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The impact of font type on reading

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Abstract

Significant differences in brain activation patterns exist between readers with and without dyslexia (Shaywitz, 1998). One possible area of difference involves font style that has led to the development of specific fonts to help individuals with dyslexia. Recent studies of dyslexia-specific fonts provide no specific evidence that they improve an individual's reading ability or speed of reading.

Dyslexia

Dyslexia, a language-based learning disability, has a life long status, although its impact can change at different stages during a person's life. The exact causes of dyslexia are not confirmed, but brain imaging has shown how the brain of someone with dyslexia develops and functions throughout life. Dyslexia is not due to a lack of intelligence; with appropriate teaching methods, individuals with dyslexia can learn to read and write successfully (IDA, 2013a). According to the International Dyslexia Association (2013a), studies show that 15-20% of the population has a reading disability, and of those, 85% of those individuals have dyslexia. It can occur in all people, regardless of gender, age, or ethnicity, and appears to run in families (IDA, 2013a).

Dyslexia is a type of learning disability. Learning disabilities have an impact on children and young adults in the United States and around the world. In 2002, nearly 2.9 million students in the United States were receiving special education services for learning disabilities, and, more recently, 39.5% of students receiving special education services in the public schools were identified as having learning disabilities (Duncan, Yudin, & Musgrove, 2015).

Over the past 20 years, governmental reports and studies have provided an overview of the impact of learning disabilities in the United States. Two-thirds of secondary education students with learning disabilities are reading three or more grade levels behind their peers, while 20% are reading five or more grade levels behind (Davies-Mercier, Chorost, Garza, Guzman, & Sumi, 2003).

Unfortunately, the longer an individual has the learning disability before being assessed for appropriate interventions, the larger the academic gap with their peers will become. More than 27% of children with learning disabilities drop out of high school compared to 11% of the general student population (Paige, Pasternack, & Smith Lee, 2001). Two-thirds of high school graduates with learning disabilities do not qualify to enter a four-year college compared to 37% of nondisabled graduates (Horn & Berktold, 1999). Only 13% of students with learning disabilities, compared to 53% of students in the general population, have attended a four-year post secondary institution within two years of leaving high school (Davies-Mercier et al., 2011). The majority of these individuals with learning disabilities have difficulties in the area of reading (Berdline, 2015), and dyslexia is the most common reading disability (The Yale Center for Dyslexia & Creativity, 2016).

While dyslexia manifests differently for each person, it has several common characteristics. The most common effects are unexpected difficulties with written language: reading, spelling, and writing. Some individuals with dyslexia have difficulty with oral language in addition to their difficulties with written language. Oral language problems involve a person's difficulty expressing oneself or

comprehending what others are saying. These can lead to major problems later in life in school, the workplace, or in relating to other people (IDA, 2013a).

Some common signs of dyslexia include learning to speak, organizing written and spoken language, learning letters and their sounds, memorizing number facts, spelling, reading, learning a foreign language, and correctly doing math operations (Petrozzino, 2016). Other common signs of dyslexia for kindergartners through fourth graders include letter and/or word reversals, inversions, transpositions, trouble with sequences, skipping punctuation, stress under pressure, sub-vocalization, and substitutions (IDA, 2013b). These common signs do not occur in all cases, and they are not limited to these lists. Formal testing is the only way to be sure if someone has dyslexia.

While dyslexia is a life-long condition, early identification is key to starting treatment to help the person with dyslexia achieve success in school and the workplace. Most people with dyslexia will need a tutor, teacher, or language therapist to help them to be trained through a multisensory, structured language approach. In addition, extra time to complete tasks or extra help might be needed during work activities. Books on tape or alternative assignments might even be necessary to assist the individual's performance (IDA, 2013b).

Formal evaluation for dyslexia should assess intellectual ability, information processing, psycho-linguistic processing, and academic skills as well as the person's family background (Ellis, 1994). Intellectual ability and information processing assessments might include comprehensive measures such as the Wechsler Intelligence Scales for Children (WISC-V), Woodcock-Johnson Tests of Cognitive

Ability (WJ-4), Stanford-Binet 5 or brief measures such as the Kaufman Brief Intelligence Test (KBIT-2) or Wechsler Abbreviated Scale of Intelligence (WASI-II). Psycho-linguistic assessments might include measures such as the Comprehensive Test of Phonological Processing (CTOPP-2) and portfolio/written language samples (IDA, 2013a). Once the assessments are completed and the individual is identified as having dyslexia, then a wide array of services and accommodations can be implemented.

Individuals can receive services and accommodations because of several laws governing their education and many areas of life. These laws include the Individuals with Disabilities Education Act (IDEA), Section 504 of the Rehabilitation Act of 1973, and the Americans with Disabilities Act (ADA)(Debunking the Myths about Dyslexia, 2016). For example, Building The Legacy of IDEA (2004) states that Individualized Education Plan (IEP) teams must consider assistive technology (AT) for every student who is eligible for special education services. This requirement includes students with learning disabilities such as dyslexia, not just those students who have severe or profound disabilities. Everyone who is eligible for services under IDEA is also eligible for appropriate AT (Winters, 2014).

