EVALUATION AND ENHANCEMENT OF WEB CONTENT ACCESSIBILITY FOR PERSONS WITH DISABILITIES

by

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Web content accessibility is to which degree a site is accessible to the largest possible range of people, especially for persons with disabilities. The current study comprises four interrelated parts revolving around evaluating and enhancing Web content accessibility.

First, a novel measurement metrics called Web Accessibility Barriers (WAB) score is constructed based on published Web accessibility design guidelines. The performance of the measurement metrics is assessed using a Web accessibility gold standard. The Receiver Operating Characteristic (ROC) curve shows that WAB score separate inaccessible Web pages well from accessible ones with Area Under the Curve (AUC) value of 0.917.

Second, using the WAB score, I evaluate the degree of Web accessibility of consumer health information websites. Mean of WAB score of the 108 selected websites is 9.31 with standard deviation of 6.29. Among those websites, government and education websites have lower WAB score – 0.39 and 1.16 respectively. ANalysis Of VAriance (ANOVA) test shows statistical significances across different functional categories of the websites ($F=9.705$, $p < 0.001$). In addition, this study shows that WAB score correlated with traffic rank of the websites with ($r = 0.32$, $p < 0.01$).

Third, a usability study is conducted to examine the performance of a Web Transcoder Gateway (WTG) server for blind Web users to access online information. The WTG server removes Web accessibility barriers in real time based on Web accessibility design guidelines. The study design is a within-subject cross-over design. A mixed model analysis is employed to examine the effect of the WTG server on time, success, errors, and subjective measurement. Sixteen blind Web users took part in the study. Results show that participants spent less time, make few errors, and succeed more on the tasks via WTG server. Participants also feel more satisfactory, less frustrated, and more confident when access online information via WTG server. Observational and anecdotal findings imply that only removing accessibility barriers may not be sufficient to achieve the best usability for blind Web users.

Finally, a usability study is conducted to examine the performance of a Web Transcoder Gateway (WTG) server for PDA users to access Web sites. The study design is also a within-subject cross-over design. A mixed model analysis is employed to examine the effect of WTG server on time, success, and subjective measurements. Twenty subjects took part in the study. Results show that participants spend less time on each task via WTG server. Each participant can finish the tasks successfully via either WTG server or non WTG server. This implies that the WTG server can serve as "Electronic Curb Cut" for Web users under constraints. However, the participants show no statistically significant preference to WTG server.

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Chapter 1 INTRODUCTION

1.1. Web Accessibility -- Definitions

Web accessibility can be defined simply as to which degree a site is accessible to the largest possible range of people. The more people are able to access a website, the more accessible is the site. At its core, Web accessibility emphasizes making website accessible to persons with disabilities and involves removing potential barriers to access caused by inconsiderate website designs.

The World Wide Web Consortium (W3C) is an international organization dedicated to the standardization of the World Wide Web [1]. In 1996, W3C established the Web Accessibility Initiative (WAI) initiating a campaign that called for a more accessible Web for persons with disabilities. For the consortium, Web accessibility was defined as "access to the Web by everyone, regardless of disability."[2] The WAI approach to Web accessibility revolves around three interrelated fronts: First is the content accessibility of websites for persons with disabilities to perceive, understand, and use. The current study concentrates on this area. Second is making Web browsers and media players usable for persons with disabilities by making them operable through assistive technologies. The third component requires Web authoring tools and technologies to support production of accessible Web content and sites, so that persons with disabilities can use them effectively.

Vanderheiden [3] provides a general definition of "accessible" in the general sense of information technology as "able to be used effectively by individuals either directly or with the assistive technologies that they will have with them and can use when they encounter the environment, device, or system." Using Vanderheiden's definition as a basis, Web accessibility can be defined as the degree to which it is accessible through assistive technologies used by persons with disabilities. For example, most blind web users use a screen reader or voice browser to access Web pages. If the assistive technologies cannot process all the information on a Web page in the way a sighted user can process, the Web page therefore is not accessible to the blind users. On the other hand, if the assistive technology can successfully process the Web page, but the audio information produced is hard for blind Web user to understand, it is not accessible either. Thus, with regard to persons with disabilities using assistive technologies, we can define Web accessibility as equivalence and understandability of Web content via assistive technologies.

Figure 1-1: Relationships among webpages, assistive technology, and persons with disabilities

1.2. Beneficiaries of Accessible Web Content

The Web, regardless of its compliance with accessibility guidelines, by default is not accessible to people with some types of disabilities because of the limitations those disabilities place on certain sensory channels. The role of assistive technology is to compensate for the limitations and to help persons with disabilities to access, receive, and interpret Web content. Assistive technology either is a piece of computer hardware or a software package that is used to increase, maintain, or assist the functional capabilities of individuals with disabilities. Therefore, accessibility to the Web for persons with disabilities is determined by the degree of communication between the Web content and the assistive technology.

People with one of the four primary categories of impairments – vision, hearing, mobility, or cognitive and learning disabilities – would benefit most from an accessible Web content because they have suffered the most from inaccessibility of Web content. In the following sections, I will briefly introduce each type of disability, and then describe ways in which these people use computers and the Internet. For more information, WAI provides a more detailed description of scenarios in which persons with disabilities use the Web [4].

1.2.1. Vision

Individuals with visual disabilities include those who are blind, colorblind, or have low vision. Usually, blind people rely on a screen reader or Braille printer to access content from a Web page. Image or any image-related Web content is not yet directly interpretable by the assistive technology used by the blind user. HyperText Markup Language (HTML) standard define an alternative text attribute with each non-textual elements to support non-visual content understanding. However, developers' ignorance in providing this alternative textual information has set up tremendous barriers for blind people. In addition, blind person find that mouse is useless because of the eye-hand coordination required. Instead, they use the "Tab" key or shortcut key combinations provided by screen reader to move the cursors on the screen. Any information requires mouse interaction will be completely inaccessible to blind Web users.

Users with low vision need the assistance of hardware or software to magnify the content on the screen. Such magnification result in reformatting the location, changing the contrast, or distorting the size and fonts of the text and objects on the Web page, therefore a redundant attributes designation is crucial in maintaining the originality of any Web content. For example, rather than using size attributes on the font element to denote a heading, the heading elements should be used to mark up a content heading correctly so that assistive technology can identify headings.

Colorblind people stumble on Web pages that present information in color-only format. For example, Web developers often use reds to stress certain words or sentences; for those who are colorblind, red has no perceived difference from other colors. Therefore, when information is presented in color only, a colorblind person may miss that information.

1.2.2. Hearing

People with hearing disabilities include those who are deaf or hard of hearing. On a Web page, they require a visual representation of any auditory information presented and can include synchronized closed caption of video clips, blinking text for alert messages, and transcripts of the audio. Individuals with hearing disabilities faces a greater number of obstacles on the Web than before, because more and more multimedia content is put online as a results of ever-increasing bandwidth.

1.2.3. Mobility

Individuals with mobility disabilities have physical impairments that substantially limit either their movement, such as lifting or walking , or fine motor control like typing. These people face difficulties using computers input devices or handling removable storage media (a floppy disk, an optical disk or other removable devices). Assistive technologies for persons with mobility disabilities include switches, latches, and controls that are easy to manipulate, and diskettes and media that are easy to plug and unplug. Other solutions include alternate input approaches, such as voice input or the ability to enter information at the user’s own pace. For instance, sequences of keystrokes can be typed, one at a time, rather than require simultaneously pressing keys Ctrl+Alt+Del. People with upper limb mobility disabilities often find a mouse useless when interacting with the computer since it mandates fine movement of arms and fingers. Other Web accessibility techniques that help individuals with mobility disabilities include decreasing the number of links in a page and providing equivalent keyboard access for mouse clicking.

1.2.4. Cognitive and Learning Disabilities

Those with cognitive or learning disabilities, such as dyslexia or short-term memory deficit, need solutions to Web accessibility that include consistent design, straightforward navigation, and simplified language. For example, a Web developer by applying a consistent design template can help users familiarize themselves with the structure and layout of webpages, so that a person with cognitive and learning disabilities can easily navigate through a website and appreciate the information. These people also benefit from redundant information like the audio output of a Web page. By simultaneously viewing the Web page and hearing it read aloud, they can utilize both their visual and auditory skills to comprehend the material.

1.3. Importance of Web Accessibility

1.3.1. Ethics

The Web is becoming the new societal platform where people can provide, share, search and locate information, as well as conduct community activities. Excluding anyone from this new platform is ethically inappropriate and unacceptable. Moreover, the Internet, and especially the Web, has brought tremendous advantages to people who have difficulty accessing information in printed formats. Persons who are visually impaired equipped with a screen reader or voice browser, for example, can access newspapers (many newspapers provide equivalent information on the Web equivalent to their printed version) without relying unduly on others, as they did before the age of the Web. The exclusion of such freedom of accessibility to information is a miserable extension of what happened in the real world to previous generations – physical abilities decided the level of inclusion in society.

1.3.2. Demographics

Lack of web accessibility affects more people than just those with of disabilities. Web accessibility is a major concern not only for persons with sensory disabilities such as hearing or vision, but also for those with communication, cognitive, mobility and other disabilities. An image button without alternative text is an accessibility barrier to blind people. A Web page that requires the user to click a number of times to progress through the site or page is likewise inaccessible to people with mobility limitations. To the degree that they restrict or prevent persons with disabilities (or people with the diminishing strength or dexterity that comes with age) from using the Internet, such features of the Web page constitute barriers to access and participation at all stages of daily life.

The U.S. Census Bureau estimates that one in five people may have certain type of disabilities [5]. To be specific, disabled persons represented 19.3 percent (49.7 million) of the 257.2 million people age five or older in the civilian, non-institutionalized population. Despite these numbers, some may still ask why access to the Internet is an issue for society as a whole. As President Bush pointed out in his New Freedom Initiative, "Disability is not the experience of a minority of Americans. Rather, it is an experience that will touch most Americans at some point during their lives."[6] In other words, should everyone in society manage to live long enough, all of us will eventually develop some sort of disability, or experience functional limitation severe enough to be considered a disability. The trend of an increasing percentage of persons with disabilities within the older age group is illustrated in

Figure 1-2. With the generation of "Baby Boomer" getting older, it is predictable that the percentage of senior citizens will increase in total population. Combining these two factors, the number of persons with disabilities will increase in the near future. Many seniors do not even consider themselves as persons with disabilities despite the decrement of their physical and cognitive functional abilities.

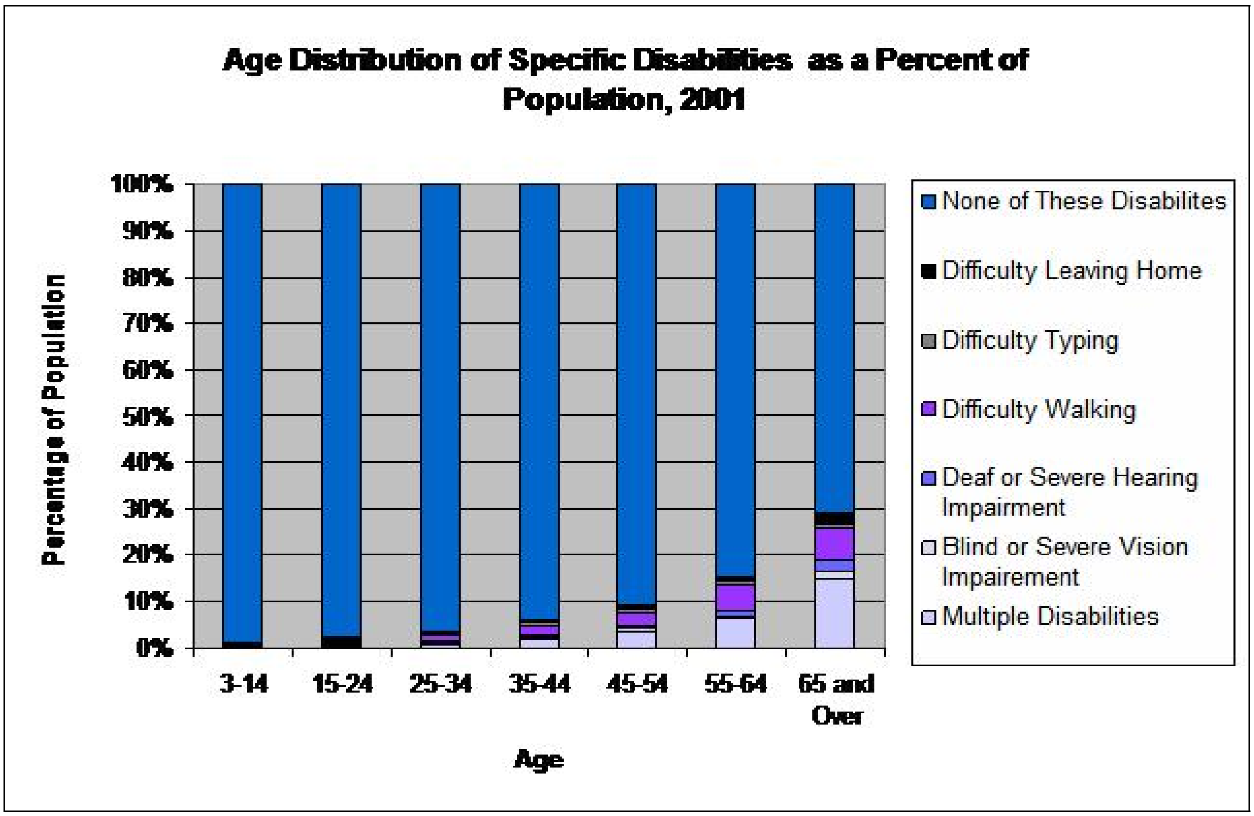

Figure 1-2: Disability by age group

1.3.3. Political and Legislative Issues

Federal legislation has been introduced to provide mandates for and to help advising the creators and developers of electronic information in their design of and compliance with accessibility concerns. Documents important to the current study include Section 504 of the U.S. Rehabilitation Act of 1973 (Section 504), the Americans with Disabilities Act of 1990 (ADA), and Section 508 of the 1998 Amendment to the U.S. Rehabilitation Act of 1973 (Section 508). The following paragraphs highlight key points in each act; Chapter 2 features a section that introduces the legislation in detail.

1.3.3.1. Section 504

Section 504 lays the groundwork for the rights of the disabled population in the public setting and receives federal funding. Section 504 establishes that disability rights are a form of civil rights and therefore are protected by the 14^{th} Amendment to the U.S. Constitution and is enforced by the Office of Civil rights. Section 504 prohibits discrimination against persons with disabilities in programs and activities receiving federal funding. Section 504 is the first civil rights statute designed to prevent discrimination against persons with disabilities and is patterned after the Civil Rights Act of 1964.

