The Effect of a Specialized Dyslexia Arabic Font, Arabolexia, on Reading Performance of Children with Dyslexia

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Abstract: Dyslexia-friendly fronts have gained interest thanks to their potential advantages on the reading performance of dyslexic children. Most studies, however, were done on Latin-based languages, such as English. Studies investigating the reading performance of people with dyslexia in languages with different writing systems, such as Arabic, remain scarce. Arabolexia, a font developed for dyslexic Arabic speakers, has demonstrated a facilitatory effect on the reading of children with dyslexia. Yet, the features contributing to these advantages have not been empirically studied. The current study examines the elements of Arabolexia —such as letterform, spacing, and font size —that might improve reading. We compared the reading performance of dyslexic children (n=45, mean age = 11.10 years) using texts in both Arabolexia and Simplified Arabic font, a widely used standard font, under four conditions: default Arabolexia, Simplified Arabic with matched font size only, Simplified Arabic with matched spacing only, and Simplified Arabic over-all matching. The results show that Arabolexia's advantages disappear when Simplified Arabic is adjusted to match its spacing. These findings suggest that the facilitatory effect of Arabolexia stems from its spacing parameters rather than its unique design.

Keywords: Arabic, dyslexia, friendly font, reading, spacing, visual crowding

1. Introduction

According to the American Psychiatric Association (2013), dyslexia is a pattern of learning difficulties that pose significant challenges, including problems with accurate or fluent reading, decoding, and spelling. It is primarily associated with deficits in processing on many levels, including the phonological, orthographic, visual, and semantic levels of a given word. Several theories are proposed to delineate the multifaceted nature of dyslexia and to understand the cognitive mechanisms underlying this impairment.

Two main theories have gained attention: phonological theory and visual theory. The phonological theory claims that dyslexia is a deficit affecting the treatment of speech sound and the elaboration of their representations in memory. Individuals with dyslexia struggle with representing, storing, and/or retrieving speech sounds. Furthermore, they have difficulties segmenting spoken words into constituent sounds, such as syllables or phonemes. While many studies support the theory at hand (Snowling 1981; Vellutino 1981), there are many cases where dyslexic individuals do not necessarily have a severe phonological deficit (Lovett, Steinbach and Frijters 2000), which indicates that other factors, such as visual factors, contribute to this impairment.

Visual theory explores this domain and suggests that reading challenges that dyslexics face can be attributed to their visual processing impairment, which affects the interpretation of letters and words. The studies that explored the visual factors suggest that many individuals exhibit deficits in visual treatments irrespective of any sensory impairment (Pavlidis 1981). The visual theory does not dismiss the role of phonological deficits; however, it highlights the role of visual factors in contributing to reading challenges (Stein and Walsh 1997). In support of this claim, some studies indicate that individuals with dyslexia exhibit widely recognized phonological deficits (Snowling 1981) and atypical sensitivity to visual crowding.

The visual crowding effect involves challenges in distinguishing specific items when surrounded by many others (Callens et al. 2013) and it is influenced by letter attributes such as type fonts and spacing. There might be a potential link between visual crowding and dyslexia, as there are studies that identified dyslexic individuals who have elevated visual crowding (Gori and Facoetti 2015; Joo et al. 2018). These studies show that these individuals read faster when presented with increased inter-letter and inter-word spacing. These findings sparked a chain of studies that explored ways to mitigate deficits in the visuospatial processing of letters and words, mainly focusing on the potential of specialized fonts to improve reading for dyslexic individuals (Marinus et al. 2016; Wery and Diliberto 2017; Duranovic, Senka and Babic-Gavric 2018).

1.1 Typographical effects on children with dyslexia

The influence of typographical attributes on dyslexia has been extensively investigated in recent years (Perea et al. 2012; Marinus et al. 2016), studies have examined factors such as inter-letter, inter-word spacing, and font type, exploring their effect on dyslexia. Nevertheless, the findings are inconsistent, and the relationship between dyslexia and typographical attributes remains unclear. For example, when font size is increased, readability for dyslexic individuals increases significantly (Rello, Pielot and Marcos 2016), and when decreasing it, the reading task becomes difficult (Cornelissen et al. 2008). Moreover, eye-tracking of normal and dyslexic individuals reading texts presented in different font types shows that font type impacts readability for people with and without dyslexia (Rello and Baeza-Yates 2016).