Intervention

The International Dyslexia Association (IDA) (2013b) states that children who receive appropriate interventions during kindergarten and first grade will have fewer problems in learning to read at grade level with their peers than those who do not receive those interventions.

Students with dyslexia need direct and explicit instruction in literacy skills. While the students are likely doing their best, they often take more time and effort to complete tasks involving reading and writing. These students also need a quiet, calm, structured, consistent, and fair environment (IDA, 2013b). For example, people should only give a student with dyslexia one to two verbal instructions at a time and use very short explanations. Using a simultaneous multisensory structured approach appears the most effective instructional approach for literacy for individuals with dyslexia. This approach includes emphasizing the visual, auditory, and kinesthetic pathways of learning simultaneously. In addition, people should give the individual with dyslexia time to process what is being said, time to respond, and time to complete an assignment to the best of his/her ability. When the individual is not paying attention or looks "glazed" over, the individual is likely experiencing an overload. For individuals with dyslexia, time is one of the most important factors leading to success in the general education classroom or workplace (Horn & Berktold, 1999).

Teachers can help eliminate stress/ the gazed over look by using explicit directions and, when necessary, repeating them, as well as by having the students repeat the directions in their own words. In addition, keeping a daily routine will help the student not experience unexpected surprises in their daily learning routine. Additionally, teachers can provide a copy of notes, graphic organizers, and step-by-step instructions as a way to increase the student's success. Combining verbal and visual information, using work samples, encouraging note sharing, and writing the

key points on the board from each lesson are other ways to help the student with dyslexia. Daily reviews can also be a great benefit to the student (IDA, 2013a).

Spelling difficulties are a significant aspect of dyslexia. People who have spelling difficulties usually have trouble in analyzing the sounds, syllables, and meaningful parts of whole words in both spoken and written language (Moats, 1994). Moats (1994) found that students with dyslexia have difficulty going through the stages of spelling development. A brief early stage of spelling development is phonetic spelling. Phonetic spelling is the representation of vocal sounds, which express pronunciations of words (Dictionary.com, 2015). An example of phonetic spelling would be the word *dog* spelled out like *dahg*. The "ah" makes the short "o" sound. If students have good phonemic awareness, such as being able to segment all of the sounds in a simple word, the student is more likely to remember the letters and letter combinations of the word. Students who do not learn spelling easily will benefit from emphasizing sounds in the word. Effective spelling practices use a multisensory approach that focuses on systematic and cumulative patterns, memorizing sight words, writing words out correctly multiple times, using words in personal writing, and knowing the sounds and letters found within the patterns of syllables (Moats, 1994).

When noticing these characteristics of individuals with dyslexia, the earliest pioneers in the field, Scottish ophthalmologist James Hinshelwood and British physician Pringle Morgan, both emphasized that the difficulty has a neurological basis. These early researchers focused on the similarities of symptoms between dyslexia and the neurological syndrome of "visual word blindness" (Lovett &

Steinbach, 1997). Since their early work on the neurological aspects of dyslexia, continuing research has confirmed and expanded their findings.

Neurological

Within the last several decades, researchers have made significant scientific advances concerning the neurological aspects of learning that are now providing a coherent theoretical framework for practitioners to approach the most common disorders in children and adolescents, including dyslexia. For example, functional neural imaging studies have demonstrated that the cognitive deficits found in dyslexia are related to a pattern of brain organization that is different from those of unimpaired readers (Shaywitz & Shaywitz, 1999).

Dyslexia is familial and heritable (Pennington & Gilger, 1996). Scarborough (1990) reported that 23-65% of children who have a parent with dyslexia have similarly been identified as having dyslexia. With dyslexia being familial, researchers have found a 40% correlation among siblings (Pennington & Gilger, 1996). Dyslexia is additionally related to a functional impairment within the brain's mechanisms for language, specifically in the component responsible for phonologic analysis (Simos et al., 2002).

Functional brain imaging provides a real-time spatiotemporal map of brain activity by directly measuring electrical currents in the brain. Functional brain imaging is noninvasive and can be used repeatedly with both individuals with and without dyslexia (Simos et al., 2002). McCrory, Mechelli, Frith, and Price (2004) reported that studies show that reduced activation in the occipitotemporal region underlies the reading and naming deficits observed in developmental dyslexia.

