Fourth International Workshop on Computational Intelligence & Applications
IEEE SMC Hiroshima Chapter, Hiroshima University, Japan, December 10 & 11, 2008

Usability of Site Map in Web Design - Design of Site Map that is Friendly to Older Adults-

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Abstract — **The information or data for Web page design that is useful, in particular, to older adults was provided in this study. The proper design of site map is necessary to enhance the usability and reduce the number of getting lost in Web navigation especially for older adults. However, no design guideline on what site map is proper exists. The usability of six types of site maps was compared as a function of age. The six types of site maps included (1) vertical tree type, (2) horizontal tree type (A), (3) horizontal tree type (B), (4) table type, (5) radial type, and (6) itemized type. The usability was evaluated using search time, subjective rating of usability, and eye movement characteristics (fixation duration and fixation number). The age affected the evaluation measures. The horizontal type (B) was found to lead to faster search time and fewer fixation numbers. Moreover, this type of site map was found to make the difference of search time, fixation number, and fixation duration between young and older adults smaller. The result indicated that the vertical arrangement of site map, especially horizontal type (B) was proper for both young and older adults, and this should be incorporated into the Web page design guidelines. The results can be utilized as a universal design guideline for providing a site map that is friendly to both young and older adults.**

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.

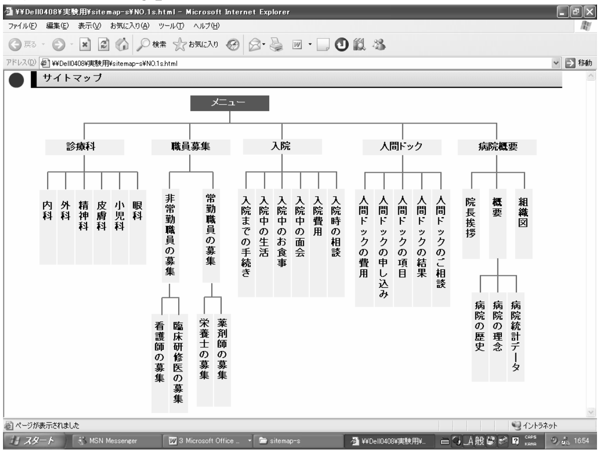
Graham, Laberge, and Scialfa[6] investigated reaction time, eye movements, and errors during visual search of Web pages to determine age-related difference in performance as a function of link size, link number, link location and clutter. Increased link size improved performance for both young and older groups. Increased clutter and links hampered search behavior, especially for older adults. Parush, Shwarts, and Chandra[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. 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.

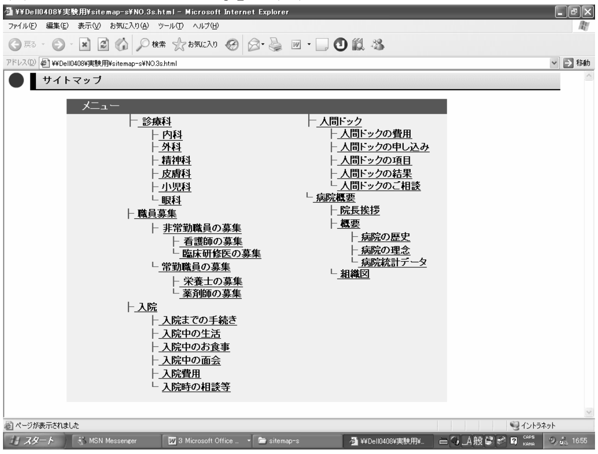
In this research, the design of site maps on Web pages was explored as a function of age so that we can provide Web designers with some useful design guidelines of site maps. The age and the type of site map were selected as experimental factors. It was investigated how the two factors affect the search performance (search time) and eye movement characteristics (number of fixations and fixation duration).

