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Effects of Image and Layered Structure on Web Search Performance
-Evaluation on the Basis of Movement Distance of Mouse Pointer-

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Abstract— **The aim of this paper was to explore the effects of image addition and layered structure on Web search performance on the basis of the search time and the movement trajectory of mouse pointer. The difference of search characteristics between young and older adults was also examined. Older adults tended to take more time to search for the linked item especially when the layered structure was deep. For the deep layered structure, both young and older adults allocate more time to think which items should be selected than to operate a mouse. For all participants, less mouse movement was observed for the image-based link condition than for the character-based link condition. This tendency was more remarkable for older adults. Moreover, it was clarified that more mouse movement was observed with the increase of the number of hyperlinks per Web page. When the layered structure was shallow, the following difference of mouse operation characteristics between young and older adults was observed: Older adults made an attempt to locate the search item while moving a mouse simultaneously. On the other hand, young adults began to move a mouse after locating the search item.**

1. Introduction

During the past decade, the World Wide Web (WWW) has become one of the most important Internet applications. Currently, older adults constitute the fastest growing WWW user groups. Although older adults are willing to use computers via the WWW pages, older adults experience more frequent problems than young adults when using the WWW. The problems include difficulty in finding broken links, viewing smaller texts and graphics, and retrieving new information.

There are many reports suggesting that older adults exhibit deficits in various cognitive motor tasks[1],[2]. Spatial abilities, that is, the capacity to acquire, manipulate, and use information on Web pages, have been shown to decline with age, and this might account for the difficulties of older adults when navigating Web pages[3]. Kelly and Charness[4] showed that spatial abilities may be important for mediating the effects of age on computing skills. Processing speed refers to the ability to acquire, interpret, and respond to information quickly and accurately. Salthouse[5] pointed out that reductions in processing speed are a common explanation for many age-related deficits in task performance.

Therefore, it is predicted that older adults require more time to complete a navigation task on the WWW. Working memory is defined as the ability to actively manipulate, store, and update information to perform a given task. Browsing Web pages have working memory demands, and require users to carry out several tasks concurrently. Such tasks also involve decision making and problems solving using working memory.

On the basis of such discussion, it is questionable whether most of the current Web pages are universally usable for both young and older populations, as the above mentioned cognitive motor functions are clearly different between young and older populations.

Graham et al.[6] investigated reaction time, eye movements, and errors during visual search of Web pages to determine age-related difference in performance as a function of link size, link number, link location and clutter. Increased link size improved performance for both young and older groups. Increased clutter and links hampered search behavior, especially for older adults. Parush et al. [7] explored the effects of visual layout factors on performance during visual search of Web pages. Although the age-related differences in performance during visual search was not examined, they found that performance was particularly poor in Web pages with many links and variable display densities. Laberge and Scialfa[8] investigated the effects of age, subject matter knowledge, working memory, reading abilities, spatial abilities, and processing speed

on Web navigation. They found that age was associated with slower search time, and this effect remained significant even after controlling for working memory, processing speed, and spatial abilities. In other words, the search performance of older adults was found to be inferior to that of the young adults due to the declined working memory, processing speed, and spatial abilities. Chadwick [9] examined how Web design affected the Web performance. Murata and Takahashi [12] found that the perceptual, cognitive, and motor abilities of older adults, in particular, the spatial memory, spatial rotation ability, and mouse operation ability, led to longer Web navigation time. These results implies the necessity of designing Web site for older adults that considers the decline of perceptual, cognitive, and motor ability. Murata and Moriwaka [11] compared the usability of six types of site maps was compared as a function of age. The result indicated that the vertical arrangement of site map, especially horizontal type was proper for both young and older adults.

