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## **Behavioral Characteristics while Searching Information thanks to Tangible Media - Kansei Evaluation and Behavioral Analysis on E-Paper, Paper and Touch-panel**

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### **1. Introduction**

Recently, a new tangible medium called 'electronic paper' has been developed. As some authors introduced (Shioda, 1998. Omodani, 2001, 2004) electronic paper developed with the merits of paper, being easy to see, easy to carry around and energy conservation, as well as the benefits of electronic media such as being rewritable, interacting with other digital-media, and reducing the consumption of paper.

As Omodani (2003) suggested that there are many kinds of electronic paper:

- A) Separation type: The display and the writing system are independent.
- B) Combination type: The display unit is combined with the rewriting unit (ex. The LIBRle of SONY Co.. and  $\Sigma$ Book of MATSUSITA Co.) .
- C) All-in-one type: This type has the rewriting function such as an LCD.

There has been research on electronic paper based on different approaches. In the research of Kou & Shiina (2005) that compared LIBRle with other media [5]; the reading process of the novel was compared with reading speed, legibility and facilitation with the SD method for evaluation. The result on the reading speed was that paperback was fastest while little differences were pointed out between the LIBRle and the display. The SD method evaluated the paperback as the best, placing the LIBRle as the second position. However, the operability of the LIBRle was inferior to the display.

In the research comparing the  $\Sigma$ Book with other media (book of paper and display), the reading time, the pupil dilation and the eye-gaze were evaluated using an eye tracker (Ogawa 2004). As a result, the legibility evaluation of paper was the best. The  $\Sigma$ Book and the display had similar results.



These researches were focused on reading efficiency. The electronic paper has other functionalities such as instant capture that may support human memory differently. However, no research has focused on this point yet.

This paper aims at clarifying an evaluation structure through behavior and subjective evaluation of each medium based on searching information. Therefore, we designed a searching product for the task of experiment to compare tangible media. For the media, we used the E-Paper, developed by Fuji Xerox Inc. as the electronic paper. Beside this, paper (printing) and touch-panel were also used.

In this experiment, we used a combined system using the E-Paper (cf. Figures 1 and 2). As the research of Koshimizu, Hayashi & Hirose (2004), the E-Paper has a liquation of an organic photoconduction material and a liquid crystal display material that is used for a copy machine. It changes the strength of light into a reflection image shortly, by irradiating light to a transparent electrode on its surface while impressing voltage. After the change, it maintains an image in the non-electric source (cf. Figure 1, the document company FUJI XEROX (2005)).



Figure 1 Scenery of experiment and E-Paper

In the experiment, we used the integrated system of the E-paper, touch-screen and projection table, called Snap table (cf. Figure 2). A computer's desktop image is projected on the screen with touch panel. On the Snap Table, the E-Paper need the power source clip for using. When users pushing the scan button on the power source clip, digital-information appears on the E-Paper instantly. In addition, this E-Paper has a function specialized to memorise the URL while scanning information on web site. Therefore, users can easily go back to a scanned web site with the E-Paper.

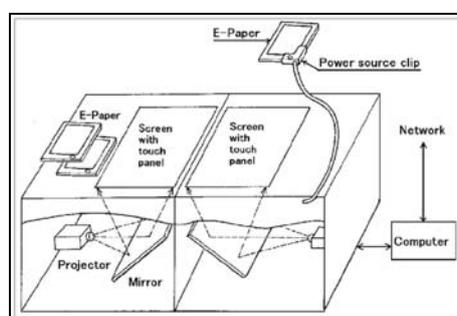


Figure 2 Touch-Panel used in experiment



## 2. Method

### 2.1. Experimental design

For the experiment, E-Paper, paper and touch-panel were used as tangible media. These conditions are named 'E-Paper', 'printing paper' and 'touch-panel' respectively.

We established the four trials with different four targets. E-Paper was used for first and fourth and other media were used for second or third to support equality of each condition. E-Paper and printing were limited to five E-Papers and five copies respectively, to keep the similar conditions for searching throughout the conditions. Neither a mouse nor a keyboard was allowed.

