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Eye tracking study on Web-use: Comparison between younger and elderly users in case of search task with electronic timetable service

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ABSTRACT

The World Wide Web provides a variety of information and services, however, its usability is still under discussion. In order to clarify concrete difficulties in Web use, the behavior of younger and elderly users was observed with eye tracking during a timetable search task using electronic timetable systems on the Web. The result shows on the one hand common difficulties for younger and elderly users caused by an inconvenient navigational structure and an inappropriate page design. On the other hand, several important differences between the two age groups are confirmed. It suggests the necessity of particular consideration for elderly users in Web design.

Keywords: *WWW, navigation, eye tracking, ergonomics, elderly*

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1 Introduction

1.1 Methodology for studies on Web usability

The World Wide Web (WWW) has become one of the most popular services of the Internet. It does not only offer diverse information resources but also various online services such as banking, shopping, booking etc. Various technologies for Web design are developed and applied, however, they sometimes make Web use difficult. A questionnaire about the difficulties in Web use shows that a slow download of the page or data, time-consuming search for information, a complex site structure and out-of-date links disturb more than 60 % of the users (Van Eimeren & Gerhard, 2000). Of these a time-consuming search for information and a complex site structure are very critical issues from the ergonomic point of view. As these problems are also pointed

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out by the users with longer user experience, they are presumably not caused by the lack of the user experience but by inappropriate Web design.

The usability of a Website is already investigated by various methods. One of the most popular methods is the subjective evaluation. By using a questionnaire or an interview individual Websites are evaluated. One other popular method is the analysis of the log-files. The navigational behavior can be traced by using log-files and the search duration, applied hyperlinks and the followed way of navigation can be analyzed. Some investigations show that the hyperlinks provided in Websites are mainly applied for the navigation and that the “back” button of the browser is also frequently used (Catledge & Pitkow, 1995; Tauscher & Greenberg, 1997). However, the use of the “back” button of the browser sometimes causes confusion. Cockburn and Jones (1996) revealed that users lose their bearings if they do not understand the stack model for the “back” button correctly. Additionally they pointed out that the navigational button embedded in Web-pages such as “back to homepage” is less confusing. For the improvement of the orientation it is a useful way to indicate the current position on the Website. Of course the site and navigational structure itself should be clearly designed. An analysis of navigational behavior is also accomplished by combining the comparison of the hierarchical structure with different width and depth (e.g. Zaphiris, 2000) or different navigational structure (e.g. Bachiochi et al., 1997; Kim, 1999; Kim & Yoo, 2000) and their influence on navigational behavior is revealed.

In order to investigate the page design eye tracking can be applied. As human beings perceive 80 % of the information through the visual channel and human eyes voluntarily and involuntarily fixate on those elements of an object which carry or may carry essential and useful information (Yarbus, 1967), eye tracking data provides us plenty of cues in order to understand human behavior. Reading, visual search, scene perception, auditory language processing, problem solving, human-computer interaction, driving, sports, marketing, aviation, plant operation etc. are only a part of the issues which are investigated by using eye tracking (see e.g. Rayner, 1998; Duchowski, 2003; Hyönä et al., 2003 for the overview of eye tracking studies). Concerning Web use, unfortunately there are not many studies with eye tracking. However, they have revealed some important issues. Stanford Poynter Project (2000), for instance, analyzed the eye movements during free reading of online-newspapers and revealed that most of the fixations concentrate on text and not much on graphics. Photos are regarded frequently in a limited situation such as getting back to the

homepage after reading some pages. The eye tracking study in the specific information search by Ohno (2000) shows that users tend to focus frequently on the left hand side or upper part of the page rather than on the right hand side or lower part of the page. A similar effect is also confirmed in the study of Goldberg et al. (2002) which assigned navigational tasks and specific tasks such as customizing the displayed elements on the Webpage. Ohno (2000) shows furthermore that the fixation duration is mostly between 200 and 500 ms and hyperlinks and menus are regarded for a long time. Goldberg et al. (2002) revealed that the eye movement-derived parameters such as dwell time, scanpath length, and number of fixated objects, provided measures of task comprehension and expertise. These studies outline the characteristics of eye movements in Web use. However, the influence of the page design on the visual information perception is not clearly shown.

The conventional research studies mentioned above regarded either navigational aspect or page design aspect. As page design is strongly related with navigational structure (hyperlinks are provided on Web-pages), these two aspects of the Web design should actually be discussed together. This study therefore investigates the navigational behavior of users by using eye tracking data. The interaction between the visual information perception of Web pages and navigational behavior will be discussed.

1.2 Comparison between elderly and younger users

The user population of the WWW is continuously increasing. In recent years the increase of elderly users is especially striking. In Germany, 13 % of people older than 60 years old are using the Internet. The users in this generation account for 5 % of all Internet users. The popular services for elderly users are quite similar to those for younger users: retrieval of the latest news or economic information, trip reservation, online-shopping or online-banking (Fittkau & Maaß GmbH, 2000; Morrel et al., 2000). On the other hand there are also Websites aiming especially at elderly people typically providing healthcare information, information about senior-friendly products, information about internet courses for elderly people etc. As information and services help to improve the daily life of elderly people, the WWW can be regarded as one object of gerontechnology[1].

[1] The study of technology and aging for the improvement of the daily functioning of the elderly (Bouma, 1992).

Actually, the usability of the WWW is still under discussion. Even younger users sometimes have great difficulties with using the WWW. For elderly users the situation is more crucial due to the influence of the aging process. For instance, it is pointed out that elderly people have difficulties with memory or organizing of visited pages (Fittkau & Maaß GmbH, 2000). It is regarded as the influence of memory function on navigational behavior. The deficit of visual function can negatively influence the visual information perception from various Web pages. Tiny characters and navigational buttons, low contrast of individual elements to the background etc. can disturb it. Furthermore, due to deficits in fine motor control placing the mouse cursor on small hyperlinks can be a difficult task for elderly users.

The problem is that the technologies exceed the capacity of human beings. The technological development in this area is very rapid. Sometimes technologies precede human beings as users and it is no longer “for” users but “against” users. As already mentioned, this issue is particularly serious for elderly users. It is easy to imagine that the deficit due to the aging process can lead to a larger gap between technologies or products and user in the case of elderly people than in the case of younger people. However, technologies and especially all so-called high-technologies are mostly developed by younger people, not by elderly people. Such products aim mainly at younger people and special remarks for elderly users are not made. Therefore, there is still a lack of data on elderly people.

The acquisition of data on elderly people is not easy. Difficulties with recruiting the elderly people as participants due to the lack of contact to elderly people, foreignness of “investigation” or “experiment”, accessibility of elderly people to the research laboratory and inconvenient construction of experimental devices are factors which can disturb the cooperation with elderly participants. However, all these factors can be solved in some way. For instance, the conventional eye tracking devices require that goggles are worn for the measurement. It is quite inconvenient for elderly people, because they often require their own reading glasses to look at visual objects. The modern type of eye tracking devices requires no goggles or helmets and they are applicable also for the elderly people wearing reading glasses. By using such devices, the comparison of data between younger people and elderly people will be possible.

In this study therefore the focus is not only on younger people but also on elderly people as target users. It should be clarified what is common and what is different between the two age groups with regard to difficulties in Web use.