These studies [6]-[9] successfully identified the factors that should be taken into account when designing Web pages for older adults. In most of the Web pages, the site map is used so that the users will not be got lost in WWW navigation and can successfully lead to the destination. The site map is one of the important factors that enhance the usability of Web page designs. There exist many types of site maps such as vertical tree type, horizontal tree type, table type, radial type, and itemized type. As mentioned above, older adults tend to get lost in WWW navigation due to declined working memory, perception speed, and spatial perception ability. Therefore, the proper design of site map is necessary to enhance the usability of Web navigation especially for older adults. However, there appear to be no definite and proper guidelines for designing the site map.

Stenfors [10] suggested that the mouse cursor was useful not only for the click or operation of hyperlinks but also for searching for information effectively. Murata and Takahashi [12] showed that the motor function of older adults represented by mouse operation ability is inferior to that of young adults. However, the detailed analysis on the basis of movement trajectory of mouse cursor has not been carried out. If the movement trajectory of mouse cursor during Web search is examined and the cause of long search time is clarified, it would be possible to propose Web design guidelines that make the movement trajectory of mouse cursor short and reduce search time. Although Graham et al.[6] pointed out the density of Web page plays an important role in Web designs, the effects of images on Web search performance have not been clarified until now.

In this research, using Web sites with different layered structure, the movement of mouse cursor was measured to clarify the difference of the characteristics of mouse cursor movement between young and older adults. Moreover, the effects of image on Web search performance including the characteristics of mouse cursor movement were also explored.

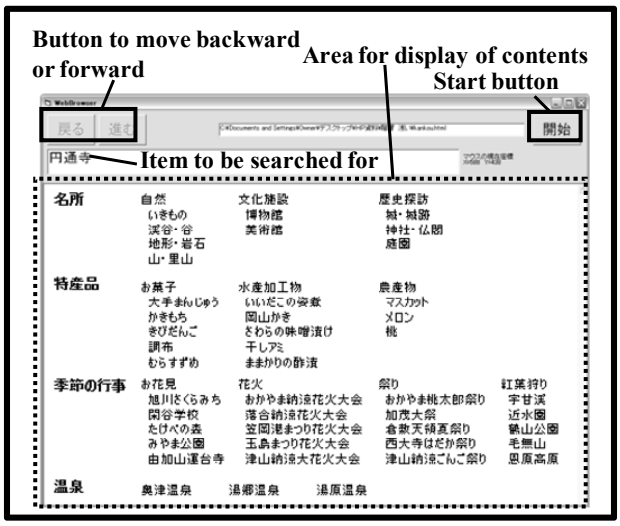


Fig.1 Top page of Web site used in the experiment (layered structure: shallow).

2. Method

2.1 Participants

T Twenty participants took part in the experiment. Ten were male adults aged from 65 to 76 years. In this study, the older adults had an average of 8.53 hours on Web navigation. Ten were male undergraduate students aged from 21 to 24 years. The young adults had an average of 13.4 hours spending on Web navigation. The visual acuity of the participants in both young and older groups was matched and more than 20/20. They had no orthopedic or neurological diseases.

2.2. Apparatus

The stimuli were presented using a personal computer (Dell, Optiplex GX270G D3C91X) with a 17-inch CRT (Nanao, FlexScan L5557). The resolution was 1024 x 768 pixels. A mouse (Sanwa Supply, MA-E3BK) was used. The temperature in the laboratory was 26 degree. The illumination and the brightness on the CRT display were 46 lx and 116 cd/m^2, respectively.

2.3 Web site and browser

The Web pages (site maps) were created using HTML editor of Home Page Builder (Ver.10, Japan IBM). Three kinds of Web pages with different layered structures were created. As the content of these Web pages were the same, the shallow-structured page has more hyperlinks at the top page. The shallow, moderate,

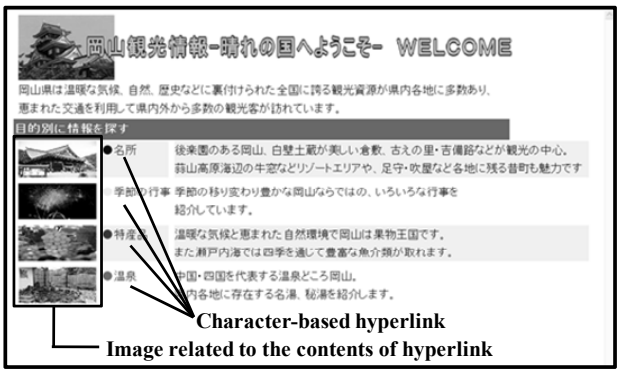


Fig.2 An example of Web site with character-based hyperlink and related image.

