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## Legibility of textbooks: a literature review

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### Abstract

The purpose of the study was to analyse findings in the field of the textbooks' legibility, readability and visual word recognition. The paper focuses on the most significant findings for comprehending the texts' spatial characteristics during reading, word and letter recognition. The aim of the study was to analyse the factors which have induced inconsistencies between the findings acquired by scientists, as well as to compare findings which continually lead to progression in this field.

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### 1. Introduction

In order to keep informed, people definitely depend on reading material (Aberson & Bouwhuis, 1977). In schools and universities, reading is the major source of input for learners and students. And yet, very little is known about how type features and spatial characteristics of texts are perceived by the readers. Studies of legibility are vital to find out the importance of type design and typographical issues in learning and reading. It is more than a century that many researchers have been concerned with legibility of print. There have been lots of recommendations and rules regarding legibility, but they were not based on scientific studies and were based on subjective findings and partly on principle of harmony in art. Few studies have been done in 19th century (Weber, 1881; Javel, 1881; Cattell, 1885) but after the first quarter of the 20th century, the researchers highly expanded their studies in this area (Messmer, 1904; Pyke, 1926; Tinker & Paterson, 1928-1950; Tinker 1963-1965; etc.). Another field of interest to researchers has always been the effect of typography and spatial features of text on reading comprehension. Reading comprehension is "the process of simultaneously extracting and constructing meaning through interaction and involvement with written language. It consists of three elements: the reader, the text, and the activity or purpose for

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reading” (Rand, 2002). The typography of textbooks is of interest for two main reasons. First, it is important that the typography not interfere with the reader’s understanding of the text. Although true for both adults and children, this issue is of greater significance for children who are just learning to read. Second, readers’ responses to the visual appearance of the text may affect their motivation to read. It was Cattell (1885) who first noticed the reading speed as a basic predictor of readability. Many studies in the English language have reported a strong association between reading speed, accuracy, and reading comprehension (Dowhower, 1987; Fuchs et al., 2001; Tan & Nicholson, 1997). Most research in this area has been concerned with English typographies (e.g., Bernard et al., 2002) and has aimed at building guidelines for designing English texts. In fact, very few researchers have examined non-English texts. Thus, guidelines cannot be simply applied to non-English script because of unique differences not only in word forms but also in letter shapes, average word length, and connectivity. Whole time of researches there has been a disagreement among the scientists and typographers and among researchers concerning the best typographical factors used in print. The aim of this study was to collect main results of legibility and readability researches together to predict the direction of further researches.

## 2. Legibility and eye movement

As Pardo (2004) cited, the content of the text, the readability of text, and the font features can influence the interaction of the reader with the text. Different typefaces have different connotations and can have influence on the readability, interpretation, and the impact of the words they represent (Thangaraj, 2004). Some important issues to be considered dealing with the best typography choices in print are font type, font size, and leading (Tinker, 1963). All these features affect legibility. Legibility is related to the capability of a text to be identified properly and it is related to the ease of eyes to detect words and letters which is important for data acquisition during reading. Since the first step in the reading process is visually acquiring the information, increasing legibility can enhance text acquisition (Sheedy et al., 2005). Typeface characters have effect on legibility by affecting the way that readers can discern words and letters. Therefore, a greater legibility leads to a greater ability to recognize and consequently to a greater ability to read the text. (McCarthy & Mothersbaugh, 2002). Reading speed is an important factor to be considered while dealing with legibility. For being legible, a text must be read rapidly and easily (Hughes & Wilkins, 2000-2002). Optimal legibility is achieved if the typographical factors, like size of type and leading, together make an easy and rapid reading with comprehension (Tinker, 1963).

Eye-movement measurement is a modern way to determine the readability of texts. The perception of information takes place in saccades. When readers finish one line, their eyes have a sweep to the beginning of the other line which is called return sweep (Nanavati & Bias, 2005). Leading (line spacing) is one factor that has a great effect on having an easy return sweep. If the space between the lines is not too much or too little, the return sweep occurs easier and faster (Vanderschantz, 2008).

In many studies, it was important to verify that readers actually read the text and acquired the information conveyed by the passage. Many researchers (Chan & Lee, 2005; Dyson & Kipping, 1998; Muter & Maurutto, 1991; Osborne & Holton, 1988) asked participants to answer questions about the text in comprehension tests immediately after finishing the reading tasks. Some studies have shown no difference on comprehension tests in different conditions of interline spacing (Kruk & Muter, 1984) and column and line length layout (Dyson & Kipping, 1998; Kruk & Muter, 1984). Some researchers (Soleimani & Mohammad, 2012) asked participants questions to check the recall of information after two or three days from the reading task.