2. Experimental method

2.1 Participants

14 elderly people (age: 62–74, mean: 67.15) and 13 younger people (age: 17–29, mean: 22.54) took part in this experiment. All the participants were German native speakers and had no problem with using a keyboard and a mouse. Each age group was divided into two groups according to the experience of Web use. An intermediate group consisted of the users with an experience of one year or longer. The participants with less than one-year experience belonged to the beginner group.

2.2 Tasks and Procedures

The task assigned to the participants was to search for a certain subway timetable. It consisted of the following subtasks.

1. Navigation from the homepage of each Website to the electronic timetable service (the page with input form).
2. Input of the search conditions (name of departure stop and destination stop, date and time are given by the experimenter).
3. Retrieval of the timetable (navigation from the input page to the corresponding timetable).
4. Navigation between timetables (for same route but for different time – earlier or later connections).
5. Navigation from the timetable page to the input form of the electronic timetable service.

During the task accomplishment the use of the browser buttons was allowed.

The experiment was started by giving the instruction for this experiment to the participants. If a participant had no experience with using the electronic timetable service, the whole task was also demonstrated. During the demonstration participants could also try it by themselves for practice. Subsequently the eye tracking device was calibrated and the experimental session was started. The above mentioned subtasks were accomplished step by step according to the instruction of the experimenter. During the task accomplishment participants were requested to express their thoughts as much as possible. After finishing the task in one Website, participants evaluated the

Website according to 22 criteria using a seven point scale. This procedure was repeated for three Websites. The order of the Websites was changed among participants.

Thinking aloud is sometimes difficult for participants because it is not natural. In order to complete a deficit in protocols of utterances and to clarify reasons for particular behaviors an interview was carried out after finishing all the sessions. As the eye movement recording is a powerful tool to support verbal retrospection (Hansen, 1991), the recorded eye movement data with utterances was shown to participants during the interview.

2.3 Stimuli

Three German Websites, here called A, B, and C, of local transportation organizations were applied for this experiment. All these Websites differed in their navigational structure and page design. No modification was made in the Websites in order to investigate the difficulties of the users in a real situation. The specifications of the applied Websites are shown in Table 1.

For the analysis of the navigational structure at first the so called nominal navigation flow for the task was defined according to the procedure in system ergonomics (Bubb, 1993). It is based only on the user demand for the corresponding task and independent of currently available technologies or the navigation flow in existing Websites. With regard to the subtasks in this experiment all the navigation (subtask 1, 3, 4, 5) should be accomplished by one click on the corresponding hyperlink. The required search conditions can be input in arbitrary order (subtask 2). For the selection of Websites the deviation between the shortest navigational flow realized in each Website without using browser buttons and the nominal navigational flow was considered. If there is a deviation in navigational flow, namely, at least two or more steps are required for a given navigational subtask, some confusion is expected. In the analysis this point will be especially focused on.

2.4 Experimental Setup

During task accomplishment the eye movements, navigational behavior and the utterances of participants were registered. For the eye movement analysis the eye tracking device “Free View” (Takei Scientific Instruments, Co. Ltd.) was applied. This system was a video-based eye tracker utilizing the corneal reflection and the center of

the pupil for the eye movement measurement. No helmet or goggles was required for measurement, instead the camera set in front of the participant recorded the picture of the eye. The data collection frequency was 30 Hz and the data accuracy was 0.2 deg in visual angle. The locus of the eye movements was superimposed on the displayed Web pages in real-time and video recorded. With the help of a microphone the utterances of participants were also recorded on this videotape. All the coordination data of gaze points was recorded on the computer during the measurement.

The Web pages were displayed with the browser "Netscape 4.5" on the flat panel display (17 inch) at a viewing distance of 65 cm. This display size corresponded to 28.07 deg width and 20.49 deg height in visual angle. Figure 1 shows the experimental setup. The participants sat in front of the display and were fixed their head with using the chin rest in order to secure the data accuracy.

Table 1: Specifications of applied Websites

Features		Website A	Website B	Website C
Position of hyperlinks	Main menu	On the left hand side in the frame	On the right hand side in the frame	At the bottom of the page in the frame
	Submenu	Below the selected item in main menu	On the top of the main part of the page	(No submenu)
	Navigational button	At the bottom of the page	At the bottom of the page in the frame, on the input page far from the input fields	At the bottom of the main part of the page
Visibility of hyperlinks	Main menu	Always visible	Always visible	Always visible
	Navigational button	On the timetable page invisible without scroll	Always visible	On the timetable page invisible without scroll
Character size	Main menu	10pt	10pt	12pt
	Submenu	10pt	8pt	(no submenu)
	Navigational button	10pt	8pt	12pt
	Main part of homepage	14pt	10pt	12pt
	Main part of timetable	12pt	10pt	12pt
Required navigation per subtask	1 From homepage to input page	twice	once	twice
	3 From input page to timetable	twice	once	once

	4 Between timetables	Three times	once	Whole search process (input of search conditions and retrieval) is required
	5 From timetable to input page	once	once	once
Other remarks		Part of the design had changed during the experiment. 20 participants made this experiment with the old design and 7 participants with the new design.	Includes animated banners	For the second step of the navigation from the homepage to the input page of electronic timetable service, the instruction was given, because only one of two given alternatives did function.

Figure 1: Experimental setup.

3. Results

3.1 Visual search of the required navigational button

Eye movements in visual search for the task relevant navigational button differed from page to page. Figure 2 and Figure 3 show the examples of the observed eye movements in the case of Website B and C. The given subtask for both cases was the retrieval of the timetable (subtask 3). On the input page of the electronic timetable

service, subsequent to the input of the search conditions (subtask 2), the corresponding navigational button should be clicked on. On Website B (Figure 2) the required navigational button “send inquiry” (originally in German: “Abfrage senden”, (12) in Figure 2) was far from the input fields. Instead of the correct navigational button, directly under the input fields, a navigational button to the other electronic timetable service was provided ((10) in Figure 2). Furthermore, under this confusing navigational button there were animated banners ((11) in Figure 2). Between the banners and the correct navigational button there was some empty space. Therefore the gaze point hardly moved to the navigational buttons and most of the participants sought for the correct navigational button for a long time.

Contrary to this in Website C (Figure 3) the navigational button for the timetable retrieval “search connections” (“Verbindungen suchen”, (4) in Figure 3) was located directly under the input fields. Therefore participants had no difficulty with finding the correct navigational button.

The gaze point mostly moved to the nearest element in the search process. The large “jump” occurred only toward salient elements or familiar elements such as the main menu which was provided in a fixed position.