### 2.2. Task

We set the target task to search by comparing various goods on the Internet pages. For the experiment process, we selected digital camera, cellular phone, vacuum cleaner and laptop computer as target goods. The subjects were instructed to finish from searching to decision within ten minutes.

### 2.3. Subject

The subjects were five males (ave. of age =23.4) and five females (Ave. of age = 24.8). All of them were university students.

### 2.4. Record and analysis

We used two camcorders to record actions of hands on touch screen and the upper body. We converted recorded information into digital image on a computer, and checked behaviors according to the elapsed time. Subsequently, we observed the checked video images and the feature of the medium when subjects searched information to choose a favorite product.

After all trials were finished, we asked subjects for rank evaluation of medium. Then, we explored cause of subject's evaluation to each medium as well as behaviors while searching information.

## 3. Results And Discussion

### 3.1. Rank evaluation

As a result from the rank evaluation to each medium, the E-Paper scored highest. It means that subjects preferred E-Paper to any other one. The evaluation of touch-panel was the lowest (cf. Table 1).

We checked the relevancy of the evaluation among media thanks to the Friedman's Test. The result showed a significant tendency ( $\chi^2(2) = 5.6, p < 0.10$ ).

The multiple-comparison by the Scheffe's way showed a significant tendency between the E-Paper and the touch-panel ( $p < 0.10$ ).



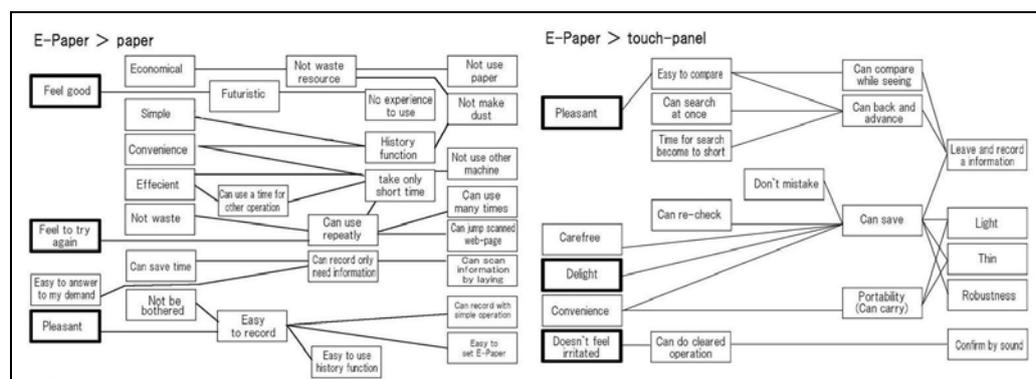
	Rank		
	the first	the second	the third
E-Paper	5	4	1
paper	3	6	1
touch-panel	2	0	8

**Table 1** Rank evaluation

### 3.2. Evaluation structure by a repertory grid method and laddering

The subjects' evaluation structure can be compared with the models of the repertory grid method and laddering. The evaluation structure was based on six comparative situations, since the experiment was done with three media. The six comparative situations were: 1) E-Paper > paper, 2) E-Paper > touch-panel, 3) paper > E-Paper, 4) paper > touch-panel, 5) touch-panel > E-Paper, 6) touch-panel > paper.

There were 261 evaluated words, including 41 negative ones. Three experimenters observed the evaluated words and their causative structure. We classified the structure by preferred media. Therefore, the six causative structures could be organized independently for each medium (cf. Figures 3-5).



**Figure 3** Causative structures for the E-Paper

In the case of E-Paper preferred condition, subjects were able to take and keep only necessary information. It became easy to compare saved information based on the recording function only (cf. Figure 3). Therefore, the E-Paper was considered as a functional medium for the searching process.

Since subjects were able to compare products using a lot of information (taken and kept with good quality images), the paper was considered as a medium supporting good choice (cf. Figure 4).

The touch-panel was found highly operable. Subjects were able to search colorful information in a simple accustomed way, without any unnecessary operation. (Figure 5)

Next, we chose the words which show subjects' affections among all evaluated words for each medium, such as 'feel good', 'pleasant', 'delight', 'does not irritate', 'become dislike', and 'feel sick'. Then, we checked and



organized the reason of subjects' evaluations. On Figures 3 to 6, the words highlighted by squared frame have the meaning 'affection'.

