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Before there was reading there was seeing.

People navigate the world and probe life's meaning through visible language. *Visible Language* has been concerned with ideas that help define the unique role and properties of visual communication. A basic premise of the journal has been that visual design is a means of communication that must be defined and explored on its own terms. This journal is devoted to enhancing people's experience through the advancement of research and practice of visual communication.

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The effect of age and font on reading ability

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Chiron A.T. Oderkerk

To inform our knowledge of the typographical variables of stroke weight, letter width, and letter spacing, and their effects on different age groups and reading scenarios, we used Radner Reading Chart, where we measured reading speed at different sizes, to compare the fonts KBH Text, KBH Display, and Gill Sans Light. The experiment showed that for older participants, reading Gill Sans resulted in faster reading speed compared to KBH Text. However, Gill Sans could not be recognized at small sizes by either the younger or older participants. For critical print size (CPS), older participants were better at reading small print sizes at a regular reading speed when the text was set in KBH Text than when it was set in Gill Sans. The findings indicate that older readers are more sensitive to font legibility differences than younger readers.

We discuss the implications of different reading scenarios putting different demands on the fonts as well as the perspective of older readers benefitting from certain visual qualities of fonts.

Keywords

readability
legibility
font
age
reading

Context

Different font styles vary on a range of typographical features such as stroke weight, letter width, and letter spacing. The research literature shows that the effects of these variables differ depending on the experimental study design, which suggests that the effects also vary between different reading scenarios. Based on a commissioned test on font legibility, we will present an overview of these typographical features and their influence on reading ability and discuss the findings of three test conditions involving both younger and older readers.

The experiment reported here was conducted to inform the choice of fonts between Gill Sans Light (from here on Gill Sans) and two versions of the KBH font (Figure 1). The City of Copenhagen had commissioned a new visual identity from the design agency E-types and was interested in including a customised font family, which was to replace Gill Sans in all written communication from the municipality to the public. As the new font family (named KBH) was to be implemented across multiple platforms, it was important to ensure that the new fonts could meet this challenge of functioning across many different reading scenarios. It was further essential that a broad selection of the adult public would participate in the testing as participants.

FIGURE 1.

Examples of the sentences from the Danish version of the Radner Reading Chart set in the three test fonts.

KBH Display Regular

Min morfar havde også tømt sit handskerum, hvor vi børn stadig gemte alle æbleskrog

KBH Text Regular

Min morfar havde også tømt sit handskerum, hvor vi børn stadig gemte alle æbleskrog

Gill Sans Light

Min morfar havde også tømt sit handskerum, hvor vi børn stadig gemte alle æbleskrog

Age-related changes

With growing age follows a decline in perceptual abilities, which results in decreased perceptual sensitivity to a range of visual targets. The decline is evident even for older adults who are free from ocular diseases (Owsley, 2016). By testing participants of all ages, researchers have found that reading speed stabilises around the age of 40, after which it gradually continues to decrease over the lifespan; that the critical print size (CPS)[1] slowly decreases from the age of 23, with a rapid decline from the age of 68; and, finally, that reading acuity[2] tends to worsen from the age of 16 (Calabrese et al., 2016). The decline in reading speed can be explained by a change in reading patterns, as demonstrated by an eye-movement study showing that older participants had a greater tendency to maintain longer fixations on individual words, skipped words, and engaged in a greater number of regressions (Rayner, Reichle, Stroud, Williams, & Pollatsek, 2006). Such reading patterns suggest a more risky reading strategy than what is seen among younger readers.

Older participants are also more affected by added 'noise' or blurring of the test fonts in lexical decision tasks of identifying words or non-words (Wolfe, Dobres, Kosovicheva, Rosenholtz, & Reimer, 2016); they tend to retain less visual information from the peripheral visual field (Rayner, Castelhano, & Yang, 2010); they are more easily distracted by irrelevant elements in the text (Connelly, Hasher, & Zacks, 1991; Darowski, Helder, Zacks, Hasher, & Hambrick, 2008; Kausler & Kleim, 1978); and they have greater difficulty tuning into a specific font style than younger participants (Zineddin, Garvey, Carlson, & Pietrucha, 2003). Furthermore, sensitivity to higher and middle spatial frequencies decreases from around 40 to 50 years, which also leads to a decline in contrast sensitivity (Evans & Ginsburg, 1985; Owsley, Sekuler, & Siemsen, 1983). All in all, the list of age-related factors that have a negative influence on reading is long. In this study, we are interested in seeing whether the difference in visual perception also results in different demands to the fonts used.

