Reading Text on a Smart Phone

Scrolling vs. Paging: Toward Designing Effective Electronic Manuals

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Abstract— **This study investigates the influence of reading-manipulation on small touch devices such as smart phones and, more specifically, how scrolling and paging actions affect a user's comprehension of texts and the operating performance of the interface. Two different types of texts were distinguished using (a) a recall task and (b) an operation task. In the recall task, the user's comprehension levels of narrative texts were measured in both the scrolling and paging conditions. Also, the operation time of the virtual interface and number of errors during the reading of a procedural text were examined in the operation task. The results indicated that the comprehension level of narrative texts was slightly better in paging and that operation time and number of errors makes no difference in the reading of procedural texts in both conditions. Narrative texts could be better understood in paging actions on small touch devices and both scrolling and paging are suitable for procedural texts, and it is also true that scrolling contributes to reading procedural texts for users who have long experience with using devices such as smart phones.**

Keywords – smart phone; scrolling; paging; comprehension; reading; procedural text; designing manuals

I. INTRODUCTION

In recent years, environments in which people read a text on a small high-resolution display are developing more and more. People have many opportunities to read texts not only on special terminals for e-books such as the Kindle but also on other small display devices such as the iPhone or iPad. Many book reader applications have been developed for these devices, and most have implemented a function of scrolling up and down or turning a page, or both, by directly touching the screen, despite the fact that most Web pages employ a form of scrolling. Of course, it is user's preference to scroll or page when they read a text. However, since texts printed on paper media such as newspapers or textbooks have been turned into texts on electronic screens, it is important to investigate how the difference in manipulation (scrolling and paging) on small screen affects reading performance.

The influence of scrolling and paging on reading has been investigated from various angles, particularly in parallel to the growth of the Web. Nimwegen et al. investigated the influence of the structure and reading-manipulation of hypertexts on the PC screen, and they suggested that a purely hierarchical hypertext with scrolling is most useful [1]. Bernard et al. reported that people performed Web search tasks best on layouts with both reduced paging and scrolling, and when forced to pick between the two, they clearly preferred paging [2]. Piolat et al. conducted an experiment to investigate the effects of scrolling and paging on text reading and revising and found that there was no difference in reading speed, but paging resulted in better comprehension and memory information [3]. A study conducted by Mead et al. on Web searching by younger and older people suggested that it is efficient to use a page layout for older people [4]. Similarly, Imai and Omodani evaluated the reading performance under the scrolling and paging conditions and reported that both the reading time and comprehension level were superior in paging than in scrolling [5]. Sanches et al. also reported that the scroll format reduced reading comprehension if the content was complex, especially when working memory was low [6]. In addition, according to Wastlaund et al., when people read a text with a page layout, their mental load was lower than for scrolling, but there was no difference in text comprehension between scrolling and paging [7]. Nowadays, although most Web pages require scrolling for browsing, these research studies seem to indicate the existence of advantages in paging for text reading. One reason is that information processing is interrupted by scrolling, which reduces visual cues, as Wastlaund indicated [7]. According to him, in the absence of visual cues, the reader is obliged to match the movement of the page with lines of text, which, in turn, has to be matched against the memory of the text to determine whether or not the text has been moved a satisfactory distance or whether more scrolling is necessary.

However, these findings were all based on experiments with PC displays, and the types of texts examined in these research studies were inconsistent. Therefore, we focused on small touch devices such as smart phones. Compare to reading-manipulation on a PC display, people generally manipulate Web pages or other kinds of text by directly touching the screen with a finger, but there is little information about how this touch manipulation affects text reading. Similarly, we focused on procedural texts because these kinds of texts, such as recipes and instructional manuals, are very popular on the Web and will be read more on smart phones in the near future, but little information is currently available regarding this scroll/page context.

The purpose of this study was to investigate the effects of scrolling and paging on reading comprehension, performance, and mental load on small touch devices such as smart phones. To clarify the effect of scrolling and paging, the following two tasks were used:

- a “recall task”, and
- an “operation task”.

In the recall task, the subjects read an narrative text in both the scrolling and paging conditions, and then they answered fill-in-the-blank questions. Similarly, in the operation task, they handled a virtual console while reading a procedural text.

II. EXPERIMENT

A. Subjects

Twelve Japanese corporate workers (8 males, 4 females, average age 35.3) participated in this study as volunteers. Five of them had rarely used a smart phone, while others were familiar with them.