Furthermore, individuals with dyslexia showed little or no activation of temporoparietal areas in the left hemisphere, while children with no reading impairments activated those areas easily (Simos et al., 2002). Also, individuals with developmental dyslexia showed strong functional correlation between the left angular gyrus and other left hemisphere regions involved when reading is absent (Horwitz, Rumsey, & Donohue, 1998). Activation in the left angular gyrus was dramatically reduced in children with dyslexia compared to children without dyslexia (Simos et al., 2002). In the left angular gyrus, there is a functional disconnection from visual areas like Wernicke's area and the inferior frontal cortex. The absence of this correlation is exposed in people with dyslexia and demonstrated that, as a group, they are not using the same network of controls. Instead, they appear to have compensated to some degree over their lifetime for the dysfunctional network in the left hemisphere (Horwitz et al., 1998).

Shaywitz (1998) found significant differences in brain activation patterns between non-impaired and dyslexic readers. These differences appeared when there was a demand for phonological awareness using a non-word rhyming task. In readers with dyslexia, a disruption is found in the posterior region involving the superior temporal gyrus and angular gyrus with an increase in activation in the inferior frontal gyrus anteriorly. Children without dyslexia demonstrated significantly greater activation than children with dyslexia did in the left hemisphere (See Figure 1) (Shaywitz et al., 2002).

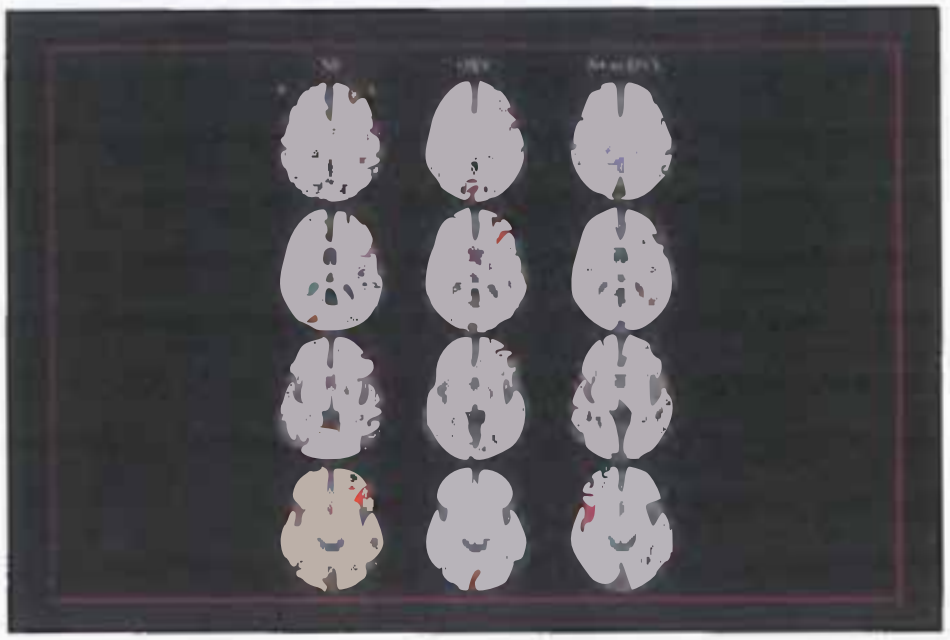

Figure 1. (Shaywitz et al., 2002) The left column is a nonimpaired reader, the middle is a reader with dyslexia, and the right is a comparison.

A report by Shaywitz et al. (2004) showed that an evidence-based and phonologically mediated reading intervention program improved the reading accuracy, reading fluency, and reading comprehension of readers with dyslexia. These findings suggested that the nature of remedial educational intervention is critical to successful outcomes of children with reading disabilities, especially dyslexia. The researchers suggested that the use of evidence-based phonological reading intervention facilitated the development of the natural systems that underlie skilled reading (Shaywitz et al., 2002). As a result, this intervention led to the development of neural systems both in the anterior and posterior brain regions (see Figure 2).

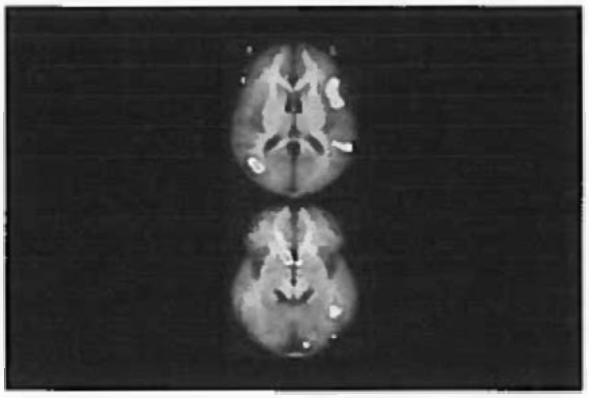

Figure 2. (Shaywitz et al., 2004) Intervention year three vs. year one

Phonological awareness is the realization that words are made of a combination of smaller units like syllables and phonemes, while lexical retrieval refers to the ability to quickly retrieve the phonological forms of words (Ramus, Marshall, Rosen, & Van Der Lely, 2013). People with dyslexia also have difficulties with lexical retrieval, which is primarily accounted for by a single underlying cognitive deficit. People perceive and identify a visual stimulus and retrieve its associated lexical form, which is then output during articulation (McCrory et al., 2004). During the process of reading and naming, a phonological code is retrieved and this code consists of phonological segments that become activated and assembled into a sequence that controls the creation of words (Levelt, Praamstra, Meyer, Helenius, & Salmelin, 1998). Lexical retrieval persists into adulthood, but on a more subtle level (McCrory et al., 2004).