(a) Vertical type

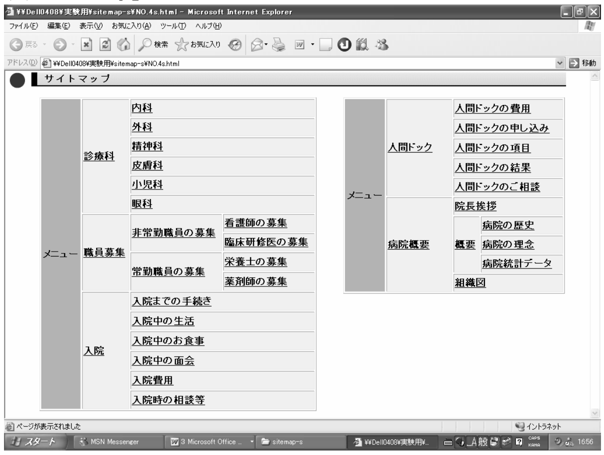


(b) Horizontal tree type (A)

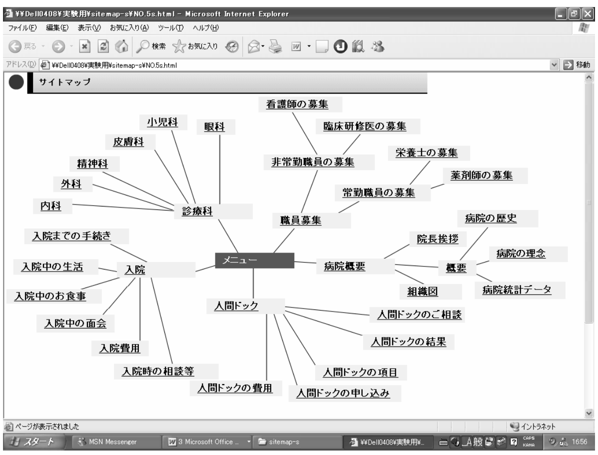
(c) Horizontal tree type (B)



(d) Table type



(e) Radical type



(f) Itemized type

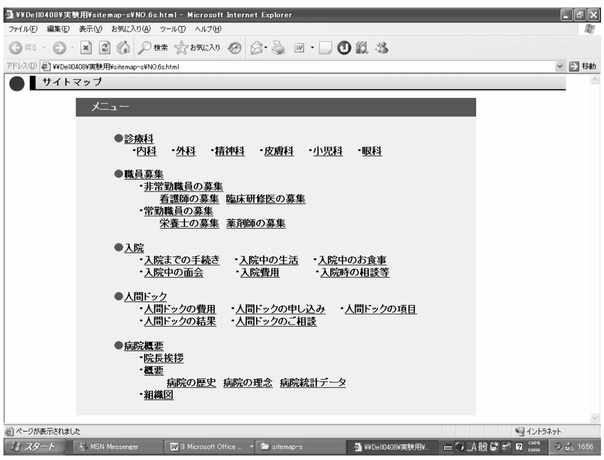


Figure 1 Six site map.

2. Method

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 orthopaedic or neurological diseases.

Apparatus

The stimuli were presented using a personal computer (Dell, Optiplex GX270G D3C91X) with an 15-inch CRT (EIZO, FlexScan L5557). An eye-tracking device (EMR-VOXER, Nac Image Technology) was used to measure eye movements characteristics during the search task. This apparatus enables us to determine eye movements and fixation by measuring the reflection of low-level infrared light (800 nm), and also admits the head movements within a predetermined range.

The Web pages (site maps) were created using HTML editor of Home Page Builder (Ver.9, Japan IBM). Six types of site maps were prepared. The six types of site maps included (1) vertical tree type, (2) horizontal tree type (A), (3) horizontal tree type (B), (4) table type, (5) radial type, and (6) itemized type. The six types of site maps are shown in Figure 1 (a)-(f).

Task

The experimental task was a search task in which the participants were required to search for the pre-specified target item included in the site map. In each site map, the hospital information shown in Figure 1 (a)-(f) was included. The site map was presented on one page. The participant did not need to scroll CRT when they search for a target.

Design and Procedure

The between-subjects experimental factor was participant age (young and older adults). The within-subjects experimental factor was the type of site map (six levels).

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. The experiment began with an EMR-VOXER calibration in which the observer had to fixate on a target that was displayed sequentially in nine locations on a 15-inch CRT.

Once the calibration was carried out successfully, the target item was displayed on the center of the CRT. The participant fixated the center of the CRT, where the system displayed the target item they should locate. When any key on the CRT was pressed, a site map was displayed to the participant. When the participants located the target, he or she pressed any key on the keyboard. One block contained ten trials for one site map. A total of six blocks were included in the experiment. The order of six blocks was randomized across the participants. Accuracy feedback was given after every trial. Participants were required to respond as quickly as possible while keeping their accuracy as high as possible, and they were allowed to rest between blocks. After each block was completed, the psychological rating of the site map was carried out for the following items. The rating was carried out using a seven-point scale (1=very poor, 7=very good).