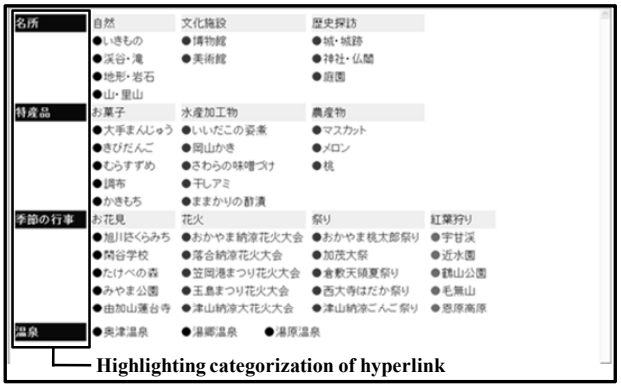


Fig.3 An example of Web site in case the addition of image is impossible.

and deep layered structures were prepared. In the deep layered structure, the number of structured layers ranged from three to five. In the moderate and the shallow layers, the number of structured layers ranged from two to three. While the percentage of three-layered pages to total pages was 77 % for the moderate structured layer, the corresponding percentage was 20 % for the shallow structured layer. The numbers of links at the top page were 4, 13, and 45 for the deep, moderate, and shallow structured layer, respectively.

The Web browser was programmed using Visual Basic (Microsoft, version 6.0). The Web browser was equipped with "Back" and "Forward" buttons. The "Back" button was for going back to the previous pages. The "Forward" button was used to cancel the page movement carried out using the "Back" button. These functions are equipped with the well-known browsers such as Internet Explorer or Fire Fox. The time measurement function was also added to the browser. In Fig.1, an example of Web browser and top page of Web site used in this experiment is demonstrated.

2.4 Addition of image

Two addition methods of images were used. One is the addition of image to the left of hyperlink (See Fig.2).

Fig.4 An example of Web site with image-based hyperlink.

Table1. Image size of image-based link according to the number of links per page.

Number of links per page	Image size of image-based link [pixel]
2 links	250 × 170
3 links	230 × 145
4 links	145 × 100
5 links	130 × 90

It must be noted that clicking of the image does not lead to the next page. In other words, the images in Fig.2 are not link-based ones. As one page of the deep layered structure has at most four hyperlinks and there is enough space to arrange images, the images were arranged to the left of all hyperlinks. As the number of hyperlinks per one page for the moderate and shallow structures is more than that for the deep structure, the images were added to only the page where there is enough space to arrange an image. When it was impossible to arrange images, the hyperlinks were highlighted as shown in Fig.3. The images were added to 7 pages out of 10 pages in the moderate structure. The images were added to only the second page in the shallow structure. In such a way, the number of added images differed among the condition of layered structure.

The second method of image addition is the hyperlink-based one. As shown in Fig.4, one image corresponded to one hyperlink. As enough space is necessary in this method of addition, this method was applied to only the deep layered structure. As it is possible that the contents of hyperlink cannot be guessed on the basis of only an image, the text was added to the image (See Fig.4). In case of 5 links per page, the text size was 17 pixel. In other cases, the text size was fixed to 19 pixel. The location of the text was consistent

throughout the pages. The size of image-based link was adjusted according to the number of hyperlinks per page as shown in Table 1.

In such a way, text-based link, text-based link with an image, and image-based link conditions were created. The text-based link and text-based link with an image were prepared for all of three layered structure. The image-based link was prepared for only the deep layered structure. It must be noted that the content of one page was the same irrespective of the condition of image addition.