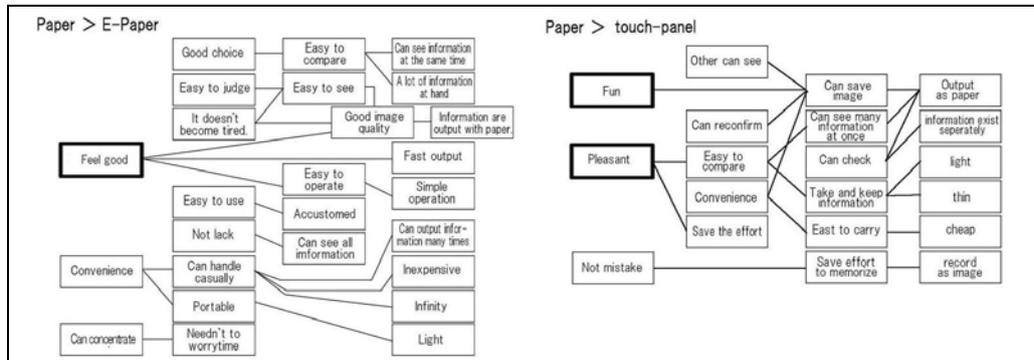


Figure 4 Causative structures for the paper

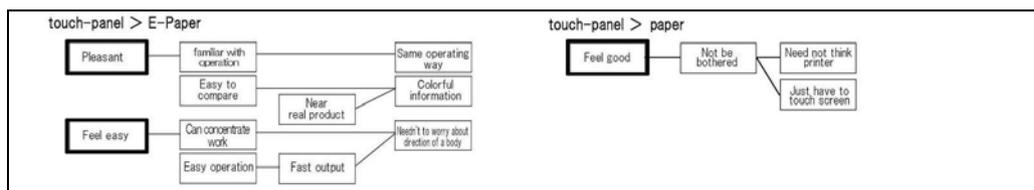


Figure 5 Causative structures for the touch-panel

In the case of E-Paper preferred condition, 'feel good', 'pleasant', 'fun', and 'hesitate' were chosen. As the E-Paper was futuristic, the subjects estimated to feel good. As they were able to use it repeatedly, they were motivated to try to use many times. As the E-Paper was easy to record and to compare, they also felt pleasant. On the other hand, subjects felt sick by rough image quality, and became dislike since operation was troublesome (cf. Figure 3, 6).

In the case of paper preferred condition, the subjects felt good by good image quality, fast output, easy to operate. As the paper is easy to compare and save the effort, it was pleasant to use. In addition, as subjects could save many images, it was a fun media. However, subjects tend to hesitate to use it when information involves lots of paper (cf. Figure 4, 6). (In the figure 6, the X/axis stands for the first principal component score and the Y/axis stands for the second principal component score.)

In the case of touch-panel preferred condition, 'pleasant', 'feel easy', 'feel good', 'feel worry' and 'be irritated a little' were chosen. As the operation of touch-panel was familiar condition, Using the touch panel was pleasant. The subjects felt easy. Therefore, they were able to focus on their task. In addition, as they were not bothered, they felt good. However, as the way to push the touch-panel was uneasy and sometimes it did not react to the subjects, as they wanted, some subjects felt irritated and worried (cf. Figure 5).



From the repertory grid method and laddering, it was clear that even if the word to evaluate each medium was identical, the reason of the evaluation was different. For example, the words of ‘pleasant’ and ‘easy to compare’ were evaluated commonly for all the conditions. However, the reason was different for E-Paper and paper on one side, and touch-panel on the other side. The former, once were evaluated so because great quantity of information could be taken, kept and treated at once. The later was also evaluated such way since it was not necessary to record information even if choose product.