(A) understandability of site map structure
(B) visibility of site map
(C) ease of searching for a target
(D) total usability of site map

Experimental measures

The measures were (i) mean search time, (ii) psychological rating for each site map, and (iii) eye movement characteristics (fixation duration and number of fixations). Here a correct trial was defined as one in which the target was successfully searched in Web navigation.

3. Results

Search time

A two-way (age by type of site map) analysis of variance (ANOVA) conducted on the search time revealed main effects of age ($F(1,16)=104.972$, $p<0.01$) and type of site map ($F(5,80)=5.570$, $p<0.01$), and age by type of site map interaction ($F(5,80)=2.659$, $p<0.05$). In Figure 2, the search time is plotted as a function of age and type of site map.

Fixation duration

A similar two-way ANOVA conducted on the fixation duration detected a main effect of age ($F(1,16)=11.465$, $p<0.01$). In Figure 3, the fixation time is shown as a function of age and type of site map.

Number of fixations

A similar two-way ANOVA conducted on the fixation duration detected a main effect of site map ($F(5,80)=6.860$, $p<0.01$). In Figure 4, the fixation time is shown as a function of age and type of site map.

Psychological rating

In Figure 5, the results of psychological rating for the questionnaire items (A)-(D) are summarized as a function of age and type of site map. As a result of

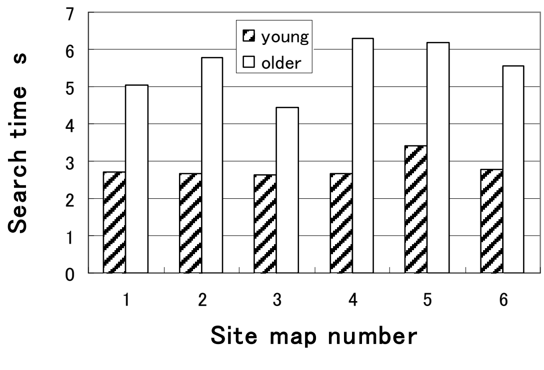


Figure 2.Search time as a function of age and type of site maps.

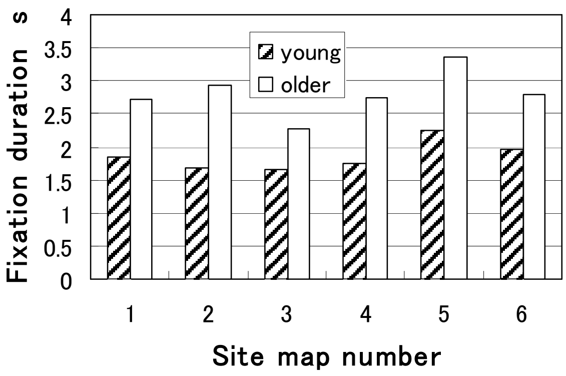


Figure 3.Fixation duration as a function of age and type of site map.

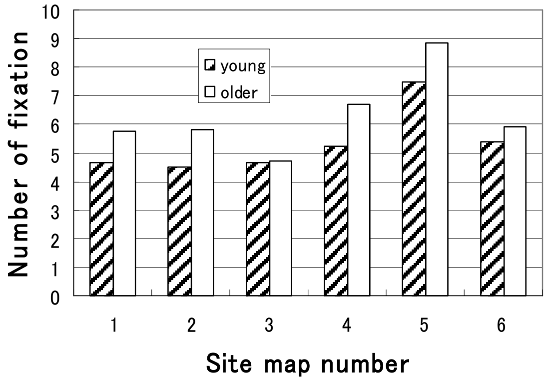


Figure 4.Number of fixation as a function of age and type of site map.