2.5 Task

The experimental task was a search task in which the participants were required to search for the pre-specified target item. In order to control the effects of knowledge of each participant on the Web search performance to the minimum, the Web contents were selected so that all participants are accustomed to them. As all participants had been lived in Okayama Prefecture for more than three years, Web contents included sightseeing information in Okayama Prefecture. All contents were displayed on one page without requiring the participants to scroll the page. After clicking the start button in Fig.1, the item to be searched for was shown to the participant, and the measurement of search time began.

2.6 Design and Procedure

The between-subjects experimental factor was participant age (young and older adults). The within-subjects experimental factor was the layered structure (three levels: deep, moderate, shallow) and addition of images (text-based hyperlink, text-based hyperlink with an image, image-based hyperlink).

A total of seven Web sites were prepared. The text-based hyperlink and the text-based hyperlink with an image were prepared for three layered structures. The image-based hyperlink was prepared only for the deep layered structure. For each Web site, a total of 10 trials were carried out. The order of performance of 10 search trials was randomized across the participant. The order of performance of seven Web sites was also randomized across the participants.

Prior to their involvement in the experiment, participants signed an informed consent document. The participant was asked to adjust his seat so that the task could be comfortably performed. Before the experiment began, participants were given instructions for the search task and allowed a few practice trials.

As soon as the participant clicked “Start” button (See Fig.1), the measurement started. When the participant located the target, any key on the keyboard was pressed. For each trial, whether the answer was correct or not was displayed on CRT. The search time and the mouse cursor movement were measured. The mouse cursor movement was sampled at the sampling frequency of 60 Hz.

2.7 Analysis of mouse cursor movement

The percentage of mouse movement time to total search time was examined. On the basis of the mouse movement trajectory, the difference between the minimum distance and the actual movement trajectory was calculated to evaluate search efficiency.

We assume that the search item exists in N-th page. The mouse cursor data collected during the search at i-th page is denoted by j_i=0,..., k_i. The coordinates of mouse cursor j_i=0,…, ki is denoted by (S_{xi}, S_{yi}) and (L_{xi}, L_{yi}), respectively. The actual movement distance d_{1i} and the minimum distance d_{2i} at i-th page is given by Eq.(1) and Eq.(2), respectively. The evaluation index S is given by Eq.(3).

$$d_{1i} = \sum_{j_i=0}^{k_i-1} \sqrt{(x_{j_i+1} - x_{j_i})^2 + (y_{j_i+1} - y_{j_i})^2} \quad (1)$$

$$d_{2i} = \sqrt{(Lx_i - Sx_i)^2 + (Ly_i - Sy_i)^2} \quad (2)$$

$$S = \sum_{i=1}^{N} (d_{1i} - d_{2i}) \quad (3)$$

The smaller S is, the more effective the mouse cursor movement is. In a Web site where S becomes larger, the mouse cursor is moved more than necessary and the unnecessary movement is carried out.

3. Results

In Fig.5, the mean search time is shown as a function of age, layered structure and addition of image. In Fig.6, the percentage of mouse operation time is plotted as a function of age, layered structure and addition of images. As a result of a three-way (age, layered structure and addition of image) ANOVA conducted on the percentage of mouse operation time, a main effect of layered structure ($\boldsymbol{F}(2,36)=24.5$, $\boldsymbol{p}<0.01$) and a significant layered structure by addition of image interaction ($\boldsymbol{F}(2,36)=6.1$, $\boldsymbol{p}<0.01$) were detected. Foe each age group, a two-way (layered structure and addition of image) ANOVA was conducted on the percentage of mouse operation time. For both age groups, a significant main effect of layered structure (young adults: $\boldsymbol{F}(2,18)=7.9$, $\boldsymbol{p}<0.01$, older adults: $\boldsymbol{F}(2,18)=20.9$, $\boldsymbol{p}<0.01$) was detected. The results of multiple comparisons foe percentage of mouse operation time are summarized in Table 2.