B. Equipment

An Apple iPod Touch 4G (3.5-inch Multi-Touch display, 960×640-pixel resolution at 326 per inch) was used as a text reader device, and two applications were adopted as text readers (Document Reader as a scrolling reader and Perfect Reader Mini as a paging reader). The iPod Touch was used for both types of tasks. In the operation task, a Mitsubishi RDT195LM 19-inch monitor displayed the virtual console application.

C. Materials

The following two types of texts were used: (i) narrative texts and (ii) procedural texts. Four themes (Belarus: country, Surinam: country, Heterocephalus glaber: animal, and Malacochersus tornieri: animal) of narrative texts in Japanese were prepared for the recall tasks. These themes might have been unfamiliar to subjects, and they were selected to avoid knowledge bias. Each text was extracted from Wikipedia and edited to approximately 1,500 words in Japanese. (What is considered a word is not as clear-cut as in Western languages. Here, it is close to one character. Native Japanese readers read at a rate of 700 characters per minute [8]. Meanwhile, an average reading speed can range from 200 to 300 words per minute in English [9]).

In addition, four different procedural texts (Fig. 1) were prepared for the operation task. The procedural text had 5 sequences, and each sequence consisted of 6 steps. The operation procedure was different in each text, but the number of operations that the subjects had to perform was the same. All of these texts were prepared as PDF documents, and the text for the scrolling application had no page segmentation. A page had 17 lines and each line had 19 characters in the recall task. Dyson and Kipping suggested that readers appear able to adjust their scrolling patterns according to the line length they are reading [10], but the number of characters per line here was fixed.

D. Recall Task

To measure reading comprehension, 10 fill-in-the-blank questions were prepared for each explanation text. Each question required the participant to memorize the content of the text to be answered (i.e., “The main language used in Belarus is …”). Half of the questions were derived from the body of the text layout and the other half were derived from the peripheral parts (first 3 lines or last 3 lines) of the text to see whether the location of the text affected the memorization or not.

E. Operation Task

To measure time and the number of errors during operations, a virtual console application such as a remote controller (Fig. 2) was implemented on a PC, and all subjects operated it while reading a procedural text on the screen of an iPod Touch. When a participant finished a 6-step operation (1 sequence) from the procedural text, a Greek character such as “ Ω ”was displayed beside the sequence number in the application. If he or she made an operation error, then an error message appeared in the error window and he or she had to redo the same step.

F. Workload Evaluation

All subjects evaluated the workload using NASA-TLX [11] after they had finished an operation task in both the scrolling and paging conditions.

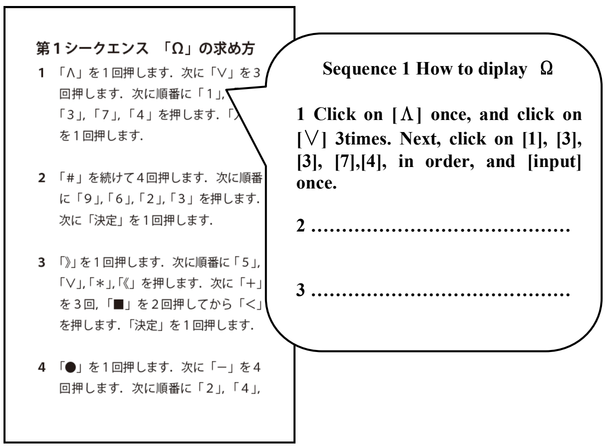


Figure 1. Example of procedural text used in the operation task.

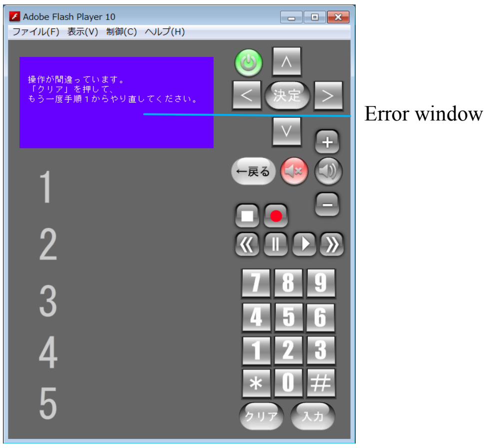


Figure 2. Virtual console used in the operation task

G. *Procedure*

Prior to the experiment, all subjects read an explanation text for 5 minutes as practice in both the scrolling and paging conditions and then answered 3 fill-in-the-blank questions as well. After that, they practiced operating the virtual console on the PC screen for 7 minutes while reading a procedural text in both conditions. In the paging application, page-turning was done by a horizontal finger touch, whereas scrolling was done in the vertical direction.

