Original Paper

Readability of character size for car-navigation systems

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Abstract: An experimental examination of the readability of a car-navigation system by elderly, middle-aged and young people was conducted. Subjects (127 people: 19-76 years of age) evaluated ease of reading of displayed characters. The experiment evaluated characters displayed on a liquid crystal display (LCD) similar to those used in car-navigation systems, and evaluated subjective evaluation of readability in 9 stages. Traffic terms were shown in 5 character sizes (2 mm, 4 mm, 6 mm, 8 mm, and 10 mm height) and two languages (Japanese and English) in the experiment. The experiment was conducted with the LCD in two positions: frontal position of the subject and left diagonal position (about 30 degrees). The results showed that the frontal position was significantly more readable than the left diagonal position. The subjective evaluation of readability included both Japanese and English characters. This result shows that English characters were more readable than Japanese ones. The values from the self-rated evaluation of readability were examined using a two-way analysis of variance (ANOVA), and the results showed a significant difference in readability between character sizes. In addition, significant differences were seen between the age groups in the readability of characters in the left diagonal position.

Keywords: Car-navigation system, Character size, LCD, Subjective evaluation of readability , Elderly people

1. Introduction

Use of liquid crystal displays (LCDs) in communication terminal equipment has spread rapidly. For example, LCD is used for screens such as the personal computer, the televisions, and mobile phones. LCDs are also used in car-navigation systems. There are two trends in the sizes of car-navigation systems, with some increasing while others are decreasing in size and weight to achieve power-saving features.

There have been many studies on the readability or legibility of printed characters and characters on cathode ray tubes (CRTs) or liquid crystal displays (LCDs) for computers [1-6], and character size recommendations have been standardized for sign displays and video display terminal (VDT) work [7-10]. These standards can be used as a reference for the design of characters on car-navigation terminals.

However, car-navigation systems have far smaller screens than desktop computers. Therefore, the standards for desk-top computers can not be directly applied to car-navigation systems. Few reports, however, have been made on the subjective evaluation of readability of characters displayed on car-navigation system screens in terms of the size of the character used or with a focus on elderly people.

In this study, the appropriate size of characters used in car-navigation systems was examined in people at 3 different age levels, including elderly subjects.

2. Methods

2.1 Subjects

Subjects (127 people: range 19-76 years old) with normal vision or normal corrected vision were divided into 3 groups: 72 young people (range 19-44 years old), 30 middle-aged people (range 45-64 years old), and 25 elderly people (range 65-76 years old). The average vision at a distance of 70 cm was 1.2 for the young, 0.9 for the middle-aged, and 0.7 for the elderly.

Subjects who wear eyeglasses or contact lenses in daily life, for example, in the car or while walking in town, also wore eyeglasses or contact lenses in the experiment.

2.2 Experiment description

This experiment was conducted indoors, with subjective evaluation of readability of characters displayed on an LCD screen. Performance evaluation is difficult for the elderly people. However, subjective evaluation can surely be measured. The subjective evaluation of readability of the character was an evaluation of whether it was felt that the characters could be read. A 9-point scale was used for the subjective evaluation of readability: very easy to read (9 points), easy to read (7), neutral (5), difficult to read (3), very difficult to read (1). Subjects were instructed to tell the experimenter when the characters were too small to read. Terms in the different character sizes were displayed simultaneously in the respective languages.

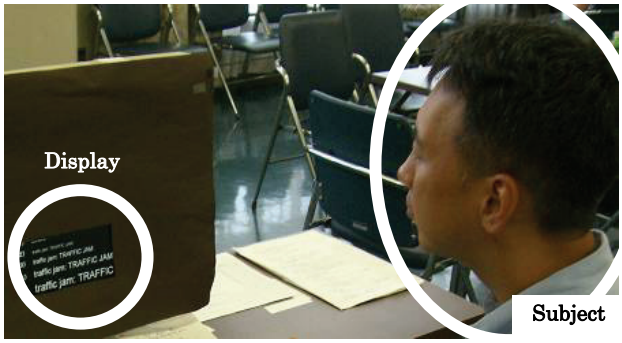
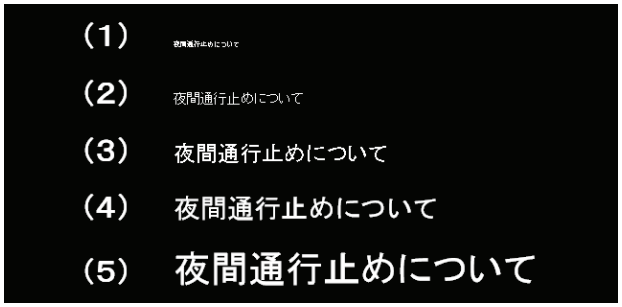


Fig. 1. Experiment Scene (Photo).



