font Dyslexie and as control font the sans serif font Arial. The performance is based on reading speed and the amount of errors made while reading texts

out loud. The hypothesized benefits of using the color yellow as background color and the hypothesized benefits of using the font Dyslexie could reinforce each other. For this reason the combination of the color yellow and the font Dyslexie could provide the best reading performance. Based on these expectations the following hypotheses are made:

Hypothesis 1a: The reading speed of dyslexics will increase when the color yellow is used as background color while reading text.

1b: The reading speed of dyslexics will increase when they read a text in the font Dyslexie.

Hypothesis 2a: The reading accuracy of dyslexics will improve when the color yellow is used as background color while reading text.

2b: The reading accuracy of dyslexics will improve when they read a text in the font Dyslexie.

Hypothesis 3a: The reading speed and accuracy of dyslexics will increase when they read a text in the font Dyslexie with a yellow background.

3b: The reading speed and accuracy of dyslexics with a lower reading level will increase more with the font Dyslexie and a yellow background than the reading speed and accuracy of dyslexics with a higher reading level.

All these hypotheses will also be examined for children without dyslexia. Owing to this the differences between dyslexics and non-dyslexics for color and font can be viewed.

Design. This study has a within subject design and consists of several independent and dependent variables. The independent within subject variables are the background color and font, with gender and dyslexia as independent between subject variables. The dependent variables are the reading speed and reading accuracy in order to measure the reading performance with the background color yellow and the font Dyslexie. By using a fixed sequence of the texts a 2 x 2 x 2 design was used for color and font which resulted in four test conditions, the children were assigned to one of them. Table 1 gives an overview.

Table 1

Conditions color-font combinations

Texts Conditions	Text 1 Color font	Text 2 Color font	Text 3 Color font	Text 4 Color font
1	Yellow Dyslexie	White Dyslexie	Yellow Arial	White Arial
2	White Dyslexie	Yellow Arial	White Arial	Yellow Dyslexie
3	Yellow Arial	White Arial	Yellow Dyslexie	White Dyslexie
4	White Arial	Yellow Dyslexie	White Dyslexie	Yellow Arial

Method

Participants

Sixty-four children (age range 8.11 to 12.10, *M*age 10.05) participated in this study. The experimental group consisted of children with diagnosed developmental dyslexia. None of the children had co-morbid diagnoses like AD(H)D or dyscalculia. This also applied to the children of the control group.

The experimental group consisted of 22 children and was divided by their reading level. Namely 13 children with a lower reading level (8 boys and 5 girls, age range 10.00 to 11.11, *M*age 10.07) and 9 children with a higher reading level (2 boys and 7 girls, age range 11.03 to 12.10, *M*age 11.07).

The control group consisted of 42 non-dyslexics divided into two groups. Twelve children (6 boys and 6 girls, age range 8.11 to 10.09, *M*age 9.01) matching the lower reading level and 30 children (14 boys and 16 girls, age range 10.00 to 12.02, *M*age 10.07) matching the higher reading level.

The parents of the children received a letter, drafted by the researcher, or a phone call from the internal supervisor of the school whether or not to give consent for participation of their children in this study. All children received a small gift as thanks for their participation.

Material

Reading material. Every child read four different short texts from a Dutch teaching method, Nieuwsbegrip. There were two different reading levels of the texts, lower and higher, and so there were two sets of four different texts. The children read the texts on their own reading level no matter which class they were in.

To equal the texts they were compared with the number of words and the readability of the texts. To compare the readability of the texts the Flesch Reading Ease [FRE] was used. The FRE is a formula to score the readability of a text. The FRE score ranges from 0 to 100

(Graesser, McNamara, Louwerse & Cai, 2004). A higher score means that it is easier to read. The formula uses the average sentence length which is computed with the number of words in a text divided by the number of sentences. It also uses the average number of syllables per word which is computed with the number of syllables divided by the number of words (Graesser et al., 2004).

Three different calculators were used to calculate the FRE of each text. The first calculator implemented the FRE for the Dutch language (Van der Gun, 2009). The second calculator used was for the English language (MyBylineMedia, n.d.). Although this differs with the Dutch language it treated the texts in Dutch equal so the deviations within the scores were the same. This also applied to the third calculator which was also for the English language (McNamara, Louwerse, Cai & Graessar, 2005). The last calculator did not work adequately with all texts. The retrieved scores of some texts were included in the comparison because of the incompletion the scores will not be mentioned here. The results of the calculators were compared and the texts with the most equal readability scores were used in this study.

For the higher reading level the mean readability score with the Dutch and English calculator was respectively 73 (range 70 to 76) and 59.1 (range 55.3 to 61.2). The mean readability score of the lower reading level was 75.3 (range 72 to 78) and 62.9 (range 60.8 to 64). The range of the scores almost all fall in one category. The category with the scores 70 – 80 is seen as fairly easy texts and the categories with scores 50-59 and 60-69 are seen as respectively fairly difficult and standard (MyBylineMedia, n.d.). These scores showed that the higher reading level texts had a slightly more difficult readability than the lower reading level texts.

The number of words for the higher reading level texts ranged from 400 – 402 words. The number of words for the lower level reading texts ranged from 310 – 311 words. The number and length of paragraphs in each text was also taken into account. The higher reading level texts all had between four and six paragraphs and the lower reading level texts all had four or five paragraphs.