Comparing fonts of different styles

There is a well-established practice within the research field of font legibility of comparing the legibility of fonts that belong to different families. Some look to identify the best fonts for low vision readers (Mansfield, Legge, & Bane, 1996; Xiong, Lorsung, Mansfield, Bigelow, & Legge, 2018), the best font for vehicle displays or road signage (Dobres, Reimer, Parikhal, Wean, & Chahine, 2015; Phillip M Garvey, Eie, & Klenna, 2016; Philip M Garvey,

1 The smallest font size at which the participant maintains a reasonable reading speed

2 The smallest font size at which the participant can read at any reading speed, also with multiple errors.

Zineddin, & Pietrucha, 2001; Reimer et al., 2014) or the best font for online text presentation (Bernard, Liao, & Mills, 2001; Garcia & Caldera, 1996; Kingery & Furuta, 1997) or medical products (Smither and Braun 1994), while yet others use the font comparison paradigm to investigate various aspects of information processing (Pušnik, Podlesek, & Možina, 2016; Soleimani & Mohammadi, 2012; Subbaram, 2004). The fact is that fonts that belong to different font families vary on so many visual features that it can be difficult to identify the specific typographical variable that is the source of a given difference in performance. We will follow up on this in the discussion, as these difficulties also relate to the experiment reported here. However, in cases where the test fonts are designed to control for the typographical variables – by altering only a single visual variable between test fonts – the studies produce findings that most likely can transfer to the use of other fonts as well (Beier & Dyson, 2014; Beier & Larson, 2010; Larson & Carter, 2016; Morris, Aquilante, Yager, & Bigelow, 2002).

Methods

Participants

A total of 42 participants took part, ranging in age from 19 to 86 years (M_{age} = 47.67 years, SD = 21.89 years, 26 women). Thus, 20 participants over the age of 50 were grouped into the old age group (M_{age} = 67.36 years, SD = 10.3 years, 8 women), while 22 participants under the age of 50 were grouped into the young age group (M_{age} = 28.45 years, SD = 8.9 years, 18 women). They received DKK 200 or a box of chocolates upon completion of the experiment. All reported normal or corrected-to-normal vision. Participation in the experiment was advertised through the participant recruitment website Forsoegsperson.dk. All participants provided written consent prior to participation in accordance with the tenets of the Declaration of Helsinki and the Danish Code of Conduct for Research Integrity.

Procedure

We used psychophysics as the methodological approach and applied a reading chart based on the well-documented Radner Reading Chart, which is a vision test developed for standardised measurement of reading ability and reading speed (Radner, 2017). The Radner Reading Chart is empirically tested internationally and is available in numerous languages, including Danish (Munch, Jørgensen, & Radner, 2016).

The purpose of our experiment was to identify whether the font family KBH is more legible than Gill Sans under different reading situations. The Radner Reading Chart is an excellent test method for this purpose, as it allows for simultaneous testing of reading speed – related to reading of long paragraphs of text; of reading acuity – related to reading at small visual angles such as signage and small point sizes; and of CPS – related to effortless reading at the smallest possible font size.

The test is based on 28 sentences from the Radner Reading Chart, which were written to have the same degree of difficulty, structure, and number of words (Figure 1). The physical size of the sentences decreased logarithmically from x-height 0.456 to 0.046 mm, or 0.9 to -0.1 logRAD when read at a distance of 40 cm. The participant read the sentences consecutively, beginning with the largest print size, and continued until they were unable to accurately read more than 80% of the text (Chung, Mansfield, & Legge, 1998).