1.3.3.2. Americans with Disabilities Act (ADA)

The Americans with Disabilities Act of 1990 (ADA) applies to all goods and services provided by the government and requires that all public facilities, not just those receiving federal funding, be accessible to the disabled population. In addition to the physical plant, businesses with fifteen or more employees must make both their facilities and information technologies accessible to disabled employees.

1.3.3.3. Section 508

Section 508 of the U.S. Rehabilitation Act of 1973 (Section 508) was specifically legislated to require better access to publicly funded electronic information, including websites, for persons with disabilities. §1194.22 of Section 508, "Web-based Intranet and Internet Information and Application", requires that Web pages and other digital media be created in compliance with rules defined by Section 508. The Architectural and Transportation Barriers Compliance Board

(Access Board) creates the standards governing Web accessibility in Section 508. The ultimate goal of Section 508 is to ensure that individuals with disabilities seeking information or services from federal agencies or any one receiving federal funding have access to this information comparable to the way in which it is provided the non-disabled public.

1.3.4. Economics

After the initial cost of implementation, many techniques and methods introduced by accessible Web design often lead to longer-term economic benefits. Such economic benefits include expanding the audience; improving usability under constraint situation for disabled users and non-disabled users alike; improving search engine ranking because of the availability of text alternatives; supporting a future semantic web; and reducing site maintenance [7]. Many guidelines and checkpoints for making accessible Web pages will bring expanded business market and improved technique efficiency to a website.

The cost of making accessible websites depends on the developmental stage at which the website developers want it accessible. The later in the developmental stage, the more costly to make a site accessible. Although the cost of making an accessible page depends on the time and money spent in training Web developers and investing in tools for quality assurance, they can be minimized if Web accessibility is considered in the early stage of the design process.

One important benefit of an accessible website is its natural extension of the principles of universal design. Universal design is the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design [8]. Universal design, with its multi-modality – support for visual, auditory, and tactile access – benefits other users who access the Web through mobile phones with small display screens, Web-TV, and kiosks. It also increases the usability of websites under a variety of circumstances such as low-bandwidth (images slow to download using dial-up modem); noisy environment (difficulty hearing); non-functioning monitors (difficulty seeing the screen); and distraction impossible (driving). Web accessibility requires providing redundant text, audio and video information to people using different channels of perception. Consequently, it supports those with different learning styles or low level of, and English as second language.

1.4. Research Questions

This current study concentrates evaluating and enhancing Web accessibility for persons with disabilities. A novel metrics that measures Web accessibility has been constructed, and its performance is evaluated against a gold standard. Accessibility to consumer health information websites is measured using the metrics. To make existing Web pages accessible to persons with disabilities, we developed a Web Transcoder Server that provides real-time retrofitting of existing Web pages. The server's performance is evaluated from the perspective of usability for persons with disabilities. We also evaluate the idea of an "electronic curb cut" – enhanced Web accessibility can provide auxiliary benefits to users under other circumstances.

The current study focuses on four key research questions.

1.4.1. Measuring Web Accessibility

How can we measure the degree of Web accessibility with considerations for the complexity of the website?

- Can we construct a measurement metrics including both true violations and potential violations of Web accessibility-related elements?
- What is the performance of the measurement metrics?

1.4.2. Evaluation of Web Accessibility of Consumer Health Information Websites

- For people with disabilities, what is the degree of Web accessibility of websites for persons with disabilities, especially that providing consumer health information?
- Is there a relationship between the degree of Web accessibility and the functional categories of these websites?
- Is there a relationship between the degree of Web accessibility and the popularity of these websites?
- Is there a relationship between the degree of Web accessibility and the importance of these websites?

1.4.3. Performance of the Web Transcoder Server for Blind Web Users

- Is there any difference in time spent by blind Web users in accessing websites via the Web Transcoder Server or not?
- Is there any difference in error rates by blind Web users in accessing websites via the Web Transcoder Server or not?
- Is there any difference in success rates by blind Web users in accessing websites via the Web Transcoder Server or not?
- Is there any difference in subjective rating by blind Web users in accessing websites via the Web Transcoder Server or not?

1.4.4. Performance of Web Transcoder Server for PDA Web users

- Is there any difference in times spent by PDA Web users in accessing websites via the Web Transcoder Server or not?

- Is there any difference in success rates by PDA Web users in accessing websites via Web Transcoder Server or not?
- Is there any difference in subjective rating by PDA Web users in accessing websites via Web Transcoder Server or not?

1.5. An Outline of the Dissertation

Chapter 2 provides a background review of works, in three parts, relating to Web accessibility. Part 1 examines the specifications related to the definitions and implementations of Web accessibility. Part 2 reviews the evaluation studies of Web accessibility across different fields including higher education, library, government, and health care websites. Section 3 provides an assessment of the approaches to Web accessibility enhancement, focusing primarily on the Web intermediary approach, which functions as an information proxy for people with disabilities and general Web users as well. Part 3 also provides a technical overview of the Web Transcoder Server currently under development at the Department of Health Information Management at University of Pittsburgh.

Chapter 3 describes the measurement metrics, developed for the current study, which is an instrument that assesses the degree of Web accessibility for each website. This chapter introduces a new metrics called the Web Accessibility Barrier (WAB) as a way of measuring the Web accessibility degree of a website that takes into consideration the number of potential violations of Web accessibility checkpoints and total webpages of a website. Chapter 3 also reports on the performance of WAB scoring ability in separating accessible from inaccessible Web pages.

Chapter 4 offers a cross sectional evaluation study using the measurement metric established in Chapter 3. This evaluation study concentrates on the degree of Web accessibility of consumer health information websites for persons with disabilities. In addition to the status of Web accessibility, the functions, importance, and popularity of these websites and their relationship to the degree of Web accessibility are investigated as well.

Chapter 5 underscores the impact of removal of Web accessibility barriers on usability for persons with disabilities. I employ usability-testing methods that measure the degree of the usability both before and after the removal of Web accessibility barriers stipulated by Web accessibility specifications. Measurements used in the current study include error rate, success rate, time spent on certain tasks, and users' level of satisfaction.

Chapter 6 investigates the auxiliary benefits of the solution of Web accessibility for people using Personal Digital Assistant (PDA). The Web Transcoder Server removes the barriers or limitations for Blind Web users as well as for PDA users. Similar scenarios from Chapter 5 are adopted here as well.

Chapter 7 summarizes my studies in the dissertation and provides further insight into future research in the area. This section also offers broad overview and discussion of previous chapters, and examines the directions the research and applications of Web accessibility can take in future.

Figure 1-3 lists al of the research involved in the current study and provides a roadmap f their interrelationship.

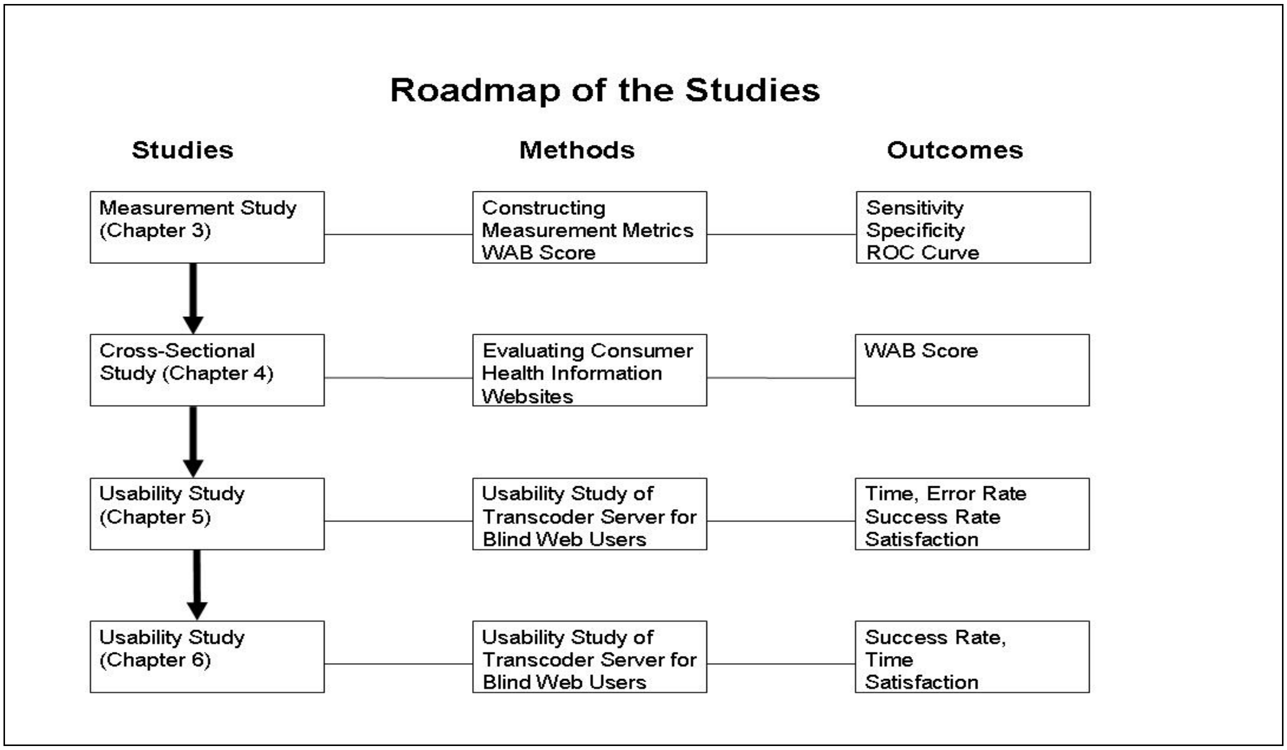

Figure 1-3: Outline of the studies

Chapter 2 BACKGROUND

2.1. Overview

This background chapter presents three sections related to the current study. Section one covers standards, laws and regulations, and guidelines on web accessibility. Section two includes a literature review on the evaluation methods already adopted by previous studies and their results. Section three briefly discusses the Web Transcoder Server, an information intermediary server that can adapt Web pages to designated formats in real time. The Web Transcoder Gateway serves as the intervention in the usability studies discussed in Chapter 5 and 6.

2.2. Standards and Legislations

2.2.1. Standards

The essence of the Web accessibility issue is about designing webpages with which users can interact according to their needs and preferences. Although improved Web accessibility will benefit all users, the current primarily focus on accessibility for persons with disabilities. The inventor of the World Wide Web, Tim Berners-Lee, once said, “The power of the Web is in its universality. Access by everyone regardless of disability is and essential aspect.”[9]

The concept of Web accessibility is not completely new. In the 1990s, Web accessibility information was available from organizations such as Trace Research and Development Center and companies such as IBM [10, 11]. One of the earliest web content design standards for access by persons with disabilities was developed in San Jose, California [12]. In 1997, Australia’s standards for accessible web design were made available to the web page authors [13]. That same year, the World Wide Web Consortium established the Web Accessibility Initiative (WAI) [9]. In 1999, The WAI published the Web Content Accessibility Guidelines (WCAG) 1.0, which contained their definitive recommendations [14].

W3C is responsible for establishing standards for web technologies. These standards include guidelines concerning mainly with the use of descriptive alternative tags, color, the avoidance of tables, and other suggestions that allow greater accessibility to the visually impaired and the use of screen readers [14]. Flowers, Bray & Algozzine [15] underscore the W3C's commitment to provide standards, which promote accessibility for persons with disabilities and stress that the building of accessible websites should be a high priority for Web page developers. Paciello [12] comments on W3C:

> The W3C is committed to removing accessibility barriers for all people with disabilities – including the deaf, blind, physically challenged, and cognitive or visually impaired [.. and] to work aggressively with government, industry, and community leaders to establish and attain Web accessibility goals. (p2)

Paciello [12] further said that "The World Wide Web Consortium is the international industry consortium whose mission is 'to lead the World Wide Web to its full potential by developing common protocols that promote its evolution and ensure its interoperability" (p.2).

WAI is an initiative created by a subgroup of W3C. Paciello [12] reports the WAI's mission as follows: "The W3C's commitment to lead the Web to its full potential includes promoting a high degree of usability for people with disabilities" (p2). The WAI's Web Content Accessibility Guideline 1.0 (WCAG1.0) examines accessibility issues and provides solutions for improving accessibility of websites for the disabled population. WCAG 1.0 is recognized as the governing standard and explains how to make Web content accessible to persons with disabilities. Its guidelines are intended for all Web content developers (both Web page authors and website designers) and for developers of authoring tools. The primary goal of these guidelines is to promote accessibility. However, following them will also make Web content more available to and usable for all users, regardless of user agent (e.g., desktop browser, voice browser, mobile phone, or automobile based personal computer) or constraints under which users are operating under (e.g., noisy surroundings, under- or over-illuminated rooms, or a hands-free environment). Heading these guidelines also helps users find information on the Web more quickly. They do not discourage content developers from using images, video, and other multimedia contents, but rather explain how to make multimedia content more accessible to a wide audience.

In providing guidelines for accessible Web page development, the WAI coordinates with organizations world wide in order to pursue Web accessibility through five primary areas: technology, guidelines, tools, education and outreach, and research and development [12].

In addition to WAI standards, other entities have also produced other types of guidelines that assist the Web designer in creating accessible websites for the disabled population.

The National Council on Disability (NCD) [16] suggests the following when developing accessibility guidelines:

- Organization processes to ensure consideration of accessibility (universal design) at all levels of product development and delivery;
- Built-in access versus access via assistive technology such as screen readers and specialized input devices;
- Industry-based or government-established standards versus voluntary guidelines;
- Techniques for accessible input, output, and controls;
- Methods to provide access to online help and product documentations; and methods to ensure customer support for disability access. (p.8)

Rowland and Smith (1999) provide guidelines for Web accessibility which are adapted from both the WAI WCAG 1.0 guidelines and from Microsoft's Accessibility website[17]:

- Provide a good text equivalent for every non-text element (i.e. images, image maps, animations, applets, frames, scripts, sounds, audio or video files, or PDF files).

    - Use ALT tags to convey important information about these elements.
    - For complex elements, provide a link to a separate page with a more detailed description.
- Do not rely on color alone.
- Provide good keyboard navigation.
    - Verify that the TAB key moves between links and image maps in the order defined.
    - Utilize the TABINDEX attribute to specify alternate orders.
    - Use the ACCESSKEY for all controls.
- Properly use style sheets and tables.
    - Do not require the use of style sheets.
    - See style sheets to control layout and presentation.
    - Avoid using tables for layout.
    - When tables are used, make sure that they make sense when read left-to-right, top-to-bottom.
    - Provide alternative pages for complex tables.
- Support the reader's formatting options.
    - Do not rely on specific fonts, colors, or sizes.
    - Use real heading tags, not just formatted text.
    - Do not require a specific window size.
    - Do not assume things will line up vertically, because horizontal distances may change.
    - Do not require the use of style sheets.
- Use good design principles.
    - Link text should be meaningful but grief.
    - Use link text that can stand alone, as when the user is given a list of the links
    - In the file, as a general rule, menus should be kept to between 7 and 9 items. Provide textual (verbal) cues where needed.
- Test your site for accessibility.
    - Turn off graphics to make sure the ALT text displayed makes the page usable
    - Turn off sounds to make sure no important instructions are lost
    - Turn off style sheets to make sure page is still readable.
    - Navigate using the keyboard to make sure the TAB traverses all links in a reasonable order.
    - Copy all text and paste it into a world processor. Make sure it is still readable.
    - Use BOBBY to examine you page..
    - Test your pages in specialized browser used by people.

