

Comparison of Performance among Different Situations of Operation in Web Display - Comparison of Behavioral Features between Young and Older Adults -

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Abstract— In order to clarify the situation where older adults feel inconvenient when carrying out various Web operations, the differences of Web search behavior between young and older adults were examined using Web sites with different layered structures. The following two situations were used to address the issue above: (1) operation of a “Back” button, and (2) operation of a hyperlink. When the operation of “Back” button was necessary, the task completion time of older adults was 2.3 times as long as that of young adults. Such a difference must be obtained, because older adults need more time to recognize and understand the layered structure. When operation “Back” button in a raw, the task completion time of older adults was 3.9 times as long as that of young adults. Moreover, the task completion time of older adults increased in case of searching in the deep layered Web site due to the slower and declined cognition and judgment. When selecting a hyperlink, the task completion time of older adults was 12.1 times as long as that of young adults. On the basis of this tendency, we inferred that older adults took more time and became more careful when selecting a hyperlink.

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 [10] 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, and this should be incorporated into the Web page design guidelines.

These studies 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.

Until now, there are few studies that examined the difference of search characteristics according to the different situations of operation in Web display. In most of studies [6]-[11], search efficiency has been assessed on the basis of a unitary measure such as percentage

correct or search time. These studies have not carried out a detailed analysis according to the situations of operation in Web search. Identifying situations under which older adults feel inconvenient and unusable is very important to design a Web site that is useful and friendly even for older adults. During a Web search task, there are a variety of tasks such as click of hyperlink, and press of "Back" button within a Web page.

In this research, using Web sites with different layered structure, it was explored how search characteristics differ according to the operational situation between young and older adults.

2. Method

2.1 Participants

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 15-inch CRT (EIZO, FlexScan L5557). A mouse (Sanwa Supply, MA-E3BK) was used. The temperature, the illumination, and the brightness in the laboratory were 26 degree, 46 lx, and 116 cd/m², 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 swallow-structured page has more hyperlinks at the top page. The shallow, moderate, 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

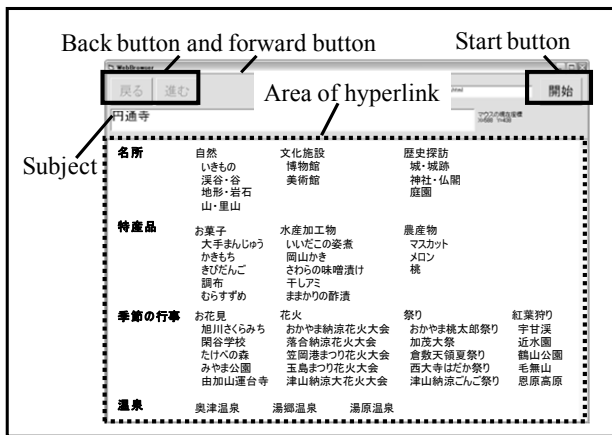


Fig.1 Top page of Web site used in this study (Layer structure: shallow)

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 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. When moving to other Web pages, it was recorded whether the movement was due to the hyperlink or due to the press of functions (“Back” or “Forward”) equipped with the Web browser. In this case, the time course and the page number were also recorded.

2.5 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).

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.

One session consisted of ten trials. For each layered structure, a total of two sessions were carried out. A total of six sessions were conducted. Within a session, the order of presentation of the searched item was the same for all participants. The order of performance of six sessions was randomized across the participants. For example, one participant carried out sessions in the following order: “moderate”, ”shallow”, “deep”, “moderate”, “deep”, “shallow”. Other participants order of performance was “deep”, “shallow”, “moderate”, “moderate”, “deep”, “shallow”.

As soon as the participant clicked “Start” button (See Fig.1), the measurement started. When the participant located the target, he or she pressed any key on the keyboard. For only the first trial at each session, the search task started from the top page. For other trials, the search task started from the site (page) where the previous search ended. This is because the aim of this experiment was to verify whether a participant can move around the Web site by understanding the location in the site and making use of “Back” button or hyperlinks properly.