Working memory has a limited capacity (Oberauer & Kliegl, 2001). Therefore, for giving a chance to short term memory to be able to comprehend the text, there should be some levels of automatic decoding. If too much energy is needed to recognize the words, less mental energy will be left for comprehending (Pardo, 2004). Features of the text affect the interaction between reader and the text for comprehension (Pardo, 2004), the spatial characteristics, like font type and size, leading and margins noted as factors that can influence reader-text interaction. Features of a text are really important for readers to be able to make meaning. For example, Serif fonts in 16 points is deemed as the most preferable ones considering legibility (Hughes & Wilkins, 2000). Legibility of a text affects its readability which means the ease of comprehension (Mills & Weldon, 1987). Consequently, it affects reading comprehension (Woods, Davis, & Scharff, 2005).

It was shown that typographical variables, such as text size and type, line length, density, margins, and spacing, affect readability of online text (Dyson, 2004; McPherson, Nunes, & Zafeiriou, 2003) and readers' preferences (Bernard, Fernandez, & Hull, 2002), too. However, some previous researches on text spacing on webpages has produced mixed results (Chaparro & Bernard, 2001; Spool et al., 1997). Reading text with margins affected both reading speed and comprehension, so that reading margined text was found to be slower, whereas comprehending the text with no margins was better (Chaparro et al., 2004). In another study, moderate webpage spacing in comparison to less and more spacing produced higher user preference but no performance differences in a series of search tasks (Chaparro & Bernard, 2001).

### 3. Font selection

Although readers can read words in different fonts, it is not deniable that recognizing words with some fonts is easier than with others (Van Rossum, 1998). People always appreciate the fonts they like and complain the ones that they don't like but they have to use (Friedman, 2009). Many researchers consider serif fonts more legible and it is because of their serifs which add more information to the eyes (Geske, 1996) and enhance the legibility of a text by helping the readers to distinguish the letters and words more easily (McCarthy & Mothersburgh, 2002). Mills & Weldon's (1987) research on paper shows that the texts which have descenders are easier to read comparing to the texts that do not have descenders. The results of the study done by Beymer, Russell, & Orton (2008) and the results of studies by De Lange, Esterhuizen, & Betty (1993) showed out equal legibility between serif typefaces and sans serif typefaces. Shaikh's (2005) research also confirms these findings, he has concluded that there is no difference between perceived legibility of serif and sans serif fonts. A number of scientists believe that serif fonts are read faster. For example, Romney (2006) has written that serif fonts are believed to be read faster due to their invisible horizontal line made by serifs, so it increases the saliency of letters as Arditi & Cho (2005) have stated. Another reason for their belief about superiority of serif fonts over sans serif fonts is that the horizontal strokes that sit along the baseline help the readers to track the lines easier; therefore, they lead to faster and more efficient reading (Arditi & Cho, 2005). Moret-Tetay & Perea (2011) are against the prominence of serif fonts. The space between letters in serif fonts is slightly reduced due to the ornaments that they have. Consequently as Woods, et al. (2005) have mentioned, serifs in serif fonts act as visual noise when the readers' eyes attempt to detect the letters and words. The reduction of the space leads to other problems: One is a problem which is called lateral masking or crowding which is hindering of letter recognition when a letter is flanked by other letters (cited in O'Brien, Mansfield, & Legge, 2005) and the other is that letter position coding may be hindered which decreases the ability of word recognition (Perea, Moret-Tatay, & Gomez, 2011).

The results of many studies have pointed out that there is no difference between reading the serif or sans serif typefaces (e.g. Paterson & Tinker, 1932; Poulton, 1965; De Lange, Esterhuizen, & Beatty, 1993). The results provided by certain researchers could not be considered externally valid, which some of the researchers themselves concluded (Tinker, 1963; Zachrisson, 1965; Lund, 1999) since they noticed great differences in readability within the group of either serif or sans serif typefaces. Land says that the presence or absence of a serif could be an influential factor, but for the process of reading, a completely ephemeral for measurement (Lund, 1999). Gasser et al. (2005) maintain that the typefaces are not legible by nature but it is the familiarity of the readers which gives that feature to typefaces.

A number of other factors have been noticed as more significant for both readability and legibility, such as: sizes of the typefaces, line width, tracking, paragraph uniformity and the relations of the text color–the background (Paterson & Tinker, 1944; Tinker & Paterson, 1946); x-height, stroke width (Paterson & Tinker, 1932; Cheetham, Poulton, & Grimbley, 1965; Poulton, 1965; Poulton, 1972). Chandler (2001) examined font type and size to investigate their influence on reading speed and comprehension of onscreen reading. He used Palatino and Helvetica in 8, 10, and 12-point. Type size was proven to have a significant effect on reading speed: 12-point font was read faster. However, there was no significant effect of font type selection on reading speed, and he did not find any effect of type size and font selection on comprehension. Font size has been always of interest for researchers in relation to the legibility of print (Tinker, 1963). Tinker claims that in smaller sizes, eyes have more fixations and move slower and have more pauses for recognizing the letters and words. He has stated that the eye fixation for smaller sizes have fewer words. Also they believe that the perception time for smaller sizes is longer and more

