Investigating the Effects of User Age on Readability

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Abstract. This paper focuses on creating a guideline for style, line spacing, size, text box and age group combinations of Korean fonts for different electronic displays. Reading time and recall time were measured to analyze the readabilities among various typographical layouts. The importance of typographical elements were different among the age group: line height and font sizes are the most important element for 20s to skim through the documents; font style and line height for 30s; line height and font size for 50+. Although, 20s, 30s and 50s had similarities on recalling speed since the font size and the line heights were the two most important readability elements. Thus, it is clear that the typographical layouts need to be designed differently based on the target user of the design. The optimized font combination for readability was also generated.

Keywords: Font Readability, Conjoint Analysis, Korean Typography.

1   Introduction

Understanding the effects of the styles and the layout of the fonts on the readability of reading materials has been one of the primary subject of study for the wide range of disciplines such as interface design, typeface design, graphic design and other related fields. One reason for such phenomenon is the merits of effective space management. The management of screen real estate is critical for ensuring both aesthetics and high readability of the screen-based textual content [8]. However, the effectiveness of screen real estate management on readability can vary among the text of different display sizes and the age of target readers. According to Myung [7], the readability importance hierarchy comes in the following order: line-spacing (53%), font style (35%), followed by font size (12%). Furthermore, each product line of mobile phone differs in screen resolution, making large fonts unsuitable for mobile displays [4]. Therefore, the ideal combinations of font style and the layout should also change in accordance with the size of the display and the age group of the target users, since the layout must be transformed to accommodate the same amount of textual content on various screen sizes.

The readability of a text varies with the font style as well as the layout of the text. From the aspect of legibility, line-spacing, font face, and font size are the dominant factors [7]. Passage length and letter spacing also affect the legibility of the textual

material. Typically, a graphic design expert carefully constructs an ensemble of font style and layout, which consists of features such as line-spacing or letter-spacing that aim to increase the readability of the content, based on personal aesthetic preferences or subjective estimates on screen real estates. However, since the text layout and the font sizes are inevitably modified due to the various shapes and sizes of the display screens, it is important to understand the correlation among font style, screen size, and the age of the target users.

The objective of the paper is to create a guideline for combining style, line spacing, and size of Korean fonts for different age groups and for electronic displays that differ in orientation, a desktop monitor and a mobile phone, for example.. Analyzing the accuracy and the duration of reading activity of the readers among various font and layout combinations can help identify the optimal font and layout combinations for the different screen size among different age groups.

A conjoint analysis was conducted to measure the readability among different font styles, font size, line spacing, screen sizes, and age groups. A total of 54 combinations of fonts, line spacing, size, age group and screen size were evaluated. 3 font styles were analyzed for the evaluation – Gothic (san serif), Myeong-Jo (serif) and Pen (cursive) font styles from Nanum font family (Fig. 1). It is widely known that serif style typefaces provide better readabilities on printed material while san serif style displays better on screens [1]. However, this widely spread knowledge on serif and san-serif styled fonts may vary depending on the overall layout, the size of the font and screen sizes [2]. Three degrees of line spacing was used for this experiment (50%, 100%, and 150%). The age groups is form in 3 groups (20 ~ 29, 30 ~ 39 and 50 ~ 59).
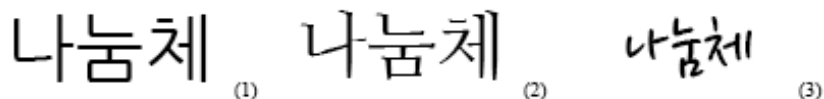

Fig. 1. Nanum font family: (1) Nanum Gothic; (2) Nanum Myeongjo; (3) Nanum Pen

According to Mo et al [6], the smallest Korean font size that are readable to the age group between 20 and 30 is 10.7 pt, and 16.6 pt for 40 and older. Therefore, we have evaluated 3 sizes: 10.7pt, 16.6pt, and 22.5pt.   Two representative instances of screen size was used: 1366x768 and 480x320 (most used PC screen and mobile phones resolution according to w3school's screen resolution statistics, and Android Market). Based on the possible combinations of the above features, the readability of each text in 4 categories was measured by the means of accuracy (counting error) and reading time (duration of reading the given text.

The results can be used in identifying optimal font size, font type and lay-out for presenting screen-based text on electronic display.