(Japanese Character)

(English Character)

Fig. 2. Displayed characters.

Five character sizes for traffic terms (character height: 2 mm, 4 mm, 6 mm, 8 mm, and 10 mm) and two languages (Japanese and English) were used in the experiment (Fig. 2). The fonts used in this experiment were Japanese MS P Gothic font in boldface type (e.g. in Japanese 夜間交通止め (Yakan Kotsu Dome)) and English Arial font (e.g. traffic jam: TRAFFIC JAM). The font types were selected so that they looked similar to the typefaces used on some car-navigation systems.

2.3 Display device

A desktop computer monitor (ADTEC TL700A) was used as an LCD with white characters on a black background (white color luminance: 15 cd/m^2, black color luminance: 0.9 cd/m^2). The illuminance was 404 lx in the vertical direction and 283 lx in the horizontal direction.

To make the display area size similar to a car-navigation system's screen, the LCD screen was covered with a black paper with an 8-cm height/14-cm width rectangular cutout. The characters displayed within the rectangular cutout were evaluated as if displayed on a car-navigation system's screen.

The LCD was set in two positions: frontal position of the subject and left diagonal position (about 30 degrees). In both positions the LCD was set at a distance of 70 cm from the subjects' eyes. In addition, the subjects were told to move their head only when they looked at the screen in the left diagonal position.

3. Results

The subjective evaluation of readability was evaluated for each language, LCD position, character height, and age group. Figure 1 shows the average values and standard deviations for subjective evaluation of readability of Japanese characters when the LCD was in the frontal position, for each font size and age group. Figure 2 shows the average values and standard deviations for subjective evaluation of readability of Japanese characters, with the LCD in the left diagonal position, for each font size and age group. Figure 3 shows the average values and standard deviations for subjective evaluation of readability of English characters, with the LCD in the frontal position, for each font size and age group. Figure 4 shows the average values and standard deviations for subjective evaluation of readability of English characters, with the LCD in the left diagonal position, for each font size and age group.

The results shown in the figures indicate that the subjective evaluation of readability of the character heights of 8 mm and 10 mm was high, and that of the character heights of 2 mm and 4 mm was low.

The overall comparison in subjective evaluation of readability of Japanese characters was overall comparison with that of English characters (paired t-test). Significant differences were seen ($p<0.001$) and it was demonstrated that English characters were more readable than Japanese ones. Next, the frontal position and the left diagonal position of the LCD were compared (paired t-test) in terms of subjective evaluation of readability. Significant differences were seen ($p<0.001$) between the positions, and it was demonstrated that English characters were more readable than Japanese ones.

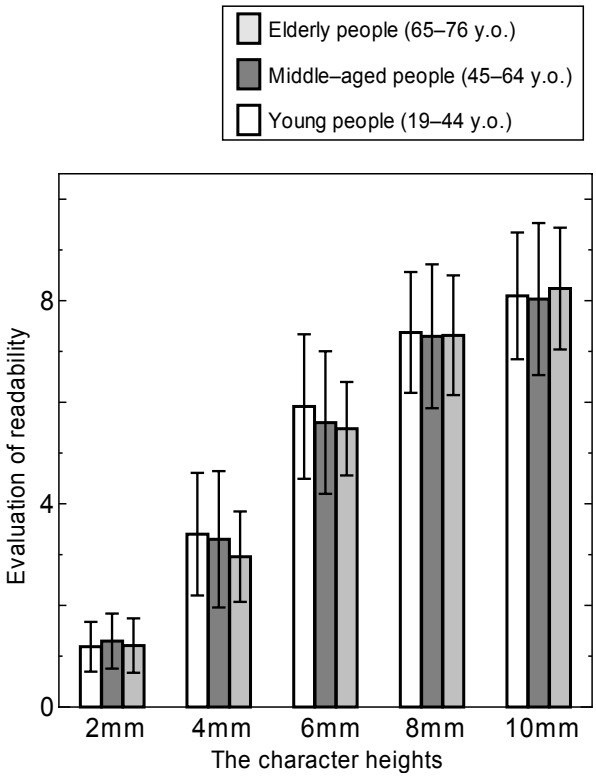


Fig 3. Subjective evaluation of readability of Japanese characters (the frontal position).