Test. In order to establish or exclude a cognitive profile for dyslexia each child administered a test, the Dutch Continuous Naming and Word Reading (in Dutch: Continu Benoemen & Woorden lezen) [CB&WL]. The first part of the test consists of four tasks: naming of colors, figures, images and letters. The second part of the test contains two tasks: reading words consisting of one syllable and reading words correctly in one minute. The test

was conducted conform the manual of the CB&WL. The raw score in seconds on every task has been converted into standard scores and also into three standard combination scores. The combinations scores are: reading words, alphanumeric consisting of the tasks naming numbers and letters, and non- alphanumeric consisting of the tasks naming colors and images. Certain combinations of the combinations scores indicate a cognitive profile for dyslexia, a risk for dyslexia, or no dyslexia. These indications are based on the diagnostic instructions described in the manual of the CB&WL. Table 2 shows the outcomes. These outcomes were being left out of consideration for further analyses.

Table 2

Outcomes of CB&WL

Groups	*N*	*Dyslexia*	*At risk for dyslexia*	*No dyslexia*
Dyslexics	22	10	10	2
Lower reading level	13	7	5	1
Higher reading level	9	3	5	1
Non-dyslexics	42	3	2	37
Lower reading level	12	2	2	8
Higher reading level	30	1	0	29

Font. The experimental font was Dyslexie. This font was adapted to the point size of the standard font used by the teaching method Nieuwsbegrip, namely Arial. The higher reading level texts had Arial point size 10 which equals Dyslexie point size 9. The lower reading level texts used by Nieuwsbegrip had Arial point size 11 which equals Dyslexie point size 10. See Appendix I for an example.

Paper. The texts were printed on white and yellow paper. Both types of paper had A4 size and were 80 grams. The color measurement of the yellow paper has been done with a spectral meter with a white underground. The measure of luminance, color dimension green-red and color dimension blue-yellow (L*a*b*) was L: 94.45; a: -3.72; b: 33.3. The measure of cyan, magenta, yellow and black (CMYK) was C: -0.01, M: 0.02, Y: 0.31, K: 0.00. See Appendix II for an approximation of the color yellow.

Procedure

The procedure was equal for all children and was conducted individually. First, they read the four different texts. The children read the texts out loud so the time could be measured and it could be recorded for analysis of the reading errors. Second, they

administered the CB&WL. When they were ready, they received a small gift.

Analyses

Design. The reading performance consists of the reading speed and reading accuracy. The reading accuracy was measured through the amount of errors and the kind of errors. The reading speed was the raw score in seconds. A lower score means a better reading speed. The analysis of the errors is based on the reading errors described by Grossar and Fiddelaers (2004). Table 3 gives an overview of the most common reading errors made by dyslexics (Grossar & Fiddelaers, 2004). The raw score of the amount of errors was the number of times the error was made in the text. The errors were labeled with the error type. The analysis of the errors lead to the addition of a few types of reading errors besides the specific errors listed in Table 3. These added errors are listed at the bottom of Table 3.

Table 3

Overview reading errors

Reading error	*Description*
Switching letters	Switching of mirror letters like ‘b’ and ‘d’ or rotating letters like ‘e’ and ‘a’.
Complex vowels	Complex vowels consists of two vowels. A complex vowel is replaced by another complex vowel or double vowel.
Open or closed syllables	An open syllable is read closed or a closed syllable is read open.
Consonant cluster shift or deletion	In a cluster of consonants some consonants are shifted in the word or deleted.
Deletion or addition of letters	A letter is deleted or added.
Deletion or addition of words	A word is deleted or added.
Replacement of words	A word is replaced by another word.
Read guessing	A word is guessed instead of well read.
Added reading errors	
Word reverse	A word is reversed with another word.
Number error	A number in the text is read wrong.
Pronunciation error	A letter is pronounced wrong, like ‘c’ pronounced as ‘k’.

Analysis. For the analyses parametric and non-parametric tests were used. This was done to compare the background colors yellow and white in spite of the font and to compare the fonts Dyslexie and Arial in spite of the background color. Regarding the reading speed and total amount of errors the distribution was very slightly skewed to the right close to a normal distribution. So for this reason the parametric test paired samples t-test was used for analyses. With regards to the different error types the statistics showed that these were more skewed to the right. For these analyses the non-parametric test Wilcoxon signed-rank test was used. For both parametric and non-parametric tests one-tailed tests were used because of the directional hypotheses.

For further specified analyses repeated measure analyses were used. This was used to compare the four different color-font combinations with each other: Yellow-Dyslexie, White-Dyslexie, Yellow-Arial and White-Arial. The assumption of sphericity has been taken into account to test if the variances of the differences between conditions were equal. When the differences were significant and so the condition of sphericity was not met the Greenhouse-Geisser correction was used when values were under 0.75 and the Huyn-Feldt correction was used when values were above 0.75.

Besides significant results also trends will be described. Trends are mentioned when the value was between $0.05 < p < 0.10$ in the predicted direction.

Results

The effect of background color on reading speed

The hypothesis that the reading speed of dyslexics will increase when the color yellow is used as background color (H1a) was first analyzed by a parametric test comparing the background colors yellow and white in spite of the font. Table 4 gives an overview of the results. Further specified analyses were conducted with repeated measure analyses. Table 5 gives an overview of the results.

Dyslexics lower reading level. On average dyslexics with the lower reading level read slower with the white condition (M = 414.62, SD = 49.16) than with the yellow condition (M = 406.00, SD = 60.92). However this difference was not significant (t (12) = -0.78, p = 0.23). Table 5 shows that the mean reading speed with the combination Yellow-Dyslexie (M = 200.39, SD = 33.94) and Yellow-Arial (M = 205.62, SD = 33.11) was faster compared to the combinations White-Dyslexie (M = 208.54, SD = 28.26) and White-Arial (M = 206.08, SD =

26.20). However, the results show that the time needed to read each text was not significantly affected by any type of color-font combination (F (3, 36) = 0.43, p = 0.73).