2.2.2. Law and Regulations

Both legislative policies as and the aforementioned standards and guidelines are two driving forces ensuring Web accessibility for the disabled. Three legislative documents in the U.S. relating to the current study include Section 504 of the U.S. Rehabilitation Act of 1973 (Section 504), the American with Disabilities Act of 1990 (ADA) and Section 508 of the 1998

Amendments to the U.S. Rehabilitation Act of 1973 (Section 508). These government documents lay the groundwork for website accessibility issues in three ways: 1) Governments can establish accessibility rights to certain information for the disabled; 2) require that products sold meet accessibility standards; or 3) require that information procured by government agencies meet accessibility guidelines [18].

2.2.2.1. Section 504 of the U.S. Rehabilitation Act of 1973 (Section 504)

Section 504 addresses the rights of the disabled population in a school setting, establishing that disability rights are a form of civil rights and, as such, are protected by the 14^{th} Amendment of the U.S. Constitution and is enforced by the Office of Civil Rights (OCR). Section 504 prohibits discrimination against persons with disabilities by programs and activities receiving federal funding, which includes virtually every institution of higher education except the U.S. military academies and a few small religious schools. Patterned after the Civil Rights Act of 1964, it was the first civil rights statute designed to prevent discrimination against persons with disabilities. Section 504 affects institutions of higher education, requiring they provide reasonable accommodations for disabled students and equal opportunities for attending courses, programs, activities, and extracurricular activities. Colleges and Universities had to make academic adjustments in order to protect the rights of disabled students including providing auxiliary aids and a variety of services to the student at no cost.

2.2.2.2. The Americans with Disabilities Act of 1990 (ADA)

The 1990 Americans with Disabilities Act passed provides equal protection and access to public accommodations for people with a variety of disabilities including visual, auditory, mobility, and other mental and physical health-related conditions. The bill requires that businesses with fifteen or more employees make both their facilities and their equipment, including information technology accessible to the disabled. The U.S. Department of Justice [19] explains that the

ADA 1990 extended the 1973 legislation of public and commercial facilities, and not just those receiving federal funds. In 1996, the ADA further clarified those government entities on the Internet to require that those providers whose services are deemed to be public also accommodate the disabled population. Schmetzke [20] clarified that when the ADA was first passed, the Web as we know did not yet exist. Furthermore, Schmetzke states:

> Most electronic information was provided in text format, which is easily read with screen readers. The potential barriers created by poor web design was certainly beyond the horizon of legislators and federal administrators. Thus, it does not come as a surprise that the ADA, while mandating equal access to an institution's resources, does not specifically address the design of web-based information services. Subsequent interpretations of the ADA, however do.

2.2.2.3. Amendment of the U.S. Rehabilitation Act of 1973 (Section 508)

Section 508 was amended to ensure that persons with disabilities have equal access to electronic information, directing the Architectural and Transportation Barriers Board (Access Board) to set standards for federal agencies to ensure compliance. In addition, Section 508 provides a means for self-evaluation of electronic and information technology by federal agencies affected by the ruling. The Access Board issues final accessibility standards for electronic and information technology covered by Section 508 of the Rehabilitation Act Amendment of 1998. Section 508 requires the Access Board to publish standards that set forth a definition of electronic, information technology, and the technical and functional performance criteria necessary for such technology in order to comply with Section 508. It also requires that when Federal agencies, when they develop, procure, maintain, or use electronic and information technology, shall ensure that this electronic and information technology allows Federal employee with disabilities access to and use of information and data comparable to the access to and use of information and data by Federal employees who are not individuals with disabilities, unless, in complying, an undue burden would be imposed on the agency. Section 508 further requires that individuals with disabilities, who are members of the public seeking information or services from a Federal agency, access to and use of information and data comparable to that provided to the public who are not individuals with disabilities, unless undue burden would be imposed on the agency.

The U.S. Department of Justice [21] reports in its Section 508 resource guide that the Access Board is responsible for developing standards for complying with Section 508 in consultation with certain other government agencies and private organizations. Their responsibilities include developing standards for electronic and information technologies covered by Section 508, and defining which technologies constitute 'electronic and information technology' for purposes of Section 508.

The Access Board clarifies that a website complies by meeting standards outlined in Part 1194.22, Web-Based Intranet and Internet Information and Application, paragraph (a) through (p), which address that:

> (a) A text equivalent for every non-text element shall be provided (e.g., via "alt", "longdesc", or in element content).
>
> (b) Equivalent alternatives for any multimedia presentation shall be synchronized with the presentation.
>
> (c) Web pages shall be designed so that all information conveyed with color is also available without color, for example from context or markup.
>
> (d) Documents shall be organized so they are readable without requiring an associated style sheet.
>
> (e) Redundant text links shall be provided for each active region of a server-side image map.
>
> (f) Client-side image maps shall be provided instead of server-side image maps except where the regions cannot be defined with an available geometric shape.
>
> (g) Row and column headers shall be identified for data tables.
>
> (h) Markup shall be used to associate data cells and header cells for data tables that have two or more logical levels of row or column headers.
>
> (i) Frames shall be titled with text that facilitates frame identification and navigation.
>
> (j) Pages shall be designed to avoid causing the screen to flicker with a frequency greater than 2 Hz and lower than 55 Hz.

> (k) A text-only page, with equivalent information or functionality, shall be provided to make a website comply with the provisions of this part, when compliance cannot be accomplished in any other way. The content of the text-only page shall be updated whenever the primary page changes.
>
> (l) When pages utilize scripting languages to display content, or to create interface elements, the information provided by the script shall be identified with functional text that can be read by assistive technology.
>
> (m) When a web page requires that an applet, plug-in or other application be present on the client system to interpret page content, the page must provide a link to a plug-in or applet that complies with §1194.21(a) through (l).
>
> (n) When electronic forms are designed to be completed on-line, the form shall allow people using assistive technology to access the information, field elements, and functionality required for completion and submission of the form, including all directions and cues.
>
> (o) A method shall be provided that permits users to skip repetitive navigation links.
>
> (p) When a timed response is required, the user shall be alerted and given sufficient time to indicate more time is required.

Section 508, though responsible only for federal websites, may eventually trickle down to the private sector. McKenzie [22] writes that vendors of information technologies already felt the pressure. The U.S. government is the biggest consumer of goods and services in the world, should these vendors want to do business with the government, they will have to adopt the ir technology to comply with Section 508. Prencipe [23] agrees that private sector companies will have to comply with Section 508 rather than developing a separate product line to accommodate government contracts.

However, Section 508 requires that all "federal agencies to conduct an annual self-evaluation of their current electronic technologies and information and to report the results of these evaluations to the U.S. Department of Justice." This self-evaluation is available online and contains a specific checklist regarding software, Web pages, Information/Transaction machines, and other information technology equipment. As part of the self-evaluation process, the U.S. Department of Justice issued *Information Technology and Persons with disabilities: The Current State of Federal Accessibility,* a report that states:

> Federal agencies 'Internet and intranet sites contain some barriers to access for persons with disabilities. The most common encountered barrier is the failure to provide appropriate and meaningful text information for visual image ("alt text" for simple images and icons and long description for more complicated graphics). This barrier, like others that are encountered less frequently, can be eliminated quite easily with minimal design changes [24].

The Report further address difficulty with technology design and recommends the followings:

1. Testing Web Pages before Posting. Each agency should evaluate for accessibility all of its new Web pages before they are posted. Existing Web pages should be tested as they are updated. Testing should be done with text-only browsers and, where possible, with assistive technology such as screen reading software to ensure that the experience of users with disabilities is comparable to that of others.

2. Agency Web Guidelines. Each agency that has developed style guidelines to maintain a consistent "look and feel" of its Web pages should review those guidelines to ensure that they will maximize the accessibility of the agency's Web pages.

3. The Government Printing Office (GPO). Many smaller agencies rely on the GPO for their website design and maintenance. While Section 508 does not apply to the GPO, the GPO should provide leadership to ensure that all Web pages it develops or maintains are accessible.

4. Dedicated E-mail Addresses. Because most accessibility problems on agency websites result from oversight or lack of awareness of accessibility issues, rather than technical or design difficulty, each agency should prominently post to its Internet pages an e-mail address through which users with disabilities can inform the agency of any accessibility barriers encountered. Each agency should be responsive to any e-mails it receives regarding the accessibility of its website to persons with disabilities.

5. Accessibility Information Logo. The National Endowment for the Arts, along with the Universal Access Working Group, GSA, and the Access Board, should develop an easy-to-recognize accessibility information logo (and alternative text label). Each agency should use this logo (and text label) to link persons with disabilities who use its Web pages with appropriate accessibility instructions and information, including an e-mail address to the agency's accessibility point-of-contact.

6. Location of Accessibility Information. Where it makes sense to do so, such as when placing a link to a text-only alternate website or when posting the accessibility instruction logo and label, each agency should place accessibility information in the uppermost left-hand corner of its Web pages. This location will facilitate use of the agency's Web pages by people who use screen readers, as it is the first location from which a screen reader will read.

7. Document Formats. As agencies put more of their programs and services online, each must remain vigilant to ensure it is not inadvertently creating barriers for persons with disabilities. Online forms created using any of the various Web technologies pose significant accessibility challenges to Web designers. Documents rendered exclusively in Adobe's portable document format (pdf) or Microsoft's PowerPoint formats may raise particular concerns. If any posted documents or forms are less than fully accessible, each agency should also post ASCII or accessible HTML versions of the same documents, where possible. Where exclusive reliance on an inaccessible format is unavoidable, each agency should provide contact information where users with disabilities can request the underlying information in an accessible format, where doing so would not impose an undue burden on the agency or result in an fundamental alteration.

Section 508 went into effect in June 2001. Websites developed after this date must comply with accessibility standards. Existing websites do not have to be redesigned to comply with Section 508; however, any new websites must follow the new guidelines. Even though existing sites do not have to comply with Section 508 standards, many government staff are redesigning their websites in order to accommodate the disabled users [25].

2.3. Web Accessibility Evaluations

A study conducted by Flowers, Bray and Algozzine (1999) targeted the accessibility of the homepages of 89 university Special Education department programs within the United States. Their findings indicated that 73% of the universities' special education homepages had accessibility errors, yet, with minimal revisions, 83% of those errors correctable. Research studies conducted within the federal and educational sector have spurred further development efforts [26]. The Department of Justice has offered surveys intended to gather information in effort to obtain current representation of the number of persons with disabilities within various federal agencies [24]. The Department of Justice Civil Rights Division reviewed 81 federal agencies within the U.S. pertaining to their 20 most popular web pages surveying total of 3,028 web pages were surveyed. Measurement instruments used in this project included the "Web page accessibility checklist" developed for the survey by the DOJ based on the Web Accessibility Guideline defined by the W3C. The evaluation also required evaluators to download and use lynx, a text-based Web browser, used by many people who are visually impaired, in order to "experience" the Web page in the same manner in which it could be experienced by someone using a screen reader.

Findings concluded that most barriers existed because of the inattention or ignorance of details on the pages. The most common error identified involved alternative text missing from many graphics or what was provided needed to be more descriptive. Because of these findings, the recommendations included testing pages prior to posting, maintaining a consistent "look and feel" among agency pages, offering a dedicated email address, and displaying an accessibility logo for accessibility information.

Although many organizations offer streamlined guidelines detailing Section 508 standards related to accessibility, Section 508 has also been implemented throughout the most current educational Web communities [27]. Heim [28] reported on an analysis of departmental webpages conducted within a university community that illustrated a 32% rate of the compliance utilizing version 3.2 of the BOBBY validation tool. Within this compliant grouping, 86% of the department websites incurred at least one accessibility error, primarily identified as lack of alternative text for images placed on the page. Finding from Rowland and Smith similarly revealed that only 22% of higher learning institutions in United States met web accessibility approval for their homepages [15]. Schemetzke [29] surveying a total of 219 sites within the University of Wisconsin campuses, found that 15.1% of the homepages were priority 1 compliant using the BOBBY validator, meaning that a small fraction of the campus's home pages were complaint with the lowest but the most necessary level of the accessibility detailed by WCAG. When the pages directly linked to the 219 homepages were included, BOBBY found 23.3% of the pages to be priority 1 accessible. Opitz, Savenye, and Rowland [30] also found that a small portion (26%) of the State Department of Education homepages in each of the fifty states achieved compliance, while a greater number of their special education pages (52%) achieved compliance. Findings regarding Section 508 conformity revealed that 16% of the state department homepages achieved approval, while a greater proportion of the special education pages (42%) achieved approval. Due to the lack of promotion of global accessibility, additional studies testing the effectiveness across independent regions and industries are still of strong need. Although studies have been conducted regarding the compliance by learning institutions with general accessibility guidelines, more remains to be investigated regarding compliance by federal agencies [20].

Romano's study [31] showed that the top 250 websites of Fortune listed companies are virtually inaccessible to many persons with disabilities. Of the 250 sites investigated, 181 of them had at least one major problem (priority 1) that would essentially keep the disabled from being able to use the site. While the study's findings make it clear that even the best companies are not following WCAG guidelines, most of the problems blocking access to the websites could be easily identified and corrected with better evaluation methods.

In 2002, McMullin [32] conduced a evaluation study on websites with the Ireland domain name using 25 checkpoints that can be automatically determined. Key findings from the study include 100% of the Irish websites failed to meet the professional practice WCAG-AA accessibility standards; 94% of the websites failed to meet even minimum WCAG-A accessibility standard; and at least 90% failed to meet minimal conformity to other generic technical standards for Web interoperability. The top five barriers to persons with disabilities include: 1) using rigid pixel for display (98.7%); 2) missing alternative text equivalent (90.6%); 3) defective HMTL coding (89.9%); 4) ambiguous or meaningless hypertext links (76.7%); and 5) inaccessible online form (69.8%). The percentage of inaccessible toal page is higher in this study than in similar studies in United States. This might be attributable to the lack of influential legislations similar to Section 508, and ineffective promotions of Web accessibility standards outside major stakeholder countries.