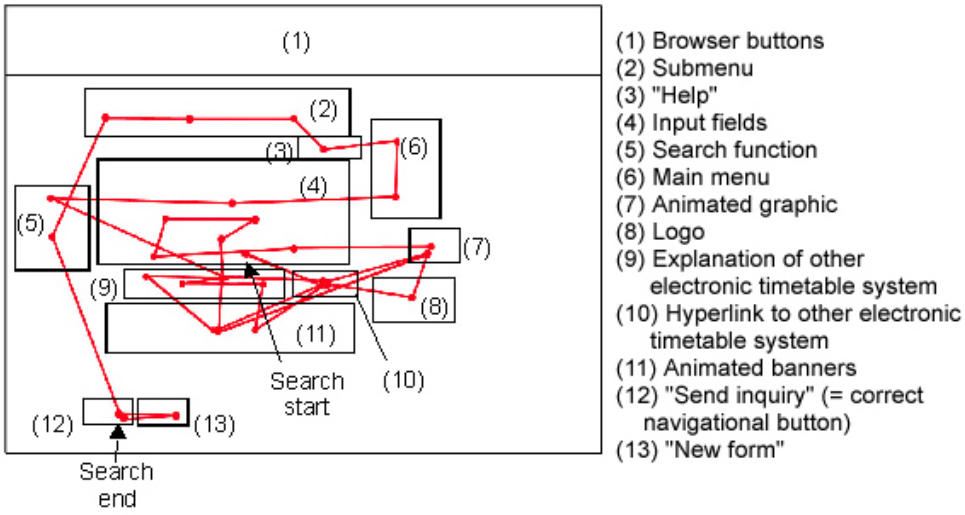

Figure 2: A typical example of eye movements for the retrieval of the timetable (subtask 3) on Website B: for the required navigational button “send inquiry” (12) was far from the input fields (4), as a result most of the participants required long eye movements to find.

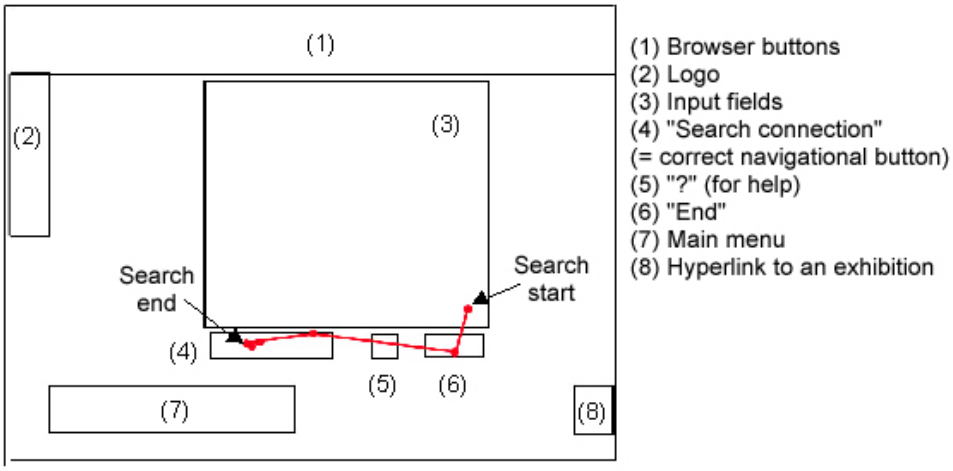

Figure 3: A typical example of eye movements for the retrieval of the timetable (subtask 3) on Website C: the required navigational button “search connection” (4) was directly under input fields (3), therefore it could be found with short eye movements.

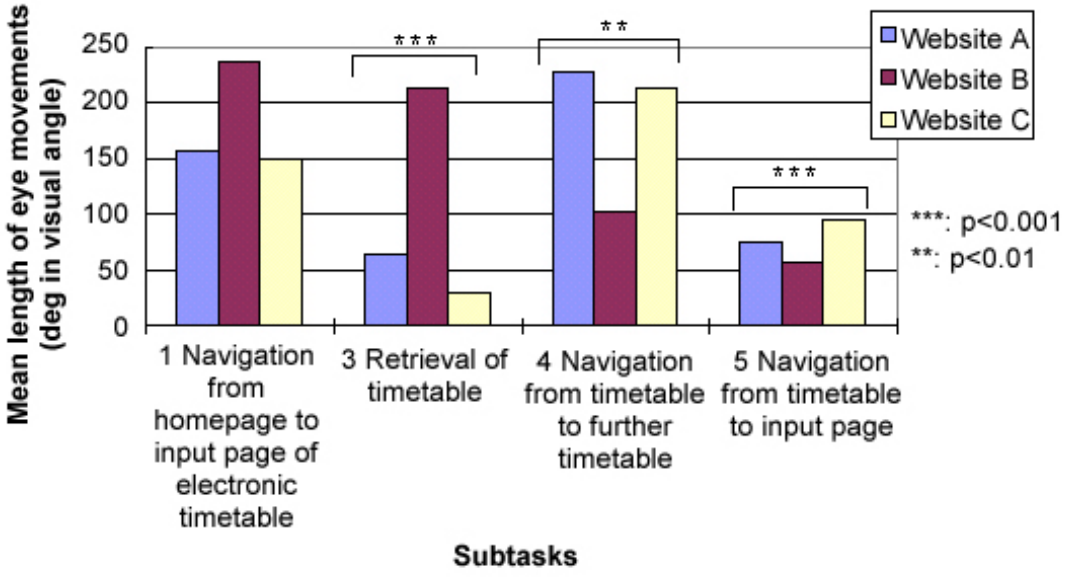

Figure 4: Comparison of length of eye movements between Websites regarding navigational subtasks: the required eye movements for retrieval of the timetable on Website B, for navigation from timetable to the further timetable on Website A and C, for the navigation from the timetable to the input page on Website A and C were significantly longer than on other Websites.

The length of eye movements on each page is outlined in Figure 4. For the navigation from the homepage to the input page of the electronic timetable service (subtask 1) and for the retrieval of the timetable (subtask 3) on Website B as well as for the navigation between timetables (subtask 4) on Website A and C extremely long eye movements were required to find the corresponding navigational button.

The homepage of Website B was designed as a subway map. Each hyperlink was likened to a station in a subway map. They were labeled with tiny characters and the correct hyperlink leading to the input page of the electronic timetable service was located on the top left of the page, immediately above a graphic in the middle of the "subway map". This graphic attracted the attention of the participants so that the elements below this graphic were mainly regarded. This task could also be accomplished by using the main menu. However, the main menu was located apart from the main part of the page. Similar to the retrieval of the timetable on Website B described above, most of the participants required long eye movements here due to the inconvenient location of the required navigational buttons.

With regard to the navigation between timetables on Website A and C (subtask 4) the corresponding navigational button was not visible without scrolling (Figure 5). In these cases participants looked around the page first of all and confirmed that the required navigational button is invisible. Consequently the page was scrolled and the required navigational button was sought further. This way long eye movements were required in order to find the corresponding navigational button. The difference between the Websites in the navigation from the timetable to the input page (subtask 5) was caused also by the invisibility of the required navigational button.

In addition the influence of the size of the required navigational button was observed. The design of Website A had changed during the experiment. For the navigation to the input page of the electronic timetable service the old version provided the choice "timetable" ("Fahrplan") in the main menu. It was so small that it was not conspicuous at all in comparison with the other larger hyperlinks in the main part of the homepage. Therefore most of the participants first looked around the main part of the homepage. Contrary to this the new version additionally provided a larger hyperlink "timetable information" ("Fahrplanauskunft") in the main part of the homepage. The attention of the participants was attracted immediately to this hyperlink. Therefore the length of the required eye movements was significantly shorter in the new version (67.7 deg) than in old version (181.0 deg).

The comparison between younger and elderly participants revealed a clear difference if a page consists of many small elements including the desired navigational button. On the above mentioned homepage of Website B elderly participants required longer than 300 deg on average to find the corresponding navigational button "timetable" and this was twice as long as younger participants take.

