

Designing a Web Page Considering the Interaction Characteristics of the Hard-of-Hearing

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Abstract. The purpose of this paper is to report a case study involving the successful redesigning of a Web page that was problematic for the hard-of-hearing. We found in our previous eye-tracking studies [1,2,3] that the page in question presented serious usability problems for the hard-of-hearing. Namely, the performance of hard-of-hearing participants was inferior to that of the hearing in terms of the following four performance measures: 1) scan patterns, 2) the number of errors and the time necessary to select the correct link, 3) the amount of time necessary to select a link, and 4) the types of selected links. We conjectured that these differences occurred because the informational organization of the original Web page was difficult for the hard-of-hearing to understand. Considering the Web interaction characteristics of the hard-of-hearing, we redesigned the page in two ways: 1) adding vertical lines that should function as visual support enabling the hard-of-hearing to grasp the informational structure easily, and 2) replacing difficult-to-understand labels with comprehensible representations. Observation of eye movements for the redesigned page revealed that the abovementioned differences disappeared, indicating that the redesign was successful. We believe that this case study exemplifies the successful redesigning of Web pages to make them more accessible to hard-of-hearing users.

1 Introduction

Recently, with continued advances in information technology, an ever-growing amount of information has accumulated on the World Wide Web. At the same time, the need to make the information accessible to any person who needs it has become a serious issue. This paper focuses on Web contents accessibility for the hard-of-hearing. This project was motivated by the fact that the first two authors, who are educators of hard-of-hearing persons, perceived in daily

classes that hard-of-hearing students interact with Web pages differently than hearing students do. These differences in material usage suggest that the hard-of-hearing may not effectively use educational materials that are not designed appropriately from their viewpoint. Therefore, as educators, the authors need to create Web-based educational materials that are accessible to hard-of-hearing users.

Consideration of Web content accessibility for the hard-of-hearing is usually limited to the issue of translating auditory information into sign language and/or text annotation (i.e. translating physically inaccessible representation of Web contents so that it is physically accessible). However, studies reveal that this simple translation is not sufficient to allow the hard-of-hearing to attain *true* accessibility. First, although a number of efforts have sought to utilize sign language in the Web environment (e.g. [4]), they are not always effective, at least in Japan, since only 10% to 20% of the hard-of-hearing can use the mother-tongue sign language. Second, the use of text annotation alone is not sufficient for the hard-of-hearing to understand appropriately the meaning of Web contents.

Using Web-based interactive materials seems effective for education since they allow the creator to control the presentation of the content. An excellent example is the Web-based educational material for film production developed by [5], which provides sign language for various countries. However, it is necessary to accumulate more knowledge about how the hard-of-hearing use the Web in a broader context, not restricted to the use of sign language, in order to help them gain the full benefits of the Web environment.

This paper is organized as follows. Section 2 describes our previous studies [1,2,3] that presented Web interaction characteristics of the hard-of-hearing. Section 3 reports on a case study concerning the redesign of a problematic Web page for the hard-of-hearing by considering the Web interaction characteristics of the hard-of-hearing. The redesign was proven successful in terms of various performance measures. We believe our practice successfully creates effective Web-based interactive materials for the hard-of-hearing.

2 Web Interaction Characteristics of Hard-of-Hearing

This section reviews our previous studies [1,2,3] that revealed differences between the Web-browsing behavior of hard-of-hearing persons and that of hearing persons when they accomplished a task on an experimental Web page that simulated a then-existing automobile site. The participants were asked to locate a page that described a designated car model, and to choose a favorite color for it. We recorded their link selections and eye movements, and analyzed the data from the top page.

2.1 Task

The task was to locate a page that described car model Z4, and to choose a favorite color for it. The subjects were given the following instruction: "Please

choose your favorite color for the car model Z4.” The task was performed on an experimental Web site modified from an actual automobile Web site. The left portion of Figure 5 illustrates the top page, which consisted of five columns (four content columns and one news column) and a field at the bottom of the page where the names of car models were listed. Content columns had a heading at the top, a picture with promotional text in the middle, and a list of topics at the bottom. An important feature of this page was that the contents were organized vertically. Successful task performance required correct understanding of the page layout, since the column boundaries were not clearly defined.

2.2 Differences in Performance

We examined four performance measures to understand Web interaction characteristics of the hard-of-hearing: 1) scan patterns, 2) the number of errors and the time necessary to select the correct link, 3) the amount of time necessary to select a link, and 4) the types of links the participants selected. The following subsections briefly discuss how the hard-of-hearing’s performance differed from that of the hearing in terms of these performance measures.

Scan Patterns. Figure 1 compares the scan path of one hard-of-hearing participant (left) with that of one hearing participant (right). The two participants took approximately the same amount of time to accomplish the task. However, it is clear from the figures that their scan paths were completely different. The left scan path (hard-of-hearing) does not reveal any clear pattern of scanning. On the contrary, the right scan path (hearing) indicates a vertically aligned scan path, consistent with the underlying semantic structure of the page.