As the number of pages differed among experimental tasks, the evaluation index in Eq.(3) was divided by the number of pages each participant moved. In Fig.7, mean S per page is plotted as a function of age, layered structure and addition of image. A two-way (age by

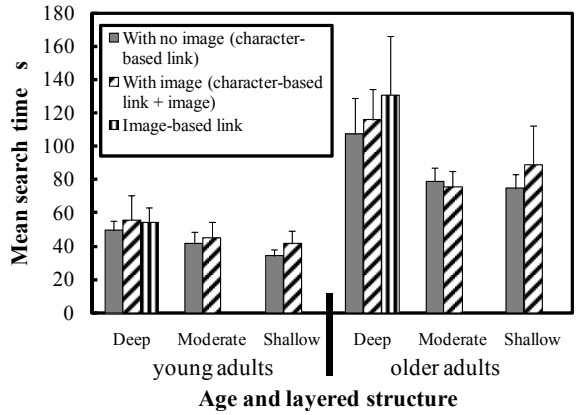


Fig.5 Mean search time as a function of age, layered structure, and whether image is added to Web site.

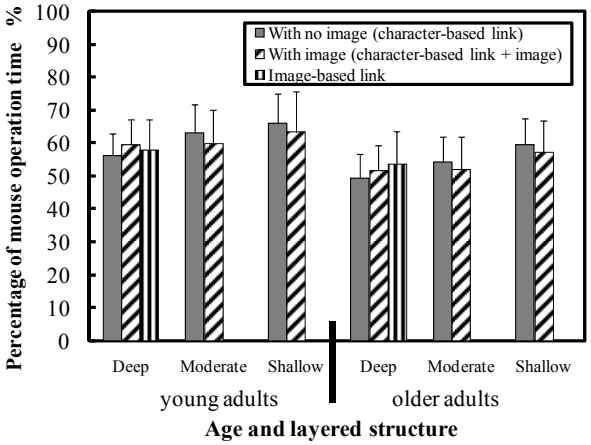


Fig.6 Percentage of mouse operation time as a function of age, layered structure, and whether image is added to Web site.

addition of image) ANOVA conducted on S per page revealed main effects of age ($F(1,18)=19.0$, $p<0.01$) and addition of image ($F(2,36)=11.3$, $p<0.01$). For each age group, a one-way (addition of image) ANOVA was carried out on S per page. For each age group, a significant main effect of addition of image was detected (young adults: $F(2,18)=6.7$, $p<0.01$, older adults: $F(2,18)=7.0$, $p<0.01$). For the moderate and the shallow layered structures, a two-way (age by addition of image) ANOVA was carried out. For both layered structure, a significant main effect of age was detected (moderate structure: $F(1,18)=14.0$, $p<0.01$, older adults: $F(1,18)=18.9$, $p<0.01$).

4. Discussion

The search time of the deep structure is longer than that of other two structures (See Fig.5). On the other hand, the percentage of mouse operation time is lower

Table2. Results of multiple comparison (Fisher's PLSD) for percentage of mouse operation time.

Layered structure	Young adults	Older adults
deep vs. moderate	$p<0.05$	$p<0.05$
deep vs. shallow	$p<0.01$	$p<0.01$
moderate vs. shallow	n.s.	n.s.