2.6 Analysis of data

2.6.1 When “Back” button is pressed

The following three situations which require the press of “Back” button were considered.

(1) Pressing “Back” button immediately after the experiment began.

This situation surely occurs in this experiment. On and after the second trial, the page which is immediately displayed after pressing the “Start” button corresponds to the page searched lastly at the previous trial. Therefore, the situation where “Back” button must be clicked surely occurs. This operational situation was defined as “Start→Back.”

(2) Pressing “Back” button while the searching.

This situation frequently occurs when pressing a wrong hyperlink or going back to the previous page. In this operation, the time required to notice that the displayed page is wrong, and the time to move the mouse cursor to the “Back” button are included. This operation was defined as “Link→Back.”

(3) Pressing “Back” button consecutively.

When going back to previous pages consecutively, this operation occurs. This corresponds to the cases when going back to previous pages after continuing to search for the link item at the wrong pages, or when going back to the top page from pages located at a deep layer. As the “Back” button is pressed in a row, it is hardly necessary to move a mouse cursor. Therefore, the operation in this situation is faster than the situations (1) and (2). This operation was defined as “Back→Back.”

2.6.2 When hyperlink is clicked

The operational situations were classified into the following three cases.

(1) Clicking a hyperlink immediately after the trial begins.

In this case, this operational situation is included in only the first trial, because only the first trial begins with the top page. In other words, in the first trial, the participant cannot move out of the top page without clicking one of the hyperlinks. If the participant quickly searches for the item related to the item to be searched for, the time necessary for this operational situation becomes shorter. This operation was defined as “Start→Link.”

(2) Clicking a hyperlink in a row.

When the participant properly and accurately understands and judges the items related to the item to be searched for, such an operation occurs. Taking the arrangement of hyperlinks in this experiment (except for the top page of shallow layered structure, the hyperlinks are arranged to the left of the display) into account, only shorter movement of mouse cursor is necessary in this operational situation. If the participant succeeds in selecting a correct hyperlink, the efficiency of search is improved. This operation was defined as “Link→Link.”

(3) Clicking a hyperlink after pressing a “Back” button.

This operational situation includes the following time: the time to judge whether there is a need to press a “Back” button, and the time to find a hyperlink relate to the task and move the mouse cursor there. The cognitive and the motor functions are needed to carry out this operational situation. In this situation, it is expected that understanding and recognizing the location within the layered structure because a “Back” button is pressed. This operation was defined as “Back→Link.”

3. Results

3.1 When “Back” button is pressed

As a result of a three-way (age by structured layer by

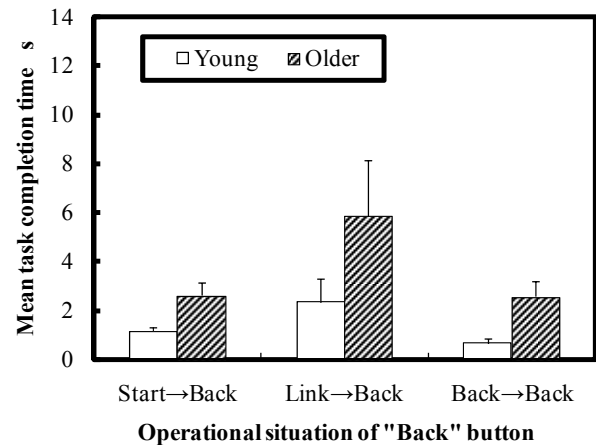


Fig.2 Comparison of mean task completion time among different situations when operating a menu button.

Table 1 Results of multiple comparison by Fisher’s PLSD for mean task completion time.