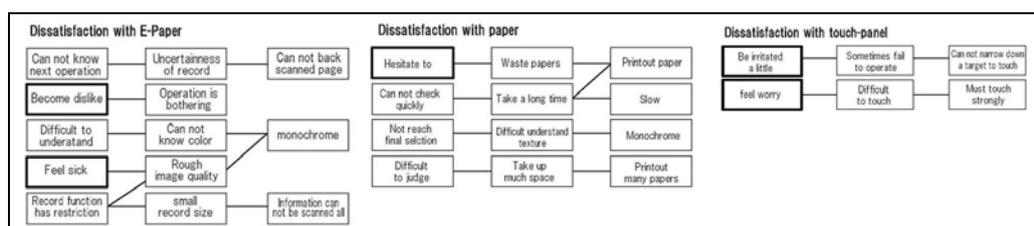


Figure 6 Causative structure of dissatisfaction for each media

### 3.3. Action analysis

During the experiment, the subjects’ actions were observed. It has been noticed that subjects had a common process for selecting a favorite product with tangible-medium:

- 1) Subjects take and keep important information.
- 2) They reconfirm the information.

The quantified subjects’ actions were compared under each medium condition. We conducted principal component analysis using quantified subjects’ actions. We classified subjects into three groups by the most preferred media. Also, we compared the principal component scores of each group of subjects.

#### 3.3.1. Action analysis for E-Paper

As for the E-Paper, the quantified subjects’ actions were as follow:

**- To scan information:**

- (A) The number of occurrence to scan; (B) The average time length taken for scanning.

**- To look at scanned information:**

- (C) The total number of occurrence the scanned E-Paper is watched; (D) The total time length to look at the scanned E-Paper; (E) The number of occurrence to confirm its content in order to use the URL history function; (F) The number of occurrence to look at the scanned contents.

**- To use a URL history function:**

- (G) The total number of occurrence the URL history function was used; (H) The number of occurrence the URL history function was successfully used.

Cumulative contributing rate to the second principal component was 88.47%. Therefore, we considered using the two principal components (cf. Table 3).



The first principal component loading shows that only the average time length taken to scan was negative and other items were positive. It means that the time length taken to operate the E-Paper was short and that the scans of information were numerous. In addition, the scanned E-Papers were well reconfirmed and the URL history function was well used.

**Table 3** Principal component analysis on E-Paper

	The first principal component	The second principal component	The third principal component
Eigenvalue	4.60	2.47	0.35
Proportion (%)	57.56	30.92	4.36
Cumulative (%)	57.56	88.47	92.84

**Eigenvector**

	The first principal component	The second principal component	The third principal component
the number to occurrence of scan	0.41	0.12	-0.49
The average time length taken for scanning	-0.41	0.02	0.58
the total number of occurrence the scanned E-Paper is watched	0.40	0.30	0.19
the total time length to look at the scanned E-Paper,	0.25	0.49	0.46
the number of occurrence to confirm its content in order to use the URL history function	0.39	-0.30	0.28
the number of occurrence to look at the scanned contents	0.11	0.61	-0.05
the total number of occurrence the URL history function was used	0.37	-0.32	0.29
The number of occurrence the URL history function was successfully used	0.37	-0.31	0.10

From this result, the first principal component was interpreted as ‘an operation and usability of E-Paper as a new medium’.

The characteristic of the second principal component is as follow: When the quantity of content observation becomes too much, when the total time length of observation becomes too long, and when the number of scan becomes too much, the second principal component loading rises greatly. When the loadings of the three items, which are concerned with the recording function, become low, then the second principal component loading also rises.

From this result, the second principal component was interpreted as ‘a disposition to handle E-Paper as a paper which merely loads up information’.

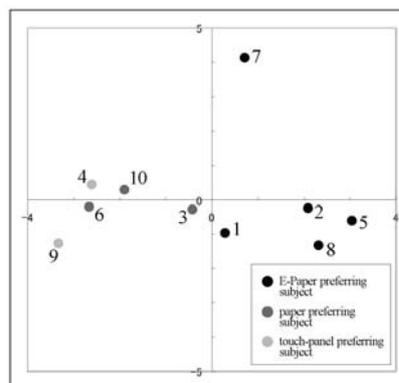
We grouped subjects by medium preferences (E-Paper preferring group, paper preferring group, touch-panel preferring group – cf. the three colors in the Table 4) and compared these first and the second principal component scores. As a result, the principal component score was the highest for E-Paper preferring group. Paper preferring group scored second and the touch-panel preferring group for third (cf. Table 4 and Figure 7). (In the figure 7, the X/axis stands for the first principal component score and the Y/axis stands for the second principal component score.)