Studies have also investigated the role of spacing. For example, Zorzi et al. (2012) found that inter letter spacing improves readability for dyslexic children when sentences were presented with increased spacing compared to standard spacing. While similar findings were reported (Perea et al. 2012), other studies that evaluated the impact of increased spacing did not come to the same conclusion. For instance, Spinelli et al. (2002) found that spacing only benefits some dyslexic children when reading words. It has also been found that manipulating spacing can make word recognition difficult, whether by making it larger (Spinelli et al. 2002; Risko, Lanthier and Besner, 2011) or smaller (Montani, Facoetti and Zorzi 2015).

Recent studies have shifted attention towards understanding how specialized fonts, known as dyslexia friendly fonts (DDFs), can influence the reading performance of dyslexic children to determine if they enhance reading. As a result, several Latin-based DDFs such as Dyslexie, EasyReading, and OpenDyslexic have been created and primary tested in English. These fonts feature two main characteristics. One is the special graphic design of the letterform, which improves letter articulation and helps avoid confusion between letters with similar shapes (e.g., p,q, and b,d). The second characteristic is the wider inter-letter and inter-word spacing that limits the crowding effect.

The investigation of these special fonts shows diverse results. For instance, Bachman and Mengheri (2018) investigated the effect of EasyReading on reading. They had 533 Italian students perform a reading task using two fonts: Times New Roman (TNR) and EasyReading. The outcome shows that EasyReading can be considered a compensating tool for dyslexic readers and a simplifying font for readers of all levels. The study, however, needs to tell us more about the effect of letter spacing. In another study, Alexeeva, Dobrego and Zubov (2020) developed LexiaD, the first Russian Cyrillic DFF. The development of this font was aimed at designing a letter form that reduces the inter-letter similarity of the Russian alphabet. Their study analyzed the readability of LexiaD on 3-4 grade children with and without dyslexia. The findings suggest that compared to PT sans and PT Serif fronts, LexiaD demonstrated a positive effect on the reading performance of dyslexic children. However, the study did not account for the potential influence of letterform and spacing. While these findings are promising, other studies could not find any advantages of DDFs. For instance, Wery and Diliberto (2017) tested OpenDyslexic with English-speaking students with dyslexia. They compared it to Arial Regular and TNR Regular, but they found no significant differences in either reading accuracy or reading speed.

In a recent PhD thesis, Broadbent (2023) compared the reading accuracy, reading speed, and reading comprehension of 40 school-age UK children with dyslexia reading English and a control group of 38 typically progressing readers when texts were presented in OpenDyslexic and Arial. The spacing effect of the default designs of the two fonts was considered by including an expanded version of Arial. Findings showed that participants from both groups achieved significantly higher test scores in reading accuracy and reading speed when texts were presented in OpenDyslexic font. No significant effect of the font was found on the reading comprehension scores for either group. The variable of spacing did not demonstrate a significant impact on the test scores recorded.

In contrast to those findings, Marinus et al. (2016) showed that manipulating the spacing of a font can result in a similar facilitatory effect of DFFs. They investigated the effect of Arial after adjusting its spacing to match Dyslexie with a group of Australian children. Interestingly, the outcomes showed that increased spacing facilitates reading speed regardless of whether the font was specifically designed for dyslexic readers. This suggests that the efficacy of Dyslexie does not stem from its unique letterform design but rather from spacing. The study was replicated by Duranovic et al. (2018) on Bosnian speakers, who investigated how dyslexics perform better when reading texts in Dyslexie compared to TNR with similar spacing. The results were consistent with the previous study in that only spacing improved reading for children with dyslexia.