Sullivan [33] conducted a study that audit content accessibility compliance of 50 of the Web's most popular sites, undertaken to determine whether content accessibility can be conceived and reported in continuous, rather than dichotomous terms. Preliminary results suggest that a meaningful ordinal ranking of content accessibility is not only possible, but also correlates significantly to the results of independent automated usability assessment procedures [33]. Sullivan's study is the first and only paper to propose evaluating the degree of Web accessibility as a continuous variable. However, two issues undermine the study's credibility: the calculation formula used by the author is misleading, and the author only used the homepage as the representative of each website. In addition, the author determined an arbitrary cut-off point for differentiating accessible vs. non-accessible Web pages.

Although the Web is considered a powerful force for reshaping the healthcare infrastructure, the accessibility of Web content to persons with disabilities is not a primary consideration for most designers of websites providing health related information. Very few research studies have been conducted on the accessibility of health information websites for persons with disabilities. Research studies on the accessibility of health information websites are for the most part about the *find-ability* and *search-ability* by online search engines of Internet websites or about the availability of information technology for the people who need it [34-38]. Current guidelines related to the quality of health information websites do not require the accessibility of website by persons with disabilities [39]. The absence of researches and discussions of Web accessibility of health information websites may result in a lack of awareness of this issue among online health information providers.

The only study known to the authors covering health information websites is the study conducted by Davis in 2002 [40]. Davis explored the extent to which Internet-based health information is accessible to visually impaired individuals who rely on automated screen readers. Davis selected 500 individual websites representing 50 common illnesses and conditions for evaluation and found that accessibility is currently very low—only 19% of the homepages examined were accessible. The study also discovered that this inaccessibility of the Web pages was the result of noncompliance with the recommended design and coding changes.

The evaluation study (Chapter 4) in current study differs from other studies in several ways: First, the current study examines the accessibility of not only homepages (main pages) of health information websites, but also secondary webpages that are certain levels below the homepages. Second, a majority of the other studies report the state of accessibility in terms of an absolute number and the consequential summarized frequency of inaccessible features for each domain. Although an absolute number of violations of Web content accessibility would provide useful information about the state of accessibility, it does not allow for a straightforward and unbiased direct comparison of overall accessibility between websites, and does not take into consideration the complexity of different webpages, such as the number and type of HTML elements. Third, most of these studies only investigate inaccessible Web page obstacles without investigating additional website properties. The current study investigates the relationship of Web accessibility to other features of a website including function, popularity, and importance.

2.4. Web Transcoder Gateway System

Web Transcoder Gateway (WTG) is an information intermediary program developed at the Department of Health Information Management, University of Pittsburgh. Current version of the system supports real-time transformation of Web pages to enhance Web accessibility for persons with visual impairment and PDA Web users [41]. This section briefly introduces the framework of the WTG system, the algorithms used for transformation, related works, and future directions.

2.4.1. Framework

The WTG acts as an information broker between information consumers (Web users) and providers (websites).

Figure 2-1 illustrates the framework of our Transcoder gateway.

Figure 2-1(a) shows the information flow via the gateway by a user, who treats the application as a proxy gateway to the Web.

Figure 2-1(b) gives a more detailed view of the WTG.

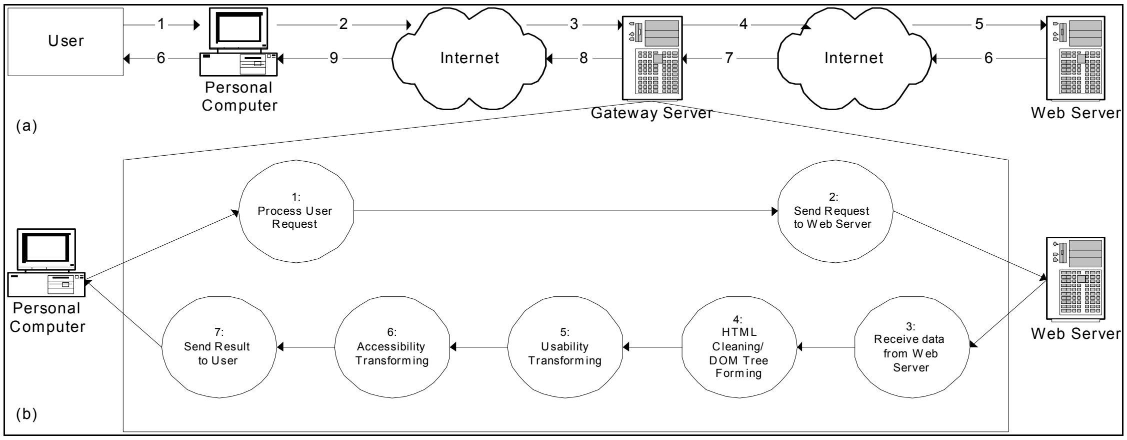

Figure 2-1: Web Transcoder Gateway Framework

When a user access a Web page, instead of entering the Web page's Uniform Resource Locator (URL) into the address window of a Web browser, the user will enter the URL of the Web page into a text field on the entry page of the gateway and submit to the WTG. The gateway receives the URL and forwards the user's request to the respective Web server.

After receiving the Web page that the user request, the WTG examines the Web page according to accessibility and usability rules. Given the user's disability or limitations, WTG removes any violations of the rules accordingly to achieve better accessibility and usability. The resulting page is then returned to the user's Web browser. The user receives a transformed Web page that assumedly better fits the user's assistive technologies or devices. All hyperlinks within the transformed Web page are manipulated with the WTG's URL appended so that users can continually access linked pages via the WTG server.

The primary objective of the gateway server is to transform webpages in real time for a various types of end users. Currently considered end users include persons with visual impairments and PDA users who want to access general websites that are originally not designed with those users in mind. To achieve this objective, the design of the gateway follows six principles:

1. Information retention and complement: The transformed pages should retain as much information as possible for different types of users. The amount of information on the

transformed page should be comparable to the one before the transformation. For information may be lost because of the perceptive or device limitation, the transcoder server will strive to maintain the information using human annotation or other mechanisms

2. Content accessibility: The transformed Web page will follow Web accessibility guideline without introducing additional accessibility barriers.

3. Usability: Users should browse and navigate the transformed Web page efficiently, effectively, and satisfactorily under their special circumstances. Although accessibility can be achieved by following normative guidelines, usability transformation will be derived based on the principles of user-centered design.

4. Real time: Although WTG adds steps of information re-authoring and transformation, it should not perceptively slow down the interaction between Web users and targeted websites. We expect that the time difference between using the gateway and not using the gateway will be perceptively negligible. This is one of the determining factors for selecting algorithms for Web page manipulation.

5. Scalability: The WTG must be scalable to incorporate new components and handle increasing number of users. Adding new components or users should not diminish the performance of the server.

6. Multiple Modalities: The WTG server should be able to handle different types of physical disability or situational inaccessibility. This decides transformation rules should be flexible enough to accommodate different accessibility requirements.

These requirements are interrelated and can influence each other. In a few cases, we had to compromise between two or more expectations that are not mutually exclusive.

Functional subcomponents of the WTG server include:

1. Page retriever: Retrieve Web pages based on user's input to the WTG. It is also the component that conduct hyperlink rendering.

2. HTML cleaner: Clean and transform not well-formed HTML file to be compatible with Document Object Model (DOM) tree structure, which serves as the input for subsequent manipulation [42].

3. Page structure recognizer: The variance of information processing ability within assistive technologies and Web devices often results in distorted or incomplete Web page structure. Structural information implicitly provides navigational assistance and browsing guides for Web users. For example, desktop users can see both navigation menu and main content of a Web page simultaneously, but blind Web users relying on screen reader to read out a Web page in linear order, which often causes delayed access to the main content of the page. Because PDA users can only see part of a Web page on its small display, they need to scroll Web page to access desired part of the page. The function of the page structure is to detect structural context of a page, so different parts of the page can be present to users based on his information needs. Algorithms used in the structure recognition include template based page recognition and landmark semantic analysis.

4. Annotator: Although our objective is to allow the WTG server to detect syntactical, structural, and semantic information using computer heuristics or algorithms, human intervention is not avoidable for information complement. The function of the annotator is to assist human annotator to provide additional information for parts of a Web page if the original information conveyed by those parts will inevitable lost due to the perceptive or device limitations. Moreover, manual annotation can achieve optimized performance

of Web page transformation. We intend to use it for website with concentric design that Web pages with in the site have similar layout and elements.

5. Transcoder: This is the core component of the WTG server. After obtaining structural and annotated information, the transcoder component will transform the cleaned Web page to designated formats for a variety of assistive technologies or unconventional Web devices. Rules used by the transcoder are adopted from Web accessibility and usability guidelines for persons with disabilities or Web design guidelines for alternative Web devices users [14, 43, 44].

2.4.2. Implementation

We implement our system in Java using Java Server Page (JSP) and Java components running on Tomcat Apache Web server. Annotation files are stored as eXtensible Markup Language (XML) documents in Oracle database leveraging the Oracle XML DB feature that supports native XML manipulation. We use our modified version of JTidy to transform HTML documents into cleaned DOM structures [45].

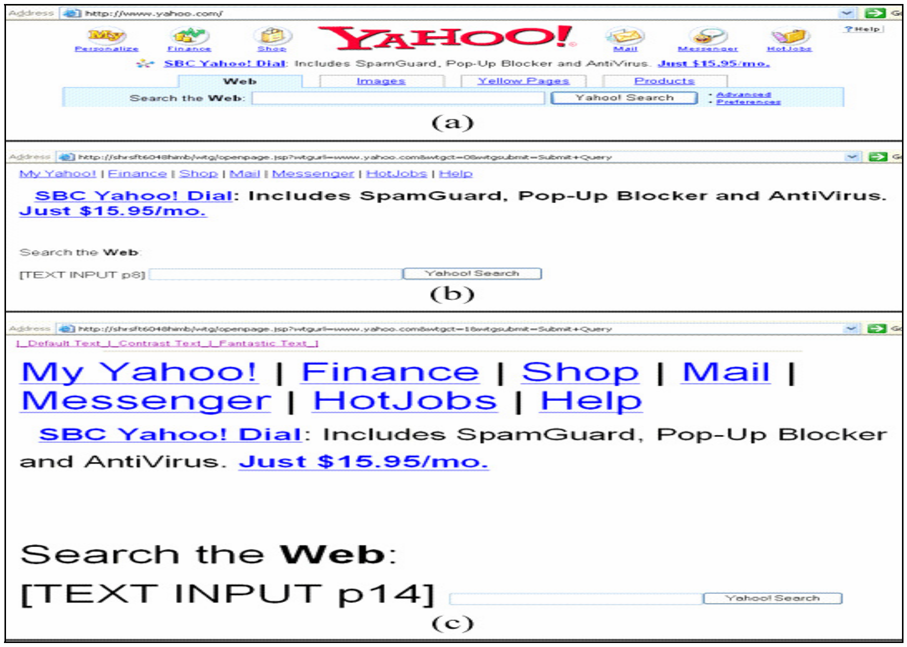

Figure 2-2: Screenshot of Gateway Transformations of Yahoo.com (3/4/2004)

Figure 2-2 shows comparisons of an original page (a), a transcoded page for blind Web users (b), and a transcoded page for low vision users (c).

This example shows our implementation of image and text contrast rule. Although blind Web users do not access images, they rely on the information conveyed by the image. So in the case of image map, we transcode it into a list of navigational links that represents the original functionality of the image map. Presenting this text without any formatting change will provide no difficulties to the blind user, but users with low-vision would need a larger font. In this example, we present the transcoded image map with a large font size and greater text contrast for low-vision users.

2.4.3. Related Works and Contributions of Web Transcoder Server

The first accessibility transcoder was probably WAB [46], an HTTP proxy developed in ETH Zurich that was not customizable. It modifies HTML to assist users who are blind to access intended website. Asakawa & Takagi [47-49] developed a customizable transcoding server using the IBM Websphere Transcoding Publisher evolved from IBM Web Intermediaries (WBI) [50]. This transcoder also uses knowledge specific to websites to enhance the accessibility transformation. Silas Brown [51] developed a customizable gateway for low-vision users that does not use the site-specific knowledge concept.

The objective of our gateway is to adapt any website by transforming it to the user's preferences and limitations, including users with disabilities, as well as PDA and cell phone users. WTG server can make the Web accessible and usable to persons with disabilities, especially users with visual impairments. In addition to implementing the WCAG checkpoints in the transformation, the WTG server also implements usability transformation to enhance the usability of any website for visually impaired users.

The objective of the WTG server is to transform *any* website in real time. Therefore, the transcoder should be able to check accessibility and conduct corresponding remediation on the fly. The WTG server contains a novel page recognition method using template-matching algorithms. Using this template-matching algorithm, the WTG server can detect the structure (template) of the Web page and apply appropriate usability transformation rules to the template.

Chapter 3 CONSTRUCITING MEASUREMENT METRICS FOR WEB ACCESSIBILITY EVALUATION

3.1. Introduction

The importance of measuring attributes of known objects in quantitative terms is crucial in advancing the state of science of any field. The Web, as one of the most interesting new objects of research, has generated many metrics to assist scientific investigation [52]. This study proposes a novel metric for measuring content accessibility of the web for persons with disabilities. Measuring web accessibility in precise and quantitative terms is important for many reasons. First it would enhance our understanding of the web in general. It would also allow us to measure the current state of web accessibility and to compare the accessibility of different websites as well as the accessibility of a single website at different times. A continuous numerical measure would be preferable to the current dichotomous measure of accessibility. A continuous scale would allow not only a more precise measure of accessibility, but also lend itself to more advanced statistical analysis for evaluating large-scale aggregate websites.

The current practice of evaluating web accessibility uses dichotomous method based on the absolute compliance with the standard guidelines, known as the Web Content Accessibility Guidelines 1.0 (WCAG), developed by the World Wide Web Consortium (W3C). A website is determined to be accessible or inaccessible by evaluating the website against the accessibility checkpoints provided by the WCAG. The WCAG contains a total of 14 broadly phrased guidelines that are translated into 91 specific checkpoints explaining how the guidelines should be applied to specific content development scenarios. These checkpoints are organized into three levels of priority: Priority 1 contains 29 checkpoints that must be satisfied, Priority 2 contains 40 checkpoints that should be satisfied, and Priority 3 contains 22 checkpoints that may be satisfied.

Considering the number of checkpoints that a website must meet in order to be considered accessible, it is not surprising that the results of accessibility studies found most websites inaccessible. Even complying with the basic accessibility in Priority 1 would be difficult. Any violation of the 29 checkpoints in Priority 1, such as forgetting to designate alternate text for one of the images on the website, will render a website to be inaccessible in this dichotomous measurement. This type of dichotomous measurement also leads to inaccuracies in the accessibility labeling. That is, the majority of websites that claim themselves to be fully accessible, conforming with Priorities 1, 2, or 3, in fact violate the guidelines with which they are supposed to comply.