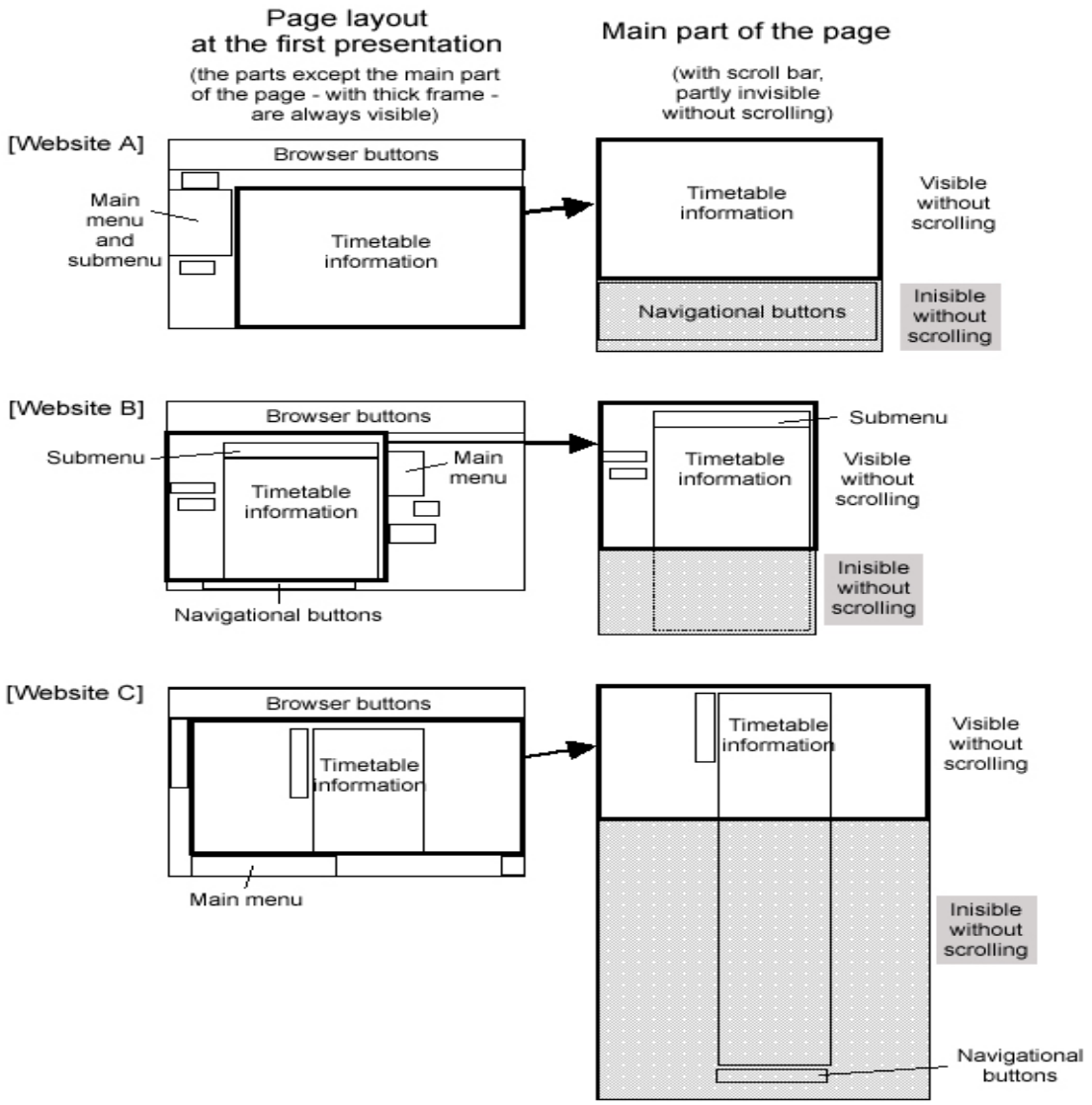

Figure 5: Design of timetable pages of Websites used in the experiment: navigational buttons required for the navigation from a timetable page to another timetable page (subtask 4) and to the input page (subtask 5) were invisible without scrolling on Website A and C.

3.2 Fixation Duration

The fixation duration indicates the difficulties in the perception of visual objects. It can be influenced both by their physical condition and by their semantic content. Figure 6 shows the average fixation duration on elements on the display. The main part of each page brings the essential information for the users. This part was mainly “read” by the users. Contrary to this the main menu and navigational buttons provide the possibility to navigate to other pages. Browser buttons have a similar function. The functional difference of each element was clearly observed in fixation duration. Fixation duration

on the contents for reading was generally shorter than on the navigation tools. Among all it was striking that the fixations on the main menu of Website A and B as well as on the navigational buttons of Website B were significantly longer than that of other Websites. These elements consisted of small characters, namely characters in 10 pt or smaller.

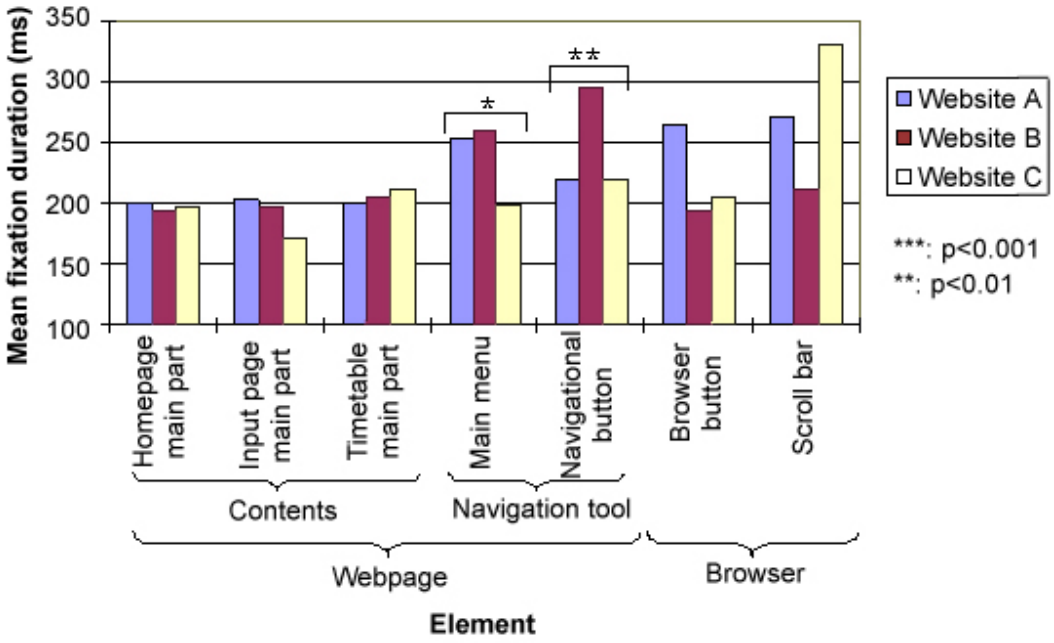

Figure 6: Comparison of mean fixation duration on elements on the display between Websites: fixation duration on navigation tools were generally longer than that on contents, especially small navigation tools caused longer fixations.