To determine the correct reading distance to the material, participants went through a pre-trial of reading other sentences set in Times New Roman. The reading distance at which the reading of the third sentence from the bottom (point size of 4.45) yielded more than 20% errors was selected as the reading distance for the subsequent test.

The participant was instructed to read the sentences out loud as quickly and correctly as possible, without correcting reading errors. The experimenter revealed the sentences one at a time while simultaneously giving an auditory instruction for the participant to begin reading. The session was recorded for subsequent registration. In order to eliminate an undesirable effect resulting from the sentences varying in linguistic content, participants were divided into three subgroups, with each group being presented with a different pairing of sentences and fonts. All sentences were read in the same order while the order of fonts was counterbalanced between the groups. The two smallest text sizes on each test sheet were identical to the two largest text sizes on the following test sheet.

Stimuli

The font family KBH was tested in two versions of the regular weight. For the present paper, we named one version KBH Display and the other KBH Text. In addition, we tested the font Gill Sans Light (Figure 1). The main differences between KBH Display and KBH Text are found in the design of the characters ‘a’, ‘g’, ‘l’, ‘r’, and ‘f’ (Figure 2).

FIGURE 2.

The font KBH Display (top row) varies from KBH Text (bottom row) in the design of the characters 'a', 'g', 'l', 'r', and 'f'.

All three fonts are adjusted to the same x-height, resulting in a smaller point size for KBH than Gill Sans. Due to a generally wider letter design, KBH takes up more horizontal space than Gill Sans even after adjusted to the same x-height (Figure 1). Further, we aimed at a perceptually similar leading (inter-line spacing) by giving KBH a leading value of 130% and Gill Sans a leading value of 120%. The test material was printed as Indigo digital print on 200-gram Scandia White paper.

Analysis of the measurements

The three variables determined were maximum reading speed in words per minute (WPM), reading acuity (logRAD score), and CPS (logRAD).

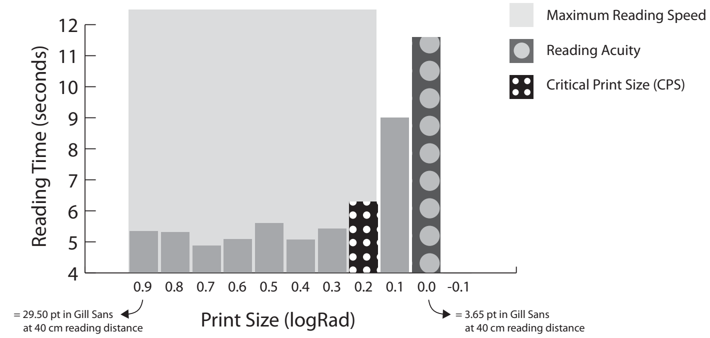
As there was no set viewing distance between the participants and the reading material, we first had to determine the correct reading acuity for every sentence read, in accordance with the Radner Reading test distance correction. At the standard viewing distance of 40 cm, no correction was needed, and the reading acuity of the sentences would range from 0.9 to -0.1 logRAD. However, when a participant was seated closer to the reading material (e.g., a viewing distance of 32 cm) the sentences would appear larger, such that a correction of +0.1 logRAD would be added to the reading acuity of the read sentences, which would therefore range from 1.0 to 0.0 logRAD. Conversely, at a viewing distance of 50 cm, a correction of -0.1 logRAD would be subtracted from the reading acuity of the read sentences, which would range from 0.8 to -0.2 logRAD.

The reading acuity score was determined as the logRAD value of the smallest sentence of which more than 80% was read correctly, corrected for the number of syllable errors made while reading the smallest sentence (logRAD score = logRAD + 0.005* syllables of incorrectly read words (Maaijwee et al. 2008).

The reading speed in WPM was calculated for each sentence as the number of correctly read words over the time taken to read that sentence (reading speed (WPM) = (14 words – number of incorrectly read words) * 60 seconds, divided by reading time). The maximum reading speed was defined as the geometric mean of the plateau of the reading speed values at which all reading speeds were within two standard deviations of the mean reading speed of the plateau (Mansfield et al. 1996). CPS was the reading acuity of the last reading speed included at the maximum reading speed plateau.