The current accessibility measurement also does not take into account the size and complexity of a website. A large website with hundreds or thousands of web pages would have a higher chance of violating the checkpoints than a simple website with only a handful of web pages. An accessibility metric that takes into account size and complexity would allow fair comparison between websites or aggregates of websites.

Sullivan and Matson [33] were the first to propose the idea of continuous accessibility measurement: measuring accessibility in term of "degrees" instead of the dichotomous accessible-inaccessible. The paper, however, does not discuss the detailed calculation of the continuous metrics. Instead, it ranks websites into four accessibility degrees: highly accessible, mostly accessible, partly accessible, and inaccessible. A numerical metric with continuous values would provide better discrimination power and promote a scientific approach to web accessibility issues.

This study proposes a novel metric for quantitatively measuring the accessibility of the web. This metric is developed using the WCAG guideline as a starting point. More precisely, this metric is based on the WCAG checkpoints that can be automatically tested using computer programs.

3.2. Background and Related Work

3.2.1. Web Accessibility Guidelines

Numerous guidelines have been developed to assist web designers in making websites accessible to persons with disabilities. In the 1990s, web accessibility information was available from organizations such as the Trace Research and Development Center at the University of Wisconsin and companies such as IBM [10, 11]. One of the earliest web content design standards for the access of persons with disabilities was developed by the City of San Jose, California [12]. In 1997, the Australia standards for accessible web design were made available to web page authors [13]. In the same year, the W3C established the Web Accessibility Initiative (WAI) [9]. The WAI published the WCAG 1.0 as its final recommendation in 1999 [14].

There are two major specifications that serve as the normative guidelines for Web content accessibility design: the WCAG and the US Access Board's Electronic and Information Technology Accessibility Standards (known as the Section 508 Guidelines). The WCAG is a stable international specification developed through a voluntary industry consensus. The Section 508 Guidelines were announced in December 2000, pursuant to the US rulemaking process as required by Section 508 of the Rehabilitation Act Amendments of 1998 [53]. Both specifications offer checklists that Web developers should follow with regard to content accessibility for persons with disabilities. These two specifications largely overlap—only three of the checkpoints defined in Section 508 are not mentioned in the WCAG. The WCAG has more comprehensive checkpoints than Section 508, and it provides a priority level to each checkpoint to reflect the severity of specific violations.

The WCAG contains 14 broadly phrased guidelines that are translated into 91 specific checkpoints that explain how the guidelines should be applied to specific content development scenarios. These checkpoints are organized into three levels of priority: Priority 1 contains 29 checkpoints must be satisfied; Priority 2 contains 40 checkpoints that should be satisfied; and Priority 3 contains 22 checkpoints that may be satisfied.

WAI has introduced the WCAG Conformance Logos to further promote accessibility on the Web. Content providers can use these logos on their sites to indicate a claim of conformance to the specific level of the WCAG. WAI expects that use of these logos on conformant sites will help raise awareness of accessibility issues. The definitions of different conformance level are:

- Conformance level “A”: all Priority 1 checkpoints are satisfied.
- Conformance level “AA”: all Priority 1 and 2 checkpoints are satisfied.
- Conformance level “AAA”: all Priority 1, 2, and 3 checkpoints are satisfied.

3.2.2. The Need for an Accessibility Metric

Since the WCAG was adopted by the W3C and Section 508 of the Rehabilitation Act became law, there have been numerous studies on Web accessibility conducted on various categories of websites. These studies used the WCAG as the basis for measuring accessibility and use the automatic assessment tool Bobby for evaluation. Such studies have usually painted a gloomy picture of the state of accessibility of the Web. A recently completed study evaluating accessibility of the 30 most popular French websites found that none of the 30 sites meets conformance level “A” [54]. A similar study conducted in Ireland found that at least 94% of the 159 websites tested failed to meet the minimum accessibility standard (“A”), and not one site met the professional practice accessibility guideline of levels “AA” and “AAA” [55].

The results of previous studies are often confusing and conflicting. A study conducted on the accessibility of US federal websites revealed that only 13.5 percent of the 148 sites had zero errors[56], indicating that they could be considered “AAA” or “Bobby approved.” This study has generated much publicity [57, 58], partly because all US federal websites were supposed to have complied with Section 508 of the Rehabilitation Act of 1973 by June 25, 2001. An earlier study conducted by a Brown University researcher found that 37% of the US government websites are accessible [59]. Another study found that only 1 percent of the US federal government websites are Bobby-approved[60], where it is defined as meeting Priority 1 (“A”) without a user check. All of these studies employed Bobby [61] – an automated accessibility assessment tool – and use the absolute measure of accessibility. The low rate of accessibility among government websites would make a good media story, but it is hardly informative for scientific or policy purposes.

We argue that the confusion and conflicting results stem from the problems of the metrics used in the studies. The current method of evaluating website accessibility relies on a simple rating based on the conformance to the priority checkpoints set forth in the WCAG. The current rating system and the so-called “Bobby Approved” measurement reflect dichotomous metric of accessibility: either the site conforms to all checkpoints with assigned priority level or it is inaccessible at the level.

To illustrate the problems with the current dichotomous absolute accessibility measures, we conducted an evaluation on a large sample of websites that considered themselves as accessible. We selected 449, 374, and 318 websites that were self-rated as A, AA, and AAA, respectively, for 1,141 websites (See Section 6.2.1 for detailed information on the sample websites). We then added 377 more randomly selected websites that violate Priority 1 as inaccessible control group. We evaluated the accessibility of all 1,518 websites to check their conformance to each priority level of the WCAG. We used only the checkpoints that can be evaluated automatically using a computer program. The results of the evaluation are presented in Table 3-1.

Table 3-1: Percentage of websites with priority violations using 25 checkpoints

	SELF-RATED CATEGORY WEBSITES			
Conformance	Non-rated	"A"	"AA"	"AAA"
True "A"	1.59%	72.83%	96.71%	97.26%
True "AA"	1.59%	7.67%	17.65%	16.35%
True "AAA"	0%	1.11%	4.28%	8.81%

It is surprising that even among the websites that considered themselves to have a AAA conformance level, only 8.81% of them are truly "AAA." Several previous studies used the "AAA" criteria or "Bobby Approved" as a criterion for accessibility [56, 60]. The percentage of websites that conform to "AAA" criteria for self-declared "AA" and "A" websites significantly lower (4.28% and 1.11% respectively) and for randomly selected website the percentage conforming to the "AAA" standard approaches zero. The results would have been worse if manual checking to all 91 checkpoints were conducted and if all pages of the websites are evaluated, rather than a check of the 25 checkpoints that could be evaluated using a fully automated method on only the main page of the website.

The table can explain the results of previous studies among the 159 Irish websites[55] that found a level "A" failure conformance rate of 93.7% and a failure conformance rate of 100% for both "AA" and "AAA". The Irish study and the French study (the 30 most visited websites which found a 100% "A" failure conformance rate) are consistent with our results of randomly chosen websites.

The overly pessimistic results show the weaknesses of the absolute measure of accessibility used in the studies. Since single checkpoint violation in a priority would render a website inaccessible, only a small percentage of websites could be considered accessible. Such results would be of a little help for shedding light into the state of the accessibility of the web. A different, better measurement is needed for scientific exploration as well as for policy formulation.

3.2.3. The Need for Automatic Evaluation

The number of unique Web pages was estimated at 2.1 billion pages as of July 2000, growing at a rate of 7.5 million pages per day [62]. The total number of the deep hidden Web pages, Web connected back-end databases, is estimated at 550 billion invisible Web documents [63]. The Web is not only characterized by its sheer enormity but also by its fluidity: websites constantly change. Brewster Kahle, digital librarian at the Internet Archive in San Francisco, estimated that the average lifespan of a Web page today is 100 days [64]. A study published in SCIENCE magazine found that the prevalence of inactive Web-referred citation in prestigious scientific journals is 10% after 15 months [65]. Given the volumes of the web, automatic scoring and evaluation would be preferable to and more productive than manual scoring. Automated Web accessibility evaluation has several advantages over non-automated evaluation, such as the cost to conduct the evaluation, the time needed to complete the evaluation, increased consistency of the accessibility uncovered, reduced need for accessibility expertise, and the possibility of incorporating accessibility evaluation into the Web development process. Similar arguments have been made for automated usability evaluation [66]. There is an even more compelling argument for automatic web accessibility evaluation: there is an internationally accepted guideline with detailed checkpoints. Automatic scoring will allow conducting evaluation against a large number of websites in a short time and at minimal cost.

3.2.4. Properties of a Good Web Accessibility Metric

To overcome the deficiencies of the current absolute metric, we propose an accessibility metric that satisfies several requirements. First, accessibility must be measured in a quantitative score that provides a continuous range of values from perfectly accessible to completely inaccessible. A quantitative numerical score would allow assessment of change in web accessibility over time as well as comparison between websites or between groups of websites. Instead of an absolute measure of accessibility that categorizes websites only as accessible or inaccessible, an assessment using the metric would be able to answer the fundamental scientific question: more or less accessible, compared to what ?[67]

Secondly, the metric and range of values must have a large discriminating power beyond simply accessible and inaccessible. A metric with good discriminating power would allow assessment of the rate of change of web accessibility over time or a significant difference in accessibility between the websites under consideration. An accessibility assessment using the metric will be able to answer the fundamental scientific question: at what rate? [67]

Third, the metric must be fair by taking into account and adjusting to the size and complexity of the websites. Websites may range from a single home page to large corporate sites comprising thousands of pages. A metric that takes into account size and complexity would allow a fair comparison between websites of various sizes.

Fourth, the metric should be scalable to conduct large-scale web accessibility studies. Large scale accessibility assessments require a metric that supports aggregation and second order statistics such as standard deviation. For a large-scale study, efficiency is paramount. Finally, the measurement should be normative, meaning that it should be derived from standard guidelines of Web accessibility such as the WCAG or Section 508.

The proposed metric is designed to work with an automated accessibility evaluation method. Although the metric is a proxy indicator of Web accessibility, not a real measure of accessibility from the user experience, it is practical and has several strengths. One of the primary strengths of an automated scoring system is objectivity: it will allow objective comparisons between sites, categories, and points of time. This method will also allow large-scale assessment of aggregate websites. Assessing all WCAG checkpoints conformance potentially requires detailed testing and evaluation of each web page in a website against each checkpoint by an expert human tester. Imagine evaluating 100 websites consisting of 1000 Web pages on each site. Large-scale web accessibility evaluation using manual evaluation would be time consuming and prohibitively expensive. As McMullin [55] has argued, it is much more preferable to have available *some* concrete, comprehensive, data relating to Web accessibility on a large scale, even if this data is incomplete.

3.3. Novel Accessibility Metric: the Web Accessibility Barrier (WAB)

One of the conclusions we can draw from the literature review is that currently accepted evaluation methods for Web accessibility have two primary weaknesses. Most of them only consider the absolute number of Web accessibility violations presented on a Web page. Simply counting the number of violations, without considering the number of potential violations, e.g., number of image elements when checking non-alternative text images, favors pages with simple designs and may underestimate the effort the Web designer put into complex websites. Secondly, most of the evaluations of Web accessibility presented the studies not as an integrated single measurement score that represents the total accessibility barriers on one Web page or website. Instead, the results are mostly presented in the category according to the checkpoints, guidelines, or priorities of WCAG. Although the presentation of the results can provide a sketchy outline of the distribution of Web accessibility among different websites, it is hard to simply use this categorical measurement to compare two web pages. These weaknesses might explain why the violation of Bobby accessibility increases when the pages are better designed, as one of the studies indicated [68].

Since the WCAG and Section 508 are largely overlap, and WCAG is more comprehensive and is the internationally accepted standard, the WCAG was used as the foundation for the accessibility metric we developed.

The number of violations of each checkpoint is a component of our scoring method called Web Accessibility Barrier (WAB) score. For example, a Web page with fewer accessibility checkpoint violations, e.g., providing no alternative description for an image object, will be considered as having fewer barriers for persons with disabilities and will have a lower WAB score. Because we are more interested in automatically evaluating the level of accessibility of a website, those checkpoints demanding manual checking are not included in the calculation of the WAB score. For example, conformance to the rule, “If you use color to convey information, make sure the information is also represented another way,” cannot be verified until a manual check is done. For a list of Web accessibility rules that need to be manually checked, please see the WCAG references [14].

As discussed in the background section, the WCAG attaches a three-point priority level to each checkpoint based on its impact on the Web accessibility. In weighting the calculation of the WAB score, we used the priority levels in reverse order. Priority 1 violations weight three times as heavily as the priority 3 violations because persons with disabilities have more difficulty accessing Web pages with priority 1 violations.

However, using only the number of violations of Web accessibility checkpoints may bias the results of the measurement. For example, a Web page with five "image without alternative text" violations may have 500 image objects embedded in the page and the Web page with one "image without alternative text" violation may have only one image object in the page. The developer of the first page may have already paid much attention to and put great effort into complying with the Web accessibility specifications while the developer of the second page may be completely unaware of Web accessibility. Therefore, the number of actual violations of a checkpoint must be normalized against the number of potential violations of the checkpoint. In the last example, true violations are the image objects without alternative text, and the potential violations include all image objects on the page. The average WAB score of all Web pages within a site will be the WAB score of the website.

$$WABScore = \frac{\sum_{p}\sum_{v}\left(\frac{n_v}{N_v}\right)(w_v)}{Np}$$

p: Total pages of a website.
v: Total violations of a Web page.
n_v: Number of true violations
N_v: Number of potential violations
Wv: Weight of violations in inverse proportion to WCAG priority level.
Np: Total number of pages checked.

Figure 3-1: The WAB formula

Figure 3-1 summarizes the calculation of the WAB score of a website as a formula. A lower score means fewer accessibility barriers for persons with disabilities, while a higher score indicates more barriers. A score of zero denotes that the website does not violate any Web accessibility guidelines and should have no accessibility barriers to persons with disabilities.

Theoretically, the WAB formula can be used to calculate the WAB scores based on all 91 checkpoints in all WCAG priorities. However, because we concentrate only on the checkpoints that can be evaluated using an automated system, we used only the 25 rules with the following breakdown: five checkpoints in Priority 1, 13 checkpoints in Priority 2 and 7 checkpoints in Priority 3. We have developed a program called Kelvin that implements this Web accessibility metric formula. Kelvin is a Java-based program consisting of two main modules: a Web crawler and an accessibility evaluator. The Web crawler is a lightweight automated crawler that follows links to visit Web pages. We did not use other available Web crawlers because many crawlers are too complex to be easily customized to our specific tasks. The crawler can access Web pages at remote websites and determine the number of potential violations of Web accessibility checkpoints. The accessibility evaluator will check the potential violations against the 25 WCAG checkpoints and calculate the accessibility scores.

