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A Cognitive Approach to Designing Manuals

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Abstract. The practice of using a cognitive approach in designing manuals is presented. The relationship between a legible text format and the users' behavior was investigated through two experiments. The factors and levels that comprise legible text were clarified, and it was found that there was no clear relation between legible text and users' comprehension. In conclusion, an actual case of the application was discussed, and the possibility of a creative use of illegible format was suggested.

Keywords: universal design font, legibility, conjoint method, decision tree, proofreading, recognition, comprehension, LF/HF, HRV

1 Introduction

The multi-functionalization of electric appliances in recent years has increased the amount of information that should be included in user manuals. Therefore, one of the most relevant issues with regard to the design of manuals is how to fit text in a limited space suitably. Indeed, good, clear writing in manuals has been explicitly stressed in the literature, so that users do not misunderstand the text, but it is also true that the best writing is wasted if the pages are visually unappealing (Schoff & Robinson, 1991). Therefore, the creativity of designers to make appealing manuals has been tested under spatial constraints. Many guidelines exist regarding the visual properties of manuals (Horton, 1991; ISO, 1995; U.S. CPSC, 2003), but ultimately, the manual's design has been dependent on the designer's sense, and little scientific information about this topic is available.

In this paper, we present a cognitive approach to designing manuals in order to identify a science-based creative solution for designers. Figure 1 shows the concept of this approach, at the start of which we focused on text format. Specifically, by employing methods such as conjoint analysis (Myung, 2003), machine learning, and analysis of variations in heart rate, the relationship between text legibility and users' comprehension was investigated.

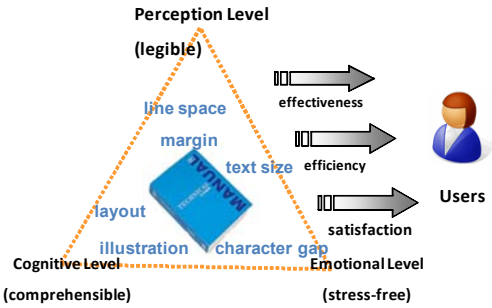

Fig. 1. Concept of cognitive approach for designing manuals

2 EXPERIMENT 1: Legibility of Texts General Method

Twenty-four Japanese subjects (12 males and 12 females) participated in two experiments; the participants had normal color vision and over 20/25 vision or corrected vision, and they ranged in age from 35 to 69 years. They evaluated printed texts in black type and in the Japanese universal design font, which had a brightness of approximately 200 cd and high contrast, on a table at a distance of 50 cm from their eyes under an illumination of over 300 lx.

2.1 Which format do people prefer?

The conjoint method was employed to highlight the relationship between various types of text formats and users' preferences, and to clarify the elements that strongly affect the legibility of texts.

Method: All subjects rearranged 16 sheets of text-printed cards (Table 1: A~P), having different visual properties and assigned to an L16 orthogonal array, in order of legibility within a time limit of five minutes. Two trials (texts 56 mm and 80 mm in width) were conducted, with the effects of text width in mind.

Table 1. Card name, selected factors, and levels assigned to L16 orthogonal array

text format	size	interline space	aspect ratio	letter space
A	7pt	0.1	1	0
B	7pt	0.2	0.85	-20
C	7pt	0.3	0.7	-40
D	7pt	0.4	0.55	-80
E	8pt	0.1	0.85	-40
F	8pt	0.2	1	-80
G	8pt	0.3	0.55	0
H	8pt	0.4	0.7	-20
I	9pt	0.1	0.7	-80
J	9pt	0.2	0.55	-40
K	9pt	0.3	1	-20
L	9pt	0.4	0.85	0
M	10pt	0.1	0.55	-20
N	10pt	0.2	0.7	0
O	10pt	0.3	0.85	-80
P	10pt	0.4	1	-40

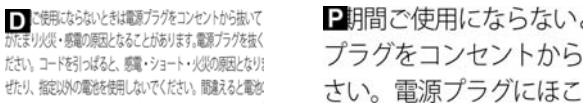

Fig. 2. Example of text on cards D and P

Result: Table 2 shows the integrated order of cards rearranged by the subjects. No typical difference was discovered between widths of 56 mm and 80 mm. Scoring the lowest card "1"and the highest card "16," we obtained the values of utility by using quantification method I. The graph in Figure 3 represents the value of utility in the text that was 56 mm in width. The values over 0 indicate positive contributions to the preference of the subjects. As the graph shows, the utility of 10 point (pt) characters had a greater effect on the subjects' preferences. In contrast, the text written in 7 pt characters or 0.55 in aspect ratio (width-to-height) showed negative effects on their preferences.