In another study conducted by Powell and Trice (2020), adjustments were made to control for the variations in size and spacing for both words and lines. The study involved 36 American school-age children with dyslexia. Their task was to read three different stories aloud in English in three different fonts: Arial, Times New Roman, and Dyslexie. In terms of spacing, stories were formatted depending on each font. The Dyslexie font was set at 12-point size, normally spaced with multiple line spacing at 1.2. Stories written in Times New Roman and Arial had 14-point font size, double-spaced between words, and spaced multiple at 1.7 between lines. The findings indicate that Dyslexie shows no effect compared to Arial and TNR fonts after adjusting them to match their font size and spacing. Further, no effect was observed on the readers' accuracy, fluency, or comprehension.

Spacing is an important factor that gives DDFs their facilitatory effect. However, there is a need to understand if all forms of spacing are helpful, including inter-letter and inter-word spacing. According to Galliussi et al. (2020), the answer might be counterintuitive. Their study attempted to evaluate spacing on different levels of the text and investigate the effect of letterforms (with vs. without dyslexia-friendly graphic features) on the reading accuracy and speed of a group of dyslexic and normal children. The results show that increased inter-letter impairs the reading speed when not combined with an adequate increase in inter-word spacing. Besides, the letterform did not have any effect. The reading performance of children with and without dyslexia was not influenced by whether they read texts presented in DFF or in a standard font.

In summary, studies have examined the impact of typographical attributes, such as a font type and spacing, on the readability for children with dyslexia. The results are mixed and often contradictory. For instance, while increased font size generally improves readability, the impact of spacing varies; some studies suggest that specialized DFF can aid dyslexic readers, but others find no significant advantages over regular fonts such as Arial or TNR. The effectiveness of these special fonts may be due more to spacing adjustments that the unique design of the letters. Overall, while some typographical changes show promise in aiding dyslexic readers, the evidence is not conclusive, indicating a need for further research.

The studies presented in this short literature review present the ongoing debate on the utility of DFF. It is, however, worth noting that most of these studies were conducted in Latin-based languages such as English, which necessitates that we look at how these special fonts work in other non-Latin languages. Arabic, for instance, can be an exciting language to explore. It is a Semitic language with distinctive features and a writing system different from English. Exploring DFFs in Arabic will enrich our understanding of how they work. It will be a foundation for developing native special fonts to promote Arabic-speaking dyslexic individuals.

1.2 Dyslexia in Arabic

To elaborate, Arabic is a Semitic language spoken by over 250 million people worldwide and holds official status in over 20 countries (Zaidan and Callison-Burch 2014) and it has many regional and social dialects, each associated with distinct socioeconomic groups across various Arabic-speaking nations (Alshehri and AlShabeb 2024). Arabic is read and written from right to left in a cursive style. Arabic has 28 letters to represent 34 phonemes, 25 consonants, and three vowels considered as long vowels. Arabic writing system employs only consonants, leaving vowel sounds to be inferred by the reader. Skilled readers are expected to read texts without short vowels, while beginners rely on texts with short vowels (Taha 2013). Arabic is characterized by a complex consonantal system and a relatively simple vowel system (Alahmari 2022). Arabic letters exhibit varying shapes based on their position within a word. Among the 28 letters, 22 have four distinct morphological forms corresponding to the initial, middle, final, or isolated positions. The remaining six letters have two morphological forms: one for when the letter appears at the end of a word and the other as a non-joinable letter. Arabic has both deep and transparent orthography (Abu-Rabia 2001). Deep orthography corresponds to the absence of diacritics or short vowels, while transparent corresponds to the presence of diacritics. Due to the complexity of the language, children first acquire the basic forms of the letters and gradually learn other variations and more complex language structures.