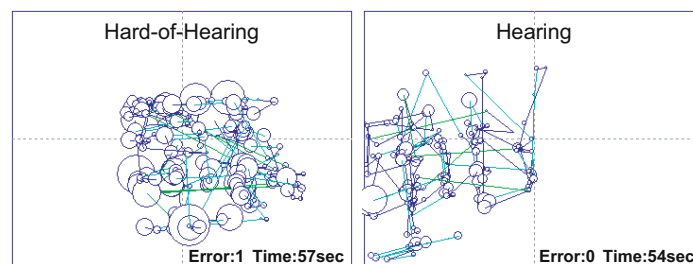


Fig. 1. Differences in scan patterns (adapted from [2])

Number of Errors / Correct Link Selection Times. In order to accomplish the task, the participants had to select a correct link on the top page, but they made a number of wrong selections. Table 1 presents the average number of errors and the average time taken to select the correct link. It is clear that the hard-of-hearing committed errors more often than the hearing did. And the hard-of-hearing took longer than the hearing to select the correct link.

Table 1. Average number of errors and average time to select correct link: hard-of-hearing vs. hearing

	Hard-of-Hearing	Hearing
Average Number of Errors	4.9	2.6
Average Time to Select Correct Link	2 min 42 sec	1 min 27 sec

Processing Times per Link Selection. Figure 2 indicates the time taken to select correct links as a function of the number of link selections. The squares denote the hearing participants. They align on the regression line; the slope corresponds to the time necessary for the hearing to click a link. In contrast, the circles, which denote the hard-of-hearing, do not reveal any correlation. These results imply that the hearing took a certain amount of fixed time before selecting a link, while the hard-of-hearing did not use such a strategic search method when selecting a link.

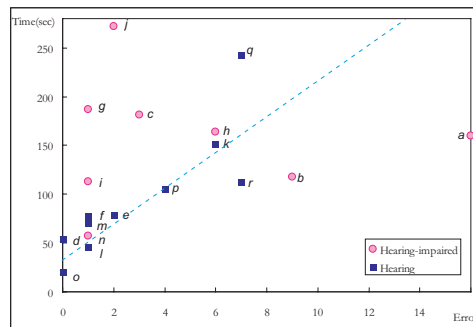


Fig. 2. Time necessary to select a link (adapted from [2])

Nature of Link Selections. We examined the types of the links that the participants selected. The two classes of links are those that contain semantic information and those that contain non-semantic information. The semantic-information links include 1) heading, 2) index, and 3) related (i.e. semantically related to the task goal) links. The non-semantic information links include 1) animation, 2) picture, 3) direct (i.e. cryptic symbol link such as “Z4”), and 4) other clickable objects.

The left pie chart of Figure 3 illustrates the types of links that the hearing participants selected, and the right pie chart depicts those that the hard-of-hearing chose. Overall, the hearing tended to select the semantic-information links more often than the hard-of-hearing did (49% versus 21%). Conversely, the hard-of-hearing selected non-semantic information links more often than the hearing did (62% versus 36%).

Figure 4 combines the two pie charts into a single chart to clarify the differences. The three link types plotted in the upper-right direction correspond

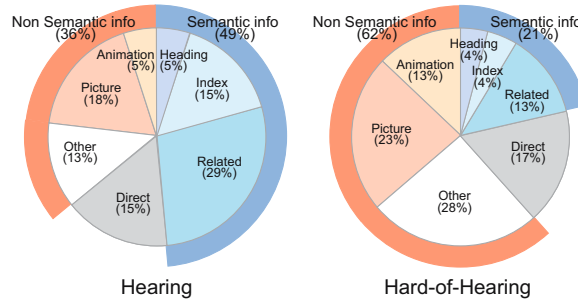


Fig. 3. The types of links that the hearing participants and the hard-of-hearing selected (the pie charts are adapted from [2])

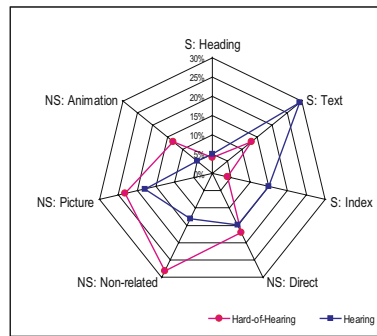


Fig. 4. Differences between the types of links that the hearing and the hard-of-hearing participants selected

to the semantic-information links, and the four link types in the bottom-left direction correspond to the non-semantic information links. The bold line denoting the hearing dominates in the upper-right direction and the thin line denoting the hard-of-hearing dominates in the bottom-left direction. It is clear from the figure that the types of links the participants selected were significantly different in terms of the amount of semantic information contained in the links.

3 Guidelines and Redesign

This section describes the accessibility guidelines that serve as guiding principles for designing accessible Web pages for the hard-of-hearing. It then reports on the redesign of the Web page used for our previous experiment to improve hard-of-hearing usability by following the principles described in the guidelines, and utilizing knowledge about the characteristics of the hard-of-hearing identified in our previous experiments.