In general elderly people required longer fixation than younger people. In relation to the above mentioned small elements the difference between the two age groups was very obvious. As Figure 7 shows, elderly people required longer fixations than younger people for the main menu of Website A and B which consisted of characters in 10 pt, whereas the main menu or Website C labeled by characters in 12 pt made no difference. Although the difference regarding to Menu A ($p = 0.072$) and Menu B ($p = 0.100$) did not reach the significant level ($p < 0.05$), the contrast to Menu C should be remarked. The strong influence of the size of the element to handle was also observable on the narrow scroll bar. Elderly people definitely needed longer fixations than younger people.

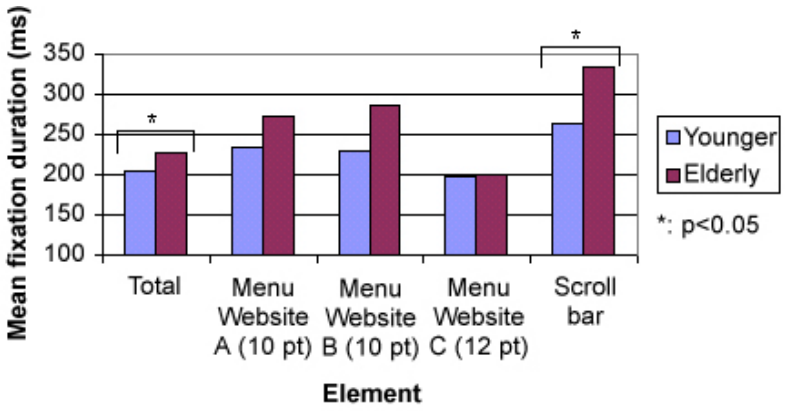

Figure 7: Comparison of mean fixation duration between younger and elderly participants: elderly participants required longer fixations especially on the small elements.

3.3 Navigational behavior

In the navigation some participants took the long way around. Among all, 85.2 % of the participants navigated differently from the shortest navigational flow for the navigation between timetables in Website A. Furthermore, for the navigation from the homepage to the input page of the electronic timetable service (subtask 1) in Website A (old design), for the retrieval of the timetable (subtask 3) in Website B as well as for the navigation between timetables (subtask 4) in Website A and C more than half of the participants did not follow the shortest navigational way. All these subtasks except the retrieval of the timetable in Website B required at least two or more navigational steps. These subtasks could be accomplished by one click in a nominal navigational flow. It is assumed that the gap between the imagination of the users and the real design caused confusion and different navigational behavior than the expectation of the Web designer. That becomes especially obvious in the utterances of the participants such as “There is no corresponding navigational button” during searching for the corresponding navigational button or “It is not the expected page” after reaching a new page by clicking on a navigational button.

On the other hand the retrieval of the timetable on Website B required only one click. This navigational step itself matched the imagination of the users. However, as mentioned in 0 (see also Figure 2), the visual search for the corresponding navigational button was difficult. As a result, more than half of the participants failed to find the correct navigational button. Here the influence of the page design on the navigational behavior was observed.

If the participants did not follow the shortest way, how did they navigate? Figure 12 shows an example of observed navigations from one timetable to another timetable (subtask 4) on Website A. This subtask could be accomplished by one click on the navigational button such as “earlier connection” in a nominal navigation. In the real navigation design on Website A however, three navigational steps were required: (1) go to the timetable overview by using the navigational button “overview” (“Übersicht”), (2) go to the timetable for the earlier time by using the navigational button “earlier connection” (“frühere Verbindungen”), (3) retrieve the detailed timetable by using the navigational button “detail” (“Detail”). At the first step the participants looked for the expected navigational button through which the timetable for earlier connections was directly retrieved. After the recognition that there was no such a navigational button the participants sought for the alternative navigational way. More than half of the participants here selected the browser button “back”. Some of them remembered the navigational button “earlier connection” on the timetable overview. Other participants thought that it could be a useful way to go back to the input page of the electronic timetable service, to modify the time and to repeat the timetable retrieval. A similar idea could also be realized by getting back to the input page through the navigational button “new inquiry” (“Neue Anfrage”). In order to “change” the timetable the navigational button “timetable change” was plausible, but it was the notification of the current change in timetable and did not correspond to the given subtask.

Concerning this example it should furthermore be noted that the deviating navigation also occurred due to the invisibility of the correct navigational button. The required navigational button “overview” was embedded at the bottom of the main part of the page so that it was invisible without scrolling (Figure 5). Some participants sought for the navigational buttons, however only in the visible area without scrolling. These participants therefore selected another hyperlink or the browser buttons that were visible. As the navigational buttons on the timetable page of Website A and C were laid out in such a way, the deviation observed on this page (subtask 4 and 5) was also influenced by the invisibility of the required navigational button.