Research on the reading performance of Arabic-speaking children with reading disabilities is scarce in specific, dyslexia is neither known nor studied enough in Arabic-speaking countries. A recent review (Wattad and Abu Rabia 2020) on the distinctive features of Arabic and readers with dyslexia emphasized the need for more rigorous studies in this field. Additionally, a more recent study (Tiruchittampalam and Ross 2024) emphasized the importance of having validated dyslexia screening tools for Arabic-speaking populations. Despite the growing interest in DFFs in Latin-based languages, only two studies have explored their application in Arabic. Benmarrakchi and Kafi (2021) developed Arabolexia, the first Arabic font specifically designed for dyslexic readers and examined its effect on native Arabic speakers with dyslexia. More recently Hejres and Tinker (2024) introduced a new design of a dyslexia-friendly Arabic typeface, offering a prototype and establishing a set of principles and references for creating DFFs in Arabic. Hejres and Tinker (2024) typeface was developed using a user-centered design approach, focusing on the letterform features of DFFs that can be adapted to the Arabic script. They aimed to establish design guidelines for a dyslexia-friendly Arabic typeface intended for public use. The study provides an intriguing visual comparison between Arabic and Latin scripts, highlighting aspects such as differences in the letters' connectivity and height, which impact reading. The visual analysis benchmarks three DFFs (FS Me, Sylexiad, and OpenDyslexic) and provides a prototype of the typeface design, including set of principles and references for designing a dyslexia-friendly Arabic typeface. However, before making this typeface publicly available, its effectiveness for Arabic readers with dyslexia needs further investigation, as the study lacks validation with the target group.

In contrast, Benmarrakchi and Kafi (2021) study involved three groups: an experimental group of school-aged children with dyslexia, a matched control group of children without dyslexia, and a third group of skilled readers. The examination mainly aimed at comparing Arabolexia to Simplified Arabic, a popular font, using two different texts. Overall, the study managed to explore DFF in Arabic and presented some evidence that Arabolexia can potentially enhance the reading accuracy of dyslexic children. This evidence, however, is not sufficient to understand how this special font works and how other font features, such as spacing and size, contribute to its facilitatory effect. This necessitates further exploration of Arabolexia and examines its various features and how they contribute to its advantages in reading. In alignment with the existing literature, this examination should cover letterforms, font size, and the spacing of this new Arabic DFF, Arabolexia.

The current study precisely tackles these areas. Its primary objective is to determine factors that contribute to the improved reading ability of children with dyslexia. Specifically, we assess Arabolexia's effectiveness by comparing it with a standard font. The comparison involves presenting both fonts to native Arabic dyslexic children and measuring their reading performances. Consequently, this study aims to address the following questions: 1) Does the unique letterform of Arabolexia account for its advantages? 2) Do larger font sizes or increased spacing offer similar advantages to those of Arabolexia?

2. Methodology

2.1 Participants

The study aims to explore the influence of Arabolexia on the reading ability of children with dyslexia. A power analysis was conducted to determine the minimum sample size needed to run the study. Using G*Power version 3.1.9.6 (Faul et al. 2007), the analysis indicates that a sample of 45 participants is required for the study to achieve 80% power at a significance level of $\alpha = .05$ for one-way repeated measures ANOVA. Accordingly, 45 children with dyslexia participated in the study. All participants are Moroccan native Arabic speakers who have been diagnosed with dyslexia. They were recruited through therapists and learning disability centers. In Morocco, the diagnosis of dyslexia is carried out by certified healthcare professionals. These professionals use primarily standardized French assessment tools such as BALE (Jacquier-Roux et al. 2010) or ODEDYS (Jacquier-Roux, Valdois and Zorman 2002). These tools have been adapted to suit the Moroccan context and language. Our exclusion criteria ensured that children with an intellectual disability, neurological diseases, attention deficit hyperactivity disorder, and vision or hearing problems were not included in the study. None of the children were familiar with Arabolexia or trained to read largely spaced text or with a larger font size. All children voluntarily participated in the study, and their parents gave informed consent, granting authorization for their children to participate. The study was approved by the local university ethics committee. All methods were conducted in accordance with the relevant guidelines.

2.2 Research design

2.2.1 DFFs selection

Arabolexia is the first specialized Arabic font for individuals with dyslexia (Benmarrakchi and Kafi 2021). It makes reading less confusing and more readable by limiting crowding effects. The main features of Arabolexia are the bold base of each letter, the differentiating special design of letters, the shape of dots, the increased size of the letters, and the increased spacing between letters and words. The typographical design is based on OpenDyslexic font, mainly the heavier bottoms of the letters (thought to prevent letters from turning upside down or rotating when the reader sees them), an increased letter size, and a stronger contrast. Arabolexia tends to minimize cognitive load memory and avoid distracting the readers with additional information (e.g., decorative elements). Arabic typography differs from Latin typography because Arabic calligraphy is developed as an art and is considered an artistic practice of handwriting. Every Arabic character has a unique appearance, making it harder for beginner readers, especially children with dyslexia. According to Benmarrakchi et al. (2017), providing much information with too many details to readers with dyslexia may negatively impact their learning outcomes and overload their cognitive capacity. Given the demands of cognitive processing in reading Arabic, which requires stronger visual-spatial processing abilities (Al-Edaily, Al-Wabil and Al-Ohali 2013), Arabolexia employs a straightforward writing style devoid of additional or ornamental elements.