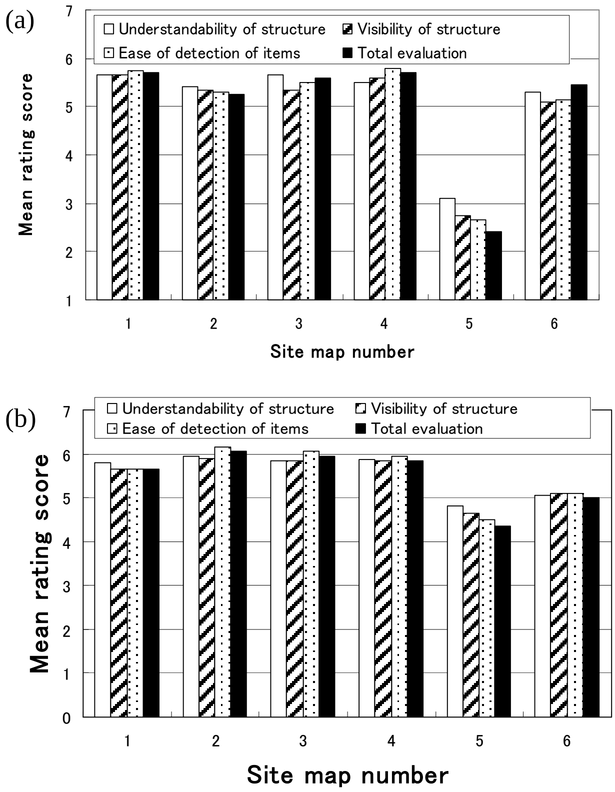


Figure 5. Psychological rating for each site map.
(a) young adults, (b) older adults

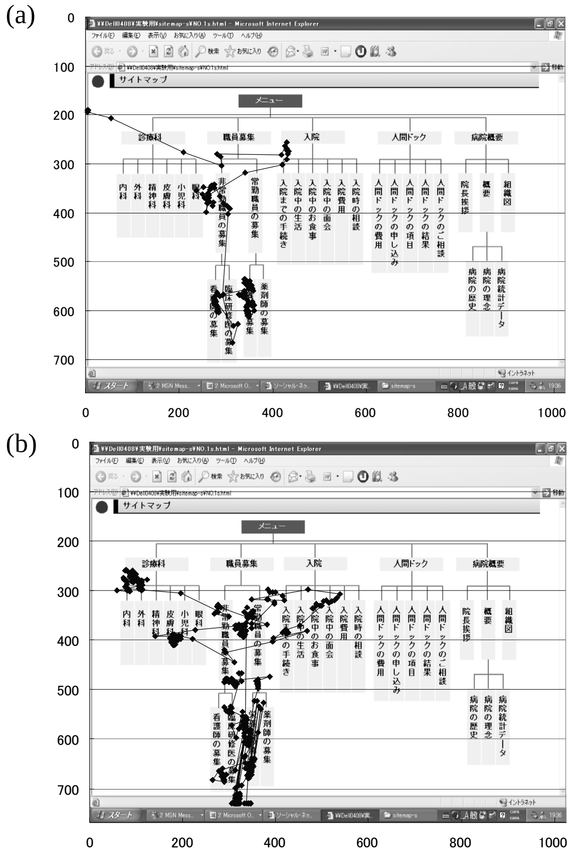


Figure 6. Trajectory of eye movement during visual search in site map. (a) young, (b) older adults.

Mann-Whitney U-test, significant main effect for items (A), (B), and (C) were detected among six types of site map.

Trajectory of eye movements

Examples of eye movements for young and older adults are shown in Figure 6 (a) and (b), respectively. The trajectory of older adults tended to be dispersive and longer than that of young adults.

4. DISCUSSION

As shown in Figure 2, it tended that the aging factor affected the search performance. The older adults took longer to search for a target than the young adults. Among six types of site maps ((1) vertical tree type, (2) horizontal tree type (A), (3) horizontal tree type (B), (4) table type, (5)radial type, and (6) itemized type), the horizontal tree type (B) led to faster search time, especially for older adults. As for the young adults, the search time was not affected by the type of site map except for (5) ratial type. The search time of (5) radial type was by about 25 % longer than other types.

The psychological rating revealed significant differences among six site maps for the following questionnaire items (A), (B), and (C).

(A) understandability of site map structure
(B) visibility of site map
(C) ease of searching for a target

The result further verified that the usability of site map (3) was high, and the usability of site map (6) leading to the slowest search time was low.

The tendency above was further confirmed by the eye movement characteristics. There were similar tendencies between type of site map and search time or fixation duration for both young and older adults. As for young adults, the fixation duration for site map (5) (radical type) was longer than other site maps. The fixation duration of older adults for site map (3) was shorter than that for other site maps. This was also true for the search time.