This tendency was stronger for the first principal component than the second one.

**Table 4** Principal component score about E-Paper

subject (preferred media)	the first	the second
1 (E-Paper)	0.29	-0.99
2 (E-Paper)	2.10	-0.23
3 (paper)	-0.41	-0.27
4 (touch-panel)	-2.61	0.42
5 (E-Paper)	3.03	-0.59
6 (paper)	-2.65	-0.17
7 (E-Paper)	0.71	4.14
8 (E-Paper)	2.33	-1.34
9 (touch-panel)	-3.32	-1.26
10 (paper)	-1.89	0.28



**Figure 7** The first and the second principal component score

From this result, it is suggested that the medium preferring group relates deeply to ‘an operation and usability of E-Paper as the new media’. But, ‘a disposition to handle an E-Paper as a paper which merely loads up information’ is not related to the media preferring group.

### 3.3.2. Action analysis for paper

On the paper condition, the quantified subjects’ actions were following.

**- To take and keep scanned information;**

(A) The number of occurrence to print out; (B) The average time length taken to print out.

**- To look at printed information;**

(C) The total number of occurrence to look at printed information on paper; (D) The total time length to look at printed information on paper; (E) The average time length to look at printed information on paper.

However, as one subject who belongs to the ‘touch-panel preferring group’ did not use a paper at all, the score of the items of ‘the total time taken to print’ and ‘the average time to see a printed paper’ became ‘0’.



Therefore, we determined the most influencing items by dividing it by discrimination-analysis into two groups: the 'E-Paper preferring group' and the 'paper preferring group'.

As a result of the discrimination-analysis, the significant degree of a wilks  $\Lambda$  (lambda) was 0.79. It means that the result of the discrimination-analysis was not intentional. From this result, the five items from the printing-action did not have an influence to evaluation media.

### 3.3.3. Action analysis for touch-panel

Concerning the touch-panel condition, subjects searched information without using any tangible media.

Therefore, the subjects searching actions were divided into two categories. One was 'to search information' and the other was 'to re-search information'. Moreover, the two categories were quantified by action analysis and divided into the following seven items.

#### - To search information:

(A) The total number of occurrence to touch the screen during the operation; (B) The total number of occurrence to search product information on a web-site; (C) The total time length taken for searching for products; (D) The average time length taken to search for a product; (E) The average time length between touch sequences.

#### -To re-search information:

(F) The total number of occurrence to re-search; (G) The number of products to re-search

Accumulative contributing rate to the second principal component was 78.34%. Therefore, we considered using the two principal components (cf. Table 5).

**Table 5** The principal component analysis on touch- panel condition

	The first principal component	The second principal component	The third principal component
Eigenvalue	3.01	2.47	1.27
Proportion (%)	43.02	35.32	17.52
Cumulative (%)	43.02	78.34	95.85

#### Eigenvector

	The first principal component	The second principal component	The third principal component
the total number of occurrence to touch the screen during the operation	-0.29	0.54	0.03
the total number of occurrence to search product information on a web-site	-0.40	0.17	0.58
the total time length taken to search for products	-0.22	-0.44	0.54
the average time length taken to search for a product	-0.44	-0.35	0.08
the average time length between touch sequences.	0.18	-0.59	-0.14
the total number of occurrence to re-search	0.49	0.08	0.41
the number of products to re-search	0.49	0.09	0.43



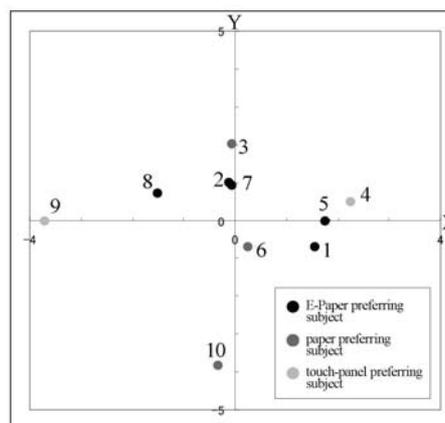
The first principal component becomes high when subjects search many products in a short time by a few number of operation times. In addition, it becomes high when ‘the total number of times to the re-search’ and ‘the number of products to re-search’ increase. However, it becomes high when ‘the time during and following the operation’ becomes too long.