The readability of the font, font size and line height can be evaluated by measuring reading speed of the text [4, 7, 8]. Tullis et al [8] considered reading time and accuracy to compare the read-abilities among the four different font styles. The result showed that the reading time and the accuracy correlated to the font size, and the users preferred larger fonts. Arial, san serif font, and MS San Serif showed small differences in the degree of readability. This result contradicts to the field myth that the san serif displays better on screen than the serif fonts.

The performance of the readability is not only defined by the style of fonts and font size, but other typographical elements such line height, and the display size – bounding box [4, 7]. Huang et al [4] have investigated the impact of font size in various display resolution on text searching time. Different screen resolutions had varying optimal font sizes. For instance, 125 dpi with 3.8mm font size; 167 dpi with 2.6mm – 3.0mm; 200 dpi with 2.6mm; 250 dpi with 2.2-2.6 provides good readability for Chinese documents.   Line height is also found to be related to the readability of the writings along with other typographical elements such as font style, font size. Myung [7] have conducted researches on levels of importance of the typographical elements with Hangeul: Korean Fonts. The line-spacing has the relative importance of the 53%, font style has 35% and font size has 12%. Tullis et al [8] discovered that the font size actually is the most influential typo-graphical element in readability, but it contradicts what Myung [7] have measured. This may suggest that the typographical guidelines are not universally applicable for both Roman alphabet and Korean alphabet due to the structural dissimilarities. Roman alphabets are efficient due to its one-dimensional left to right alphanumeric letter composition [3]. However, Hangeul characters can be assembled in two-dimensional way similar to that of building blocks. The building blocks of the Korean letters are called Jamo, and at least two or three combinations of Jamo are used to create a character [5]. Thus, it is important to research on Korean typography since the research on Roman alphabet does not correlate with Korean Typography. As such, the impact of typographical element for Korean was investigated along with age group and text box sizes to pro-vide guidelines for using Korean typography.

2   Experiment

2.1   Test Subjects

15 test subjects were selected from the three age groups: 20 ~ 29; 30 ~ 39; 50 ~ 59. The experiment subjects were recruited from Korea Advanced Institute of Science and Technology, Daejeon, South Korea. The experiment texts were taken from the elementary school book's readings and exams. The character and objects' names were replaced with new names to reduce the opportunities for recognizing the readings. The experiment was conducted on a PC with a Dell Color monitor. The experiment materials were displayed on a self-developed program writ-ten on Python as shown in the Fig. 2.
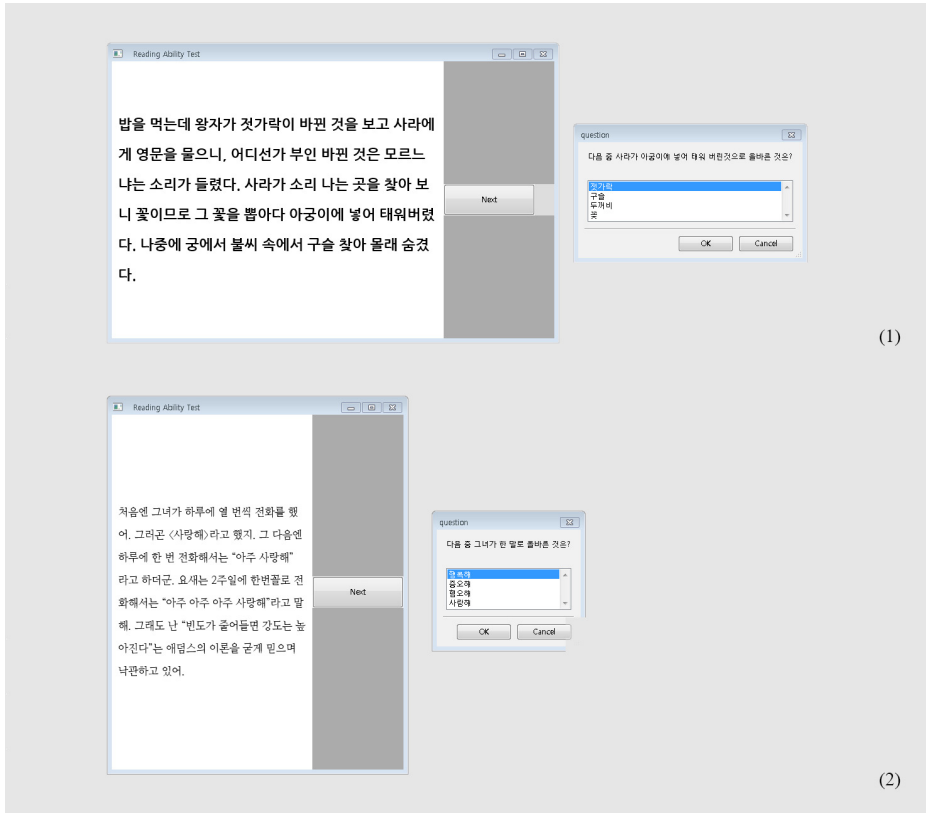
Fig. 2. User Interface for the readability evaluation is shown: (1) layout combination of Nanum Gothic, font size 16.6pt, line height 200%, 600x400; (2) layout combination of Nanum Myeongjo, 12.7pt, line height 200%, 320x480

