Original Paper

Analysis of the General Difficulty in Tasks on a Display
—Consideration of Overload to the Short-term memory for Referencing Multi Pages—

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(Received Feb.24, 2011)

People tend to feel difficulty in working on displays rather than on paper. We suppose that rather long memory holding time, in our short-term memory, requested by working on a display is a dominant reason of difficulty with complicated tasks on a display. That’s because working on a display, on which we often have to watch multi sheet of documents alternatively, generally force us longer memory holding time than when we are working on multi sheet of real papers. Subjects were requested to process tasks which need cross-reference between multi pages of documents with different viewing conditions of the pages: parallel showing and alternate showing of the multi pages. The results of measurement showed longer working time in alternate showing. We regard the longer working time in the alternate showing as a result of shortage of short-term memory, which was more eagerly requested by the alternate showing conditions.

Keywords: Display, Paper, E-paper, Short-term memory, Human interface

1. Introduction

We tend to feel difficulty in working on displays rather than on paper especially when the work requests cross references among documents. Table 1 shows comparison between a display and papers. We should consider not only the impact of media style, reflective or emissive, but also the impact of reading style: paper documents are generally processed on a large desk top, while documents on a display are generally processed on the narrow desk top of the display switching or scrolling procedure of text screen required for referencing process between different pages must request longer period of memory holding time than when we were allowed to refer multi papers for each page on a desk. Our supposition is that human ability of short-term memory is not sufficient for the rather longer holding time requested by the referencing tasks on a display\(^1\). We measured performances of tasks which request cross references between multi pages at two kinds of display conditions: parallel showing and alternate showing of multi pages\(^2,3\). We expected this measurement must clarify the reason why we tend to feel difficulty in working on displays, on which we are often forced to use alternate viewing of multi pages\(^4,5\).

2. Experiment 1: Performance measurements of tasks with cross-references between pages

2.1 Experimental methods

Subjects were requested to answer what is the best solution of transferring trains. Fig. 1 shows an example of two pages with which a subject requested to find the best solution for 2 times transfers. The first page shows departure time and total required time for transferring between two trains including train running time. The second page shows time tables at each station. Fig. 2 shows displaying modes in three viewing modes: (a) parallel showing, (b) distant showing, and (c) both sides showing. The parallel showing mode simulated a general working on papers. The both sides showing mode simulated a general working on a display. Distant showing mode simulated a middle way of the parallel showing mode and the both sides showing mode. Table 2 shows working conditions of the three
displaying modes. **Fig. 3** shows typical scene of task at the distant showing mode. **Fig. 4** shows a typical time table used in the experiments. Any writing of notes was prohibited before writing down the final answer. We prepared 5 ranks of tasks with different difficulty; the number of transfer was \((1, 2, 3, 4 & 5)\) times for each rank of task respectively. The time tables \((2-6\text{ tables})\) necessary for each task were laid out in one page. We prepared four digits of departure time and two digits of required time universally for all the tasks. Subjects were requested to memorize the departure time and required time in the first page before going to the second page in order to choose appropriate trains by using each time tables. Subjects put on eye mark recorder on their heads. We measured a frequency of eye mark jumping between the two pages. The measured frequency means a frequency of reference of re-reading the 1st page for reconfirming the original conditions of the task. We could know a frequency of reference in the both side showing mode \((c)\) simply with counting the frequency of turning over a paper by a subject. **Table 3** shows detail of

**Table 3**  Experimental conditions of experiment 1.

<table>
<thead>
<tr>
<th>Items</th>
<th>Specs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media</td>
<td>Paper (A4, A3 size)</td>
</tr>
<tr>
<td>Eye mark recorder</td>
<td>NAC IMAGE TECHNOLOGY : EMR-8</td>
</tr>
<tr>
<td>Subjects</td>
<td>12 students (twenties)</td>
</tr>
<tr>
<td>Working place</td>
<td>Noise attenuating room</td>
</tr>
<tr>
<td>Illumination</td>
<td>600 lx on the desk</td>
</tr>
</tbody>
</table>

![Fig. 1](image1.png) Page layout of a typical task with 2 transfers.

![Fig. 2](image2.png) Three display modes.

**a)** Parallel showing

**b)** Distant showing

**c)** Both sides showing

![Fig. 3](image3.png) Typical scene.

![Fig. 4](image4.png) Typical time table used in the experiments.
2.2 Results: Experiment 1

Fig. 5 shows measured working time at each task. The two alternate showing modes, distant and both sides showing indicates longer working time than the parallel showing mode. Fig. 6 shows measured frequency of reference. The parallel showing mode indicates more frequent reference than the two alternate showing modes.

3. Experiment 2: Measurement of forgetting curve

3.1 Experimental methods

Fig. 7 shows the expected memory decay curves when a subject saw a 7 or 10 digit number and then remembered it over a certain period. The inferior performance shown by the alternate display conditions should be explained with Fig. 7.

The alternate showing condition must request longer period of memory holding, at referencing situation using switching of displayed pages, than that requested by the parallel showing condition. This means that the alternate showing condition must use lower part of memory decay curve, where memory holding is further decreased, than that for the parallel showing condition. Consequently, the difference of the required memory holding time must lead the big difference of task performance between the parallel and the alternate display condition. Our next focus was then set to get actual memory decay curve: forgetting curve. Experimental conditions are listed in Table 4. Fig. 8 shows a sequence flow of the experiments 2. The sequence is as follows:

① Arabic figures of 7 digits (n = 3, 5, 7, 10, 13) were shown on a display to subjects for n seconds (n = 3, 5, 7, 10, 13); the same number “n” as for digits.