Table 2. Order of cards rearranged, based on their legibility

text width	legible ← → illegible
56 mm	P O K L N F H M I E J A G B C D
80 mm	P O K L N F H M I E A J G B C D

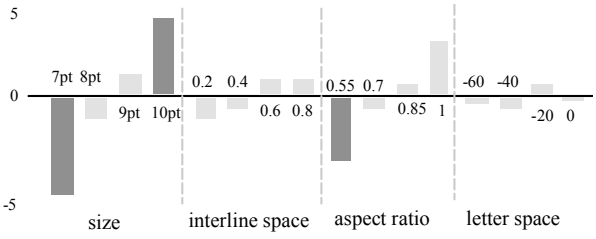

Fig. 3. Value of utility to each visual factor of text of 56 mm in width

2.2 Branch point between legible and illegible text

The above-described experiment clarified the relative dominance between the text formats and factors, but it is still unclear how legible these text formats are. In the following trial, a rating method with a rating scale of 21 steps was used to obtain quantitative evaluations and the qualitative nature of legibility for each format.

Method: All subjects rated the legibility of 80 different texts, printed on B5 papers, into 21 ranks. The visual formats of the text were combinations of size, interline space, and aspect ratio (see Table 3), and were shown randomly every 8 seconds.

Table. 3. Factors and levels of formats used in Experiment 1

size	6 pt / 7 pt / 8 pt / 9pt / 10 pt
interline space	0.2 / 0.4 / 0.6 / 0.8
aspect ratio	0.55 / 0.7 / 0.85 / 1.0
letter space	0 (fixed)

Result: Figure 4 shows the averaged evaluation for all text formats. A rating score over "0" means higher legibility. By teaching the evaluation of all subjects to a computer, we derived a decision tree that can correctly divide text formats into "legible" or "illegible" (see Figure 5). According to this tree, when a text is written in 7 pt or a lower size, it will be recognized as "illegible," even if it has efficient interline spacing and a wide aspect ratio. Additionally, if a text is written in 0.55 aspect ratio, people will evaluate it as "illegible," even if it is written in larger than 8 pt font. *These results recommend using over 8 pt size in body text, and not using strong, vertically long characters so as not to place a visual burden on the users.*

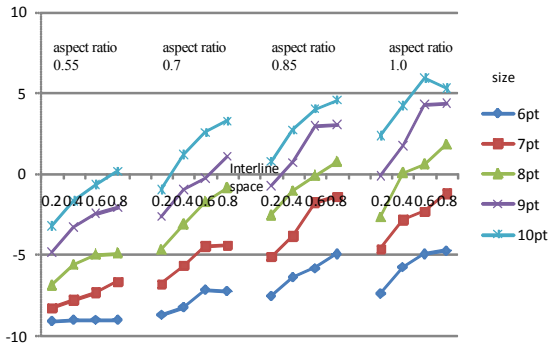

Fig. 4. Averaged evaluation by rating scale in Experiment 1

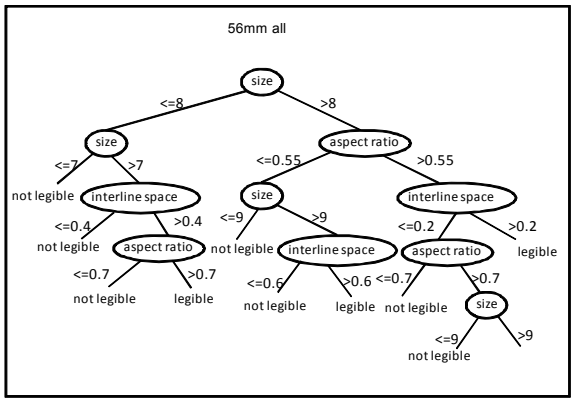

Fig. 5. Example of decision tree (56 mm in width)

3 EXPERIMENT 2: Text formats and Comprehension

3.1 Proofreading task

In experiment 2, the recognition level of subjects with regard to four text formats was investigated in order to examine the relationship between the text's format to users' comprehension. The aim of this experiment was to obtain objective pointers concerning the users' comprehension level, unlike experiment 1, which investigated users' subjective preferences for formats.

Method: All subjects read an explanatory text, after which they proofread the same but partly altered text, with a time limit of five minutes. They tried this procedure four times with different texts in different formats, as shown in Table 4. Four familiar topics (potato, onion, tomato, and carrot), treated in a text of approximately 1200 words, were chosen from an encyclopedia. Each of the four texts included two types of altered words.