2.2   Procedure

The experiment is to identify the optimized combinations of font style, font size, line height and text box for 3 different age groups. Nanum font family was used since it is the one of the most commonly used font family in Korea.   We have evaluated 3 sizes: 10.7pt, 16.6pt, and 22.5pt.   Three degrees of line spacing was used for this experiment (100%, 200%, and 300%). Two representative instances of screen size was used: 1366x768 and 480x320 (most used PC screen and mobile phones resolution according to w3school's screen resolution statistics, and Android Market).   Based on the 54 possible combinations of the above features, the readability of each text in 4 categories will be measured by the means of reading time (duration of reading the given text) and accuracy (duration of the recalling the answer).

Subjects were given five practice trials to familiarize with the experiment tasks. Each trial consists of 5 random layouts of 54 combinations in text that is different from the text used in the actual experiment. The experiment consists of repetitive process of 2-leveled experimentation (Fig. 3).
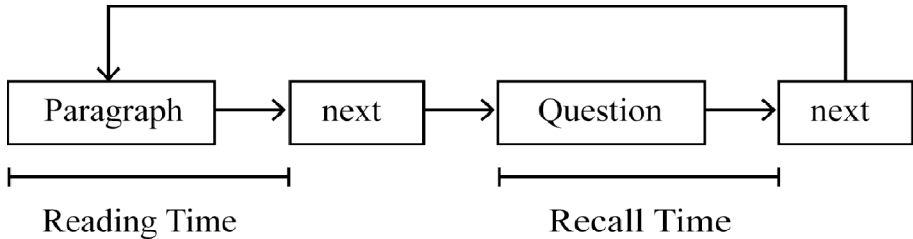

Fig. 3. Experiment process and targeted measures

As shown in the Fig.2, 54 combinations were randomly applied to 54-experiment texts that were generated in a random order. When the subject understood and finished the reading, the "next" button was pressed. The reading time was measured from when the first experiment text was shown until the subject pressed the "next" button. When the measuring the reading time is finished, a multiple choice question related to the text pops up and the subjects are required to answer the question before proceeding to the next question. Since answering questions about a short text is a very easy task, measuring the accuracy of the answers can be less useful. Instead, we track the recall time, the time the subject took to answer each question.

3   Implementation

3.1   Reading Speed

The total number of characters in experimentation paragraphs has the mean values of 100.53 and the median is 100. The reading speed of 54 typographical combinations are calculated with the formula from Myung [7]:

$$RS = \frac{\text{Number of total characters}}{\text{Search time}} \tag{1}$$

The search time in the above formula is equivalent to the reading time obtained from the experiment. A conjoint analysis is then conducted to using the calculated reading speed in order to identify significant typographic elements of readability. There were significant differences in the typographic elements influencing readability among the age groups (Fig. 4).   The significantly effective typographical elements for age group of 20 to 29 on readability are font size and line height (p-value < 0.039, $r2 = 0.243$). In contrast, font style is the most important typographical element for people in the age group of 30 to 39(p-value < 0.001, $r2 = 0.427$). The font style is the least important element to the age group of 50++ (p-value <0.02, $r2 = 0.281$).
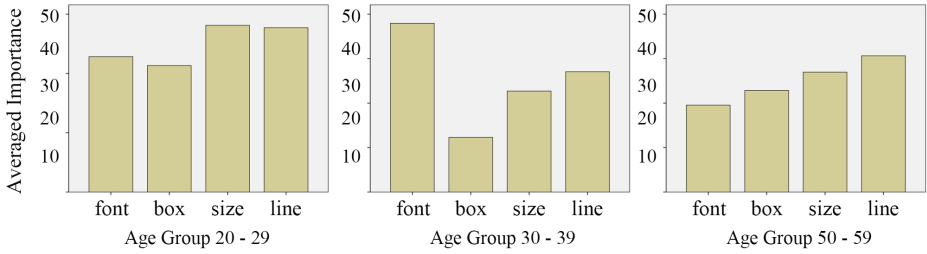
Fig. 4. Averaged importance of the typographical elements for reading speed of three age groups