Operational situation	Young	Older
Start→Back vs Link→Back	$p < 0.01$	$p < 0.01$
Start→Back vs Back→Back	$p < 0.05$	n.s.
Link→Back vs Back→Back	$p < 0.01$	$p < 0.01$

n.s. : not significant

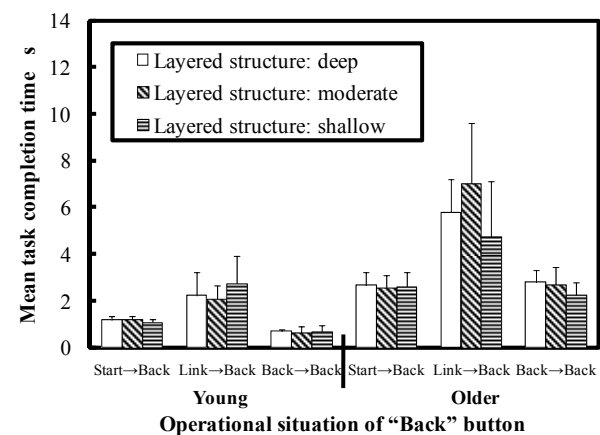


Fig.3 Mean task completion time as a function of age, layer structure, and situations when operating a menu button.

operational situation) ANOVA carried out on the task completion time, significant main effects of age ($F(1,11)=61.3, p<0.01$) and operational situation ($F(2,22)=71.6, p<0.01$) were detected. The following interactions were also found to be significant: age by layered structure interaction ($F(2,22)=5.7, p<0.01$), age by operational situation interaction ($F(2,22)=22.1, p<0.01$), and age by layered structure by operational

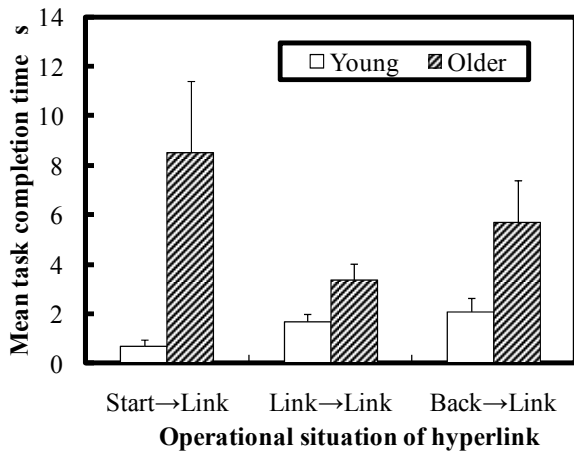


Fig.4 Mean task completion time as a function of age and situation when operating a hyperlink.

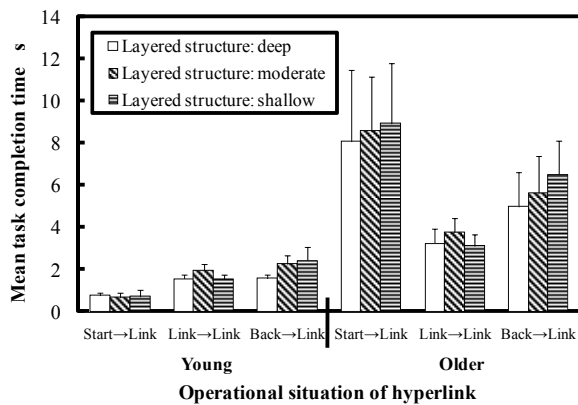


Fig.5 Mean task completion time as a function of age, layered structure and situation when operating a hyperlink.

situation ($F(4,44)=30.9, p<0.05$). In Fig.2, the mean task completion time is shown as a function of age and operational situation. The results of multiple comparisons by Fisher's PLSD (Protected Least Significant Difference) for the mean task completion time are shown in Table 1. In Fig.3, the mean task completion time is plotted as a function of age, layered structure, and situations when operating a "Back" button.

3.2 When hyperlink is clicked

A tree-way (age by layered structure by operational situation) ANOVA conducted on task completion time revealed main effects of age ($F(1,18)=126.7, p<0.01$) and operational situation ($F(2,36)=47.5, p<0.01$). An age by operational situation interaction ($F(2,36)=103.0, p<0.01$) was also significant. As a result of multiple comparisons by Fisher's PLSD (Protected Least Significant Difference) for the mean task completion time, all combinations of operational situations were

significant ($p<0.01$) for both age groups. In Fig.4, the mean task completion time is shown as a function of age and situation when operating a hyperlink. Fig.5 shows the mean task completion time as a function of age, layered structure, and situation when operating a hyperlink.