2.2.2 Text preparation

In many studies, assessments of text-reading fluency often utilized passages sourced from standardized reading assessments. For instance, Marinus et al. (2016) extracted passages from the Wheldall Assessment of Reading Passages (Wheldall and Madelaine 2006). However, these assessment instruments are only available in languages with Latin scripts, such as English. In our study, we decided to write four narrative passages in Arabic, taking into consideration factors that affect reading. According to Carver (1990), the reading rate is affected by various factors, including text difficulty, which is determined by text structure, content familiarity, and the difficulty level of the vocabulary. To ensure equivalence and consistent difficulty, the passages we wrote consider these factors. The four passages were narrative short stories, each focusing on a different subject familiar to school-age children: 'summer vacation and the sea', 'a bird in a cage', 'the child and the book', and 'children's toy store'. Each story was 80 words long, and based on OSMAN (Open-Source Metric for Measuring Arabic Narratives), which measures the readability metric (El-Haj and Rayson 2016), the stories were placed to match the fifth-grade level. OSMAN is an adapted version of the Flesch-Kincaid (Walters and Hamrell 2008) which scores the readability of a text based on the number of syllables per word and the number of words per sentence. The Arabic passages were written to have a comparable level of difficulty and were aligned with several psycholinguistic variables (see Table 1).

2.2.3 Text layout and presentation

Following the guidelines of the British Dyslexia Association (2012), we used simple sentences in a direct style. We avoided starting a sentence at the end of a line so that every sentence starts at a new line. For layout, Arabic is a right-to-left language, which means writing starts from the right and continues to the left; when text is justified explicitly, it should have the exact alignment as English. Therefore, we used the right-justified alignment. Each text was printed in black on a single white A4 size paper. The stories were presented in four different conditions. In the first condition, one text was presented in Arabolexia, while in the other three conditions, the texts were presented in Simplified Arabic font. In the second condition, Simplified Arabic font was matched to Arabolexia in letter display size and overall spacing (similar degree of increase for spacing within and between words and increased line spacing). In the third condition, Simplified Arabic matched Arabolexia in letter display size only. Finally, in condition 4, Simplified Arabic was matched to Arabolexia for spacing settings only (with a similar degree of increase in spacing within letters and between words).

2.2.4 Control font

We used Simplified Arabic font as a comparison font for two reasons. Firstly, this font has been used in previous studies as the control font (Abubaker and Lu 2012; Benmarrakchi and Kafi 2021) . Secondly, the font is widely used in learning materials, including textbooks. Given that Arabic font sizes look smaller than Latin font sizes at the same point size (they are two or three sizes smaller), they might be hard to read. According to Abubakar and Lu (2012), Arabic text in font sizes 16 and 18 points are more readable than smaller size fonts; therefore, we used a 16-point print size for all the reading material, except for condition 2 (overall matching) and condition 3 (font size matching) we used 18-point font size. Table 2 presents the details of the font, letter size, and word spacing adjustments for each condition. By comparing conditions 1 and 2, we will investigate whether the effectiveness of Arabolexia is result of its special design (letterform). In specific, we want to see if the advantage of Arabolexia disappears when the Simplified Arabic font is adjusted to control Arabolexia's overall matching. If the overall matching of Simplified Arabic covers the advantage of Arabolexia, condition one will not differ from condition 2. Conditions 3 and 4 address whether the efficacy of Arabolexia is due to bigger font size or increasing spacing. If Arabolexia is easier to read because of the letter size but not the spacing setting, reading performance will not differ between conditions 1 and 3. However, suppose the advantage lies in increased spacing rather than letter size. In that case, it is anticipated that children will perform better in condition 1 than in condition 3, and the performance in conditions 1 and 4 will not differ significantly.