FIGURE 3.

Data from a representative participant, presented here to describe the three parameters for the Radner Reading Chart. Maximum reading speed is the geometric mean for the plateau of reading speed values unconstrained by print size. The critical print size (CPS) is the smallest font size at which the participant maintains a reasonable reading speed. Reading acuity is the smallest font size at which the participant can read at least 80% of the sentence the at any reading speed.



Results

In order to investigate whether there were any interactions between the effects of the fonts and the age of the participants, participants were split up into two groups. Reading acuity, maximum reading speed, and CPS were separately analysed using mixed ANOVA with age group (older or younger) as the between groups measure and font type (Gill Sans, KBH Display or KBH Text) as the repeated measures. All post hoc comparisons were corrected for multiple comparisons using the Bonferroni correction.

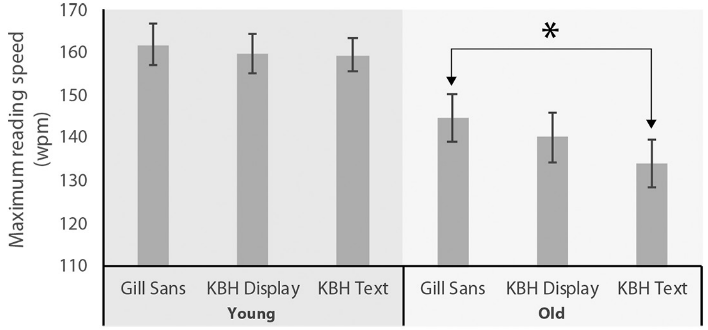
Maximum reading speed

The younger group read significantly more WPM than the older group, as there was a large significant between-subjects effect of age group, $F(1, 40) = 9.53$, $p = .004$, $\omega^2 = 0.169$, with younger participants reading faster than older participants. We found a small main effect of font on maximum reading speed, $F(2, 80) = 5.88$, $p = .004$, $\omega^2 = 0.011$, as well as a small significant interaction between age group and font, $F(2, 80) = 3.48$, $p = .036$, $\omega^2 = 0.006$.

Post hoc comparisons showed that this interaction was caused by a significantly faster mean maximum reading speed of Gill Sans compared to KBH Text, $t(19) = 3.44$, $p = .016$, $d = 0.77$, which was only found in the older participant group. There were no further significant differences between the mean maximum reading speeds for the fonts (p's > .510; Figure 4).

FIGURE 4.

Maximum reading speed in words per minute (WPM). Error bars represent standard error of the mean. The star indicates a significant difference: *p*-value of less than .05.



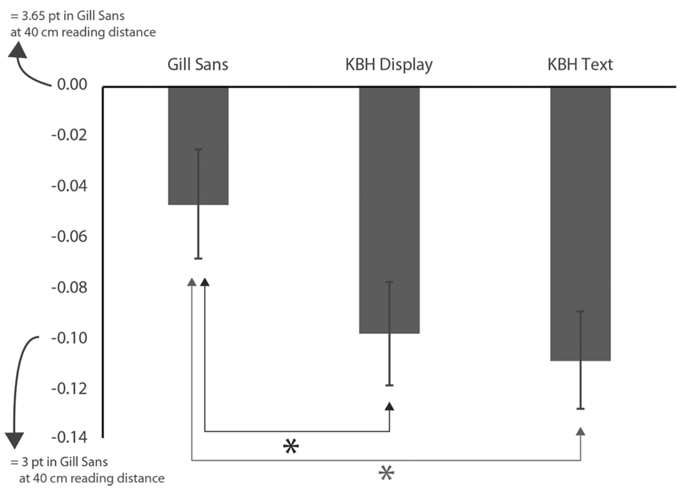
Reading acuity

Reading acuity relates to reading at smallest possible size with multiple errors and low reading speed. It is expressed in logRAD score corrected for reading errors. We found a small main effect of font on the logRAD score, $F(2, 80) = 41.80$, $p < .001$, $\omega^2 = 0.049$, as well as a large significant between-subjects effect of age group, $F(1, 40) = 11.90$, $p = .001$, $\omega^2 = 0.206$, as the younger group read significantly smaller print sizes than the older group. There was no significant interaction between age group and font, $F(2, 80) = 0.72$, $p = .490$, $\omega^2 = 0.000$.