3.2 Recall Speed

The recall speed is calculated using the response time of the subjects for answering the questions during each question session.

$$RcS = \frac{\text{Number of total characters}}{\text{Response time}} \qquad (2)$$

The recall time was then applied to conjoint analysis to identify significant typographic elements on readability. As shown in the Fig. 5, here were significant differences on the typographic elements influencing readability among different age groups. The significantly effective typographical element for age group of 20 to 29 on readability is: line height, font size, font style and text box. The line height is most important to the age group of 20 – 29 (p-value < 0.005, r2 = 0.348)   when the age group of 30 to 39 (p-value < 0.006, r2 = 0.342)   and 50++ values the font size the most. Especially, the age group of 50++ is highly dependent on font size for their effective readability (p-value < 0.005, r2 = 0.452).
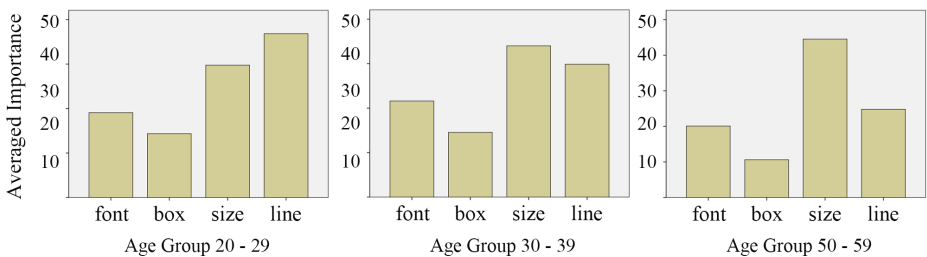

Fig. 5. Averaged importance of the typographical elements for recall speed of three age groups

The impact of the font size is different among reading speed and recall speed. It might be resulted from the skimming effect. The objective of reading is to skim through the paragraph as soon as possible to quickly overview the whole paragraph, therefore the larger font size may not always help.

3.3   Typographical Combinations

Based on the conjoin analysis on the 54 combinations of the typographical layouts, 3 highest readability layout combinations for three different age groups were generat-ed (Table 1).

Table 1. The most effective typographical combinations for the maximum readability

Age Group	Nanum Myeongjo	Nanum Gothic	Nanum Pen
20 – 29	Text box:480px Font size: 11pt* Line Height: 200%	Text box: 480px Font size: 17pt* Line Height: 300%	Text box: 600px Font size: 11pt* Line Height: 200%
30 – 39	Text box: 480px Font size: 23pt* Line Height: 200%	Text box: 600px Font size: 11pt* Line Height: 100%	Text box: 600px Font size: 17pt* Line Height: 100%
50 – 59	Text box: 600 Font size: 17pt* Line Height: 200%	Text box: 480 Font size: 17pt* Line Height: 300%	Text box: 480 Font size: 17pt* Line Height: 300%

* font sizes are rounded up for readability

Despite the importance of the font style, font size, text box and line height, the typo-graphical combination shows that different font requires different layouts to enhance the readability based on different age groups.

4   Conclusion

In this paper we attempted to create a guideline for style, line spacing, size, text box and age group combinations of Korean fonts for different electronic dis-plays such as desktop monitor and mobile phone that have various screen size. Reading time and recalling time were measured to analyze the readabilities among various typographi-cal layouts. The importance of typographical elements were different among the age group: line height and font sizes are the most important element for 20s to skim through the documents; font style and line height for 30s; line height and font size for 50+. Although, 20s, 30s and 50s had similarities on recalling speed since the font size and the line heights were the two most important readability elements. Thus, it is clear that the typographical layouts need to be designed differently based on the target user of the design. The optimized font combination for readability was also generated based on the experiment results which can be helpful reference for interface design-ers, typeface designers, and graphic designers to justify their designs, especially on responsive website designs. How other factors accompanied by age difference such as eyesight, memory, familiarity with electronic devices, and eye movement speed influ-ence the reading speed and recall time should be investigated in the future work.

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