In the real experiment, half of the subjects started to read the narrative text and were instructed to memorize the content within 3 minutes in the scrolling condition, while the other half started in the paging condition to avoid the order effect. Before answering the fill-in-the-blank questions, the participants had to perform addition with three digits to avoid memorizing rehearsal. Then, they answered the fill-in-the-blank questions.

After finishing the recall task, each participant performed an operation task in the same condition. They held iPod Touch in one hand and operated a virtual console on the PC screen using a mouse with the other hand. Also, they evaluated the workload using NASA-TLX after finishing an operation task. All subjects repeated these sequences 4 times, switching between the scrolling and paging conditions.

III. Results

Table I shows the number of subjects based on the smart phone usage experience and the manipulation preference for the task. 7 of 12 used a smart phone routinely, while the others have had no opportunity to use one. The most popular manipulation preference is reading with scrolling for both the narrative text and the procedural text. The other preferences are all 1/3 as high.

A. *Result of the Recall Task*

Table II shows the means and standard deviations of the correct answers on the recall tasks in each scrolling and paging condition. (One subject's data was lost because of an application error.) An analysis of variance was used to test the effect of scrolling and paging for narrative text. The mean was slightly high in the paging condition, and this was marginally significant (F (1,10) = 3.69, 0.05<p<0.1). A comparison of the mean of the correct answers between the body and the peripheral part of the text layout indicated no statistical significance in the scrolling condition, but the mean of the correct answers from the text body was marginally higher than that from the peripheral part of the text (F (1,10) = 3.48, 0.05<p<0.1) in paging condition.

B. *Result of the Operation Task*

Table III shows the means and SDs of the operation time in the operation tasks in both the scrolling and paging conditions. Overall, the operation time was slightly shorter in scrolling than in paging, but this was not statistically significant.

Considering the subjects who preferred scrolling in this task and those who preferred paging separately, the time of the former (Fig. 3, left) was marginally shorter in scrolling than paging (F (1,6) = 4.92, 0.05<p<0.1). In contrast, the time of

TABLE I. Experience with the Smart Phone and Manipulation Preference

	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12
1		●		●							●	
2								●	●			
3												
4	●		●		●	●	●			●		●
A	●	●	●		●					●		●
B				●							●	
C							●	●				
D						●			●			

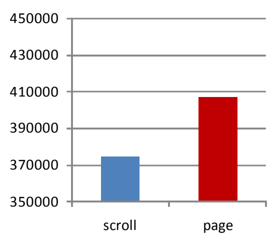
・Experience of using smart phone
 1: nothing
 2: once or twice
 3: owner but do not use
 4: every day use at home and work place
・Preference of Subjects
 A: scrolling both in narrative and procedural text
 B: paging both in narrative and procedural text
 C: scrolling in narrative text and pagng in procedural text
 D: scrolling in procedural text and paging in narrative text

TABLE II. Means (M) and Standard Deviations (SD) of Correct Answers in the Recall Task

	Scrolling		Paging	
	M	SD	*M*	SD
Total	3.72	0.51	4.36	0.65
questions from body part	2.09	0.32	2.54	0.28
questions from peripheral part	1.63	0.33	1.81	0.45
Number of operation miss	2.14		2.36	

TABLE III Means (M) and standard deviations of the operation time of in the operation task

	Scrolling		Paging	
	M	SD	*M*	SD
Total time	401262	15789	419380	15119
scroll chooser	374496	11148	406988	15363
paging chooser	448102	26478	441066	31984



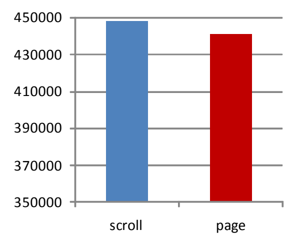


Figure 3. Left: mean of operation time (msec.) of subjects who prefered scrolling in the operation task; Right: time for subjects who prefered paging in the operation task.