2.3 Procedure

We replicated the procedures used in the study conducted by Marinus et al. (2016) to avoid repeated administration effects. The order of the short stories was counterbalanced across subjects, and the repetition of the same story across the four conditions was avoided to prevent order effects. Every story appeared in all conditions to avoid confounds between text and font. The counterbalancing procedures used in the study conducted by Marinus et al. (2016) were replicated. Latin square matrices (ABDC, BCAD, CDBA, and DACB; 1243, 2314, 3421, and 4132) were used to define the order and condition of the short stories for all participants. This resulted in 16 (4×4) different sentence and condition combinations. For example, if participant 1 got the code A1C2D3B4, it means that participant 1 read the story order ACDB with text A in condition 1, text C in condition 2, text D in condition 3, and text B in condition 4. Figure 1 illustrates an example of a passage presented in four conditions.

Table 1. Characteristics of sentences for the four conditions

Psycholinguistic variables	Passage A	Passage B	Passage C	Passage D	F	*p*
Number of words in a sentence	11.42 (0.97)	11.42 (0.78)	11.42 (0.97)	11.28 (0.75)	0.04	0.98
Number of syllables in a sentence	34.57 (3.86)	36 (4.47)	34.42 (3.69)	33.14 (1.77)	0.67	0.57
Length of words in a sentence	4.34 (0.32)	4.09 (0.48)	4.14 (0.31)	4.28 (0.28)	0.78	0.51

Means (and standard deviations) of three psycholinguistic word variables (number of words, number of syllables, and length of words) are presented for each of the four passages. The F values obtained from the Analysis of Variance (ANOVA) on the psycholinguistic variables are reported, along with the corresponding p-values in the last column, are reported. No significant differences were observed among the four passages in any of the psycholinguistic variables.

Table 2. Details of the font, letter size, and word spacing adjustments for each condition

Condition	**Font**	**Size (pts)**	**Spacing**
Default Arabolexia (condition 1)	Arabolexia	16	Arabolexia original spacing
Overall matching (condition 2)	Simplified Arabic	18	Increased 1.3 points within words and double-spaced between words and spaced multiple at 1.15 between lines.
Size matching only (condition 3)	Simplified Arabic	18	Standard spacing of simplified Arabic font
Spacing matching only (condition 4)	Simplified Arabic	16	Increased 1.3 points within words and double space between words

The reading material was administered individually to participants in a quiet room. Participants were told that they would read aloud four texts (four different short stories) while the session was audio-recorded for later transcription and analysis. The participants were instructed to start reading aloud as soon as they got the hand signal. Misread words that were self-corrected were not counted as errors. Additionally, if a participant skipped a line, they were informed of their mistake and directed to the correct line. To maintain participant engagement throughout the entire reading session, we incorporated a 2–3-minute break between stories. We initiated a conversation by asking the participants, such as 'What is your preferred color?', 'What sport do you like?' and 'What is your favorite subject?' Our dependent measures were children's reading accuracy (the number of words read correctly in each condition) and reading speed (the time, in seconds, that each participant took to finish reading in each condition).

3. Results

The mean scores for every condition for both accuracy and reading speed are shown in Table 3. All analyses were performed using R software (4.1.2). Reading accuracy and speed were analyzed using one-way repeated measures ANOVA with font conditions as a within-subjects variable. Performing ANOVA on reading accuracy showed a significant effect of font conditions (3; 132) = 60.49, $p<0.05$, indicating that one or more conditions differed. To test our specific empirical predictions, we conducted pairwise comparisons. Post-hoc analyses with a Bonferroni adjustment indicated that the difference between condition 1 (default Arabolexia) and condition 2 (Simplified Arabic font overall matching) was not significant ($p=0.34$). For condition 1 and condition 3 (Simplified Arabic font matched size only), comparison indicated that the pairwise difference was significant ($p=0.001$). For condition 1 with condition 4 (Simplified Arabic font matched spacing only), comparison indicated that pairwise difference was not significant ($p=1$). To analyze the reading speed of children on the various font conditions, we conducted a one-way repeated measures ANOVA, and we found no significant differences in the amount of time (in seconds) that children took to read $F(3, 109.01) = 2.77$, $p=0.055$.