Therefore, we interpreted this first principal component as ‘a disposition which remembers information by the touch-panel operation’.

The second principal component becomes high when ‘the total number to touch the screen during the operation’ and ‘the total number of times length which searched product information on a web-site’ increase. In addition, it becomes high when ‘the average time length between touch sequences’, ‘The total number to searched product information on a web-site’, and ‘the average time length taken for searching for one product’ become short. Therefore, the second principal component was interpreted as ‘an operability that tries to search as many products as possible using touch-panel’.

**Table 6** Principal component score on touch-panel

subject (preferred media)	the first	the second
1 (E-Paper)	1.56	-0.67
2 (E-Paper)	-0.12	1.01
3 (paper)	-0.06	2.00
4 (touch-panel)	2.27	0.52
5 (E-Paper)	1.77	0.02
6 (paper)	0.26	-0.72
7 (E-Paper)	-0.07	0.95
8 (E-Paper)	-1.53	0.72
9 (touch-panel)	-3.72	-0.02
10 (paper)	-0.36	-3.82



**Figure 8** The first and the second principal component scores



We investigated whether there was a relation between the principal component scores and the ‘media preferring groups’. The first and the second principal component scores were scattered randomly on the diagram (cf. Table 6 and Figure 8).

The first and second principal component scores did not have any relation with the ‘media preferring group’.

#### **3.4. Comparison of the action of taking and keeping information between the tangible media and medium preferring group.**

‘The average number of scan’ of the E-Paper preferring group was 5.0 times; the paper preferring group was 3.3 times; and the touch-panel preferring group was 2.0 times.

‘The average number of printing out’ of the E-Paper preferring group was 4.0 times; the paper preferring group was 2.7 times; the touch - panel preferring group was 0.5 times.

This result showed that the E-Paper preferring group had the tendency to take and keep the information more actively than the paper preferring group (cf. Table 7).

**Table 7** Comparison of the action of subjects who take and keep information

	the E-Paper evaluated group	the paper evaluated group	the touch-panel evaluated group
the E-Paper condition	5.0	3.3	2.0
the paper condition	4.0	2.7	0.5

As for the E-Paper, the average number of times of seeing scanned E-Paper was 3.6 times (E-Paper preferring group was 6.5 times, paper preferring group was 3.4 times, touch-panel preferring group was 1.0 times).

The scanning process was ending quickly. In addition, one subject did not see the scanned information. The ‘E-Paper preferring group’ has a strong tendency to see the scanned information of E-Paper.

As for the paper, the average number of occurrence to look at printed information was 2.3 times. The four subjects did not look at the printed information.

The average time to take and keep information was 19.5 second on the E-Paper condition, and 73.4 seconds on the paper condition.

From this result, the time taken to change a digital-information into tangible-information influences the action to reconfirm information.



### 3.5. Comparison of searching action between the media condition and the media preferring groups.

In this section, the searching actions were compared based on the media and the media preferring groups.

#### 3.5.1. Comparison of the number of searched products

The number of searched products was independent of the medium and of the preferring group. However, the nature of the product was pointed out as an influenced criterion (cf. Table 8).

**Table 8** Comparison of the number of searched products

	the E-Paper condition	the paper condition	the touch-panel condition
the E-Paper preferring group	17.7	14.0	19.4
the paper preferring group	14.0	16.0	13.7
the touch-panel preferring group	11.5	6.0	17.5

#### 3.5.2. Comparison of the total number of times to touch the screen during the information searching

On the E-Paper preferring group, the total number of times to touch the screen was greatest in the E-Paper and the paper (cf. Table 9). We interpreted that the E-Paper preferring group tried to gain much information on searching process.