A) Could be found only if the subject had read the altered text.
(homonym: × 2; flipped word order: × 2)

B) Could be found only if the subject remembered the contents of the text.
(era: × 2; place-name: × 2; similar word: × 2)

To observe the relationship of the text's legibility to the users' comprehension more clearly, we combined the most legible character size (10 pt) and interline space (0.6), and also the most illegible character size (6 pt) and interline space (0.2) as formats.

Table 4. Four formats and their factors and levels in experiment 2

text format	size	interline space
10pt_0.6	10 pt	0.6
10pt_0.2	10 pt	0.2
6pt_0.6	6 pt	0.6
6pt_0.2	6 pt	0.2

Result: Overall, there was no clear relation between text legibility and the number of corrected words (see Figure 6). In experiment 1, although texts written in large letters and enough interline space were evaluated as "legible," this suggests that legible text does not always affect users' comprehension of text.

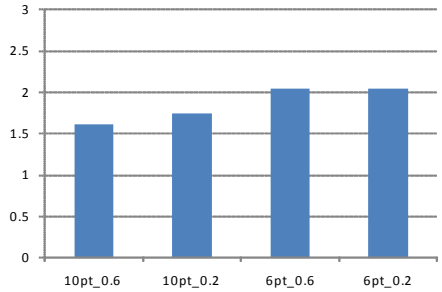

Fig. 6. Average of correct answers in proofreading task

Meanwhile, concerning type B, subjects corrected more words when they proofread the more illegible text (see Figure 7). *These results suggest that text written in large characters does not always affect users' comprehension, but that text written in small characters can also be easily memorized.*

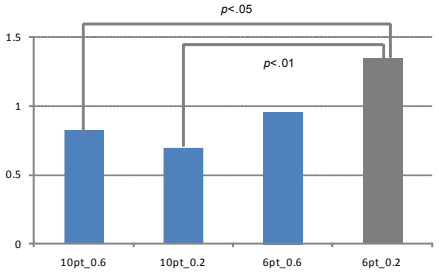

Fig 7. Average of correct answers based on subjects' memory

3.2 Handling task

Actually, most users read instructional manuals when they are operating a product. In this trial, we investigated the relationship of the text's legibility to users' comprehension while operating a machine.

Method: All subjects handled the virtual interface on a PC monitor (Figure 8) using four types of manuals printed in the same formats as Table 4. This virtual interface consisted of three transitional windows. The right side of Figure 8 shows the operational description for each window.

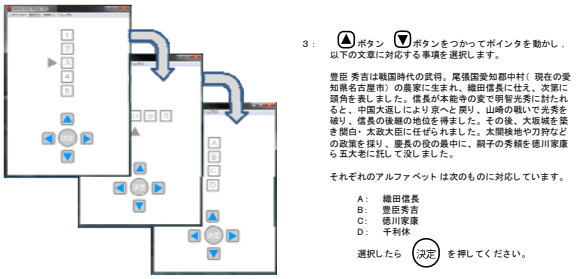

Fig. 8. Example of virtual interface window and description of manual

The subjects were required only to click a button according to the instructions in the manual at a first and second window, and then they had to read and memorize a description of about 200 words, after which they were required to choose the appropriate button. All subjects repeated this procedure 10 times within 7 minutes. After that, recognition tests, which included 10 alternative questions, were given to the subjects.

Result: As with the previous experiments, there were generally no clear differences in users' comprehension based on different text formats. Similarly, as Table 5 indicates, the rate of False-Alarm was slightly lower in the most illegible format (6 pt, _0.2) than in the most legible format (10 pt, _0.6), and it was lower in the format of 10 pt, _0.2, but there were no significant differences in these averages.

Table 5. Average of correct answers (Hit) and false alarms (FA) in handling task

	10pt_0.6		10pt_0.2		6pt_0.6		6pt_0.2	
	Hit	FA	Hit	FA	Hit	FA	Hit	FA
average	3.29	1.96	3.71	1.58	3.38	1.83	3.58	1.67
SD	1.37	1.27	1.20	1.35	1.01	0.96	1.38	1.27

Furthermore, an analysis of the correlation between the number of correct answers in the proofreading task and the number of correct answers in this handling task showed a marginally significant negative correlation (r =-0.44, p < 0.059), but only in the most illegible format (6 pt, _0.2). This means that a high scorer in the proofreading task performed poorly in this task, and a low scorer in the proofreading task performed well in this task. *As a result, it seems that users' comprehension in handling something like electric appliances is different from that of only reading. Therefore, designing manuals might require a different viewpoint from designing books or magazines.*

3.3 Text formats and users' affectivity

If there is no difference between the effect of legible and illegible formats on users' comprehension, it might seem rational to employ small letters when designing manuals. However, if users feel stressed while reading a relatively illegible format, designers should not use them. According to our pilot test, it was clear that subjective mental workload measured by NASA-TLX (NASA, 1986) was higher when people read an illegible text, but it was still not clear whether subjective workload reflected physiological affectivity. Therefore, we recorded subjects' heart rate variety (HRV) to analyze the users' affectivity (stress) level before and after the proofreading and handling tasks.