In children with dyslexia, this difficulty with lexical retrieval often shows up as early impairments in picture naming in addition to the difficulties with reading. Seemingly, children with dyslexia are slower to name the first row of stimuli than slightly younger typically developing readers. Slow naming times seen in dyslexia might be related to automaticity of retrieval or a difficulty sustaining processes

needed for retrieval (Norton & Wolf, 2012). Also, children with dyslexia present impairments on tasks of rapid automatic naming with a series of pictures that are named sequentially (Denckla & Rudel, 1976). Naming pictures provides a means to index literacy skills (McCrory et al., 2004). Furthermore, many children develop accurate decoding with basic instruction and then achieve automaticity with time and practice (Lyon, Fletcher, & Barnes, 2003).

Shaywitz and Shaywitz (1999) concluded that from kindergarten through high school, phonological awareness represents the most vigorous characteristic of reading disabilities with dyslexic readers. Research results have shown that adults with a history of dyslexia in their childhood demonstrate continuing problems in reading and spelling throughout life. When adults with dyslexia name single pictures quickly, then the impairments emerge more noticeably. Children who have low phonological awareness and slow naming speed in kindergarten make slower progress in reading development and are more likely to suffer from reading difficulties later in life (Kirby, Parrila, & Pfeiffer, 2003).

Dyslexia is not characterized by a general language or semantic deficit; rather, it is an issue with the person being able to find a logical representation image and retrieval from the brain (McCrory et al., 2004). Individuals with dyslexia have difficulties with phonemic awareness, and these deficiencies lead to poor development with word recognition skills. In addition, cognitive processes engaged when reading a word overlap with those engaged when naming an object (Geschwind, 1965). When children realize that spoken words are composed of smaller segments, also known as phonemes, they can learn to view written words as

multiple segments (Simos et al., 2002). Also, measures of reading fluency have shown that these children are slow to achieve the requisite automaticity and speed that characterizes proficient readers.

At risk children may end up developing the full phenotypic profile (which includes visible characteristics like one's height and eye color, but also more hidden characteristics like one's overall health, disease history, and even behavior and general disposition) of dyslexia because these individuals are not identified early and/or they never received appropriate intervention that would activate the brain mechanisms that mediate word recognition (Simos et al., 2002). Individuals with dyslexia showed selective deficits and phonological impairments but not semantic processing of pictures (McCrory, et al., 2004). Concerning the posterior temporal circuit established with training, children with dyslexia are not as efficient as that of children with a typical developmental history (Simos et al., 2002). Successful completion of intensive remediation programs in reading associates itself with dramatic changes in brain activation within children with severe reading difficulties (Simos et al., 2002).

To understand how people read text, psychologists have analyzed people's eye-gaze while reading text. Eye-gaze tracking uses a camera to track and record where the subject's eye is looking. It records the gaze points and maps them to the text to follow the subject's reading behaviors (Beymer, Orton, & Russell, 2008).

Increased text difficulty imposes a greater burden on cognitive processing capacity that is reflected in increased length of fixation and other features of eye movement. According to McConkie and Zola (1986), research involving eye

movement can help understanding the nature of the mental processes involved in reading, how one learns to read, and what processing strategies or characteristics are more common in children who are not showing a normal progress in learning to read.

Serif vs. Sans Serif Fonts

Typography is the style or appearance of a printed material, the visual component of the written word, and arrangement of type (Spiekermann & Ginger, 2003). Typeface and font are important properties of typography. Each font of a typeface (a particular design of type) has a specific weight, style, condensation, width, slant, italicization, ornamentation, and designer. Font is an assortment of characters all of one style and size. Typefaces can be divided into two main categories: serif and sans serif. Serifs comprise the small features at the end of strokes within letters. The printing industry refers to typeface without serifs as sans serif (Carter, Day, & Meggs, 2002).

The typography with serifs was deemed a more decorative font, but fonts with serifs were believed to be too excessive of a decorative text (Carter et al., 2002). David and Horton (2008) reported that hand drawn decorative fonts impeded the progress of reading and were slowly phased out after the invention of the Gutenberg press.

Serifs are fine lines that extend horizontally at the top and bottom of fonts' individual characters. For example, Times New Roman is a serif font because most of its characters have horizontal extensions at the top and/or bottom. Sans serif fonts are fonts that do not have serifs (Figure 3). For example, Ariel is a sans serif font

because it does not have horizontal lines extending off the tops and bottoms of the characters (Woods, Davis, & Scharff, 2005). Sans serif and serif fonts appear to have an impact on individuals with dyslexia while reading (De Leeuw, 2010).