Table 3. Mean, standard deviations of words read correctly, and reading speed for each font condition

Font Condition	**Accuracy (correct words)**		**Reading speed (second)**	
	M	**SD**	**M**	**SD**
Default Arabolexia (condition 1)	38.4	12.0	172	95.4
Simplified Arabic overall matching (condition 2)	33.6	11.6	168	99.3
Simplified Arabic font size matching only (condition 3)	29.0	11.7	166	90.5
Simplified Arabic spacing matching only (condition 4)	36.0	11.9	180	106

Figure. Font conditions, passage A presented in four conditions (Condition 1: left top, Condition 2: right top, Condition 3: left bottom, and Condition 4: right bottom)

4. Discussion

Given that only two studies have explored DFFs in Arabic, Benmarrakchi and Kafi (2021) developed Arabolexia, the first Arabic font specialized for Dyslexic speakers and examined its effect on the reading accuracy, speed, and comprehension of dyslexic native Arabic speakers. The study found that Arabolexia offers advantages over regular font in improving reading accuracy of Arabic speaking children with dyslexia. On the other hand, Hejres and Tinker (2024) introduced a new design of a dyslexia-friendly Arabic typeface developed using a user-centered design approach and based on a visual analysis benchmarking three Latin DFFs. Although the design appears promising, it’s effectiveness for Arabic readers with dyslexia requires further investigation, as the study did not include validation with the target group. Therefore, the current study is primarily concerned with the features that contribute to the facilitatory effect of Arabolexia.

Firstly, we tested whether the distinctive letterform of Arabolexia accounts for its advantage. The findings indicate that there is no statistically significant difference in reading accuracy between children with dyslexia reading texts presented in Arabolexia (M=38.40, SD=12.0) and Simplified Arabic (M=33.6, SD=11.6) when the two fonts are matched. Further, there was no significant difference in reading speed when reading text in Arabolexia (M=172, SD=95.4) compared to Simplified Arabic (M=168, SD=99.3) when overall matched. The outcomes demonstrate that the advantages of Arabolexia disappear when the control font matches it in spacing and font size. This means that the font's letterforms, which are intended to be more distinct than those in standard fonts, do not have any facilitatory advantage. These outcomes could support previous conclusions stating that the letterform of DFF has no advantages in reading over the letterform of standard fonts (Marinus et al. 2016; Wery and Diliberto, 2017).

Secondly, we investigated the contribution of spacing and font size in improving text readability. Specifically, we wanted to understand if the positive reading outcomes of Arabolexia are merely due to its particular spacing settings or bigger font size. After we matched the spacing between the two fonts, Arabolexia was no longer advantageous. That is, children with dyslexia were not more efficient in reading texts printed in Arabolexia (M=38.4, SD=12.0) than in Simplified Arabic (M=36.0, SD=11.9) when matched on spacing only. However, after we matched the font size between the two fonts, we found that children with dyslexia were more efficient in reading texts printed in Arabolexia (M=38.4, SD=12.0) than in Simplified Arabic (M=29.0, SD=11.7). The reading speed was not significantly different between Arabolexia (M=172, SD=95.4) and Simplified Arabic when matched in size (M=166, SD= 90.5) or spacing (M=180, SD=106). Our results indicate that increased spacing decreases the number of errors significantly but does not increase reading speed in dyslexic children. Additionally, font size does not appear to have any advantage in accuracy or reading speed.

Arabolexia seems to be advantageous only due to its large spacing. Comparing it to space-matching version of Simplified Arabic diminishes those advantages. This suggests that the font's benefits are not the result of a specific letter shape but rather a result of its spacing. Moreover, the main effect of font conditions on reading speed was not found to be significant. This is consistent with the findings of Duranovic et al. (2018), who reported improved accuracy but not reading speed. The study results suggest children with dyslexia may benefit from increased letter spacing when reading Arabic. This is theoretically explained by the tendency of dyslexic children to experience the visual crowding effect (Callens et al. 2013) as they struggle with identifying text elements when presented closely together.