3.1 Accessibility Guidelines for Hard-of-Hearing

Designers of Web-based materials should refer to Web design guidelines from W3C's WAI and the US Government Section 508. The guidelines are presented under "Principles," accompanied by an explanation as to who benefits from them.

In W3C's Web Content Accessibility Guidelines [6], Principle 1 suggests that providing alternatives to audio information is the key to Web accessibility for the hard-of-hearing. The US Government Section 508 recommends attaching synchronized captions to audio, video, and multimedia material for hard-of-hearing users. The primary focus of Web materials and computer-based support for the hard-of-hearing is the provision of computer-generated images of sign language and real-time text annotation. Almost all currently used guidelines involve the substitution of audio information as the only aspect of Web-based interaction. These techniques are appropriate for Principle 1. From the viewpoint of Web-material designers, it is technically easy to conform to this principle; we simply need to provide substitutes for auditory information. However, our experiments clearly demonstrated that the hard-of-hearing's style of accessing text information differs from that of hearing persons, and not all hard-of-hearing persons use sign language. Thus, the current use of guidelines for the hard-of-hearing may be seriously limited. W3C's Principle 3, in contrast, indicates that "content and controls must be understandable." This principle is important because Web-based tasks are performed interactively, requiring comprehension of information provided on the computer screen.

3.2 Redesign

We redesigned the page according to Principle 3 by considering interaction characteristics of the hard-of-hearing. More specifically, we conjectured that the design of the experimental Web page was not self-evident from the way the information was organized. Hard-of-hearing participants would have had difficulty capturing hidden semantic structure, partly because their primary language is not written language.

Considering the Web interaction characteristics of the hard-of-hearing, we redesigned the page in two ways: 1) adding vertical lines that should function as visual support enabling the hard-of-hearing to grasp the informational structure easily, and 2) replacing difficult-to-understand labels with comprehensible representations. The left portion of Figure 5 depicts the original design, and the right presents its redesign. We expected that this redesign would improve the site's usability for hard-of-hearing persons. The results of the evaluation confirmed that this redesign was effective.

3.3 Evaluation

Five hard-of-hearing persons participated in the experiment. Their eye movements were recorded with the use of an EMR-HM8 of NAC, Inc. The task images

were projected onto a flat screen 150cm in front of the subject. The projection window was 90cm wide by 75cm high, with a viewing angle of 33 degrees horizontal by 27.5 degrees vertical. The data sampling rate was 60 Hz. We recorded the participants' link selections and eye movements, and analyzed the data from the top page. The right portion of Figure 6 depicts a typical eye movement pattern of the hard-of-hearing participants for the redesigned page. Table 2 indicates the improvement of performance in terms of average number of errors and average time taken to select the correct link.

The improvement was significant. The average number of errors decreased from 4.9 for the original page to 0.8 for the redesigned page, and the average time taken to select the correct link decreased to 42 seconds, which was 2 minutes faster than the time required for the original page. The hard-of-hearing's



Fig. 5. Original design and redesign

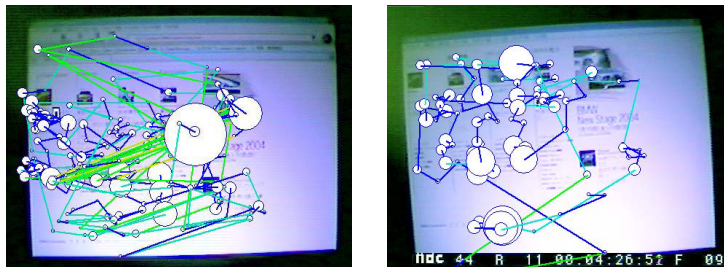


Fig. 6. Scan path of one hard-of-hearing participant (left, original design; right, after redesign)

Table 2. Average number of errors and average time to select correct link of hard-of-hearing: original page vs. redesigned page

	Original Page	Redesigned Page
Average Number of Errors	4.9	0.8
Average Time to Select Correct Link	2 min 42 sec	0 min 42sec

performance on the redesigned page was comparable to or even better than that of the hearing (right column of Table 1). These results imply that, with the redesigned page, the hard-of-hearing participants appropriately captured the informational organization of the page and as a result were able to perform the task efficiently. It was assumed that with the original page the hearing captured the hidden informational structure and therefore performed better than the hard-of-hearing, who had difficulty capturing it. The redesign appeared to eliminate the hard-of-hearing's difficulty in processing ambiguously designed informational structure and to orient the cognitive resources in the right direction.

4 Conclusion and Future Plans

An important lesson is that what is obvious for the Web-literate is not necessarily obvious for the hard-of-hearing. Hidden semantic structures caused by fancy design ideas were not easy for the hard-of-hearing to capture, resulting in a serious usability problem. Their eye movements told us clearly where the source of confusion was and suggested the effective design change. A small design consideration resulted in a large improvement of the Web site's usability.

As stated above, the W3C's Web accessibility guidelines say only *what to do*, but not *how to do it*. This study exemplifies how accessibility can be accomplished. We believe that the accumulation of techniques is important to the achievement of accessibility for the hard-of-hearing. We plan to continue using this approach with various Web sites.

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