This main effect of font on logRAD score was caused by participants being unable to read the smallest print sizes in Gill Sans. Specifically, post hoc comparisons showed logRAD scores to be significantly better for KBH Display, $t(41) = 7.06$, $p < .001$, $d = 1.09$, and KBH Text, $t(41) = 7.76$, $p < .001$, $d = 1.20$, than Gill Sans. There was no significant difference between KBH Display and KBH Text, $t(41) = 1.65$, $p = .320$, $d = 0.26$ (Figure 5).

FIGURE 5.

Reading acuity in logRAD score. Error bars represent standard error of the mean. The stars indicate a significant difference: *p*-value of less than .05.



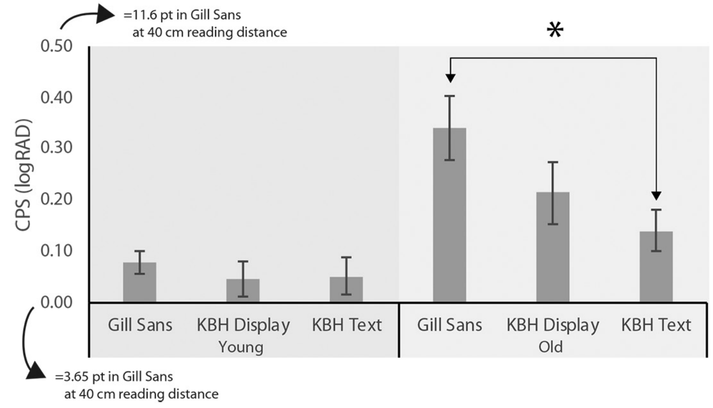
Critical Print Size

CPS is identified as the smallest font size with a regular reading speed that is included in the geometric mean of reading speed and is reported in logRAD units. A large significant between-subjects effect of age group on CPS showed that the older group performed significantly worse than the younger group, $F(1, 40) = 11.46$, $p = .002$, $\omega^2 = 0.199$. We found both a small significant main effect of font on CPS, $F(2, 80) = 7.25$, $p = .001$, $\omega^2 = 0.047$, and a small significant interaction between age group and font, $F(2, 80) = 4.00$, $p = .022$, $\omega^2 = 0.023$.

Post hoc comparisons found that this interaction was caused by a significant difference in CPS between KBH Text and Gill sans, which only occurred in the older participant group. Specifically, the older group was able to read significantly smaller CPS when reading KBH Text, compared to Gill Sans, $t(19) = 4.41$, $p < .001$, $d = 0.99$. All other differences in mean CPS between the fonts failed to reach significance (*p*'s > .204; Figure 6).

FIGURE 6.

CPS in logRAD. Error bars represent standard error of the mean. The star indicates a significant difference: *p*-value of less than .05.



Discussion

Three findings stand out from the experiment: 1) for the older participants, text set in Gill Sans resulted in significantly faster reading speed than text set in KBH Text, 2) for both older and younger participants, Gill Sans was significantly worse for reading the smallest possible print size (reading acuity), and 3) only older participants struggled with reading Gill Sans at a small print size at a regular reading speed (CPS).

It is likely that there are multiple reasons why Gill Sans resulted in better performances on reading speed and poorer performances on reading acuity and CPS. As mentioned earlier, when fonts of different families are tested, the fonts vary on several parameters, and it becomes difficult to identify which features have an effect on the results.

Gill Sans differs from KBH Text and KBH Display on the following typographical variables: it has lighter stroke weight, tighter inter-letter spacing, narrower letter shapes, and, mainly in relation to KBH Display, a different letter skeleton. We will discuss these variables in relation to the results of the Radner Reading Chart.