The current results do not support the hypothesis that DFFs improve the reading performance of children with dyslexia or surpass the utility of regular fonts when reading Arabic. Nonetheless, they showed that only spacing plays a role in reading enhancement. These findings align with previous studies conducted on Latin languages (Perea et al. 2012; Zorzi et al. 2012; Marinus et al. 2016; Duranovic et al. 2018) and conclude that increased spacing reduces crowding and improves the reading performance of children with dyslexia. This effect was supported by deep and transparent orthographies, including English (Marinus et al. 2016; Powell and Trice 2020) and French (Zorzi et al. 2012), two languages with opaque writing systems. It was also found in Spanish (Perea et al. 2012), Italian (Zorzi et al. 2012; Galliussi et al. 2020), and Bosnian (Duranovic et al., 2018) which are three languages with shallow writing systems. The current study found this effect in Arabic, a language with both opaque and transparent orthography.

Our findings revealed a significant main effect of font on accuracy, but the reading speed remained inconsistent, with no significant differences throughout the various reading conditions. This can be related to the reading task measures deployed and the length of sentences in the text. In this study, we used reading tasks that involved 80-word-long texts, which are similar to our previous study (Benmarrakchi and Kafi 2021) and reported similar findings. This necessitates exploring alternative reading tasks and ways to assess the readability of texts. For instance, Wery and Diliberto (2017) employed different reading tasks such as letter naming, word reading, and nonsense word reading. They suggested that the choice of reading task could influence reading measurements. They selected these reading tasks based on their strong correlation with reading achievement and ability to measure reading accuracy and speed. Additionally, some studies used eye-movement tracking techniques, like fixation duration, to measure reading speed (Rello and Baeza-Yates 2016). Fixation duration has been validated as an indicator of readability (Rayner and Duffy 1986; Rello and Baeza-Yates 2013). According to Pelli and Tillman (2008), reading speed is strongly related to the number of letters that can be processed during each fixation.

Future research should include explicit measurement of reading speed to draw more robust conclusions about the effect of spacing on the reading performance of children with dyslexia reading Arabic, Further, future research could explore Arabic readability through methods such as eye-tracking, to uncover any positive correlation between spacing and reading speed. Furthermore, exploring the distinct effects of inter-letter and inter-word spacing, as Galliussi et al. (2020) observed, is crucial for understanding how spacing contributes to text legibility in Arabic. Such findings could hold significant implications for improving the reading performance of dyslexic children in Arabic, potentially involving the implementation of increased letter spacing in educational materials, printed and electronic books, or online learning platforms. Although the potential benefits of spacing for enhancing reading accuracy appear promising, further extensive research is necessary to validate its effects on dyslexic children reading Arabic.

Although, this current study did not support the hypothesis that DFFs improve reading performance of children with dyslexia or surpass the utility of regular fonts when reading Arabic, it did reveal that spacing, rather than special letterforms, plays a key role in enhancing reading. However, it remains important to explore how these specialized Arabic fonts (Benmarrakchi and Kafi 2021; Hejres and Tinker 2024) might benefit learners with other disabilities, such as vision impairment, and how they can help young Arabic-speaking learners in their early stages of literacy development.

5. Conclusion

The present study attempted to determine the specific features that give Arabolexia its advantages on the reading performance of native Arabic-speaking children with dyslexia. The results suggest that children do not necessarily benefit from any feature related to the letter form but rather from its increased spacing. This can imply that the advantages of DDF stem from their increased spacing regardless of their special design. This outcome is consistent with findings in Latin-based languages like English. Therefore, improving the reading efficiency of Arabic-speaking children with dyslexia can be achieved by adjusting the font's spacing settings, without the need to change the letterforms.

Future research should explicitly measure reading to draw more robust conclusions about the effect of spacing on Arabic-reading children with dyslexia reading Arabic. Additionally, further research is needed to explore how these special fonts can benefit learners with other disabilities, such as vision impairment, and how it can help young Arabic-speaking learners in their early stages of literacy development.

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