Figure 3 Serif vs. Sans Serif

The first sans serif font appeared in Britain in 1816, and the first lowercase sans serif alphabet was introduced in 1835 (Craig, 1980). Craig (1980) attributed the origin of serifs to the Romans, who used to hit a stroke into a slab of marble or rock to correct the uneven appearances their tools made when engraving letters. Over time, publishers have used serif fonts because they have believed that these fonts provide visual spacing and accents to the end of the strokes to help the reader read faster, thus increasing the legibility of the text (Lannon, 2000). In addition, Lannon (2000) stated that the serifs help guide the reader's eye horizontally.

For the different font types of serif and san serif there is a lack of statistically proven differences in font studies to rule in favor of either of them. Those who favor serif fonts claim that the contrasting use of thin and thick lines makes the letters and words more distinctive and is easier on the eye (Beymer et al., 2008).

As noted by Erdmann and Neal (1968), legibility of text, including the presence of serifs, has a direct effect on a text's readability. Legibility and readability are two important aspects contributing to reading comprehension. Legibility deals

with the very fine details or the typeface design in operational context, such as being able to recognize individual characters and words. Readability is what makes some texts easier to read than others. It is often confused with legibility, which concerns typeface and layout (DuBay, 2004). Legibility is how easy the text is to comprehend or how easy it is to visually perceive the whole text. Also, legibility of a text has a direct effect on its readability (Erdmann & Neal, 1968).

The importance of serifs is dependent on the individual characters, not the legibility of the text (DeLange, Esterhuizen, & Beatty, 1993). Most typographers and printers have preferred and advocated for typefaces with serifs because they have believed these typefaces to be more legible. Many different authors, while getting their books published, have argued that readers prefer the serifs as well, believing that these fonts were faster to recognize, easier to read, and resulted in better comprehension (DeLange et al., 1993). However, a study by DeLange et al. (1993) found no dramatic difference in comprehension between serif and sans serif text. In this study, under the normal reading conditions of a primary education classroom, serif and sans serif fonts were equally legible to the reader. The researchers tested legibility through tasks involving word recognition, speed-reading, comprehension, and scanning. The results of this study found that serifs had no noticeable effect on legibility. Under the normal reading conditions of a primary education classroom, serif and sans serif fonts were equally legible to the reader. The researchers suggested that this outcome was due to readers' eyes moving in small steps rather than in a continuous motion. Therefore, the authors concluded that the reading process does not need the assistance of serifs.

Letter Spacing

De Lange et al. (1993) also suggested that serifs help with letter spacing and lead the reader to better distinguish characters. The font used in this study was constructed with a custom software program (Arditi, 2004) that allowed parametric font construction. Nine different constructed fonts were used for this study. Of those nine fonts, only 14 of the 26 letters in the alphabet had a serif along the baseline, which added more separation between characters (Arditi & Cho, 2005).

These lines are at the bottom of the character for added separation, which is important for readers with dyslexia. Therefore they determined that, at very small letter sizes close to the acuity limit, serifs may actually slightly interfere with legibility (Arditi & Cho, 2005).

This study concluded that people do not distinguish words by reading each letter individually; instead, they only glance over the word. De Lange et al. (1993) stated that this glancing is done at a more rapid pace when using serif fonts.

Jha and Daftuar's (1981) study showed that serifs are preferred between the ages of kindergarten and fourth grade at larger font sizes while sans serif fonts are preferred at smaller font sizes for people beyond fourth grade. During this study, the sans serif font showed much higher scores on discrimination and identification tasks, but was more consistent with 18-point font rather than 12-point font. However, in another study (Woods et al., 2005), Ariel, a sans serif font, was found to be more legible among all grade levels. Meanwhile, sans serif fonts in bold and in 12-point font or larger provided the most readable conditions for medicine labels and

flat surface labels (Russell-Minda, Jutai, Strong, Campbell, Gold, Pretty, & Wilmont, 2007).

In contrast, with small font sizes the serifs may slightly interfere with legibility (Arditi & Cho, 2005). In fact, Yager, Aquilante, and Plass (1998) found that 16 of 20 people read a sans serif font more rapidly than a serif font. Yet another study (Russell-Minda et al., 2007) showed that, while serifs may interfere with the legibility of the text, they had very little impact on the reader's actual ability to read. Because the impact on reading speed was so small, the authors believed that this study was not worth further investigation.

Also, serifs can act as a distraction on the characters, which can cause slower word recognition (Moret-Tatay & Perea, 2011). In the end, all of these studies concluded that serif use depends most on a reader's preference (Russell- Minda et al., 2007).