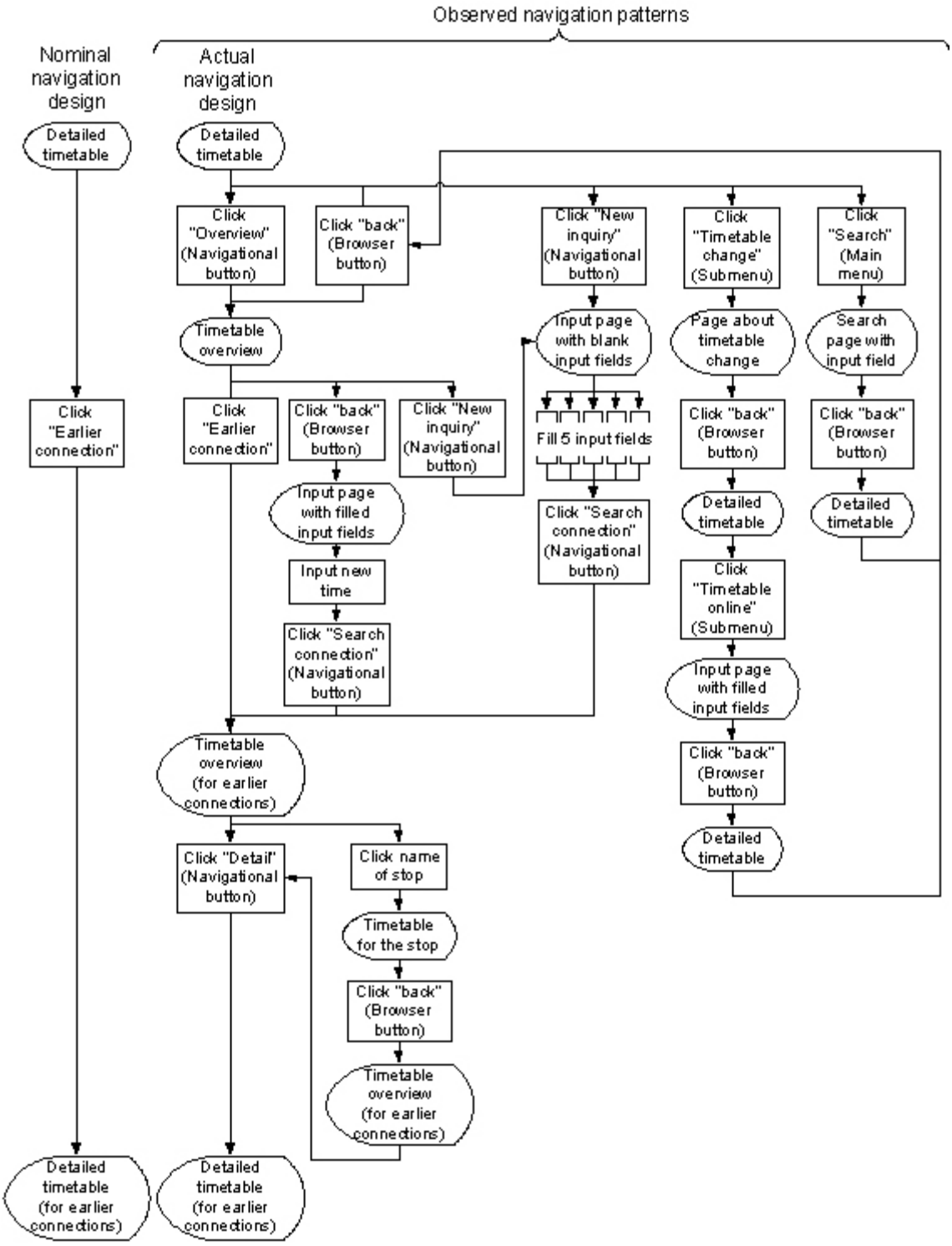

Figure 8: Flow chart of nominal navigation design, actual navigation design and observed navigation patterns in the navigation between timetables (subtask 4) on Website A: due to the deviation between a nominal navigation design and the actual navigation design, various navigation patterns were observed.

The observed navigation patterns which were deviated from the shortest navigational way can actually be divided into two groups according to the consciousness of the participants. In most cases the participants were conscious of having made a mistake after reaching an “unexpected” page. In such cases the participants frequently tried to get back to the page where the incorrect navigational button was selected and search for the “correct” navigational button. On the other hand the participants sometimes followed a different navigational way from the shortest navigational way in the given Website because that navigational way differed from their expectation. Due to the inconvenient navigational structure the participants had to think of an alternative way. Therefore the participants were not conscious of making a mistake in this situation. In addition, once the participants had noticed the inconvenient navigational structure they tended to apply their own navigational strategy in further navigation. A good example for that is the navigation from the timetable to the input page (subtask 5) on Website A and C. For this subtask about one third of the participants navigated differently than the shortest navigational way on the Website. Frequently the browser button “back” was applied instead of the navigational button provided by the Website. Because the foregoing subtask (subtask 4) could not be accomplished by one click due to the inappropriate navigational structure, some of the participants used the browser button “back” for that subtask (see also above the detailed description of the navigation between timetables on Website A). With this navigational strategy the participants reached the input page of the electronic timetable service. Based on this experience they did not regard the given navigational button much. The eye tracking data reveals that: the gaze point moves directly to the browser button in such a situation.

The application of one’s own navigational strategy was frequently observed in the case of elderly users. If they knew that one strategy had a success, they applied this strategy repeatedly. It sometimes caused a long way around. The elderly users tended to require more navigational steps. Among all the difference in the navigation between the timetables (subtask 4) on Website C and the navigation from the timetable to the input page (subtask 5) on Website A was significant ($p < 0.05$).

3.4 Duration of task accomplishment

Figure 9 summarizes the duration of each task accomplishment. With regard to three subtasks a significant difference between Websites was confirmed. The difference in the input of the search condition (subtask 2) was caused by the difference in the number of input fields. Website A provided only one input field each for the departure

and destination station whereas the other Websites provided two input fields each. Most of the remaining differences were caused by the navigational structure. If a subtask in a Website required two or more navigational steps (columns with dotted part in figure 10), it took longer than on Websites which required only one navigational step for that subtask. In these cases the duration until first click (lower half of each dotted column in figure 11) was rather short and not different from the duration on other Websites. Especially in order to retrieve the timetable (subtask 3) on Website A it took much shorter time for the click on the navigational button “search connection” (“Verbindung suchen”) than on other Websites. In this case further navigational steps caused a longer duration of task accomplishment.

On Website B it took also very long time to get the timetable although only one navigational step was required for this task. In this case not the navigational structure but page design was regarded as the main cause for the longer task accomplishment duration.

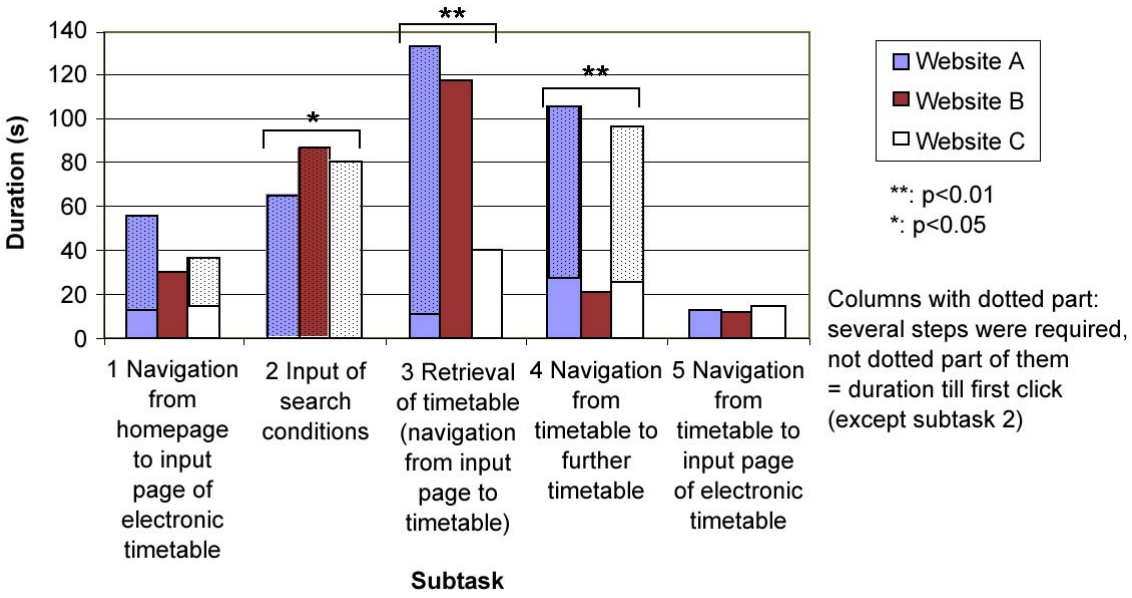

Figure 12: Comparison of accomplishment duration of each subtask: longer accomplishment duration was mostly caused by the multiple steps, in subtask 3 on Website B however by the inconvenience page design.

The difference between younger and elderly participants was very obvious. As shown in Figure 13, elderly participants required significantly longer than younger participants for most of the subtasks on all the Websites. Both inconvenient navigational structure

and inappropriate page design could strongly influence the task accomplishment duration of elderly users.

In addition it was revealed that the elderly users required more time to handle the input devices. Figure 14 shows the detailed analysis of the duration of various actions of the input task (subtask 2). It consisted of repeated placing of the mouse cursor on the target field, changing the hand from the mouse to the keyboard, input by using the keyboard (= typing) and changing the hand from the keyboard to the mouse. For all kinds of action, elderly users required approximately 50 % longer than younger users. Together with the longer duration on the scroll bar the difficulties in handling of the input devices due to deficits of fine motor function were observed.