3.4. Testing the Validity of the Metrics

3.4.1. Reliability of the Metric

Since the measurement utilizes data directly acquired by automatic machine processing, it does not involve subjective judgment or probabilistic variation. The results of the measurement objectively reflect the state of the content accessibility of the Web page to a certain extent. Traditional reliability measurements (inter-rater, test-retest, parallel-forms, and internal consistency) are not applicable to our metric.

3.4.2. Validity of the Metric

3.4.2.1. Gold Standard

To evaluate the validity of the numerical metrics, a gold standard has to be employed. A gold standard refers to a reference standard for the evaluation of a novel diagnostic test, in this study, the WAB score.

Our choice of the gold standard measurement is to rely on certain types of accreditations. Since the WCAG is designed to serve the broadest spectrum of disabilities, it is a good candidate for a gold standard of accessibility. The WAI has introduced the WCAG Conformance Logos, Level "A" to "AAA" as discussed in the background section, to further promote accessibility on the Web. Content providers can use these logos on their sites to indicate a claim of conformance to the specific level of the WCAG 1.0. After content providers make their Web pages conform to WAI checkpoints, they can add a WAI logo on their pages. The level of conformance determines what type of logo they can use. Since WAI logos themselves are image embedded in HTML Web page, they also have alternative text binding with them. For example, the alternative text for the WCAG 1.0 Level "A" conformance logo is "Level A Conformance icon, W3C-WAI Web Content Web Accessibility Guideline 1.0". By default, a conformance icon refers to a single page unless the scope explicitly claims otherwise.

The logo system from the WAI is a potential candidate for a gold standard measurement. It is comprehensive, covering the broadest range of disabilities, and is cost-effective. However, it has several drawbacks that may compromise the study's results. The logo system is a self-rated system. As discussed in the background section, this self-rating system is not perfect. While the logo system has drawbacks, it is still an optimal gold standard for the measurement study. Even though the logo system is not perfect, it indicates that the content providers have done significant work to remove the accessibility barriers from the website. Additionally, the publicity of the

Web put the Web page using these logos under consistent scrutiny from the public who can issue any charge or complaint against any incompliance with the WAI checkpoints.

We used the search engine Google to acquire Web pages that would serve as a gold standard. The Web pages returned by the search engine were examined to confirm the existence and types of Web accessibility logo they were using. We used the home pages from the top 500 websites provided by another search engine, Alexa, as a negative group, one without WAI logos. The individual Web pages in the negative group were further examined to confirm the absence of the WAI logo.

3.4.2.2. Results

The results of applying the metric on the websites collected as the gold standard are presented in Figure 3-2. The results show that WAB metric provides a good continuous representation of the websites' accessibility. On average, websites that considered themselves as "AAA" have better accessibility scores than those who considered themselves "AA," which in turn have better accessibility than "A," which have better scores than non-rated websites. Scores of the WAB metrics provide continuous "degrees" of accessibility. The average scores of "AAA," "AA," "A," and non-rated websites are 2.02, 2.74, 4.47, and 10.5, respectively [69].

Figure 3-2 also shows a number of websites in the rated categories ("AAA," "AA," and "A") that score worse than the average non-rated score. These outliers are shown at the top of the Box and Whisker graph as dots that represent data outside the 95% confidence interval. There were also non-rated websites that scored better than the average of the best websites (AAA), as shown in the bottom dots of the non-rated graph. The figure shows that the WAB metric is capable of separating the websites from each other based on their accessibility across different levels of the accessibility spectrum.

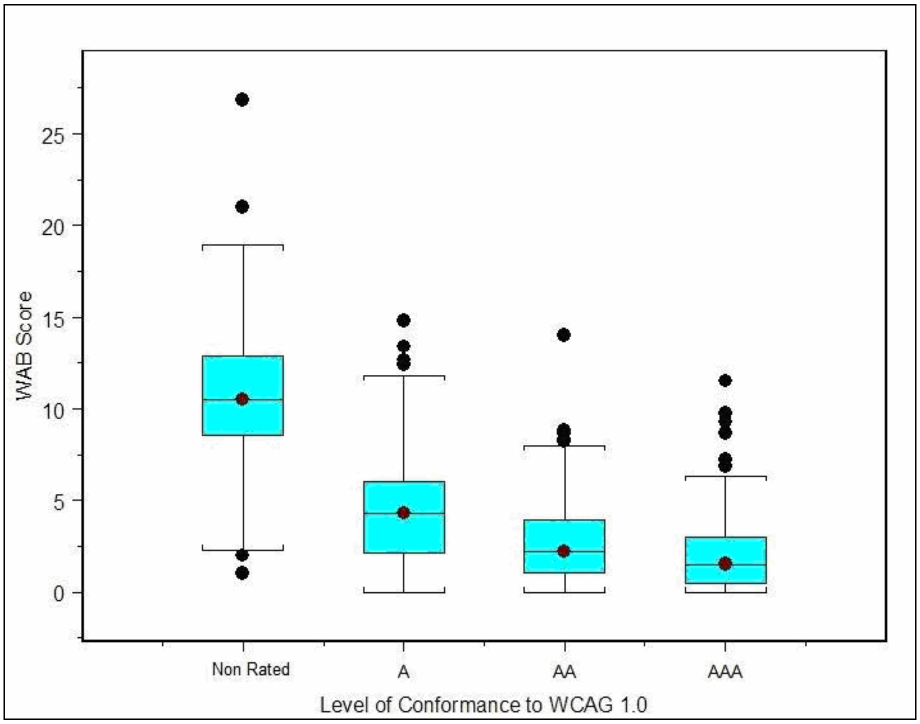

Figure 3-2: Box plot of WAB Scores in different conformance group

We tested how the scores of "AAA," "AA," "A," and non-rated websites are separated from one another. The performance of the measurement metric in predicting the individual website category (whether a website belongs to "AAA," "AA," or "A") will be calculated using Receiver Operating Characteristics (ROC) Curve [70]. The ROC Curve is more appropriate for this metric validity test than simply testing the means difference of the scores using a One-Way ANOVA [71]. The ROC curve is method to assess the ability of a predictor to discriminate between two possible outcomes. Drawing an ROC curve connects the points defined by a true positive fraction (TPF) and a false positive fraction (FPF) corresponding to different cutting points along the measurement. The Area Under the Curve (AUC) reflects the differential power of the test. A perfect separation between the two categories would yield AUC score of 1.0 and a curve that fits along the X-axis and upper Y-axis. Otherwise, a perfect non-separation would yield an AUC score of 0.5 and a curve along the straight diagonal line. Another merit of ROC curve is that a specific cutting point or criterion point can be located on the curve with preferred sensitivity and specificity.

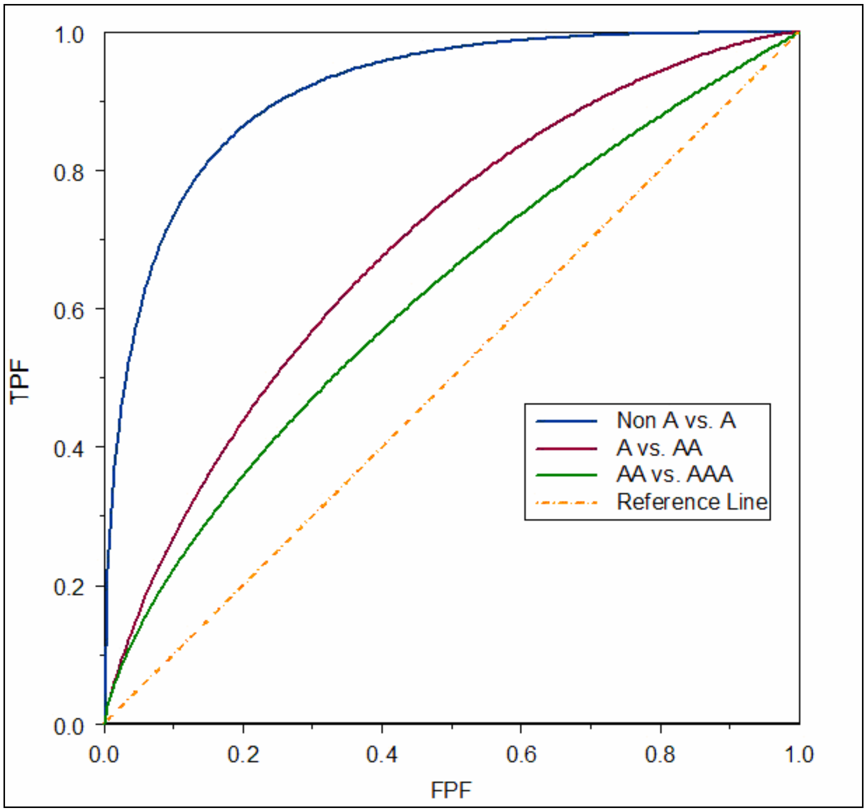

Figure 3-3: ROC of WAB Score in separating different conformance groups

Figure 3-3 show the ROC curves drawn from different cutting point from the WAB score for the gold standard websites. The curves measure how good the metric is in separating adjacent levels of website rating categories (Non-rated – "A," "A" – "AA," and "AA" – "AAA"). The separation between Non-rated and "A" is the strongest, while the separation between "AA" and "AAA" is the weakest.

Table 3-2 lists the AUC score of the metric in separating the different categories of accessibility ratings. The results show a clear separation between non-accessible websites and websites with an "A" rating. The AUC score is 9.17 with a separation between non-rated websites with "A" website very significant (p-value < 0.0001). The separation between "AAA" and non-rated websites is even higher, with a score of 9.7 and p-value < 0.0001. The weakest separation between "AA"-"AAA" is also significant (p-value < 0.0001).

Table 3-2: AUC of the WAB score in separating different conformance group

	NON-RATED - A	A - AA	AA - AAA	NON-RATED - AA	NON-RATED - AAA
AUC	0.917	0.689	0.513	0.972	0.982

We subsequently used machine-learning methods to compare the performance of the simple weighting schema used in our WAB metric with a decision tree method using a C5.0 machine-learning algorithm that would learn from the data set. The main difference between the WAB score and the machine learning method is that the WAB score uses a simple predetermined weighting score that is inversely proportionate with the priority level of the violation (the weight of 3 for priority 1, 2 for priority 2, and 1 for priority 3). Machine learning will learn from the data set and assign optimal weights for each of the 25 individual checkpoints. The purpose of this comparison is to see how good the simple weighting scheme is compared to an optimal complex-weighting scheme.

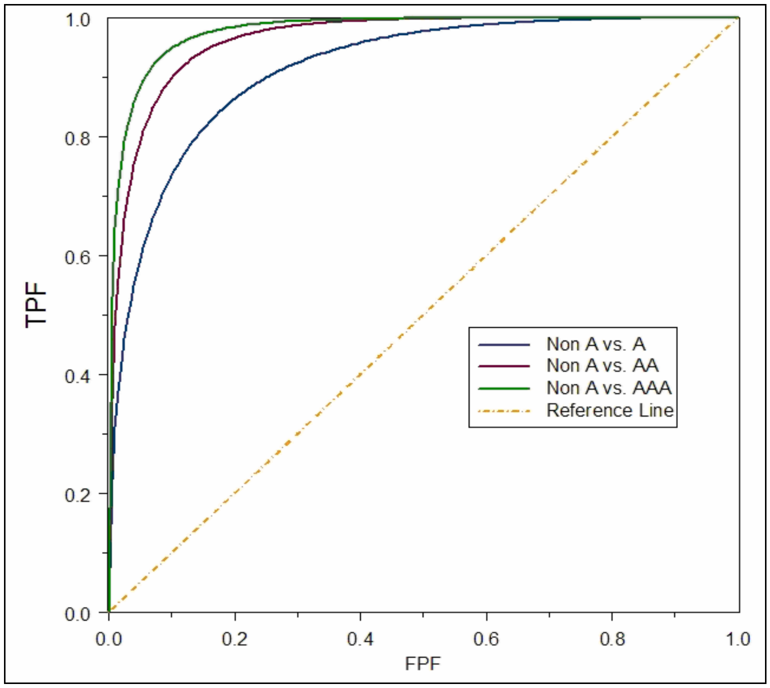

Figure 3-4: ROC of the C5.0 algorithm in separating different conformance groups

Figure 3-4 shows the ROC curves drawn from different cutting points for the complex weighting scores generated by the C5.0 machine-learning algorithm for the same websites. The C5.0 algorithm performs well in separating the adjacent accessibility categories, especially in separating "AA"-"AAA" as compared to the WAB score.

Table 3-3 shows the AUC score of the machine learning C5.0 in separating different levels of accessibility. As expected, the machine learning performance is better than the simple weighting used in the WAB metric.

Table 3-3: Value of AUC of C5.0 in separating different conformance groups

	NON-RATED - A	A - AA	AA - AAA	NON-RATED - AA	NON-RATED - AAA
AUC	0.962	0.787	0.769	0.983	0.983

Table 3-4 shows the comparison of the AUC values between the WAB score and the C5.0 algorithm. It shows that the performance the WAB metric is as good as the complex C5.0 in separating the rated categories from the non-rated one. The differences in AUC values for separating "AA"-Non-rated and "AAA"-Non-rated are not significant. Although the difference in the AUC values for separating "A"-Non-rated is significant, the performance of the WAB metric is also excellent (0.917).

Table 3-4: Comparison of WAB score and C5.0

	A-NON-RATED	AA - A	AAA - AA	AA-NON-RATED	AAA-NON-RATED
WAB	0.917	0.689	0.513	0.972	0.982
C5.0	0.962	0.787	0.769	0.983	0.983
Significance	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p = 0.0186$	$p = 0.4467$

The C5.0 algorithm is significantly better than the WAB in separating "AA"-"AAA." It is also better in separating "AA"-"A," although the performance of the WAB is also good. We dissected the decision tree of C5.0 algorithm to see how it is different from the WAB in assigning weights to the accessibility checkpoints. The decision tree algorithm performs significantly better in separating "AA" and "AAA" by giving more weight to checkpoints in Priority 3 (checkpoints that separate "AA" and "AAA").

The results show that the simple weighting method used in the WAB score performs well compared to the more complicated decision tree method in the critical separation tasks (separating rated categories from the non-rated ones). Since the decision tree is more complicated and provides different weighting schemes in different sets of data, the simplicity and reliability of the simple weighting scheme makes it more attractive.

3.5. Discussion

We proposed a novel metric for measuring Web accessibility that meets the requirements as a measurement for scientific research. This metric can be used for objective evaluation and comparing accessibility between different websites, different groups of websites, and different websites or groups of websites at different points in time. This simple metric compares well to the more complex machine learning method. We believe that the availability of an objective metric will open doors to a scientific approach to Web accessibility studies.