Serifs do not perform as expected in aiding comprehension while serifs also do not appear to support either legibility or readability, according to a study by Akhmadeeva, Tukhvatullin, & Veytsman (2012). The results of this study indicated only a small difference in legibility and/or readability between the serif and sans serif fonts. In addition, reading speed changed only slightly. For example, on the study tasks, there was only a 1.74 word per minute increase and 0.38 correct answer increase using the sans serif fonts. This study also found no real difference for Cyrillic or Western Hemisphere readers and that there is no effect on serifs and comprehension (Akhmadeeva et al., 2012). However, there has been no agreement on whether text should be in serif or sans serif fonts. For example, some debate has

happened in which teachers claim that sans serif fonts are simpler and more recognizable for their students (Coghill, 1980). Yet, studies with children have shown no difference in students' ability to read in either sans serif or serif fonts (Coghill, 1980).

Subjects in a Dickinson, Gregor, & Newell (2002) study were in agreement about the selection of a typeface: the sans serif Arial font was rated the best by almost all the subjects. This study's subjects noted that they preferred the Arial font because of its simplicity. People with dyslexia who participated in this study stated that this font was straightforward, clear, basic, and rounded. Some teachers in the study felt that applying bold to the font had a negative effect because of the letters appearing to be more condensed together. Most teachers reported that they would choose a font size larger than 12-point for their students with dyslexia because there was more space between the letters (Dickinson et al., 2002). From the teacher's point of view, the spacing between the characters, words, and lines was very beneficial to the students regardless whether the text used a serif or sans serif font.

When the study had first started, most participants with dyslexia had assumed that the process would give them the best "go to" font that they could use. Instead, they learned how to adapt the fonts to match what they were looking for by changing the font settings (Dickinson et al., 2002). With technology, spatial metrics like spacing and border size can be customized to an individual's liking.

Also, individuals who do not read individual characters within each word look at the word as a whole (Dick, Gadberry, Media, & Monge, 2014). Once these

participants found out that they could change their settings to something that was more beneficial than the default, they were able to find a setting that was better for them. This discovery led to significant improvement in their reading ability (Dickinson et al., 2002). As above, serifs appeared to have had no effect on the subject's reading ability, and, therefore, serif use in fonts appears to be a personal preference (Moret-Tatay & Perea, 2011).

In the end, whether or not a person has dyslexia, there does not appear to be any clear-cut reason for using either serif or sans serif fonts. Therefore, even though the British Dyslexia Association (2015) recommends the use of a well-spaced and plain sans serif font such as Arial, the consistent result of the research reviewed is that choice of serif or san serif font comes down to an individual's preference.

Research has shown that different types of fonts have helped and hindered students' ability to read. Specifically, the new dyslexic fonts compared to the traditional Ariel, and how serif and san serif fonts make a difference in how easy something is to read. To address these issues, "dyslexic" fonts are being developed, and researchers are closely examining the role of visual perception of text when learning to read.

Typeface/ Fonts

"Fonts are typically classified according to unique typographical features (serif, sans serif, etc.) and overall appearance" (Shaikh, Chaparro, & Fox, 2006). Typographers often are interested in the "typographic allusion" which is "the capacity of a typestyle to connote meaning over and above the primary meaning which is linguistically conveyed by words" (Lewis & Walker, 1989, p. 243).

Publishing companies have guidelines on what kind of typeface to use for their text (Woods et al., 2005). These guidelines are often based on the font types and sizes that are most frequently used by other publishing companies rather than looking at empirical data that has investigated the legibility and readability of the text (Woods et al., 2005). Legibility of text influences readability, which in turn influences the ease of comprehension (Erdmann & Neal, 1968).

Historically, publishers have believed that font types can increase or decrease the ability of an individual to read letters (Tinker, 1963). Also, data has shown that different fonts can influence reading speed as much as 30% (Chauncey, 1986). Distinctive fonts have a combination of characteristics that include serifs, stroke width, and letter height and width. As discussed above, serifs are the fine lines that extend horizontally from the main strokes of a letter (Lannon, 2000). Stroke width refers to the width of each component or stroke of a letter. There could be a uniform stroke width, like Ariel, in which each stroke is the same width. There is also a varying stroke width, like Times New Roman, in which some portions of the stroke are thinner than others. Fonts can also have a generally wide stroke width, which is referred to as "bold" or a thin stroke width, which is referred to as "light" (Yager et al., 1998).

Overall, Ariel was found to be more legible than Times New Roman across all grades. Arial's x-height (the distance between the baseline of a line of type and tops of the main body of lower case letters) is also larger than Times New Roman in the same point size, which gives Arial a size advantage. 18-point font was found to be more legible for kindergartners and first graders over the 12-point font, but after

first grade there was no significant influence on performance between these two font sizes (Woods et al., 2005).

Unfortunately, children with reading difficulties are significantly outperformed by their same age peers, although they did score similarly to their younger peers. In a study by Zascavage, McKenzie, Buot, and Woods (2012), the students with reading difficulties were divided into two subtypes, phonological and surface dyslexia; these were significantly lower in visual spatial memory than any other. These children were then broken down into smaller "clusters" by using the Phonological Core-Variable Model. The clusters were identified as serial memory deficit only, combined verbal learning and serial memory deficit, combined visual-spatial and serial memory deficits, and serial memory deficits. This was also compared to the Howes, Bigler, Burlingame, and Lawson (2003) study, which studied the same visual-spatial memory aspect.