② A blank screen was shown during memory holding time (3, 5, 10, 20 seconds).

③ The subjects were requested to write down the Arabic figures.
### 3.2 Results: Experiment 2

Memory retention rate was calculated for each condition by using the following formula:

\[
\text{Memory retention rate} = \frac{\text{Number of the subjects who could remember the full digits}}{\text{Total number of the subjects}} \cdots (1)
\]

Fig. 9 shows measured results of memory retention rate. Measured curves naturally indicate earlier decay for longer figure length. Rapid decay to less than 50% was shown in 3 seconds by the curves for 10 and 13 digits. Length of requested holding time must be critical for memory retention of larger digits.

The measured memory decay curve showed good similarity as we supposed in Fig. 7: rapid decay, which must be critical for the short holding time required for referencing between multi pages, was confirmed.

### 4. Discussion

#### 4.1 Reason of the difficulty in the working with alternate showing

Now we have confirmed that the small difference of memory holding time required for the reference between multi pages must result a big difference of load to our short-term memory. We thus regard the longer working time shown by the alternate showing modes as a result of shortage of short-term memory, which must be eagerly requested by the alternate showing modes. We supposed that the subjects needed longer time in each effort of memorizing the first page because they must want to decrease the frequency of reference in the alternate showing conditions.

#### 4.2 Significance test

We have performed significance tests to confirm our result. We checked if the difference in working time and also number of reference were statistically significant between different reading styles. We checked statistical significance between the two mean values: one was shown by the parallel showing mode and the other was shown by the both sides showing mode. We also checked statistical significance between the two mean values: one was shown by the parallel showing mode and the other was shown by the distant showing mode. We used “Student’s t test” to evaluate the statistical significance of the difference between the mean values of two independent groups. “Student’s t test” generally outputs probability \( p \) that confirms the null hypothesis that denies the difference in the mean values of the two groups. A statistical significance should be confirmed when \( p < 0.05 \); that is when the null hypothesis should be denied. We checked statistical significances for only the cases with the four and the five transfers, in which we can expect clear difference between each showing mode in both the working time and the frequency of reference. Table 5 shows the probability values \( p \) in the statistical evaluation for the working time and also for the number of reference in 4 and 5 transfers. We could confirm that the working time difference only between the two conditions, the parallel showing mode and the both sides showing mode in the four transfers task, is statistically significant because its level of significance \( p \) is 0.013 \( (p<0.05) \). We could confirm that the difference in frequency between the two conditions, the parallel showing mode and the both sides showing mode in the four and five transfers tasks, is

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**Table 4** Experimental conditions of experiment 2

<table>
<thead>
<tr>
<th>Items</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure length requested for memorizing (digits)</td>
<td>3 5 7 10 13</td>
</tr>
<tr>
<td>Showing time for memorization (sec.)</td>
<td>3 5 7 10 13</td>
</tr>
<tr>
<td>Memory holding time requested</td>
<td>3, 5, 10, 20 sec.</td>
</tr>
<tr>
<td>Conditions during memory holding time</td>
<td>Watching a blank screen</td>
</tr>
<tr>
<td>Displaying conditions</td>
<td>LCD with back light (20.1 inch., UXGA)</td>
</tr>
<tr>
<td></td>
<td>Font: MS Ming style, 44 point</td>
</tr>
<tr>
<td>Subjects</td>
<td>6 students (twenties)</td>
</tr>
<tr>
<td>Working place</td>
<td>Noise attenuating room</td>
</tr>
<tr>
<td>Illumination</td>
<td>600 lx on the desk</td>
</tr>
</tbody>
</table>

**Table 5** Calculated level of significance : \( p \).

<table>
<thead>
<tr>
<th>Parallel vs. Both sides</th>
<th>Parallel vs. Distant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working time</td>
<td>Number of reference</td>
</tr>
<tr>
<td>4 transfers</td>
<td>0.013 0.030 0.322 0.144</td>
</tr>
<tr>
<td>5 transfers</td>
<td>0.479 0.012 0.289 0.153</td>
</tr>
</tbody>
</table>

**Table 4** Experimental conditions of experiment 2

**Table 5** Calculated level of significance : \( p \).
statistically significant because each level of significance \( p \) is 0.013 \( (p<0.05) \) and 0.030 \( (p<0.05) \) respectively.

5. Summary

1. The alternate showing modes indicated longer working time than the parallel showing mode.
2. The parallel showing mode indicated more frequent reference than the alternate showing modes.
3. The measured forgetting curve implied that only a small difference in the short memory holding time requested in the different showing modes is critical for our ability in the short-term memory.
4. We regard that the longer working time in the alternate showing modes was as a result of limited ability of their short-term memory.

References


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Sonomi Inoue was born in 1987. She received her B.E. degree in 2009 from Tokai University. She is expected to receive her M.E. degree from the graduate school of Tokai University in 2011. She is now engaged in a study of readability as a target of Electronic Paper.

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Makoto Omodani received his B.S. and M.S. in Mechanical Engineering from Tohoku University in 1978 and 1980, respectively, and his Ph.D. from Tokyo University in 1987. He joined NTT in 1980 working on printing technologies at Yokosuka Electrical Communication Laboratories. He has moved to Tokai University in 1997. His current position is a professor of Department of Optical and Imaging Science & Technology of Tokai University. He is now engaged in imaging technologies, especially electronic paper technologies.