Dyslexics higher reading level. Table 4 shows that children with dyslexia with the higher reading level read significantly faster with the white condition (M = 448.11, SD = 69.98), t (8) = 1.95, p = 0.04 than with the yellow condition (M = 457.33, SD = 65.41). Table 5 also shows that the mean reading speed of the dyslexics with the higher reading level was slower when they read with a yellow background. The analyses showed that the time needed to reach each text was not significantly affected by the color font combination, (F (1.57, 12.56) = 0.72, p = 0.47).

Non-dyslexics lower reading level. Table 4 shows that non-dyslexics matching the lower reading level benefitted more from a white background. Subsequent analyses showed that these benefits were not significant. Table 5 shows similar results of repeated measure analyses. The reading speed of these children was not significant affected by color.

Non-dyslexics higher reading level. Table 4 and Table 5 show that non-dyslexics matching the higher reading level read on average slightly faster with the yellow condition than with the control condition. However this difference in reading time was not significant.

Table 4

Effect of background color on reading speed, time in seconds

Groups	*N*	*Yellow background*	*White background*
Dyslexics		*Mean (SD)*	*Mean (SD)*
Lower reading level	13	406.00 (60.92)	414.62 (49.16)
Higher reading level	9	457.33 (65.41)*	448.11 (69.98)*
Total	22	427.00 (66.47)	428.32 (59.42)
Non-dyslexics			
Lower reading level	12	402.83 (87.99)	397.17 (76.17)
Higher reading level	30	353.70 (44.65)	356.70 (51.27)
Total	42	367.74 (63.18)	368.26 (61.31)

*Note: *p < 0.05*

Table 5

Effect of color-font combination on reading speed, time in seconds

Groups	*N*	*Yellow-Dyslexie*	*White-Dyslexie*	*Yellow-Arial*	*White-Arial*
Dyslexics		*Mean (SD)*	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
Lower reading level	13	200.39 (33.94)	208.54 (28.26)	205.62 (33.11)	206.08 (26.20)
Higher reading level	9	224.67 (37.33)	223.22 (38.66)	232.67 (34.16)	224.89 (34.10)
Total	22	210.32 (36.59)	214.55 (32.87)	216.68 (35.45)	213.77 (30.41)
Non-dyslexics					
Lower reading level	12	205.50 (54.29)	199.58 (41.72)	197.33 (34.84)	197.58 (35.53)
Higher reading level	30	175.13 (23.35)	176.90 (27.60)	178.57 (23.84)	179.80 (26.52)
Total	42	183.81 (37.00)	183.38 (33.37)	183.93 (28.30)	184.88 (30.04)

The effect of font on reading speed

The prediction that the reading speed of dyslexics will increase when they read a text in the font Dyslexie (H1b) was first measured with a parametric test comparing the fonts Dyslexie and Arial in spite of the background colors. Table 6 gives an overview of the results. Further specified analyses were conducted with repeated measure analyses. See Table 5 for the results.

Dyslexics lower reading level. Table 6 shows that the mean reading time of dyslexics with the lower reading level was slightly faster with the font Dyslexie (M = 408.92, SD = 55.12) than with the font Arial (M = 411.69, SD = 54.85). This difference was not significant ($p = 0.40$). Table 5 shows that the combination Yellow-Dyslexie resulted in the best reading time, but the combination White-Dyslexie resulted in the slowest reading time. Analyses showed that the time needed to read each text was not significantly affected by the type of color-font combination (F (3, 36) = 0.43, $p = 0.73$).

Dyslexics higher reading level. Children with dyslexia with the higher reading level also showed a faster reading time with the font Dyslexie (M = 447.89, SD = 72.81) than with the font Arial (M = 457.56, SD = 63.60). See Table 6. Analysis showed that this difference was not significant ($p = 0.12$). Table 5 also shows that they seem to have benefitted more when they read the text in the font Dyslexie (M = 224.67, SD = 37.33; M = 223.22, SD = 38.66) compared with the font Arial (M = 232.67, SD = 34.16; M = 224.89, SD = 34.10). However the results showed that the time needed to read each text was not significantly affected by the type of color font combination (F (1.57, 12.56) = 0.72, $p = 0.47$).

Non-dyslexics lower reading level. The results in Table 5 and Table 6 show that the non-dyslexics matching the lower reading level seemed to benefit more from the font Arial. Further analyses showed that these differences were not significant.

Non-dyslexics higher reading level. Non-dyslexics with the higher reading level seemed to benefit more from the font Dyslexie, see Table 5 and Table 6. Analyses showed a trend of a statistically significant difference in reading time with the font Arial (M = 358.37 SD = 48.60) compared with the font Dyslexie (M = 352.03, SD = 47.92), t (29) = -1.59, p = 0.06.

Table 6

Effect of font on reading speed, time in seconds

Groups	*N*	*Dyslexie font*	*Arial font*
Dyslexics		*Mean (SD)*	*Mean (SD)*
Lower reading level	13	408.92 (55.12)	411.69 (54.85)
Higher reading level	9	447.89 (72.81)	457.56 (63.60)
Total	22	424.86 (64.34)	430.45 (61.58)
Non-dyslexics			
Lower reading level	12	405.08 (94.80)	394.92 (66.22)
Higher reading level	30	352.03 (47.92)	358.37 (48.60)
Total	42	367.19 (68.00)	368.81 (55.92)

The effect of background color on reading accuracy

The hypothesis predicted that the reading accuracy of dyslexics will improve when the color yellow is used as background color while reading text (H2a). Table 7 shows the results of comparing the background colors in spite of the different fonts. Further specified analyses were conducted with repeated measure analyses. Table 8 gives an overview of the results.