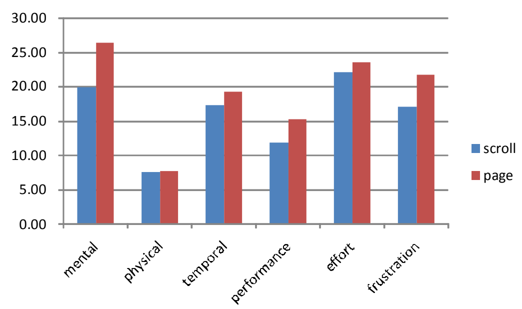


Figure 4. Weighted workload of scrolling and paging on the operation task, according to NASA-TLX.

the latter in paging (Fig. 3, right) was slightly shorter than in scrolling, but this was not significant.

The number of operation errors was slightly higher in paging than in scrolling Table II, but this was not significant.

C. *Mental Workload*

Fig. 4 shows the mental workload according to NASA-TLX in the scrolling and paging conditions. All subjects evaluated their workload in the operation task from the viewpoint of mental demand, physical demand, temporal demand, performance, effort, and frustration level. The results show that workloads in the scrolling condition were wholly lower than in paging and, especially, in terms of mental demand, there was a large gap between scrolling and paging. In contrast, there was no physical load difference in the two conditions.

IV. Discussion

The effects of scrolling and paging in reading text on small touch devices such as smart phones were studied empirically using a narrative text in the recall task and a procedural text in the operation task.

As for reading the narrative text, the main finding of this research is that comprehension level was marginally higher in paging than in scrolling, even though the text was displayed on a small touch screen. In previous research studies, the effects of scrolling and paging in reading were investigated using a PC screen, and many studies suggested that paging was superior to scrolling [2]-[5], [7], [12]. The results of this study may support these previous findings even if the display device is small and paging is done by touching the screen directly. Indeed, Piolat et al. [3] and Wastlund [7] et al. indicated that scrolling required more working memory compared to paging, and our results for the recall task seemed to partly support this. In addition, because there were marginal differences in the number of correct answers between the peripheral and body parts of the texts, it might be better to design page layout consciously when we edit on a small screen.

In terms of the procedural text, because previous research has not treated it in the context of a comparison between scrolling and paging, we focused on this and examined reading performance using an operation task. Although there was no statistical difference in operation time and the number of errors between scrolling and paging, the time for subjects who preferred scrolling in this task was marginally shorter in scrolling than paging. As Bernard et al. said, scrollable pages may facilitate more efficient scanning [2], and our results may be similar to this in one sense because, in the operation task, the subjects were not required to comprehend the context of the text. These findings suggest that, for some particular text types such as recipes and instructional manuals, which require procedural action and reading in parallel, scrolling might be effective on small touch devices. Similarly, in this experiment, the tendency for subjects with smart phone experience to prefer scrolling in both tasks suggests that people might prefer scrolling when they use a smart phone, whether it is effective or not. By contrast, though the number of samples was small in this study, the subjects who had no experience with smart phones preferred paging in the operation task. This is similar to previous findings indicating that it is efficient for older people to use a paging layout [2].

The NASA-TLX results showed that mental load in the operation task was totally lower in scrolling than paging, contrary to the experiment of Wastlund et al. using a PC screen [7]. In particular, for people with experience, a paging action might be clumsier for reading on a smart phone. It might be more important for users to read smoothly to avoid interference with their operating something than to comprehend text when they read a procedural text on a smart phone. Most subjects who preferred scrolling in the operation task gave a reason such as, “To scroll past the finished lines, there was no need to move the eye from line to line.” In other words, paging in the operation task was clumsy on smart phone for half of the subjects. The large gap between scrolling and paging in the item of mental demand in NASA-TLX might support this.

Although more research is needed to investigate other types of texts, the results of this study suggest that reading would be better done, not only on a PC screen but also on a smart phone, with paging. Additionally, scrolling would also be effective for procedural texts, especially for heavy smart phone users.

V. CONCLUSION

This study investigated how scrolling and paging influence reading on a smart phone, using narrative texts and procedural texts as materials. The experimental results show that the comprehension level for narrative texts was slightly better in paging and that operation time and errors made no difference in the reading of procedural texts in both conditions. However, the time for subjects who preferred scrolling in the operation task was marginally shorter in scrolling than paging. These results indicate that, with smart phones, reading performance might increase if a paging layout were used, especially for text types that should be memorized such as textbooks or reference books. Meanwhile, for procedural texts such as instructional manuals, recipes or other kinds of how-to books, scrolling would also be efficient, especially for people who are familiar with smart phones.

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