The value of LF/HF is known as a guideline that reflects autonomic nervous system activity. Generally, LF/HF will rise when people feel tense because of sympathetic activity. On the other hand, it will decrease when people feel relaxed because of parasympathetic activity.

In the proofreading task, the average of all subject's LF/HF decreased significantly when they read a text with legible format (10 pt, _0.6), as Figure 9 shows. Meanwhile, in the handling task, opposite tendencies to the proofreading task were observed, but they were slight and insignificant (see Figure 10).

These results suggest that legible text written in large letters and enough interline spacing may calm people. On the other hand, there was no significant rise in tension when people read an illegible text.

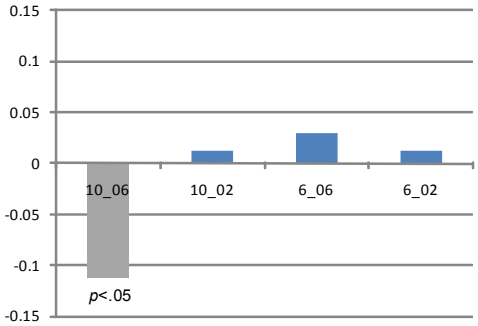

Fig. 9. LF/HF in proofreading task

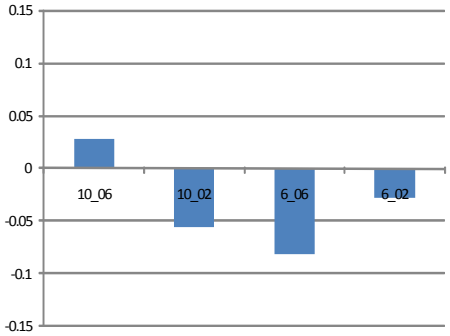

Fig. 10. LF/HF in handling task

4 Discussion and Conclusion

This paper described the use of a cognitive approach to designing manuals. In experiment 1, various types of text formats were examined, based on users' subjective feelings and in which texts of large letter size and enough interline spacing were evaluated as more legible. Moreover, a decision tree derived from these evaluations will support the creativities of designers by clarifying the choice of which formats should be used in limited spaces. Figure 11 shows an actual page of a manual for an analytical instrument. The appropriate character size character and interline space from the results of experiment 1 were applied to it. Despite the difficulty of its contents, this manual received an award from the Japan Manual Award due to its legible and appealing appearance.

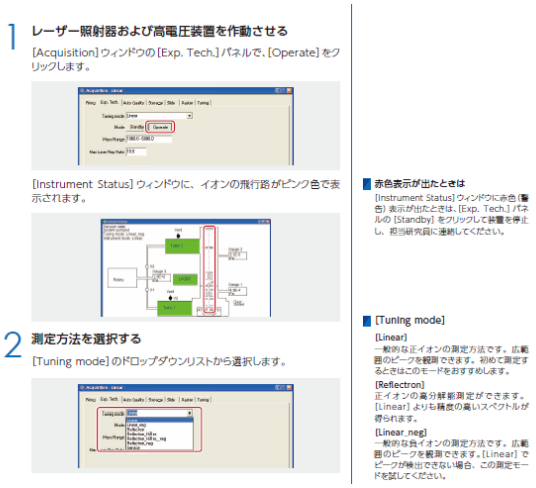

Fig. 11. Example of instruction manual reflecting the results of experiment 1

In contrast, experiment 2 revealed that no clear correlation exists between the legibility of texts and users' comprehension. Instead, the subjects' scores in the proofreading task were higher for the most illegible text (6pt, _0.2), when they had to memorize information. These results suggest a possibility of using an illegible text format consciously to designing manuals.

If designers want to apply these results to design manuals, the following may be useful to observe: for the body text, use 10-pt font for greater legibility, and use 6-pt text for supporting font to make users memorize the content. If a designer uses small letters in the text, thereby detracting from users' motivation to read the manual, it might be possible to compensate by using a devised caption or icon, while simultaneously saving layout space.

Thus, a cognitive approach to designing manuals has the possibility of contributing to a creative solution for designers.

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