The participants in the Howes et al. (2003) study were also tested for their visual-spatial memory (right hemisphere activity). Howes et al. (2003) stated that verbal and visual-spatial deficits appear to characterize memory problems differently with the different, yet specific, dyslexia subtypes, whereas all subtypes showed serial memory impairments. Variance reported for the cluster combined verbal learning and serial memory deficit in serial memory was .474 with a visual-spatial variance of .178 and a verbal variance of .375. This finding contrasted with the cluster results for visual- spatial and serial memory deficits of .343 in serial memory with a visual-spatial variance of .423 and verbal variance of .052.

The testing indicated that children with reading difficulties were significantly outperformed by their chronologically same-aged peers, but scored similarly to younger readers.

With a study group consisting of all individuals with dyslexia, researchers distributed a text printed in three dimensions to see if this visual spatial attribute could help or hinder their reading. For the students who were having the most difficulty reading the sight words in a non-three dimensional test, reading accuracy improved by nearly three words when reading the three-dimensional print version. However 63 out of 214 students were impeded by the three-dimensional print, which was identical to the flat print but with shadows and a subtle block appearance (Zascavage et al., 2012). Overall Helland and Ashjornsen (2003) concluded that, while visual spatial skills should be considered when assessing for dyslexia, they should not be an indicator of assessing dyslexia while reading.

While visual spatial skills should not be the sole indicator of assessing for dyslexia, individuals with dyslexia do appear to suffer from crowding, which is the inability to recognize objects in clutter. Many people with dyslexia have problems with crowding; they are distracted by the words surrounding the word that they are trying to read (Hill, 2010). Therefore, larger font size helps them as they read because it creates more space between the letters and lines, which reduces crowding (Chung, 2007). However, throughout these larger texts, individuals with dyslexia obtained their optimal rate of reading (Martelli, Di Filippo, Spinelli, & Zoccolotti, 2009).

Whitney and Levi (2011) stated that their results showed that a quick and efficient fix to help someone with dyslexia learn to read more efficiently was to use extra large letter spacing. The benefit of extra large letter spacing might also be linked to sluggish visual spatial attention, allowing people to selectively process visual information through prioritization of an area within the visual field. As mentioned before, special spatial attention diminishes crowding, which will usually improve the accuracy of identification. Sluggish spatial attention is also observed even in at-risk readers who later become identified as having dyslexia (Zorzi et al., 2012).

In some cases, when information is made harder to learn by using disfluent fonts (fonts other than the typically used fonts like Ariel and Time New Roman), there is significant improvement in retention and recall (Anderson, Bjork, & Bjork, 2000). Disfluent fonts, making material harder to learn while aiding retention and recall, can be easily introduced by changing the font in which information is written (Alter, Oppenheimer, Epley, & Eyre). Alter et al., (2007) studied students reading star facts (specific facts needing memorization in a unit of study) in various fonts. Some of the participants in the study had dyslexia. Overall, the mean score on accuracy was 12.8% higher for students who read their star facts written in a disfluent font like Monotype Corsiva compared to those who read their star facts in the Ariel font.

The British Dyslexia Association (2015) suggests that students with dyslexia should be using simple fonts to aid in reading. Alter et al. (2007) found that, surprisingly, the students with dyslexia in their study followed the overall trend of a

higher score on the star facts if they had read the information in the disfluent font. This improvement was even higher than the general group of students; the students with dyslexia had a mean score of 19% higher (Alter & Oppenheimer, 2009). These harder to read fonts appeared to promote recall and retention of the written information (French et al., 2013).

Arditi (2004) found that fonts that were modified using a prototype font-adjustment software, such as Font Tailor, enhanced legibility on average by more than 75%. Also, Chung, Mansfield, & Legge, (1998) found that larger print size is required to achieve the maximum reading speed in peripheral version than in central vision. Based on evidence within this study, additional research has shown that typefaces including Ariel, Helvetica, Verdana, and Adsans (an unmodified sans serif font) are more readable than Times New Roman (Garvey, Pietrucha, & Meeker, 1998).

In recent years, people have developed a multitude of fonts specifically aimed for individuals with dyslexia. Examples of these fonts are *Lexia Readable*, *Open Dyslexic*, and *Dyslexie Font* (British Dyslexia Association, 2015). *Lexia Readable* is free to download (see Figure 4) and is an adaption of Comic Sans, in which letter symmetry is avoided and spacing between letters, words, and lines is increased. This font was designed by Keith Bates specifically to address legibility and readability issues related to dyslexia. It features good-sized descenders (part of a letter that extends below the level of the base of a letter such as *g* and *p*), and ascenders (a part of a letter that extends above the main part such as *b* and h), generous spacing and excellent screen clarity (Ryan, 2016).