4. Discussion

4.1 When "Back" button is pressed

The "Start→Back" operation corresponds to the first operation carried out on and after the second trial, because the page displayed after pressing "Start" button includes no hyperlinks and the operation to be carried out is only to press "Back" button. Therefore, there is no need to judge whether to use the "Back" button or not. In this operation, only the movement of mouse cursor from the "Start" button to the "Back" button is necessary. As pointed out by Murata and Takahashi [11], it was shown that the mouse operation time of older adults was twice as long as that of young adults. In this experiment, the mean task completion time of older adults for this operation was 2.3 times as long as that of young adults. This clearly reflects the declined motor function of older adults.

As shown in Fig.2 and Fig.3, there was no significant difference of task completion time of older adults between "Start→Back" and "Back→Back" operational situations. The young adults showed a different tendency. The task completion time of "Back→Back" situation was the shortest of all of three operational situations. The task completion time of young adults for the "Back→Back" situation was by 1.9 s shorter than that of older adults. This might mean that older adults take more time to judge whether getting back or not in the "Back→Back" operational situation.

For both young and older adults, the task completion time for the "Link→Back" situation was the longest of all of three operations. This "Link→Back" situation includes not only the time required to move the mouse cursor to the "Back" button but also the time needed to judge whether the "Back" button should be pressed. Therefore, the task completion time for this operation must be the longest for both age groups. As shown in Fig.3, the task completion time of older adults for this operation was by far longer than other conditions. This operational situation must induce higher workload especially to older adults. Generally, it is probable that the task completion time of older adults is prolonged when both cognitive and motor functions are

simultaneously required.

If we assume that older adults judge whether they press the “Back” button or not according to the contents of hyperlinks, the number of hyperlinks might affect the task completion time in the “Link→Back” operational situation. This is further discussed on the basis of Fig.3. As mentioned above, the “Link→Back” operation does not occur at the top page. The mean numbers of links at other than the top page of the deep, moderate, and shallow structures are 4.2, 7.5, and 4.8, respectively. As shown in Fig.3, the task completion time of older adults for the “Link→Back” operation was the longest. This can be accounted for the largest number of links at other than the top page for the moderate layered structure. Some cautions are needed for older adults when the number of links is increased for the moderate layered structure.

4.2 When hyperlink is clicked

As has been demonstrated by the significant interaction between age and operational situation, how the mean task completion time differs among operational situations differed between two age groups (See Fig.4 and Fig.5). The task completion time of young adults was the longest when clicking (selecting) a hyperlink after clicking the “Back” button (“Back → Link” situation). While the task completion time of older adults was the longest for the “Start→Link” situation, the task completion time of young adults was the shortest for the same situation.

The percentage of noticing the wrong selection and pressing “Back” button after the “Start→Link” operation was calculated. The mean percentages for young and older adults were 18% and 7%, respectively. From this, we can interpret that older adults take more time to judge whether the linked page is related to the item to be searched for than young adults. Consequently, this might lead to the lower percentage of pressing “Back” button after the “Start→Link” operation of older adults.

Older adults completed the “Link→Link” operation sooner than other two operational situations (“Start→Link” and “Back → Link”). Except for the shallow layered structure, the hyperlinks were arranged to the left of Web pages. Such an arrangement must enable the participant to shorten mouse movements and enhance usability, because the arrangements of hyperlinks do not differ between Web pages. The “Link→Link” operation makes the comprehension of the present location of a Web page easier than the “Back→Link” operation. The reason why the task completion time increased at the deep layered structure must be due to the frequent

occurrence of “Back” operations.

Future research should explore a method that can classify hyperlinks more easily in order to decrease the frequency of “Back” operations. In order to increase the usability of older adults, it is also important to develop a system that reduces the operation time of “Back” operation and prevent frequent “Back” operations from arising.

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