The number of fixations for site map (5) tended to be longer for both young and older adults. The number of fixations of site map (3) for older adults tended to be fewer than that of other site maps, and was nearly equal to that for young adults. This further verified the effectiveness of site map (3) for both young and older adults.

Because the effects were generally seen in both performance and oculomotor variables such as number of fixations and fixation duration, it is clear that there are both oculomotor and attentional components to the task and these components could be influenced by Web page design.

In order to investigate the differences of eye movement characteristics between young and older adults, the relationship among eye movement characteristics and search time was obtained using a multiple regression model according to Murata and Furukawa (2005). The following multiple regression model was used.

$$search\ time = a + b_1(number\ of\ fixation) + b_2(fixation\ duration) \quad (1)$$

Here, a, b_1, and b_2 are multiple regression coefficients. Multiple regression was obtained for each site map, and for each age group. The standardized regression coefficient (beta) for young and older adults is shown as a function of type of site map in Table 1 (a) and (b), respectively. Comparing Table 1 (a) and (b), it is apparent that the eye movement characteristics differ between young and older adults. As for the young adults, the contribution of number of fixation to search time was larger that that of fixation duration. This tendency was more and more enhanced for older adults. The contribution ratio relatively shows which of the two eye movement characteristics (number of fixation and fixation duration) contributed to the variation of search time.

It seems that the eye movement characteristics during search behavior differ between young and older adults. The older adults use mainly the variable number scheme in a visual search task. They seldom use the variable fixation model. On the other hand, the young adults use both the variable number and the variable fixation model to search for a target.

As for the contribution to search time variation between fixation duration and number of fixations, the variable duration model was dominant for older adults. However, as shown in Table 3, the dominance of variable duration model was lessened for site map (3). This might be one of the potential factors in explaining the shorter search time of site map (3) for older adults. Moderate contribution of fixation duration and number of fixations to the variation of search time might lead to faster search performance. This would be verified by the slower search time of young adults for site map (5) that lead to lower contribution of fixation duration to search time variation. When the search time is moderately shorter, the contribution between fixation duration and number of fixations is moderately balanced.

Table 1. Standardized regression coefficient (beta) and contribution ratio (young adults).

Site map number	Standardized regression coefficient		|standardized coefficient| (Number of fixations) / |standardized coefficient| (fixation duration)
	Number of fixations	Fixation duration	
1	0.448	0.386	1.161
2	0.235	0.374	0.628
3	0.54	0.247	2.186
4	0.541	0.259	2.089
5	0.119	0.689	0.173
6	0.525	0.265	1.981

Table 2. Standardized regression coefficient (beta) and contribution ratio (older adults).

Site map number	Standardized regression coefficient		|standardized coefficient| (Number of fixations) / |standardized coefficient| (fixation duration)
	Number of fixations	Fixation duration	
1	0.637	0.072	8.847
2	0.569	0.096	5.927
3	0.631	0.192	3.286
4	0.709	0.018	39.389
5	0.984	-0.148	6.649
6	0.559	-0.181	3.088

The longer search time of older adults relative to young adults might be accounted for by the different eye movement characteristics mentioned above and the declined motor-cognitive function below.

The age-related differences in search of site map identified above might be due to the different cognitive-motor functions between young and older adults. In other words, these differences can be accounted for by the declined cognitive slowing, declined working memory capacity, and declined motor function of older adults[1, 2]. Spatial abilities, that is, the capacity to acquire, manipulate, and use information Web pages, have been shown to decline with age[3], and this might account for the difficulties of older adults when navigating Web pages. 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.

Domain Knowledge is a strong predictor of Web search performance (Graham, 2004). It may be possible that this expertise mitigate the effects of perceptual and cognitive factors that can render Web navigation frustrating for older adults. This viewpoint must be explored in future research. Simple changes in Web design may not be helpful for older adults and lead to higher performance and satisfaction of older adults. The cognitive abilities or intelligent factors such as verbal and visuospatial memories, perceptual speed and spatial ability, and reading abilities also affect the search performance of Web pages. In future research, we should clarify how such factors would affect the Web navigation performance.

ACKNOWLEDGEMENT

This study was partially supported by Japanese Scientific Fund (770:2004-2006).

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