One of the conclusions we can draw from the literature review is that currently accepted evaluation methods for web accessibility is not flawless. Most of them only consider the absolute number of Web accessibility violations presented on a Web page. Simply counting the number of violation favors the page with simple design. Without considering the potential violations, e.g. number of image elements when checking non-alternative text images, may underestimate the effort the Web designer put on complicated pate. Second, most of the evaluations on web accessibility presented the studies in the category according to the checkpoints, guidelines or priorities of WCAG. Usually the researchers did not integrate all the checkpoints into one measurement score can represent the total barriers of web accessibility for one Web page. Although the presentation of the result can provide a sketchy outline of the distribution of the different Web accessibility, it is hard to use this categorical measurement to compare two web pages. Third, even for scarce papers that consider the Web page complexity, the classification is rather arbitrary and unrealistic. As we can see from this study, even the WAI AAA conformance page may come with imperfect score due to ignorance of the web page designer. One of the studies mentioned that the number of violations of bobby accessibility increases with design that is more complicated [72].

Because the current measurement method cannot fulfill our requirements for an unbiased and comprehensive evaluation of websites, we need to construct ourselves. The new measurement matrix should achieve such requirement for the measurement of web accessibility. First, it should intuitively be able to compare two websites in one measurement yet it may not reflect the overall distribution of web accessibility barriers. Secondly, the measurement should consider the level of complexity might influence the level of violations of web accessibility checkpoints. For example, the number of images in one page may be correlated with the non alterative text violations. It is not quite fair to say a page is not accessibility if it only has one non alternative text violations among 1,000 images, especially comparing to page with same number of violation but 5 total images. Third, the measurement may not be comprehensive but must be efficient. In some senses, it should be able to be completed by computer program automatically and reliably. The computer program can only check a relative small part of the checkpoints defined by the web accessibility guidelines. The automatic checking part should be working as a proxy to reflect the whole landscape of the web accessibility barriers. Last, the measurement should be normative, which is it should be derived from standard guidelines of web accessibility such as WAI and section 508 checklists.

3.5.1. Alternative Gold Standards

Several other candidate measurements can be adopted as the gold standard in this study. First, we can use persons with disabilities as a judge to determine the accessibility of a Web page. Although this method should be the ideal approach to acquire gold standard data, this approach appears to be hard to manage. Persons with disabilities themselves are a very diverse group with regard to different types and levels of disabilities. One of our participatory researchers who is a blind computer user, once said:

> How do you know if I am able to access everything a sighted user can. For instance I may just not be aware that there are menus on the page that are activated when you mouse over them. JFW may read the page perfectly but I might not even have inkling that some functionality of the page that I am missing. There might be colored text that conveys info but I may not realize that. Also there could be blinking text etc that I cannot access. But I may be able to access other content of the page. One form may be accessible while another may have some problems. Also there can be usability issues that make navigation inefficient and frustrating though not impossible. So how do I rate such a page?[73]

The accessibility requirements from each subgroup are very specific and often conflicted. An extreme example would be a text-dominated Web page, which is very accessible to visually impaired people while it is inaccessible to a person with a learning disability [74].

A second alternative is to use a comprehensive evaluation of Web pages following Web accessibility standards—manual checking. The WAI published a template for comprehensively evaluating the level of Web accessibility of a Web page [75]. It involves multiple steps, a variety of tools, and large amounts of manual checking. It once took me 2 hours to check the accessibility features of a Web page according to the WAI outlines. Other proposals for thoroughly evaluating Web accessibility of a website involve usability testing and several cycles. The overhead of such kind of evaluation is tremendous and prohibitively expensive for large numbers of Web pages.

3.5.2. Limitations of the Metric

The accessibility metric developed in this paper is intended for objective and systematic measurements of the accessibility of the Web as an instrument. This metric is not appropriate for checking the accessibility of an individual website for the purpose of accessibility repair or remediation. The metric will only serve as a proxy measure of accessibility, not a real measure of accessibility, which requires manual checking and human judgment. A developer may intentionally fine-tune their website to yield a perfect score from our formula, but the website may have many other inaccessible features that cannot be automatically included in the formula.

Chapter 4 EVALUATION OF WEB ACCESSIBILITY OF CONSUMER HEALTH INFORMATION WEBSITES

4.1. Introduction

The World Wide Web (WWW) has been an increasingly essential resource for the health information consumers. One recent study estimated that 73 million US residents searched for health information online during the year 2002 [76]. It is estimated that seventy-odd percent of the population search online for health-related information for their decision-making. With the advances of computer and Internet technology, the distribution of the online population is becoming representative of the general population in terms of demographic and socioeconomic status.

The ability to obtain accurate medical information online quickly, conveniently, and privately provides health consumers with the opportunity to make informed decisions and participate actively in their personal care [77]. Little is known, however, about whether this online information is accessible to persons with disabilities who must rely on special devices or technologies to process online information due to their visual, hearing, mobility, or cognitive limitations.

The latest report on Internet use from the National Telecommunication and Information Administration (NTIA) demonstrated that people of all ages, races, and ethnicities, including persons with disabilities, are moving more and more of their activities online [78]. A recent investigation on the use of Internet by persons with disabilities reported that this population is far less likely than those without disabilities to use the Internet [79]. Persons without disabilities are four times more likely (38.1%) to use the Internet than persons with disabilities (9.9%). Similar patterns remain even when factors, such as income, gender, and educational attainment, are taken into account. The large disparity in Internet usage can be attributable in large part to problems with accessibility of Web content. Nielsen (2001) reported that the usability of the Web is about three times better for users without disabilities than it is for users with disabilities [80].

For persons with disabilities, the Web is very often the only source of information that they may access without having to depend unduly on others . Equivalent Internet access to health information will open a door to persons with disabilities by offering them exciting possibilities for independent living and community participation. Persons with disabilities can find a wealth of information on the Internet that addresses many issues of special concern to them, including chronic disease information and rehabilitation and assistive technology services [81]. According to a recent report, persons with disabilities tend to seek health related information online more frequently than the able-bodied population [82]. Nevertheless, for health information websites to be of real use to persons with disabilities, they must first be accessible to them. Health information websites are a classic example of the "inverse information law:" access to appropriate information is particularly difficult for those who need it most [77].

4.2. Background and prior work

Web content accessibility helps persons with disabilities directly access Web pages. Persons with disabilities have to rely on specialized software or hardware to access the Web. For example, blind people have to install a software package called Screen Reader to read all the content on the Web page aloud to them. Some blind people also use a talking browser like IBM Homepage Reader to access the Web page aurally. Some blind people prefer a hardware-level solution like the computer-controlled Braille embosser to help them haptically perceive content of the Web page. Regardless of the solution favored by the users with disabilities, if the content of the Web page is not available to their remaining sensory channel, then the page is not accessible to them.

The Web inadvertently has become increasingly inaccessible to persons with disabilities as it adopts numerous emerging multimedia technologies. The Web was initially designed for sharing and accessing documents across different computer systems and platforms. These documents are primarily text-based and mostly accessible to assistive technology, such as screen readers. With the introduction of appealing multimedia content, however, the Web is becoming an information medium that is not accessible to or not easily interpreted by assistive technology. Graphics, animations, and even video/audio clips, now commonly appear on the Web. The absence of alternative information about multimedia content makes them less accessible to persons with disabilities than those with multimodal access to the multimedia content. The rapid expansion of e-commerce also makes the Web even more complicated and less accessible for persons with disabilities. As Herb Simon once stated, “What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it.”[83] Web page developers believe that multimedia content will lure more visitors to the website and make them stay longer. However, they overlook or ignore the accessibility of persons with disabilities to that multimedia content because its primary purpose is to draw attention from potential consumers, the majority of whom are not persons with disabilities.

Realizing this dilemma, the World Wide Web Consortium (W3C), the international organization that oversees the standardization and operation of the Web, announced the establishment of the Web Accessibility Initiative (WAI) on April 7, 1997 [84]. Supported by all W3C members, including such heavyweight stakeholders as Microsoft and IBM, the WAI plays the central role in promoting and correcting the functionality of the Web for persons with disabilities. The first major responsibility of the WAI was to formalize guidelines for Web content developers and designers. WAI introduced Web Content Accessibility Guidelines (WCAG) to the public as a draft in 1998 and developed it into a full recommendation, after many rounds of discussion and revision, in 1999 [85]. WAI extended the guidelines to be applicable in the design of user agents (e.g., Web browsers or assistive technology agents like the screen reader JAWS), authoring tools (e.g., Microsoft FrontPage or Macromedia DreamWeaver) and related techniques, as well as a practical checklist [86, 87].

There are two basic themes reflected in the WAI WCAG: ensuring graceful transformation of Web pages and making content understandable and navigable. By providing Web pages that transform gracefully, persons with disabilities or users with device limitations will be able to access them without constraints. Keys to graceful transformation include separating structure from presentation, providing text equivalents to non-textual element, creating documents that work even if the user cannot see and/or hear, and creating device-neutral documents. When the content is understandable and navigable, end users can utilize the page in a more effective, efficient and satisfactory, manner. Keys for making content understandable and navigable include providing a navigating context and orientating information, providing a clear navigation mechanism, and ensuring succinct content descriptions.

Another initiative in the development of accessibility standards is Section 508, conducted by the US Access Board. The Access Board issued standards for accessible information technology under the Reauthorized Rehabilitation Act. These amendments strengthen Section 508 of the Rehabilitation Act of 1973. Section 508 mandates that when federal agencies develop, procure, maintain, or use electronic and information technology, they shall ensure that the electronic and information technology allow federal employees with disabilities access to and use of the same information and data as accessed and used by federal employees who are not individuals with disabilities, unless an undue burden would be imposed on the agency. Section 508 also mandates that agencies ensures equal access to individuals with disabilities who are members of the public seeking information on data that is comparable to that provided to the public who are not individuals with disabilities, unless undue burden would be imposed on the agency. Section 508 clearly defines the accessibility for persons with disabilities for federal government websites. Section 508 took effect on February 20, 2001 [88].

Researchers from different disciplines have evaluated Web accessibility and usability of websites in various domains. The Journal *Library Hi Tech* published two special issues dedicated to Web content accessibility of Web-based information resources for persons with disabilities [89, 90]. Axel Schmetzke maintains a Web accessibility survey site that aspires to be a clearinghouse for studies involving the collection of accessibility data pertaining to websites and online resources in education [29]. The site listed many Web accessibility evaluation studies on libraries and higher education websites. Another related effort is the Web Usability Index (WUI), a free Web usability statistics database provided by UsableNet [91]. It employs an automatic Web usability evaluation tool for testing Web accessibility to obtain daily statistics of the Web usability of sample websites from the Internet. According to WUI, only about 43% of current websites provide excellent or good Web usability design.

Although the Web is considered a powerful force for reshaping the healthcare infrastructure, the accessibility of Web content to persons with disabilities is not a primary consideration of most designers of websites providing health related information. Very few research studies have been conducted on the accessibility of health information websites for persons with disabilities. Research studies on the accessibility of health information websites are for the most part about the find-ability and search-ability of Internet websites by online search engines or about the availability of information technology for the people who need it [34-38]. Current guidelines related to the quality of health information websites do not require the accessibility of website by persons with disabilities [39]. The absence of studies and discussion on Web accessibility of health information websites may result in a lack of awareness of this issue among online health information providers.

The only study known to the authors that covers health information websites was the study conducted by Joel Davis in 2002 [40]. Davis explored the extent to which Internet-based health information is accessible to visually impaired individuals who rely on automated screen readers. She selected 500 individual websites representing 50 common illnesses and conditions for evaluation. She found that accessibility is currently very low—only 19% of the examined sites' homepages were accessible. She also found the reason for the inaccessibility of the Web pages was noncompliance with the recommended design and coding changes.

Our study will be different from other studies in several ways: first, the study will check the accessibility of not only homepages (main pages) of health information websites, but also other Web pages within certain levels below the homepages. Secondly, the majority of other studies report the state of accessibility in terms of the absolute number of violations of accessibility checkpoints. Although absolute numbers of violations of Web content accessibility provide useful information about the state of accessibility, it is not straightforward for direct comparison of general accessibility between websites, and it does not include the complexity of the Web page into the evaluation. Thirdly, we will investigate the relationship between Web accessibility and other features of a website including function, popularity, and importance.

4.3. Research Questions

The overall objective of the study was to evaluate the accessibility of consumer health information websites for persons with disabilities. We were interested in the following specific research questions:

- What is the current level of accessibility for consumer health information websites?
- What is the relationship between web accessibility and the functional category of the website?
- What is the relationship between web accessibility and the popularity of the website?
- What is the relationship between web accessibility and the importance of the website?

4.4. Materials and Methods

4.4.1. Design

The study is primarily a cross-sectional descriptive study with concentration on the Web accessibility of websites providing consumer health information. We used established Web accessibility specifications (WCAG and Section 508) as the sources for constructing the measurement framework. Additionally, we investigated the relationship between Web accessibility and other features including function, popularity, and importance.

4.4.2. Materials

Individual website providing consumer health information is the unit of analysis in the study. Because the exact number and distribution of websites are not pre-determinable due to the tremendous size and rapid increment of the Web, probability based sampling methods, such as random or stratified sampling, are not applicable. Alternate sampling approach widely adopted by researchers conducting studies on websites is to use search engines or online website directories.

We acquired a list of consumer health information websites from the directory service of the Google search engine. Google's directory service obtained data from the Open Directory Project, the largest, most comprehensive human-edited directory of the Web [92]. We included all websites under the subdirectory "Health/Resources/Consumer" as our candidate websites for evaluation. We excluded ones that had their content changed to non-health related areas or were continuously unavailable during our study period after we reviewed the home page of each website.

After selecting the sample websites, we needed to delimit the scope of the Web pages to be included within each site. Since WCAG only applies to Web pages written in HTML (HyperText Markup Language), other content formats such as PDF (Portable Digital Format) files were not considered. However, server side scripting such as Active Server Page (ASP), or Java Server Page (JSP) is able to dynamically produce HTML-based code at the client side, so we took these types of page into consideration as well. Secondly, we needed to determine the number of Web pages from each website to be included in the analysis. Due to the large number of Web pages in some websites, it was not feasible to include all the pages into the study. We selected only the first two layers from the homepage within a domain of a website in our sample. We assume that the first two layers are most visited and will reflect the overall accessibility of the website for the study. The other reason for choosing only the first two layers is that the assessing program measuring the accessibility has limited processing ability and often encountered an "out of memory" alert if all pages of a website were included.