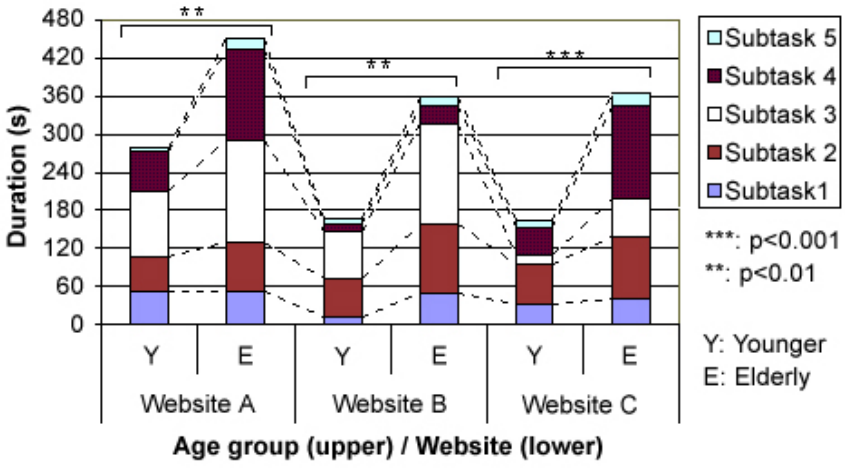

Figure 13: Comparison of task accomplishment duration between younger and elderly participants: generally elderly participants took longer time than younger participants, especially for the subtasks which required multiple steps and were accomplished on an inconveniently designed page.

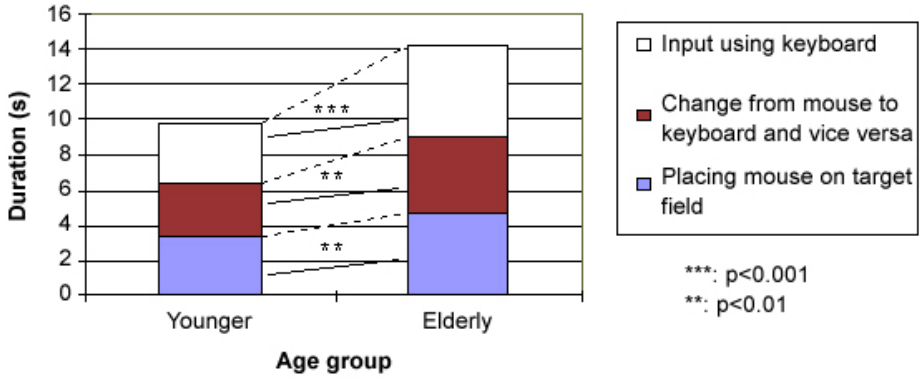

Figure 14: Comparison of duration of input task between the two age groups: for all kinds of action, elderly users required approximately 50 % longer than younger users.

3.5 Subjective evaluation

Although the above mentioned objective data revealed several difficulties in the search task most of the subjective evaluation was positive on average (Figure 15). Only the evaluation of the legibility of Website B was slightly negative on average. The differences between Websites were only observable with a view to the evaluation criteria which could be directly related to the objective data showing a clear difference between the Websites. With regard to legibility, layout, comprehensibility, orientation, and flexibility, there was a significant difference between the Websites. Among all, the legibility of Website B and the flexibility of Website C were obviously considered to be worse than that of the other Websites. Legibility is an important factor of page design and flexibility is related to navigation.

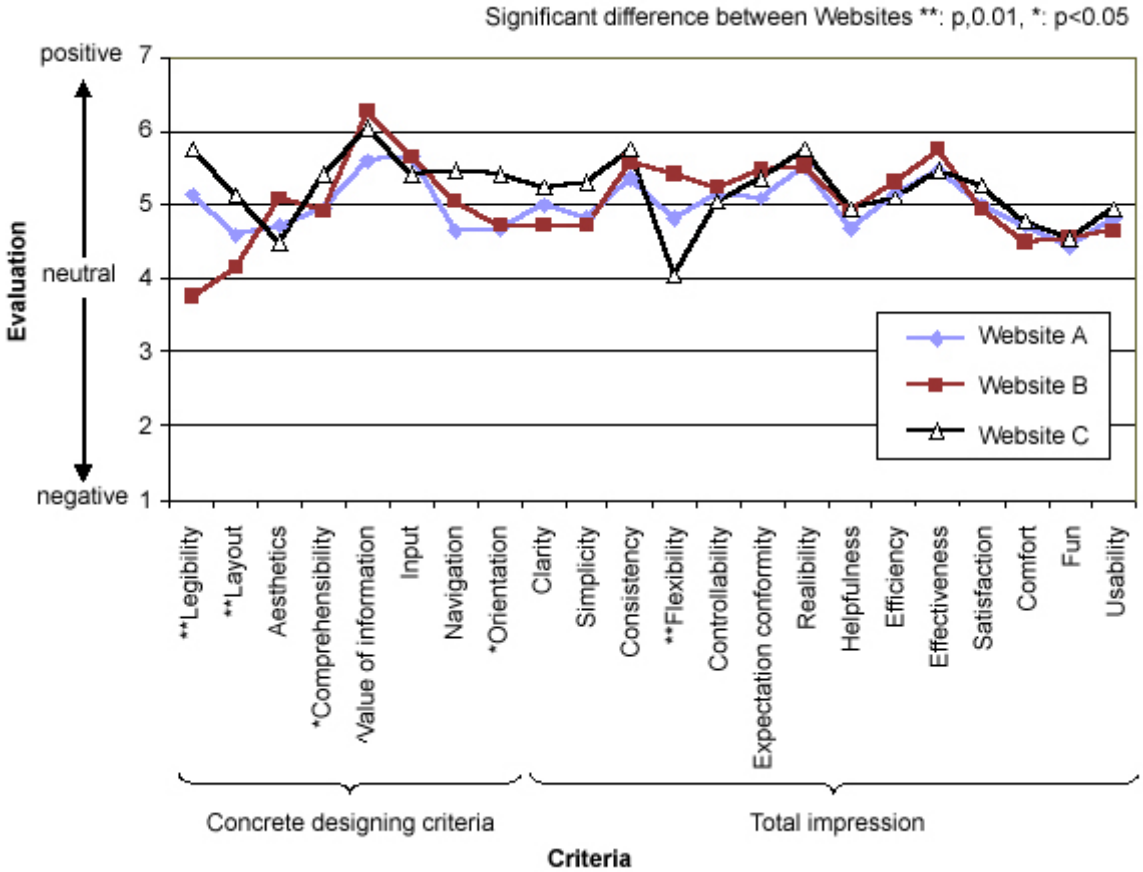

Figure 15: Profile of subjective evaluation: a significant difference between Websites was only observed with regard to few criteria.

With regard to the comparison between the two age groups, the evaluation of legibility by elderly people could be worse than the evaluation by younger people because elderly people required longer fixation and more eye movements to find the target navigational button. Actually, the difference according to age was not clear. On

the other hand the comparison between beginners and intermediates showed some significant differences. The evaluation by intermediates was generally more negative than that by beginners.