Dyslexics lower reading level. Regarding children with dyslexia with the lower reading level Table 7 shows that the mean amount of errors is less with the yellow background (M = 46.15, SD = 24.52) compared to the white background (M = 51.54, SD = 26.53). However subsequent analyses showed that this difference was not significant (p = 0.23). Further analyses showed a significant result on the sub error ‘open or closed syllables’. More syllable errors were made with the white background (M = 4.46) than with the yellow background (M = 3.38), p = 0.05. However less ‘deletion of words’ errors were made with a white background (M = 4.38) than with a yellow background (M = 8.00), p = 0.03.

Table 8 shows the results of the repeated measure analyses. The mean amount of errors made by the dyslexics with the lower reading level was lowest with the combination Yellow-Dyslexie compared to the combinations with a white background. However, the combination Yellow-Arial had the highest amount of errors. The total amount of errors made shows a trend towards a significant affect by the type of color-font combination, (F (3, 36) = 2.41, p = 0.08. The difference between Yellow-Dyslexie and White-Dyslexie was not significant (p = 0.26). However analyses did show a significant result on the sub error 'deletion of words'. With the combination Yellow-Dyslexie these children made significant less word-deletion errors (M = 0.85) compared with the combination White-Dyslexie (M = 1.85), p = 0.01.

Dyslexics higher reading level. Dyslexics with the higher reading level showed a less amount of errors when reading with the yellow background (M = 51.44, SD = 21.29) compared with the white background (M = 58.67, SD = 21.37). See Table 7. This difference showed a trend towards a significant difference between a yellow and white background (p = 0.09). Further analyses showed a significant difference on the sub error 'addition of words'. The children added more words with a white background (M = 8.89) than with a yellow background (M = 6.00) (p = 0.05). Table 8 also shows that when the color yellow is used as background color the total amount of errors is slightly less (M = 24.33, SD = 10.72; M = 27.11, SD = 15.66) than with a white background (M = 27.22, SD = 12.23; M = 31.44, SD = 10.43) . Subsequent analyses showed that the amount of errors was not affected by color-font combination (F (3, 24) = 1.06, p = 0.39).

Non-dyslexics lower reading level. Table 7 shows that non-dyslexics matching the lower reading level had less errors with the white background than with the yellow background. Table 8 also shows that these children benefitted more from a white background reading with the font Dyslexie and Arial. Analysis showed that these differences were not significant.

Non-dyslexics higher reading level. Non-dyslexics matching the higher reading level seemed to make slightly less errors with a yellow background than with a white background. Table 8 also confirms this finding. Subsequent analyses showed that this difference between the colors yellow and white was not statistically significant. However these children did made

significant less ‘addition of letters’ errors with a yellow background (M = 1.33) than with a white background (M = 1.90), $p = 0.02$.

Table 7

Effect of background color on reading accuracy, the total amount of errors

Groups	*N*	*Yellow background*	*White background*
Dyslexics		*Mean (SD)*	*Mean (SD)*
Lower reading level	13	46.15 (24.52)	51.54 (26.53)
Higher reading level	9	51.44 (21.29)	58.67 (21.37)
Total	22	48.32 (22.87)	54.45 (24.27)
Non-dyslexics			
Lower reading level	12	44.42 (20.87)	42.67 (20.16)
Higher reading level	30	28.83 (16.66)	30.77 (16.84)
Total	42	33.29 (19.08)	34.17 (18.42)

Table 8

Effect of color-font combination on reading accuracy, the total amount of errors

Groups	*N*	*Yellow-Dyslexie*	*White-Dyslexie*	*Yellow-Arial*	*White-Arial*
Dyslexics		*Mean (SD)*	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
Lower reading level	13	18.23 (9.78)*	25.69 (14.73)	27.92 (16.13)*	25.85 (14.49)
Higher reading level	9	24.33 (10.72)	27.22 (12.23)	27.11 (15.66)	31.44 (10.43)
Total	22	20.73 (10.39)	26.32 (13.47)	27.59 (15.56)	28.14 (13.01)
Non-dyslexics					
Lower reading level	12	21.08 (11.00)	20.58 (12.94)	23.33 (11.80)	22.08 (10.77)
Higher reading level	30	13.77 (8.66)	15.07 (8.76)	15.07 (9.46)	15.70 (9.89)
Total	42	15.86 (9.83)	16.64 (10.27)	17.43 (10.72)	17.52 (10.44)
*Note: *p < 0.05*					

The effect of font on reading accuracy

The results of parametric tests of the hypothesis that the reading accuracy of dyslexics will increase when they read with the font Dyslexie (H2b) are shown in Table 9. Subsequent analyses were conducted with repeated measures. Table 8 gives an overview of the results. Table 9 shows that there is a significant main effect of the font Dyslexie (M = 47.05) in comparison with Arial (M = 55.73) on reading accuracy for the total group of dyslexics.