regressions take place in reading with smaller sizes. Most of the publishers state that 10 or 11 point size is the smallest one that should be used for books. Although, there is no agreement among them. Geske (1996) conducted a study to find out which point size is suitable for on-screen reading. He used 9, 10, and 12-point sizes in Helvetica but results did not indicate any significant differences. Finding of Bernard et al. (2010) is similar to that of Geske (1996). Subbaram (2004) found that the largest font which was 14-point size was proven to be more legible. Beidler (2006) also has stated that the first thing for improving the legibility is increasing the type size. As Silver & Braun (1993) have concluded, the higher legibility of the larger size could be because of creating more visual angle which makes the words and letters more distinguishable. Delamate (2010) has stated that reading speed could be affected both vertically and horizontally by crowding. As he presents, larger font sizes can make more spaces between lines, therefore, they can decrease crowding. Legibility of print increases as the size of the characters is increased up to a point which is called CPS (Critical Print Size). Decreasing the size of letters below it will decline speed of reading (Rubin, 2008). Another issue influencing speed of reading is visual span. Visual span is the number of neighboring letters that can be recognized without moving eyes (Legge et al., 1977). Reading speed declines when visual span gets smaller. Fewer letters can be recognized in one fixation; consequently reading speed slows down (Legge & Bigelow, 2011).

The influence of font size on comprehensibility was found by Chandler (2001) and Fuchs, Langenhan, & Hippius (2008). Woods et al. (2005) confirmed that present legibility of a text affects its readability and the ease of comprehension. Gasser et al. (2005) focused on the effect of font type on information recalling. They wanted to find out whether the existence of serifs has any role in information recalling. They used two serif fonts (Courier and Helvetica) and two sans serif fonts (Palatino and Moraco). All materials were typed in 12-point size. The study revealed a significant effect of serif fonts on information recalling. As cited in Gasser et al., (2005), markings of serif fonts make the row of lines to be separated more easily, consequently, reading becomes easier and it uses fewer attentional resources for reading. Then more attentional resources remain for processing the message of the text which results in deeper processing and easier recall of information. Another reason for having the result above could be due to familiarity of the participants with serif fonts (Gasser et al., 2005).

#### **4. Line spacing and leading**

Nearly all researchers believed that line spacing has an impact on reading speed (Scales, 2011; Hooper & Hannafin, 1986). Set solid (no leading) is tiring of eyes because single line spacing requires more fixations in each line which means fewer words could be read in each fixation, so reading time becomes longer (Mills & Weldon, 1987). In printed materials intended for adults, it is generally accepted that the addition of two or three points of extra space between lines improves text readability and legibility (Spenser, 1968). Hughes & Wilkins (2002) argued that the additional space makes it easier to follow each line and facilitates an accurate return sweep of the eyes to the beginning of each successive line; it may also help with word recognition, as there will be less visual interference or “contour interaction” from lines above and below that being read. Tinker (1965) reported a series of experiments involving tests of silent reading speed with adults and found that although line spacing greater than the point size of the type conferred a significant advantage with some type sizes and line lengths, it was not always the case, and too much space could be detrimental. He concluded that optimum line spacing depends on line length, type size, and typeface. The greater the line length, the more important it is to add extra space between lines. He advised that for optimal sizes of type (9, 10, 11, and 12 points), an interlinear space of 1 to 4 points can be added to increase legibility. The majority of studies on reading English words support the double-line-spacing advantage for reading on computer screens (Kolers, Duchnick, & Ferguson, 1981; Kruk & Muter, 1984; Muter & Maurutto, 1991). In fact, doubleline spacing decreases lateral masking, reduces the number of fixations, and results in more accurate return sweeps during reading (Kolers et al., 1981; Kruk & Muter, 1984; Morrison & Inhoff, 1981). The relation between line spacing and word spacing is also important. According to the principles of Gestalt psychology, there is a tendency to group elements in the visual field on the basis of their proximity (Bruce & Green, 1985). Given that the typographer’s aim is to group words into lines, the space between lines must therefore be greater than the space between words. If not, distracting vertical “rivers” of white space may be created. Hartley (1994) argued that to avoid “optical bridging” between lines, the minimum line spacing must be increased by an amount equivalent to the specified word spacing.

A new approach to assess the legibility is suggested by Tarasov et al. (2013) and Sergeev & Tarasov (2013). The reading speed was examined with dissociated text samples. It helped to reveal the inherent features of texts with no influence of the cognitive component. The samples were built with one font size (12 points which equal to 4.50 mm) and different line spacing factors. The authors also used a metric scale jointly with typographical one. As shown in Tarasov & Sergeev (2013), the highest reading speed was obtained with leading factor 1.7 which equal to 9,64 mm or 2.14 times of x-height.