Lexia Readable is a font for dyslexic people. The quick brown fox jumps over the lazy dog.

Figure 4. (Ryan, 2016)

OpenDyslexic (see Figure 5) is also free and can be used in the new Microsoft Office software and downloaded for Nook, Sony Readers, and iBooks, but not the Kindle. This typeface was created by Abelardo Gonzalez, who also has dyslexia. The typeface includes regular, bold, italic, and bold-italic styles, and two typefaces: *OpenDyslexic*, and *OpenDyslexic-Alta. OpenDyslexic* was created to help with some visual characteristics of dyslexia. The letters have heavy weighted bottoms to indicate direction. *OpenDyslexic –Alto* has other features, such as wider letter spacing and a unique italic style (OpenDyslexic, 2016). Gonzalez believed that consistently weighted bottoms could also help reinforce the line of text. This feature may also enable the reader to quickly figure out which part of the letter is downward. The weighted bottoms also aid in recognizing the correct letters and may keep the reader from rotating the letters around. The unique shapes of each

letter may help prevent confusion with flipping and swapping. *OpenDyslexic –Alto* has other features, such as wider letter spacing and a unique italic style (OpenDyslexic, 2016).

OpenDyslexic is a new open source font created to increase readability for readers with dyslexia. The typeface includes regular, bold, italic, and bold-italic styles. It is being updated continually and improved based on input from other dyslexic users.

Figure 5. (OpenDyslexic, 2016)

Dyslexie is also free to the public and has an uppercase "Q" even for the lower case setting (British Dyslexia Association, 2015) (see Figure 6). Christian Boer invented *Dyslexie* while in college to help combat his own dyslexia. In Christian Boer's words, "It is simply like a wheelchair to help dyslexics function, and it makes each letter significantly unique" (Boer, 2015). *Dyslexie* uses a heavier line thickness to emphasize the bottom of the characters as a way to "anchor" the letters. Some people with dyslexia may see letters moving or in three dimensions. Since people with dyslexia tend to get the letters *b*, *d*, *p*, and *q* mixed up, it also emphasizes a slight slant downwards on the curvature of the letters. Letters such as *c* or *e* may separate slightly more, or slump slightly in one direction. Also, in letters such as *n* or *h*, the font elongates or diminishes the stem on the letters. Therefore the letter *h*

would have a longer line, and *n* would have a shorter line. In addition, the font also thickens or bolds capital letters and punctuation, so that it is easier to identify when a sentence starts or ends (DyslexieFont, 2016).

Dyslexie acknowledges that letters can be viewed as 3D objects. If letters are 3D objects, then gravity applies. Dyslexie weighs down the bottom of each letter, preventing it from tipping upside down.

Figure 6. (DyslexieFont, 2016)

Mana and Mich (2010) also made a web tool so the reader can personalize the visualization of the text using the tool's buttons in a toolbar at the top of the page (see Figure 1). The tool bar was made simple and intuitive for easy access for children to use. After the study conducted on nine children was performed it was confirmed that there was a positive impact of text visualization on the text comprehension (Mana and Mich, 2010).

Figure 1. Customized toolbar (Mana and Mich, 2010)

The developers of these special fonts geared toward individuals with dyslexia believe that the fonts can impact their effectiveness, reading time, and perceptions of legibility (Nalewicki, 2011; DyslexieFont, 2016). However, this belief may also be true for all readers, including those who do not have dyslexia

(Debunking the Myths about Dyslexia, 2016). When considering font or typeface choice, individuals would likely benefit from comparing the fonts side-by-side. This comparison allows the individual to see the direct differences in the font and to make decisions based off of his/her own comparisons. Many factors need to be taken into account when comparing fonts, including text characteristics, size, spacing, and, if using a computer, the computer display settings.

Conclusion

The purpose of this literature review was to determine if individuals with dyslexia are positively impacted by recently invented fonts developed specifically for persons with dyslexia. While the creation of these specialized fonts is very recent, the research to date suggests no significant evidence for these specialized fonts to improve the reading comprehension, reading speed, or general reading ability of an individual with dyslexia. These early findings are consistent with previous research on the generally insignificant impact of typography, typeface, and font features for readers with and without dyslexia. Instead, the literature suggests that personal preference for typography, typeface, and font type and size influences the legibility and readability for each person whether he/she has dyslexia or not.

However, research does appear to show that there is a relationship between fonts, reading accuracy, and reading speed. While some studies have shown that some fonts that are faster to read, they still might be less accurate. Experimenting with different fonts is the most effective and worthwhile way for individuals with dyslexia to determine what works best for them. Deciding a font type boils down to personal preference. This field of inquiry will become more important as it is

starting to be the focus of many learning disabilities. With more and more individuals being diagnosed with dyslexia, there will be more inventions attempting to ease individuals' frustration while reading.

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