Dyslexics lower reading level. Analyses showed that on average, dyslexics with the lower reading level had a significant more amount of errors when reading with the font Arial (M = 53.77, SD = 24.89) than with the font Dyslexie (M = 43.92, SD = 21.96), t (12) = -2.28, $p = 0.02$. Further analyses showed trends for the sub errors ‘consonant shift’ ($p = 0.06$), ‘addition of letters’ ($p = 0.05$), ‘deletion of letters’ ($p = 0.09$), ‘replacement of words’ (p =

0.06), ‘word reverse’ ($p = 0.09$) and ‘number error’ ($p = 0.08$) for the font Dyslexie. The sub error ‘deletion of words’ showed a significant difference between the font Dyslexie (M = 2.69) and the font Arial (M = 5.54), $p = 0.01$. Further specified analyses on this sub error showed a significant difference between Yellow-Dyslexie (M = 0.85) and Yellow-Arial (M = 3.00) ($p = 0.01$).

Subsequent analyses with repeated measure also showed that these children had the least amount of errors with the font Dyslexie compared to the font Arial, see Table 8. The results showed a trend by the total amount of errors made and the type of color-font combination (F (3, 36) = 2.41, $p = 0.08$). Further analyses with the Bonferroni method showed that the mean difference of the combination Yellow-Dyslexie compared with Yellow-Arial was statistically significant ($p = 0.04$).

Dyslexics higher reading level. Children with dyslexia with the higher reading level showed a less amount of errors when reading with the font Dyslexie (M = 51.56, SD = 19.21) compared to the font Arial (M = 58.56, SD = 24.01). See table 9. This difference inclines towards a trend of font on reading accuracy ($p = 0.13$). Further analyses of the sub errors showed that these children made significant less ‘consonant deletion’ errors with the font Dyslexie than with the font Arial, $p = 0.03$. They also made less ‘deletion of words’ errors with the font Dyslexie (M = 6.33) than with the font Arial (M = 9.11), $p = 0.07$.

Table 8 shows that dyslexics at the higher reading level had the lowest amount of errors with the font Dyslexie in combination with a yellow background. They also had a fewer amount of errors when they read with the font Dyslexie with a white background (M = 27.22, SD = 12.23) compared to the font Arial with a white background (M = 31.44, SD = 10.43). Analysis showed that the total amount of errors made was not significantly affected by the type of color-font combination (F (3, 24) = 1.06, $p = 0.39$).

Non-dyslexics lower reading level. Table 9 shows that non-dyslexics matching the lower reading level made fewer errors with the font Dyslexie than with the font Arial but this difference was not significant. However these children did made less ‘replacement of words’ errors with the font Dyslexie (M = 5.08) than with the font Arial (M = 6.58), $p = 0.04$. Table 8 shows that these children had the least amount of errors with the combination White-Dyslexie compared with the other color-font combination. Further analysis did not show a significant result.

Non-dyslexics higher reading level. Non-dyslexics matching the higher reading level made fewer errors with the font Dyslexie than with the font Arial, see Table 9. Analyses showed a significant less amount of the sub error 'replacement of words' with the font Dyslexie (M = 3.13) than with the font Arial (M = 4.73), $p = 0.00$. Further analyses showed trends for the amount of errors for the sub errors 'deletion of letters' ($p = 0.11$), 'deletion of words' ($p = 0.05$) and 'word reverse' ($p = 0.08$) with the font Dyslexie compared with Arial. However these children made more 'consonant deletion' errors with the font Dyslexie than with the font Arial, $p = 0.05$.

Table 9

Effect of font on reading accuracy, the total amount of errors

Groups	*N*	*Dyslexie font*	*Arial font*
Dyslexics		*Mean (SD)*	*Mean (SD)*
Lower reading level	13	43.92 (21.96)*	53.77 (24.89)*
Higher reading level	9	51.56 (19.21)	58.56 (24.01)
Total	22	47.05 (20.76)*	55.73 (24.07)*
Non-dyslexics			
Lower reading level	12	41.67 (20.17)	45.42 (19.71)
Higher reading level	30	28.83 (15.49)	30.77 (18.21)
Total	42	32.50 (17.70)	34.95 (19.59)

*Note: *p < 0.05*

The effect of color and font on reading speed and accuracy

The hypothesis predicted that the reading speed and accuracy of dyslexics will increase when they read a text in the special font Dyslexie with a yellow background (H3a). Results of repeated measure analyses are shown in Table 5 and Table 8. Figure 4 and Figure 5 show the results in charts.

Dyslexics lower reading level. Table 5 and Figure 4 show that dyslexics with the lower reading level had the best results for mean reading speed and amount of errors for the color font combination Yellow-Dyslexie. Although repeated measure analyses showed that the mean difference concerning the reading speed between this color-font combination (M = 200.39, SD = 33.94) compared to the other color-font combinations (White-Dyslexie: M = 208.54, SD = 28.26; Yellow-Arial: M = 205.62, SD = 33.11; White-Arial: M = 206.08, SD = 26.20) was not significant there is a considerable difference in mean scores.

Analyses showed an interaction effect of color and font regarding reading accuracy. The mean difference of the amount of errors between the combination Yellow-Dyslexie and

the combination Yellow-Arial was significant (p = 0.04), see Table 8 and Figure 5. Compared to the other color-font combinations analyses showed no significant differences however there is a considerable difference in scores.