4. Discussion

4.1 Common difficulties for younger and elderly users

The results showed various common difficulties in Web use for younger and elderly people. Eye tracking data revealed that inconvenient page design leads directly to an inefficient visual search for the required navigational button and further navigational failure. The following three factors for inconvenient page design should be mentioned.

- Visibility of navigational button

If the target navigational button is visible only with scrolling this is very critical for easy use. First of all it takes long time to notice that the required navigational button is not visible. Therefore, long eye movements are spent for the visual search on the visible area of the page. After that the page is scrolled and further visual search is done in the area which appears new. As a result, in order to find such “invisible” navigational buttons, obviously longer eye movements are required than for the visual search for navigational buttons which are visible without scrolling.

More crucial is the fact that there is no guarantee that all the users scroll the page. In worst case the users fail to find the appropriate navigational button after a long visual search in the visible area of the page and select another hyperlink in that area without scrolling. The effect of the invisibility of the navigational button on the navigational behavior was observed in this experiment.

- Location of navigational button

Even if the target navigational button is constantly visible without scrolling, its location can influence the visual scan performance. In the visual search the gaze point moves mostly to the near elements. That means the elements apart from the other elements may possibly be disregarded. Some very important navigational buttons such as main menu can always be gazed at immediately after the gaze on any other elements. However, it is only possible if such navigational buttons are already familiar to the participants.

This characteristic of the visual search also implies the importance of the consideration of the tasks which are accomplished on the page. The elements relevant to the tasks which are accomplished one after another should be located nearby, so that the relationship between these tasks is easily seen. If an irrelevant element is located between them it confuses the user.

- Size of navigational button

The size of the navigational button affects its conspicuousness. A large element attracts more attention than a small one. In addition, it also influences the approximation of the importance of each navigational button. If the important navigational buttons are designed as small elements it affects the visual search for them negatively. Longer fixations on them are then required and the length of the required eye movements becomes longer. Disregard of such small elements is also possible.

Concerning the navigational design, as supposed before, the difference between the expectation of the user, namely the nominal navigational flow, and the given navigational structure caused confusion in Web use. The problems are classified in two issues: unclear navigational structure and lack of the desired navigational possibilities.

- Unclear navigational structure

All the tasks in this experiment except the input of search condition could actually be accomplished by one click. However, some of them required two or more navigational steps. If the click on a plausible navigational button or hyperlink leads to an unexpected page, the users are confused by it. Then on the displayed page, the users should search for a further navigational button to reach the desired page. This could be observed in the task accomplishment duration. It did not take long till the first click because the selected navigational button is plausible for the user. The duration till second try obviously took longer due to confusion and surprise.

- Lack of the desired navigational possibilities

Contrary to the above case sometimes a Website does not provide the expected navigational button. If this is the case the users should think about the alternative navigational way by themselves. It helps the development of one’s own navigational

strategy. As a result it influences further navigational behavior and causes the deviation in navigation from the shortest navigational way sometimes meaning the long way around. The visual search strategy for the navigational button may also be influenced by one's own navigational strategy.

As mentioned above the problems in page design also influence navigational behavior and the problems in the navigational structure can affect the visual search on each page. The combination of analysis of navigational behavior and eye tracking revealed the interaction between both aspects in Web design.

4.2 Elderly users' specific difficulties

In the objective data some clear differences between younger and elderly users were confirmed. They are related to the decline of visual and fine motor function.

- Visual information perception

The visual information perception of elderly people is less efficient than that of younger people. For individual fixations elderly people require longer time. This tendency is especially strong if the regarded visual objects are very small. Concretely, this experiment revealed that characters in 10 pt or smaller were crucial for elderly people. This point is common with the assertion of Ownby et al. (2003). Such small elements also cause long visual search for the expected navigational button. Especially characters in 8 pt were not readable for a part of the elderly participants even with their reading glasses.

- Eye-hand coordination

This problem is also strongly related to the deficit of visual function. In order to move the mouse cursor to the target hyperlink or scroll bar these elements must be gazed at carefully. For the handling of the input device itself fine motor function is required. However, this function declines also due to the aging process. Small navigational buttons and/or the narrow scroll bar make their handling very difficult.

- Inefficient navigation

Elderly users tend to apply their own navigational strategy if they have learned that their navigational strategy works. It corresponds to the argument of Gilbert (1996) that elderly people may develop an inefficient strategy which is difficult to change

afterwards. The application of their own navigational strategy sometimes causes more navigational steps.

Although elderly users had more difficulties than younger users, the relevant subjective evaluation was not always worse than that of younger users. The deficiency of sensory perception and motor functions due to the aging process is, so to speak, “normal” for elderly people. Therefore, they blamed their difficulties on themselves not on an inconvenient design of Websites. Generally said, elderly people are afraid of so called high-technologies. It could also be one reason for the disproportionately good subjective evaluation by elderly users. It implies the limit of subjective evaluation and importance of objective data.

4.3 Some recommendations for Web design

In order to avoid the observed difficulties some recommendations can be made.

- Character size

With regard to page design, it should be emphasized first of all to apply the characters in appropriate size. This point is especially important for elderly users. As the elderly users in this experiment had definite difficulty with characters 10 pt or smaller, especially in the case of Websites aiming at elderly users, the character size should be at least 12 pt. It not only influences reading them but also finding them. Small characters applied to navigational buttons do not attract much attention from the users.

- Design of navigational buttons

It is recommended to make the navigational buttons constantly visible. The application of frame function would be useful for that. Moreover, the layout of the whole page should also be balanced. Though this experiment did not investigate the influence of the different locations (top, bottom, right, or left) of navigational buttons, the bottom of the page would be appropriate for the navigational button because the navigational button is required mostly after looking at the contents of each page. Provided that the gaze point generally moves downwards, it is quite natural to seek for the navigational button below the content part after looking at it. Actually, the navigational buttons are frequently located at the bottom of the page. The function of the navigational button is in most cases strongly related with the contents of the main

part of the page. As the gaze point tends to move from one element to the nearest element, a great distance between the contents and navigational buttons should be avoided.

As regards the size of the navigational buttons it should be not too small. It is important both for the visual search for it and for clicking on it. This point is particularly important for the design of Websites aiming at elderly users.

- Detailed analysis of the nominal navigation flow

The deviation between the nominal navigation flow and the actual navigational structure frequently causes confusion in the navigation. In order to avoid such confusion a detailed analysis of the required navigational steps is recommended. In order to understand the demand and expectation of the users a cooperation with the users is an effective way. Ellis & Kurniawan (2000) already show a successful example in the cooperation with elderly users in “participatory design”. The ideas of elderly users certainly support a better design of Websites.

5. Conclusion

This experiment investigated the navigational behavior by using eye tracking. The result showed that most of the difficulties in Web use were common for younger and elderly users. In addition, some elderly user specific problems were confirmed. Most of these problems were related with the aging process such as the decline of the visual function and motor functions. The result of this experiment itself is maybe relatively easy to imagine. However, the important thing is that the difficulties for elderly people and their influences on human behavior were concretely shown based on objective data. Subjective evaluation also provides useful data for a better user interface design. However, as this experiment has revealed, subjective evaluation is filtered from the users’ point of view. Objective data is, on the contrary, convincing and skills from experimental studies are directly applicable to product development. The issues treated in this study are only one part of the whole aspect of Web design. Further experiments regarding other factors are expected.

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