Stroke weight

Earlier studies have shown that small visual angles generally benefit from fonts of greater letter weight (Kuntz & Sleight, 1950; Sheedy, Subbaram, Zimmerman, & Hayes, 2005, Beier, S., & Oderkerk, C. A., 2019). Gill Sans is lighter in stroke, as it has a stroke width/height ratio of 1:14, and KBH Text and KBH Display have a stroke width/height ratio of 1:9 (Figure 7). With the greater weight of KBH Text and KBH Display, the present findings could suggest that for small print sizes there is a positive effect of greater letter weight.

If we analyse our present results solely in relation to letter weight, we could argue that we have confirmed the findings of previous research and added to this by showing that the positive effect of weight at smaller visual angles can be found in a small weight difference of 1:14 and 1:9 ratio, and that this small weight difference has no effect on larger visual angles, as demonstrated by the finding that Gill Sans Light resulted in the faster maximum reading speed for older participants.

FIGURE 7.

The stroke width/height ratio based on the stem of 'h', is 1:14 in Gill Sans Light and 1:9 of KBH Display and KBH Text.

Letter spacing

As added space between letters is known to minimise the effect of crowding (Bouma, 1970; L. Liu & Arditi, 2001), we speculate that the greater inter-letter spacing of KBH Text and KBH Display had a positive influence on the results found for these fonts in the reading acuity measure for both age groups. Evidence for this assumption has been revealed by previous research which showed that participants were able to read at smaller font sizes with greater inter-letter spacing (Latham & Whitaker, 1996), and that greater inter-letter spacing also enhanced recognition and reading speed for small font sizes (Chung, 2002; Tai, Shun-nan, Hayes, & Sheedy, 2006). Arditi, Knoblauch, and Grunwald (1990) had a similar finding by demonstrating faster reading speed at smaller sizes with greater inter-letter spacing; however, interestingly, they also showed that at larger sizes, the fastest reading speed was with a narrow inter-letter spacing setting. This latter finding might suggest that the narrower inter-letter spacing of Gill Sans could have had a positive influence

on the faster reading speed of Gill Sans for the older test group.

Arnold Wilkins et al. (2007) developed a model to demonstrate that fonts with stems that create a pattern of uneven distribution of vertical space (spatial periodicity) produce faster reading speed than fonts with stems that create a more even distribution of vertical space. The narrower inter-letter spacing of Gill Sans results in uneven distribution of vertical space in the setting of a word such as 'minimum' (Figure 8). This is the result of greater inter-letter spacing between the stems of letters such as 'n', 'm', 'u', and 'h' than between two adjoining letters such as 'nn' or 'mu'. This model could explain the faster reading speed for Gill Sans.

FIGURE 8.

The vertical strokes of Gill Sans produce a more irregular rhythm than the vertical strokes of KBH.

Letter width

As better performances at smaller visual angles have been found to correlate with greater letter width (Berger, 1948, 1950; Roethlein, 1912; Waller, 2007), it seems evident that the narrower letter width of Gill Sans must have contributed to its negative performance on reading acuity.

It is much more difficult to identify the influence of letter width on the maximum reading speed. When reading running text, readers with normal vision draw on visual information from within a perceptual span of about 8–15 characters to the right of fixation; thus, access to fewer characters outside the current fixation will negatively affect reading (McConkie & Rayner, 1975; Rayner, Well, & Pollatsek, 1980; Underwood & McConkie, 1985). Following this, one could imagine that narrower letters would fit more letters into the perceptual span, as acuity is known to decrease rapidly with retinal eccentricity. However, research indicates that this is not necessarily the case, as the number of letters within the perceptual span remains the same independent of scaling the stimuli (Miellet, O'Donnell, & Sereno, 2009), and as the number of characters within a saccade is the same for different font sizes (Morrison & Rayner, 1981). We are, however, yet to see if these findings persist beyond simple scaling and in wider and narrower font styles. In the present experiment, we did not isolate letter width from the remaining typographical variables, which means that we have no way of knowing if letter width was a contributing factor to the higher reading speed for Gill Sans among older participants.