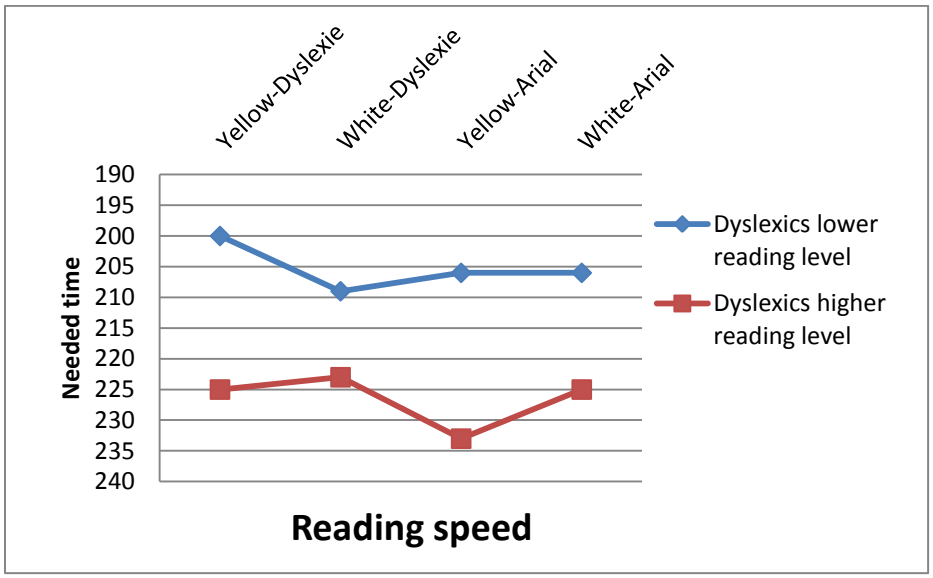

Figure 4. Effect of color-font combination on reading speed.

Dyslexics higher reading level. Regarding the dyslexics with the higher reading level Table 5 and Figure 4 show that the color-font combination Yellow-Dyslexie seems to have had no real beneficial effect on reading speed. Concerning the amount of errors this beneficial effect does seem to be present with the combination Yellow-Dyslexie, shown in Table 8. However analyses showed that these mean differences were not significant.

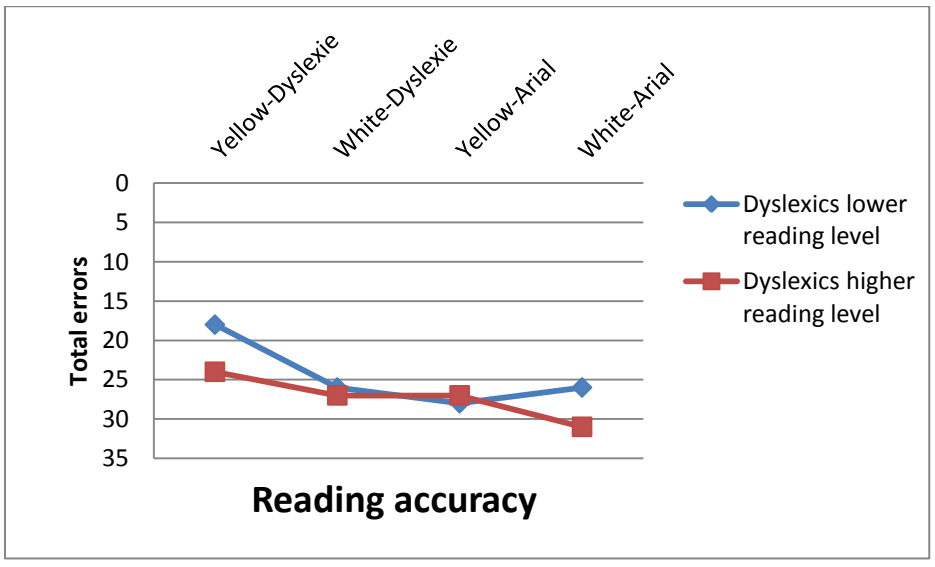

Figure 5. Effect of color-font combination on reading accuracy.

Non-dyslexics lower reading level. Table 5 shows that non-dyslexics matching the lower reading level did not had better reading times with the combination Yellow-Dyslexie. Regarding the reading accuracy Table 8 shows that these children had no significant better results with the combination Yellow-Dyslexie in comparison with the other color-font combinations.

Non-dyslexics higher reading level. Non-dyslexics matching the higher reading level did had better results on reading speed and reading accuracy with a yellow background and the font Dyslexie in comparison with the other color-font combinations, see Table 5 and Table 8. However these results were not significant.

Reading performance of dyslexics with the lower reading level versus the higher reading level

The last prediction was that the reading speed and accuracy of dyslexics with a lower reading level will increase more with the special font Dyslexie and a yellow background than the reading speed and accuracy of dyslexics with a higher reading level (H3b).

Dyslexics lower reading level versus dyslexics higher reading level. Analyses with repeated measures showed that dyslexics with a lower reading level improved more than dyslexics with a higher reading level on reading speed with the condition Yellow-Dyslexie in comparison with the other color-font combinations. See Table 5 and Figure 4. Although analyses showed that these differences were not significant, the mean score of dyslexics with a lower reading level improved with this condition while the mean score of dyslexics with a higher reading level got worse.

Concerning reading accuracy dyslexics with the lower reading level improved more with the color-font combination Yellow-Dyslexie in comparison with the other conditions than dyslexics with the higher reading level. Table 8 and Figure 5 give an overview of the results.

Non-dyslexics lower reading level versus non-dyslexics higher reading level. Non-dyslexics with a higher reading level showed more improvement on reading speed and reading accuracy with the combination Yellow-Dyslexie in comparison with the other conditions than dyslexics with a lower reading level. However these were slight improvements and analyses showed no significant differences.

Discussion

The goal of this study was to examine whether a yellow background and the special font Dyslexie could improve the reading performance of dyslexics.

Hypothesis 1. The results do not show support for the hypothesis that the reading speed of dyslexics will increase when the color yellow is used as background color (H1a) and when they read a text in the special font Dyslexie (H1b).