## 5. Column setting and line length

Efficient use can be made of space by combining shorter line lengths and a multicolumn format. Newspapers and magazines, which typically use such formats, are available on the World Wide Web. Presenting text in multiple columns allows short line lengths to be compared with longer line lengths with a similar amount of text, since there is an inevitable column setting–line length trade-off. A number of studies comparing single and multiple columns formatting and layouts have been reported (Neal & Darnell, 1984; Tinker, 1963), with inconclusive findings regarding the column setting and line length, making it difficult to draw conclusions. On one hand, Poulton (1959) reported that single columns with long line length were read faster than were double columns, showing evidence of the disadvantages of a multicolumn layout with medium or short line length in English print text (Duchnick & Kolers, 1983; Dyson & Kipping, 1998) and online text (Zaphiris & Kurniawan, 2001). On the other hand, Foster (1970) found an advantage for a multicolumn layout with medium or short line length in print and online text (Andreyev & Martynov, 2000; Lam et al., 2000). A single-column layout with long line length makes it difficult for the reader to accurately locate the beginnings of new lines after the long lateral eye movement, particularly when there is close vertical spacing (Bouma, 1980), suggesting a possible interaction of column setting and line length with line spacing. However, some studies showed no difference between double-column presentations with medium line length and single-column presentations with long line length (Creed, Dennis, & Newstead, 1987; Hartley, Burnhill, & Fraser, 1974).

## 6. Conclusion

Almost equal numbers of studies showed advantages and disadvantages of serifs, as well as a preference of numbers of columns in text. The preferences of specific line length and font size are highly dispersed. The mean value of legible line length is about 100-120 mm. The mean value of the most legible font size is close to 12 points but without specification of typeface.

This review demonstrated a substantial inconsistency between many findings of previous studies which were held at various times. Although there are massive bodies of analysis considering typography, there is no agreement among researchers regarding legibility factors in print. Perhaps the problem can be solved with further replication of prior studies, especially to non-English languages. This review confirms that reading speed, which is the main predictor of legibility, is more sensitive to typographical factors rather than to comprehension and recall. As Tinker (1963) mentioned, using larger font sizes make the peripheral vision perceives fewer words and consequently reading speed decreases. However, many of subsequent studies have found no significant differences between different font sizes. It can be suggested that legibility is more sensitive to some combinations of spatial features of text. Since this review, also, did not reveal any difference between the different typefaces over reading speed, comprehension, and recalling, no special type font is suggested to use in print and everyone is free to choose it themselves. The point to pay attention to is the familiarity of the subjects with special typefaces and subjects' preferences.

In this review we detected the similar problem in all of studies above. It is an absence of a unified approach. We suggest it is the principal reason of such contradictory results obtained. Firstly, the lighting within the studies has to correspond to a standard light condition. As Daly (1993) showed, the light conditions are extremely effect the subject's perception, it concerns both the colour assessment and qualimetric measures. All of that are the different kinds of psychophysical studies, as well as reading tasks. Secondly, paper and other substrates contribute to the text appearance. The spectral features of paper should be under strict control, too. Since deficiencies in light sources and viewing conditions can distort the appearance of texts and substrates, they are likely to cause miscommunication

about text stimulus, processing and perception. All this requires a certain viewing conditions, which are described in some international standards, such as ISO 3664:2009. It's known that the most important feature of lighting is photometric brightness of a stimulus. The main goal of light standardizing is to achieve a predictable brightness of text stimulus. The universal light booth used during the psychophysics and qualimetric studies (Tarasov et al., 2012) is a good sample of such standard light source. A new research methodology based on use of this booth is developed (Tarasov et al., 2013). The lack of unified measuring units is a big drawback, too.

We offer the following solutions to the problem of uniformity. It's necessary to use an International system of units (SI) during all text-based measurements, instead of different uncoordinated measurement units. We propose to use x-height (in millimeters) as the only measure of specific typeface. Line spacing should be expressed as a fraction of x-height or it should be measured in millimeters. The light conditions should agree with ISO 3664:2009 (low level). Each study should be described in details: illuminance level, spectra, geometric parameters of viewing (we suggest the distance to the stimulus to be 0.4 m), view angle, subject's visual acuity and the presence of glasses, etc. The text stimuli, also, should be fully described: sheet size (in mm), column setting and line length (in mm), margins (in mm), x-height (in mm), mean inter-word spacing (in mm or in x-height), mean inter-letter spacing (in mm or in x-height), inter-line spacing (in mm or in x-height), full specification of typeface, optical density of paper and text, etc.

Obviously this review leads to some questions. A better understanding of these questions will come through further and continued research.

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