Letter skeleton

When fonts of different families, such as KBH versus Gill Sans, are compared, the fonts vary on so many variables that the chances of finding a significant difference between their effects on performance is much greater than when we isolate just one variable. It is, however, difficult to tell how the variables are interrelated. On the other hand, isolating a single variable, such as when comparing KBH Text and KBH Display (the different skeleton of five lowercase letters), should, in theory, enable us to identify the specific feature of the fonts that causes the difference in performance. However, in such experiments, there is also a greater probability that the one variable is not strong enough to produce an effect, or that the test method is not sensitive enough to measure the effect. In the experiment reported here, there was no evidence of a significant difference between the two styles of KBH.

Age-related variations

The age-related reading differences found in our study can be summed up as follows: 1) the maximum reading speed: older participants read Gill Sans significantly faster than KBH Text, while no difference was found for the younger participants; and 2) the CPS: KBH Text was more legible than Gill Sans for the older participants, while no difference was found for the younger participants. In addition, older participants were generally much slower readers than their younger counterparts, which confirms previous experiments demonstrating a general age-related decline in reading performance (Calabrese et al., 2016; Rayner et al., 2006; Wolfe et al., 2016).

What is interesting here is that, when comparing the maximum reading speed, Gill Sans outperformed KBH Text, while KBH Text's CPS outperformed that of Gill Sans. This finding substantiates the argument that there is no such thing as an all-round most legible font, as the most legible font differs between reading scenarios (Beier, 2012).

The CPS involves elements of both reading speed and reading acuity. We saw a general positive effect of KBH Text on the reading acuity. As both CPS and reading acuity relate to the measurement of small font sizes, it is likely that the positive effects of KBH Text on the reading acuity parameter can be transferred to the CPS as well.

Further, in contrast to reading acuity, which is a measure of the acuity of words, the maximum reading speed measure involves aspects of oculomotor factors, where older participants are known to show different reading patterns (Rayner et al., 2006).

From the literature we know that the ageing eye is more sensitive to letter crowding (R. Liu, Patel, & Kwon, 2017). Hence, the negative influence at small font sizes of the narrower spacing and the narrower letter shapes of Gill Sans might be greater for older readers. Further, as mentioned above, with growing age, a loss of sensitivity in the higher and middle spatial frequency regions can be seen (Owsley et al., 1983; Wright & Drasdo, 1985), and this age-related perceptual decline of edges and details may also have a negative influence on reading smaller font sizes of Gill Sans Light.

The fact that only older participants showed a significant difference between the effect of the fonts on the maximum reading speed and the CPS could indicate that younger participants found it easier to adjust to the font and maximize reading speed when the font was less than ideal for that reading scenario.

With age follows cognitive decline, which results in older readers being more affected by distractions (Connelly et al., 1991; Darowski et al., 2008; Kausler & Kleim, 1978; Wolfe et al., 2016) and finding it more difficult to tune into a font style (Zineddin et al., 2003). This could suggest that the perceptual deficits at smaller font sizes of lighter stroke weight, narrower spacing, and narrower letter shapes have a greater influence on the performance of older readers. It might also suggest that the uneven distribution of vertical space and narrower inter-letter spacing of Gill Sans had a greater influence on the reading speed of older readers than on younger readers.

Conclusion

The experiment indicates that the typographical variables of stroke weight, letter width, and letter spacing vary in their influence on reading ability depending on the reading scenarios.

In summary, we suggest that the reason KBH Text and KBH Display were readable at smaller font sizes than Gill Sans for both younger and older participants is related to the positive effect of the greater inter-letter spacing, wider letters, and bolder weights found in KBH; that the reason Gill Sans resulted in faster reading speed for the older participants is related to the narrower spacing of the font and the uneven distribution of vertical space; and that the reason Gill Sans had a negative effect on the CPS of older readers is related to this reader-group being more easily distracted by the negative influence of letter crowding and lighter weights of Gill Sans, while younger readers are better at adjusting to reading font styles that are less ideal for a given reading scenario.

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