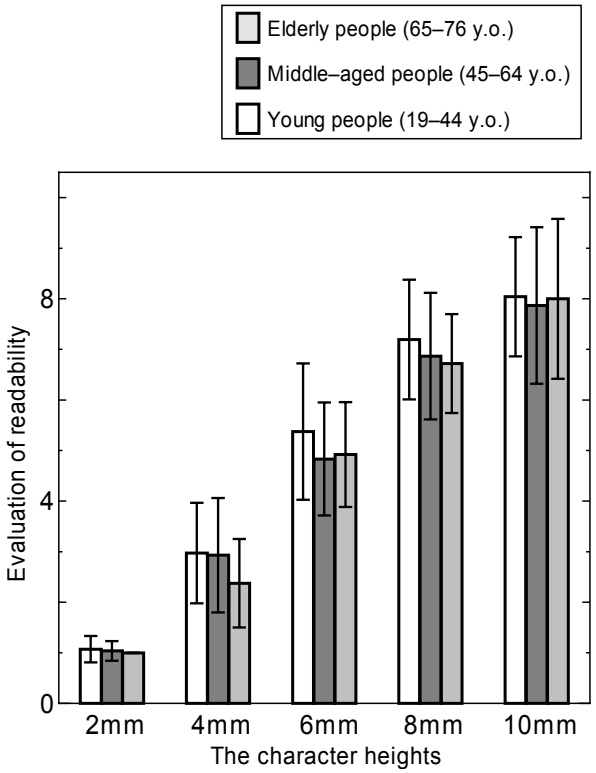


Fig 4. Subjective evaluation of readability of Japanese characters (the left diagonal position).

The overall comparison in subjective evaluation of readability between the frontal and the left diagonal positions of the LCD (paired t-test) seen significant differences ($p<0.001$) and it was demonstrated that subjective evaluation of readability is higher when the LCD is in the frontal position than in the left diagonal position. The subjective evaluation of readability was then evaluated according to character height (paired t-test), both in the frontal and the left diagonal position, in the two languages. Significant differences were seen ($p<0.001$) in both languages, and it was demonstrated that subjective evaluation of readability is higher in the frontal position than in the left diagonal position.

As Figure 3 shows, Japanese characters displayed in front of the subjects were the most readable at the height of 10 mm and the least readable at the height of 2 mm in all age groups. In addition, 2 young, 3 middle-aged, and 6 elderly subjects reported that Japanese characters in the frontal position at the height of 2 mm were too small to read.

The values from the self-rated evaluation of readability of Japanese characters in the frontal position were examined using a two-way analysis of variance (ANOVA), and the results showed a significant difference in readability between character heights ($p<0.001$). The result of the follow-up of the character heights showed significant differences between all combinations of heights ($p<0.001$ in all). It showed subjective evaluation of readability increasing as character size increased. In the subjective evaluation of readability of characters in the frontal position, however, little difference was seen between the age groups.

As Figure 4 shows, Japanese characters displayed in the left diagonal position were the most readable at the height of 10 mm and the least readable at the height of 2 mm in all age groups. In addition, 3 young, 4 middle-aged, and 9 elderly subjects reported that Japanese characters in the left diagonal position at the height of 2 mm were too small to read. Moreover, 1 middle-aged and 1 elderly subject reported that Japanese characters in the left diagonal position at the height of 4 mm were too small to read.

The values from the self-rated evaluation of readability of Japanese characters in the left diagonal position were examined using a two-way ANOVA, and the results showed a significant difference in readability between character heights ($p<0.001$) and age groups ($p<0.01$). The result of the follow-up on character height showed significant differences between all combinations of heights ($p<0.001$ in all), except for the combination of 8 mm and 10 mm. It showed subjective evaluation of readability increasing as character size increased. In addition, the follow-up on age groups showed significant differences between the young and the elderly ($p<0.05$), with subjective evaluation of readability higher in the young than in the elderly.

As Figure 5 shows, English characters displayed in front of the subjects were the most readable at the height of 8 mm for the young and at the height of 10 mm for the