n.s. : Not significant

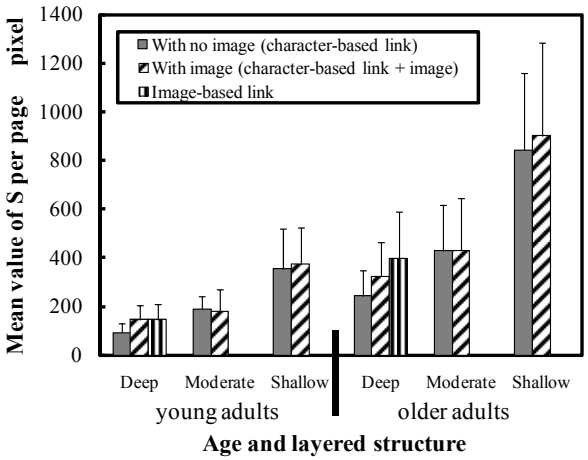


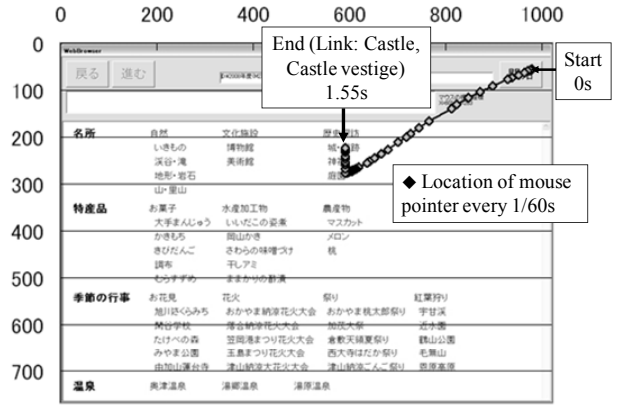
Fig.7 Mean value of S per page as a function of age, layered structure, and whether image is added to Web site.

than that of other two structures as shown in Fig.6. The deep structure seems to require the participant to concentrate not on the mouse operation but on which hyperlink should be selected.

From Fig.7, it is clear that S per page if the largest at the shallow structure. This might be due to a lot of hyperlinks at the top page. In particular, the mouse cursor movement of older adults meandered as shown in Fig.8. As a result of a three-way (age, layered structure and addition of image) ANOVA conducted on the percentage of mouse operation time, a main effect of age was not detected. This might be interpreted as follows. Although the percentage of mouse operation time was nearly constant irrespective of age, older adults carry out unnecessary mouse cursor movement. Young adults moved the mouse cursor after identifying the site to be moved next. Contrary to this, older adults identified the site to be moved next while moving the mouse cursor. The movement of mouse cursor makes the search task more and more complicated for older adults. Such a difference of search strategy between young and older adults should be investigated in more detail using an eye movement measurement technique.

How age, layered structure and addition of image affected *S* per page is discussed below. For both age groups, *S* per page differed significantly between

(a)



(b)

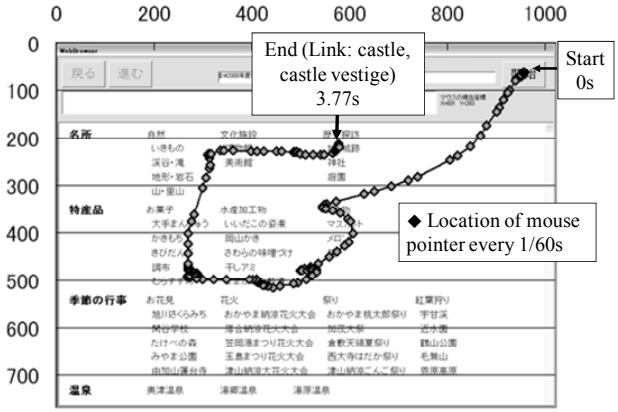


Fig.8 Examples of mouse movement trajectory for both age groups (layered structure: shallow) (a) young adults, (b) older adults

text-based and image-based links. Accurate mouse movement is not required for the image-based hyperlink, because the click area is larger than that of the text-based hyperlink. This must lead to a larger value of *S* per page for the image-based hyperlink. When the user is not accustomed to mouse operation, the image-based hyperlink might be effective. As shown in Fig.5, the search time was the longest when the image-base hyperlink was used. Therefore, some effective measure that can reduce the search time of image-based hyperlink must be proposed.

Almost all of hyperlinks are arranged to the left of the Web page. Future research should explore how the arrangement of hyperlinks affects the search performance or mouse cursor movement. Moreover, the analysis using not only search time and mouse cursor movement but also eye movement during a Web search like Stenfors [10] must be carried out.

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