Although dyslexics with a lower reading level had a faster reading time with a yellow background this was not significant. A possible explanation could be their sensitivity for color. Research from Dain, Floyd and Elliot (2008) showed that with the blue/yellow opponent color impaired readers had less contrast discrimination in comparison with normal readers. Wearing a colored yellow lens reinforces this blue/yellow color and gives positive reading results (Ray et al., 2005; Stein, 2003). This study used a yellow background with black letters. The influence of the color black and the level of luminance could have give dyslexics with a lower reading level too little visual comfort to improve reading speed. Dyslexics with a higher reading level read significantly faster with a white background. The reason for this result could be that they are more like non-dyslexics and have a better color contrast discrimination. In this way the color yellow is of no help for them. Future research could focus more on this blue/yellow opponent color in using blue letters instead of black letters and the influence of luminance to examine the effect on reading speed between dyslexics with a lower and higher reading level.

In addition, Leslie (1980) found that below average readers continue to try decoding an unknown word. In doing so they rely on graphic information (Leslie, 1980). The color yellow changes the contrast of the colors, which could make it easier to distinguish words but it does not per se help with decoding graphic information of words. This could explain the faster but the non-significant result for reading time.

All dyslexics read faster with the experimental font Dyslexie but this was not significant in comparison with the standard font Arial. This effect may be related to adaptations in the font Dyslexie. For instance, an increase in inter-letter spacing produces less crowding and therefore faster word-identification and faster reading times (Chung, 2002; Perea et al., 2012). However, there is a limit about the effectiveness of inter-letter spacing. Beyond a certain point reading speed stays the same or decreases (Chung, 2002). Changing the inter-letter spacing of the font Dyslexie could result in a significant faster reading time.

Further research is needed to explore the best inter-letter spacing for the font Dyslexie. Another example is the point size of the font Dyslexie. In this study the size of the font Dyslexie was adapted to the point size of Arial. This could explain the non-significant result. Several studies showed that a larger point size of a font results in better reading times (Bernard et al., 2003; Hughes & Wilkins, 2000; Wilkins et al., 2009). A larger font size is more legible and increases the reading speed (Bernard et al., 2002; Wilkins et al., 2009). Making the font size of Dyslexie larger could ensure a significant faster reading time. Future research is needed to fully examine the effect of a larger size of the font Dyslexie on reading performance.

Hypothesis 2. The hypothesis that the reading accuracy of dyslexics will improve when they read a text with a yellow background (H2a) was partly supported by the results of this study.

The reading accuracy of dyslexics with a lower reading level did improve with a yellow background but this was not significant. The reading accuracy of dyslexics with a higher reading level showed a trend in improving with a yellow background. These non-significant effects might be due to the earlier described blue/yellow color opponent. The effect of the color yellow in combination with the color of black letters was not strong enough to really make a significant difference for reading accuracy. Especially for dyslexics with a lower reading level the effect was less strong than for dyslexics with a higher reading level. As described earlier dyslexics with a higher reading level could be more alike non-dyslexics. Unlike with reading speed the color yellow could serve as a intensifier of contrast with letters and words and therefore sees to a better reading accuracy.

Another explanation for the less strong effect of the color yellow for dyslexics with a lower reading level are their reading skills. Research showed that more impaired readers have difficulty in phonological, naming-speed and orthographic skills (Badian, 1997). Besides below average readers rely more on graphic information than semantic information (Leslie, 1980). Using the color yellow as background color does not change the graphic outlay of words, it only changes the contrast of colors. As findings showed this could explain the improvement on reading accuracy but the non-significant result.

The second part of the hypothesis was that the reading accuracy of dyslexics will improve when they read a text in the font Dyslexie (H2b). The font Dyslexie is especially designed to make it easier for dyslexics to distinguish letters and therefore reduce reading errors (Boer, 2011). The results support the hypothesis and showed a significant result for

dyslexics with a lower reading level and an incline towards a trend in the predicted direction for dyslexics with a higher reading level. Besides both dyslexics with a lower and higher reading level made significant fewer mistakes with several sub errors with the font Dyslexie.

Hypothesis 3. The first part of the third hypothesis predicted that the reading speed and accuracy of dyslexics will increase when they read a text in the special font Dyslexie with a yellow background (H3a). This hypothesis is partly supported.

Dyslexics with a lower reading level had the best results with the condition Yellow-Dyslexie. Findings showed an interaction effect of the color yellow and the font Dyslexie for reading accuracy. Regarding reading speed there were no significant results. Dyslexics with a higher reading level did not improve on reading speed with the condition Yellow-Dyslexie. They slightly improved on reading accuracy but analysis showed that this was not significant. Striking herewith is that the color-font combination Yellow-Dyslexie does not show any result while looked at separately both yellow as Dyslexie show a trend on reading accuracy. It would be interesting to further study the effect of color and font on each other and the influence of them both on the readability of texts.

The second part of the third hypothesis predicted that the reading speed and accuracy of dyslexics with a lower reading level will increase more with the special font Dyslexie and a yellow background than the reading speed and accuracy of dyslexics with a higher reading level (H3b). This hypothesis is supported by the findings.

Results showed that dyslexics with a lower reading level improved more with the condition Yellow-Dyslexie in comparison with all the other conditions than did dyslexics with a higher reading level. A possible explanation for these findings is the difference in reading skills between dyslexics with a lower and higher reading level. Research from Badian (1997) showed that the more impaired readers had more problems in phonological, naming-speed and orthographic skills. These children have less compensatory skills to fall back on during reading (Badian, 1997). The visual elements used in this study, the background color yellow and the font Dyslexie, could serve as a compensator for the dyslexic children with a lower reading level. The less impaired dyslexics have better reading skills and they probably need these visual compensators less.