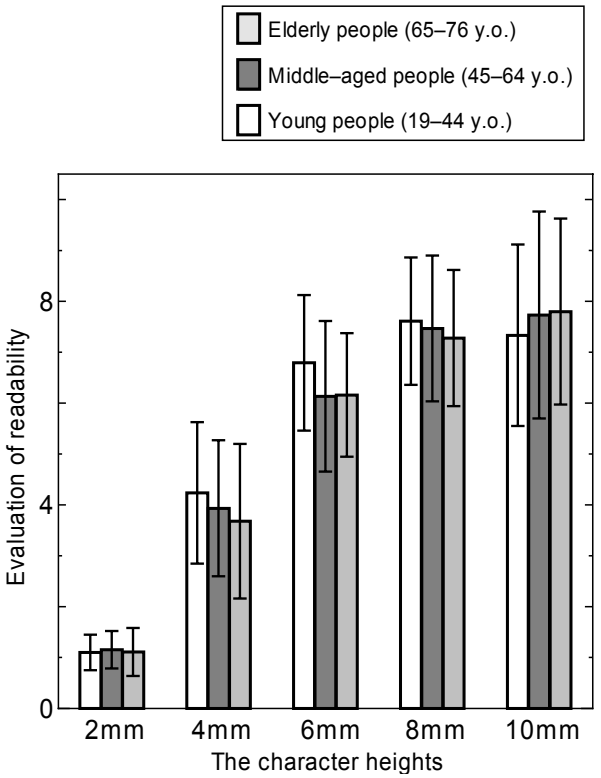


Fig 5. Subjective evaluation of readability of English characters (the frontal position).

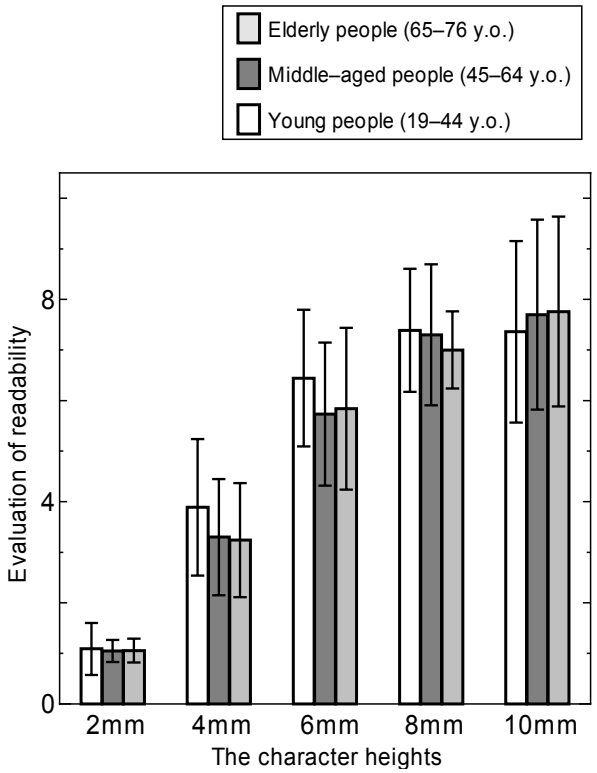


Fig 6. Subjective evaluation of readability of English characters (the left diagonal position).

middle-aged and the elderly. English characters were the least readable at the height of 2 mm in all age groups. In addition, 3 young, 4 middle-aged, and 7 elderly subjects reported that in the frontal position English characters at the height of 2 mm were too small to read.

The values from the self-rated evaluation of readability of English characters in the frontal position were examined using a two-way ANOVA, and the results showed a significant difference in readability between character heights ($p<0.001$). The result of the follow-up on character height showed significant differences between all combinations of heights ($p<0.001$ in all), except for the combination of 8 mm and 10 mm. It showed subjective evaluation of readability increasing as character size increased. In the subjective evaluation of readability of characters in the frontal position, however, little difference was seen between the age groups.

As Figure 6 shows, English characters displayed in the left diagonal position were the most readable at the height of 8 mm for the young and at the height of 10 mm for the middle-aged and the elderly. English characters were the least readable at the height of 2 mm in all age groups. In addition, 5 young, 9 middle-aged, and 7 elderly subjects reported that in the left diagonal position English characters at the height of 2 mm were too small to read.

Finally, the values from the self-rated evaluation of readability of English characters in the left diagonal position were examined using a two-way ANOVA, and the results showed a significant difference in readability between character heights ($p<0.001$). The result of the follow-up on character height showed significant differences between all combinations of heights ($p<0.001$ in all) except for the combination of 8 mm and 10 mm. It showed subjective evaluation of readability increasing as character size increased. In the subjective evaluation of readability of characters in the left diagonal position, however, little difference was seen between the age groups.

4. Discussion

The frontal position and the left diagonal position of the LCD were compared in terms of subjective evaluation of readability. Significant differences were observed between the positions. The LCD is not suitable for viewing at angles. Therefore, frontal position of the LCD is more readable than the left diagonal position.

The subjective evaluation of readability of Japanese characters was overall comparison with that of English characters. Significant differences were observed and it was demonstrated that English characters are more readable than Japanese ones. However, this study's subjects were all Japanese people. Due to the basic differences of English and Japanese font structure, and it is thought that this influenced the result. Another reason may be that English characters are simpler than Japanese ones.