**Table 9** Comparison of the total number of times to touch the screen during the operation

	the E-Paper condition	the paper condition	the touch-panel condition
the E-Paper preferring group	193.4	224.6	191.0
the paper preferring group	150.8	167.8	166.7
the touch-panel preferring group	172.5	191.0	199.0

On the E-Paper preferring group, the average of the total number of times to touch the screen during operation was 203.0 times; on the touch-panel preferring group, 187.5 times; and the paper preferring group, 161.8 times.

#### 3.5.3. Comparison of the average time taken to search for one product

The E-Paper preferring group took the shortest time to search for information on one product (18.4s), where as the touch-panel and the E-Paper preferring groups took 22.6s and 24.3s, respectively (cf. Table 10).



**Table 10** Comparison of the average time spent searching information on one product

	the E-Paper condition	the paper condition	the touch-panel condition
the E-Paper preferring group	18.8	21.7	14.8
the paper preferring group	22.7	25.8	24.6
the touch-panel preferring group	20.8	22.5	24.6

### 3.5.4. Comparison of the average time length between touch sequences

The E-Paper preferring group was the quickest on searching information using necessary operations (average: 2.9 sec.), while the subjects of the touch-panel preferring group took 3.3 seconds between touch sequence, and subjects of the paper preferring group took 4.1 seconds (cf. Table 11).

**Table 11** Comparison of the time transition between the operations

	the E-Paper condition	the paper condition	the touch-panel condition
the E-Paper preferring group	2.9	2.7	3.2
the paper preferring group	3.7	4.5	4.1
the touch-panel preferring group	3.4	3.3	3.2

### 3.5.5. Comparison of the time length allotted for actual information searching during ten minutes.

In this section, we compared the percentage of time that subjects obtained information from all product information sites during the 600 seconds of total task.

The paper preferring group spent 48.2%, the E-Paper preferring group spent 45.7%, and the touch-panel preferring group spent 34.5% (cf. Table 12).

**Table 12** Comparison of the percentage for actual information searching

	the E-Paper condition	the paper condition	the touch-panel condition
the E-Paper preferring group	48.7	47.0	41.4
the paper preferring group	49.8	49.6	45.8
the touch-panel preferring group	37.0	26.6	40.3

### 3.6. Comparison of the re-searched frequency (reconfirmation)

In this section, we compared the information reconfirming action according to the medium used. In this case, we compared only E-paper and touch-panel, since one subject in the paper condition did not print out. Therefore, reconfirmation was impossible for printed paper.



The average frequency on the E-paper to reconfirm information was 6.4 times, which was greater than the touch-panel (3.8 times).

The subjects of the E-Paper preferring group reconfirmed information with an average of 7.4 times; the paper preferring group 5.2 times; and the touch-panel preferring group 2.8 times (cf. Table 13).

**Table 13** Comparison of the re-searched frequency

	the E-Paper preferring group	the paper preferring group	the touch-panel preferring group
the E-Paper condition	8.0	6.3	5.0
the paper condition	6.8	4.0	0.5

It is suggested that the E-Paper was more efficient for reconfirming information than paper, and that the E-Paper preferring group reconfirmed information more than other groups.

#### 4. Conclusion

The purpose of this research was to clarify an evaluation structure to tangible-media while information searching. Therefore, we conducted an experiment on information searching task on internet with three tangible media. From the structure model of the repertory grid method and laddering, and quantified analysis of behavior, we confirmed the tendency of differences of behavior depending on media and personal characteristics.

The results were as follow:

- 1) The information searching is more influenced by subjects' individual characteristics than by the media used. Even if the medium was changed, the subjects' tendency to search information, to take and keep important information, and to reconfirm information did not change.
- 2) The subjective evaluation was ordered as E-Paper > paper > touch-panel on information searching. Especially, the E-Paper was not efficiently used by all subjects.
- 3) The E-Paper was more effective for subjects who had a disposition to search information quickly, to take and keep the information, and to reconfirm important information.
- 4) The time taken to change digital-information into tangible-information influences the action of reconfirming. Especially, the instantaneity of the E-Paper scan makes it easy to confirm saved information.
- 5) We clarified factors related to subjective evaluation of media by using the repertory grid method and laddering.



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