Another explanation could be the difference in level of prior knowledge between dyslexics with a lower and a higher reading level. The level of prior knowledge affects word identification skills (Priebe et al., 2010; Taft & Leslie, 1985). Children with low prior knowledge and a below average reading level made more oral reading errors and relied more

on graphic cues. Children with high prior knowledge relied more on semantic information. (Leslie, 1980; Priebe et al., 2010; Taft & Leslie, 1985). The combination of the yellow background and the font Dyslexie changes the color contrast and the graphic outlay but not the semantic information. This could explain the difference in level of increase between dyslexics with a lower and higher reading level. Future research is necessary to fully explore the role of level of prior knowledge between dyslexics with a lower and higher reading level and the influence on reading performance.

Limitations

An important limitation in this research is that the children read the texts with the different color-font combination only once. Thus, they did not have time to get more familiar with a yellow background or with the special font Dyslexie while reading. A larger exposure of reading with these visual adaptations could further improve the reading performance of dyslexics. In addition, another limitation of this study is the sample size of the dyslexics, 13 dyslexics with a lower reading level and 9 dyslexics with a higher reading level. Though this study shows interesting findings more dyslexics of the lower and higher reading level are needed to be certain of the positive effects of a yellow background and the special font Dyslexie on reading performance. Future research should include the aspect of more exposure and a larger sample size so the effect of color and font could be analyzed with more certainty.

In this study measurements of reading performance were speed and accuracy. Another aspect of reading performance is comprehension. The visual elements used in this study, the background color yellow and the font Dyslexie, could also influence reading comprehension. For future research it would be interesting to study the effect of a yellow background and the font Dyslexie for reading comprehension.

Conclusion and practical implications

This research was the first to examine the use of a colored background in combination with the font Dyslexie. In addition, this research was also the first in examining the influence of a yellow background with texts on paper with dyslexics. The findings of this study could lead to several practical implications. These implications could exist of the implementation of the color yellow and the font Dyslexie for dyslexics with a lower reading level and perhaps the implementation of a yellow background or the font Dyslexie for dyslexics with a higher reading level. In view of these different findings for dyslexics implementation of these visual elements should be looked at individually. As a consequence implementation requires more

flexibility, time and money of primary schools. On the other hand these implementations could lead to a better reading performance of dyslexics and more pleasure in reading.

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Appendix I

Example of a small piece of text per font of the lower reading level

Standard font Arial

Walvis overleden tijdens reddingsactie

Een walvis zwom een paar dagen in de rivier de Theems in Londen. Reddingswerkers probeerden hem te redden. Maar de reddingsactie is voor niks geweest. De walvis is tijdens de reddingsactie doodgegaan.

In het nieuws
De walvis was vrijdag ontdekt. Hij zwom midden in Londen in de rivier de Theems. Dat was heel bijzonder. Er zwemt niet vaak een walvis door Londen. Journalisten gingen er snel naar toe. Ze gaven het dier de bijnaam *Wally*. Journaals openden met het nieuws. Op de Britse televisie was de reddingsactie *live* te zien. *Sky news* vloog zelfs met een helikopter boven de rivier. Duizenden mensen kwamen in Londen naar de rivier. Ze stonden langs de kant naar de walvis te kijken.

Special font Dyslexie

Walvis overleden tijdens reddingsactie

Een walvis zwom een paar dagen in de rivier de Theems in Londen. Reddingswerkers probeerden hem te redden. Maar de reddingsactie is voor niks geweest. De walvis is tijdens de reddingsactie doodgegaan.

In het nieuws
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Appendix II

Example of a small piece of text per font of the lower reading level with an approximation of the yellow background used in this study

Standard font Arial

Walvis overleden tijdens reddingsactie

Een walvis zwom een paar dagen in de rivier de Theems in Londen. Reddingswerkers probeerden hem te redden. Maar de reddingsactie is voor niks geweest. De walvis is tijdens de reddingsactie doodgegaan.

In het nieuws
De walvis was vrijdag ontdekt. Hij zwom midden in Londen in de rivier de Theems. Dat was heel bijzonder. Er zwemt niet vaak een walvis door Londen. Journalisten gingen er snel naar toe. Ze gaven het dier de bijnaam *Wally*. Journaals openden met het nieuws. Op de Britse televisie was de reddingsactie *live* te zien. *Sky news* vloog zelfs met een helikopter boven de rivier. Duizenden mensen kwamen in Londen naar de rivier. Ze stonden langs de kant naar de walvis te kijken.

Special font Dyslexie

Walvis overleden tijdens reddingsactie

Een walvis zwom een paar dagen in de rivier de Theems in Londen. Reddingswerkers probeerden hem te redden. Maar de reddingsactie is voor niks geweest. De walvis is tijdens de reddingsactie doodgegaan.

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De walvis was vrijdag ontdekt. Hij zwom midden in Londen in de rivier de Theems. Dat was heel bijzonder. Er zwemt niet vaak een walvis door Londen. Journalisten gingen er snel naar toe. Ze gaven het dier de bijnaam *Wally*. Journaals openden met het nieuws. Op de Britse televisie was de reddingsactie *live* te zien. *Sky news* vloog zelfs met een helikopter boven de rivier. Duizenden mensen kwamen in Londen naar de rivier. Ze stonden langs de kant naar de walvis te kijken.