The character height with the best subjective

evaluation of readability was mostly 10 mm for all conditions. The subjective evaluation of readability of 8 mm character height was similar to that of 10 mm character height. The subjective evaluation of readability of 6 mm character height was lower than the 8 and 10 mm character heights, but the differences were minor. The character heights of 2 mm and 4 mm had considerably poorer subjective evaluation of readability for all conditions. Therefore, character height of 4 mm or less cannot be recommended for use in car-navigation systems.

Moreover, since Japanese characters displayed in the left diagonal position were less readable than those in the frontal position, smaller Japanese characters in the left diagonal position were less readable for the elderly.

As VDT work criteria, the ISO 9241-3 (1992) recommends that the minimum alphabetical or numerical character height should be 16 minutes of the arc, with character heights of 20 to 22 minutes of the arc preferred [8]. The visual angle of 20-22 minutes of the arc corresponds to an assumed character height of 4.1-4.5 mm at a viewing distance of 70 cm in VDT work. Character heights used in this experiment were from 2 to 10 mm. The three larger character heights of 6 mm, 8 mm and 10 mm exceeded the recommended character height. Thus, the results of this experiment differed from the recommended character size. Reasons for this may be that, first, the present experiment used a subjective evaluation of readability, whereas ISO 9241-3 (1992) is aimed the minimum criteria or optimum minimum criteria [8]. Second, the display was set below the eye level of the subjects. Moreover, the positional condition of the LCD, was the left diagonal position, and it seems that the LCDs were not easy to read in that position. Since drivers have to maintain a constrained posture in the car, they cannot move to a position where the display is more legible. However, LCDs are not suitable for viewing from angles.

For readability of characters, the ISO proposes methods using performance results and subjective rating [7][8]. Some studies on readability of characters shown on the LCD displays of mobile phones have indicated that performance results and subjective evaluations follow the same trends [11]-[13]. Thus, subjective evaluations may be practical in investigations of readability.

Previous studies have suggested that character height has a marked influence on the readability of English/numerical characters [14]. On both VDTs and printed material, the character size required for readability of Japanese writing including Chinese characters is larger than that for alphanumerical characters [9][10]. Miyao et al. (1989) indicated the need for greater character height on CRTs with low resolution [2]. Character readability differs between CRTs and LCDs [3] [15]. Even using characters of the same size, readability may differ according to the specifications of the LCD or the typeface and form of characters. In addition, viewing distance probably increases in aged groups because near vision acuity decreases due to the influence of presbyopia in many subjects, but these influences differ markedly among individuals [11] [14]. Universal designs allow the transmission of information to all people including the elderly.

In recent years, there have also been some studies on the readability of characters on mobile terminals [15]-[18], but research remains inadequate for standardization or the proposal of guiding principles. The use of character information on mobile terminals has expanded applications not only for personal correspondence but also to obtain social information, daily living information, disaster information [19], and other types of information.

In this study, subjects (127 people: 19-76 years of age) evaluated the ease of reading of displayed characters. Five character sizes for traffic terms (2 mm, 4 mm, 6 mm, 8 mm, and 10 mm) and two languages (Japanese and English) were used in the experiment. The experiment was conducted with the LCD in two positions: directly in front of the subject and the left diagonal position. The results showed that the directly frontal position was significantly more readable than the left diagonal position. The subjective evaluation of readability was done for both Japanese and English characters. The results showed that English characters were more readable than Japanese.

Also, the results show that readability increased as character height increased. These results suggest that a small character size should not be used for car-navigation system displays. They also show a significant difference between the young and the elderly, with readability higher in the young than in the elderly.

5. Conclusions

Using a self-rated evaluation, display positions and character font sizes used in car-navigation system were subjectively evaluated for readability by people at 3 different age levels, including the elderly.

The character height with the best subjective evaluation of readability was 10 mm or 8 mm for the present experimental conditions. The subjective evaluation of readability of the 6 mm character height was slightly lower than the 8 to 10 mm character heights. The character heights of 2 mm and 4 mm had considerably poorer subjective evaluation of readability for all conditions. In the present experiment, 6 mm character height seems to be the minimal limit for readable car-navigation systems.

It was found that subjective evaluation of readability decreased as the font size decreased in all age groups, and in both frontal and the left diagonal position s. In the subjective evaluation of readability of Japanese characters, significant differences were found between the age groups when the display was in the left diagonal position but not in the frontal position. Moreover, since Japanese characters displayed in the left diagonal

position were less readable than those in the frontal position, smaller Japanese characters in the left diagonal position were less readable for the elderly. On the other hand, English characters were more readable than Japanese ones, one reason for which may be that English characters are simpler than Japanese ones.

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