4.4.3. Measurements

4.4.3.1. Web content accessibility

One of the objectives of the study is to construct a measurement framework to assess the accessibility of consumer health information websites. As we discussed in the background section, two major specifications served as the normative guidelines for Web content accessibility design. The first—the W3C Web Content Accessibility Guideline 1.0 (WCAG)—is a stable international specification developed through a voluntary industry consensus. The US Access Board published the second specification—Electronic and Information Technology Accessibility Standards—in December 2000, pursuant to the US rulemaking process as required by Section 508 of the Rehabilitation Act Amendments of 1998 [88]. Both specifications offer checklists or rules that Web developers should follow with regard to content accessibility for persons with disabilities. These two specifications largely overlap—only three of the checkpoints defined in Section 508 are not mentioned in the WCAG guideline 1.0. WCAG is more comprehensive than Section 508 on checkpoints of Web content accessibility, and it provides a priority level to each checkpoint to reflect severity of violations. Therefore, WCAG was used as the foundation for the accessibility metrics we developed.

The number of violations of each checkpoint is a component of our scoring method called Web Accessibility Barrier (WAB) score. For example, a Web page with fewer accessibility checkpoint violations, e.g., providing no alternative description for an image object, will be considered having fewer barriers for persons with disabilities and will have a lower WAB score.

Because we are more interested in automatically evaluating the level of accessibility of a website, those Web accessibility checkpoints demanding manual checking are not included in the calculation of the WAB score. For example, conformance to the rule "If you use color to convey information, make sure the information is also represented another way" cannot be verified until a manual check is done. For a list of Web accessibility rules that need to be manually checked, please see the WAI references [14].

WCAG attaches a three-point priority level to each checkpoint based on its impact on accessibility to persons with disabilities. Priority 1 checkpoints mandate the largest level of compliance while Priority 3 checkpoints are optional for Web content developers. In weighting the calculation of the WAB score, we used the priority level in reverse order. Priority 1 violations are weighted three times more heavily than the priority 3 violations because persons with disabilities have more difficulty accessing Web pages with priority 1 violations.

However, using only the number of violations of Web accessibility checkpoints may bias the results of the measurement. For example, a Web page with five “image without alternative text” violations may have 500 image objects embedded in the page and the Web page with one “image without alternative text” violation may have only one image object in the page. The developer of the first page may have already paid much attention to and put great effort into complying with the Web accessibility specifications while the developer of the second page may be completely unaware of Web accessibility. Therefore, the number of actual violations of a checkpoint must be normalized against the number of potential violations of the checkpoint. In the last example, true violations are the image objects without alternative text, and the potential violations include all image objects on the page. The average WAB score of all Web pages with in a site will be the WAB score of the website. Please see Figure 3-1 in Chapter 3 for the formula to calculate the WAB score.

We employed several program tools to examine the true and potential violations of the Web pages. Bobby is a checking program that can examine a Web page and report violations of Web accessibility checkpoints [93]. It is the most widely used accessibility checking software package and has been around longest. Bobby was originally developed by the Center for Applied Special Technology (CAST) [94], and is now maintained and distributed by Watchfire Corporation [95].

Bobby desktop version 4.0.1 was used in this study. The desktop version can check compliance with WCAG of an entire website or only certain layers from the homepage. The version 4.0.1 can check non-compliance issues with both WAI and Section 508 checkpoints. After checking a website, Bobby generates a report in eXtensible Markup Language (XML) format that can be further processed to extract data about true violations.

Bobby implements 91 distinct testing rules, each of which maps onto a specific WCAG checkpoint. The Bobby tests are classified into a number of different "checking" categories, as follows: (1) Full: Bobby automatically checks this rule and decides whether there is an error. (2) Partial: Bobby automatically performs some checking of the rule, but cannot decide the existence of violations. Instead, the line number is used as a warning to the testers. (3) Partial Once: Similar to the Partial category, but the warning is not specific to an individual line. (4) Ask Once: Bobby does not have a mechanism to check the rule, so the rule is presented as a reminder to the testers.

For all categories other than Full, a human tester must manually evaluate the site further to determine the WCAG conformance, which is not practical for a large scale website study like this one. We used only the 25 rules that Bobby implements with "Full" checking capacity for our evaluation. Even for the rules with "Full" checking capacity, we still cannot determine the quality of the conformance to WCAG. For example, the Web page developer can simply put the file name of the image into the "alt" attribute of the <IMG> element to avoid a flag from Bobby. The quality of such conformance is much less acceptable than providing detailed description in the "ALT" attribute.

Table 4-1: Checkpoints and the determinant of the number of potential violations

WAI Priority	Checkpoint	Determining the number of potential violations
1	Provide alternative text for all images.	All <img> elements
1	Provide alternative text for each APPLET.	All <applet> elements
1	Provide alternative content for each OBJECT.	All <object> elements
1	Provide alternative text for all image-type buttons in forms.	All <input type="image" …> elements
1	Provide alternative text for all image map hot-spots (AREAs).	All <area> elements
1	Each FRAME must reference an HTML file.	All <frame> elements
1	Give each frame a title.	All <frame> elementS
2	Use a public text identifier in a DOCTYPE statement.	1*
2	Use relative sizing and positioning (% values) rather than absolute (pixels).	All <table>, <th>, <td>, and <frame> elements
2	Nest headings properly.	All heading
2	Provide a NOFRAMES section when using FRAMEs.	All <frameset> element
2	Avoid blinking text created with the BLINK element.	Same as the number of true violations#
2	Avoid scrolling text created with the MARQUEE element.	Same as the number of true violations#
2	Do not cause a page to refresh automatically.	1*
2	Do not cause a page to redirect to a new URL.	1*
2	Make sure event handlers do not require use of a mouse.	Number of event handler for both keyboard and mouse
2	Explicitly associate form controls and their labels with the LABEL element.	Number of form elements such as <input>, <select>, and <textarea>
2	Create link phrases that make sense when read out of context.	Number of <a> elements
2	Do not use the same link phrase more than once when the links point to different URLs.	Number of <a> elements
2	Include a document TITLE.	1*
3	Client-side image map contains a link not presented elsewhere on the page.	Number of <area> elements
3	Identify the language of the text.	1*
3	Provide a summary for tables.	Number of <table> elements
3	Include default, place-holding characters in edit boxes and text areas.	Number of <input type = "text">, <text area>, and <select> elements
3	Separate adjacent links with more than white space.	Number of links.

* This feature is determined at the entire page level. Therefore, we assign 1 to the number of potential violations.
# The number of potential violation of this feature is not able to be determined. Therefore, we use the same number as the true violations as the number of potential violations. The frequency of the violations is simply 0 or 1 according to the formula of Web Accessibility Barrier (WAB) score.

The data of corresponding potential violations of each checkpoint can be extracted using a Web crawler program. A Web crawler program is an automated program that follows links to visit Web pages. We developed a lightweight Java-based Web crawler program to access Web pages at remote websites and determine the number of potential violations of Web accessibility checkpoints. We did not use other available Web crawlers because many crawlers are too complex to be easily customized to our specific tasks. We can also make use of the crawler as the basis for future development of tools for Web accessibility evaluation. For a list of rules for extracting data of potential violations, please see Table 4-1. Since Bobby and the "homemade" Web crawler may retrieve an unmatched number of pages for the different capacities of both crawlers, we only used the Web pages retrieved by both programs in the study.

4.4.3.2. Other features of the websites

We measured three variables—function, popularity, and importance—as the features of the websites. We classified the candidate websites based on their functions. We used a taxonomy that classifies the websites into 6 functional categories: e-commerce, corporate, portal, community, government, and education. We derive the taxonomy from a similar one from the Web Usability Index database [91]. An e-commerce website conducts online transactions of health related products or services. A Corporate website represents a health care service corporation online. A Portal website provides patients entrance to various health related information resources. A Community website hosts online activities for patients or health information seekers. Government and education website are sites with the postfix ".gov" and ".edu," respectively in their domain names. Table 4-2 lists example websites from each category.

Two evaluators individually assigned each website to one of the aforementioned categories. In case of a disagreement about the assignment, both evaluators discussed it until reaching a consensus. Each website falls into only one of the categories. It is possible that a website belongs to different categories. For example, HealthFinder.gov is a governmental website provides portal service. In this case, the domain of the website will take precedence because we are interested in views the performance from the public domain specifically because of the existence of legislations.

Table 4-2: Example websites of each functional category

CATEGORY	DEFINITION	EXAMPLES
Portal	Website provides patients entrance to various health related information resources	Web MD (http://www.webmd.com)
Government	Website has the postfix ".gov" in the domain name	Health Finder from U.S. Department of Health and Human Services (http://www.healthfinder.gov)
Corporate	Website represents a health care service corporate online	Mayo Clinic (http://www.mayoclinic.com)
E-commerce	Website conducts online transaction of health related products or services.	Health Windows (http://www.healthwindows.com)
Community	Website hosts online activities for patients or health information seekers.	Health Forum (http://www.healthforum.com)
Education	Website that has the postfix ".edu" in the domain name	HealthLink from medical college of Wisconsin (http://healthlink.mcw.edu)

We obtained traffic-ranking data from each website using the search engine Alexa [96]. Using a downloadable toolbar installed on its users' desktop, Alexa calculates statistics about the traffic pattern of a website. Because the toolbar is only available for Microsoft Windows and Internet Explorer, it limits itself on the accuracy of the traffic ranking of the website. However, it may reflect the popularity of the website on the Web to a certain extent. We retrieved the ranking data of the entire candidate websites from Alexa on February 25, 2003.

We measured the level of importance based on the PageRank score of each website available from the Google search engine. The PageRank score relies on the uniquely hypertext nature of the Web by using its vast link structure as an indicator of an individual page's value. In essence, Google interprets a link from page A to page B as a vote by page A for page B. Therefore, the PageRank score of a page can be viewed as an indicator of the importance of the page. But Google looks at more than the absolute volume of votes, or links a page receives; it also analyzes the page that makes the vote. Votes cast by pages that are themselves "important" weigh more heavily and help to make other pages "important." Because Google does not provide PageRank in a numerical value from its searching interface, we had to rank the sites according to an implicit PageRank score and use the ranking number as the value of the variable of importance. We retrieved the ranking of importance of all candidate websites from Google on February 26, 2003.

4.4.4. Data Analysis

All statistical analyses were performed with alpha value at 0.05 and power at 0.80. Descriptive statistics (means and standard deviation) were calculated for each variable considered in the study. Univariate statistics of the WAB scores were calculated at the level of each category. Then a one-way ANalysis Of VAriance (ANOVA) test was applied to the WAB scores at the level of the website's functional category. If the ANOVA test indicated a large difference in the WAB scores among different categories, the post hoc Bonferroni test of the WAB scores between different categories was conducted. The alpha level was adjusted for multiple comparisons in the Bonferroni test.

Google does not provide numeric value for its PageRank measurement, but it ranked websites with a sub-category from highest to lowest PageRank value. Therefore, we use the ranking sequence as the value of web page importance for Nonparametric Spearman correlation. We Nonparametric Spearman correlation statistics were also conducted to measure the level of correlation between the WAB scores and the popularity of the websites. All statistical analyses were conducted using the SPSS 11.0 software package.

4.5. Results

4.5.1. Descriptive Statistics of WAB Score

The Google sub directory "Health/Consumer/Resources" lists One hundred twenty-two websites, fourteen of which were excluded because of health-unrelated content and broken links. The assessing program retrieved 7,109 Web pages for these remaining 108 sites. The WAB score means and standard deviations for the remaining sites were calculated. Mean WAB score of total websites is 9.31 with 95% standard deviation of 6.29. No website was completely accessible (WAB score = 0). The National Institutes of Health (NIH) Combined Health Information Database (CHID) site achieved the lowest WAB score -- fewest accessibility barriers -- of the sites tested (0.97), while a community website (http://www.discussyourhealth.com) received the highest WAB score (24.99). The five most frequently violated checkpoints among all pages are: "identify language of the text" (77.0%), "use a public text identifier in a DOCTYPE statement" (65.6%), "provide a summary for tables" (61.6%), "use relative sizing and positioning (% values) rather than absolute (pixels)" (60.0%), and "provide alternative text for all images" (52.2%).

4.5.2. WAB Scores in Different Categories

Among the six categories of websites, government websites were most accessible and had the lowest WAB scores, and portal websites were least accessible to persons with disabilities, indicated by higher WAB scores (Table 4-3).

Table 4-3: Web Accessibility Barrier (WAB) scores in different categories

CATEGORY	MEAN	NUMBER OF WEBSITES (N)	STANDARD DEVIATION
Portal	13.17	30	6.16
Government	1.42	6	0.39
Corporate	9.03	25	3.94
E-commerce	8.53	8	3.39
Community	9.92	29	6.8
Education	2.06	10	1.16
Total	9.31	108	6.29

Average WAB scores and standard deviations of Web accessibility were calculated for each of the Web categories and the results indicate possible clustering among the six categories, as shown in Figure 4-1.

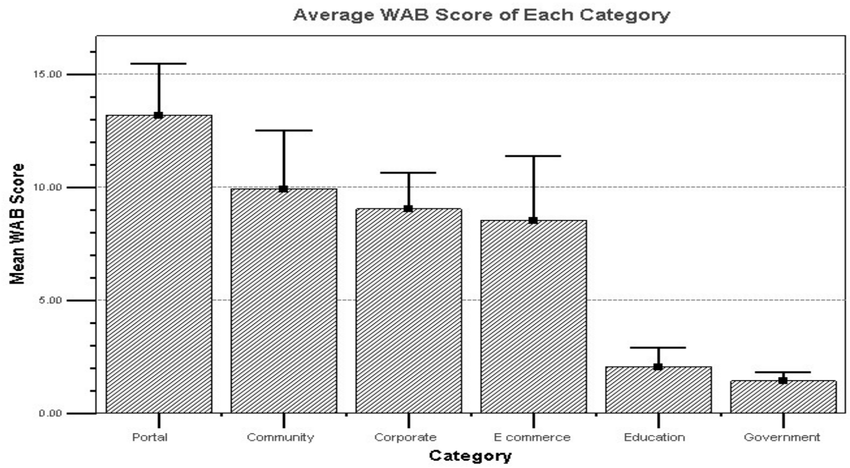

Figure 4-1: WAB score in each category

Statistically significant differences among the category groups were found using the ANOVA test on the WAB scores ($F = 9.705$, $p < 0.001$). In addition, the post hoc Bonferroni test found that the mean WAB scores of governmental and educational websites are significantly different from the rest of the categories ($p < 0.001$). There is no statistically significant difference between any two categories within these two clusters.

4.5.3. WAB Score, Alexa Ranking and PageRank

Table 4-4: Correlation between WAB, Alexa Ranking, and PageRank

	WAB SCORE	ALEXA RANKING	PAGERANK
WAB score	1.00	0.28**	0.15
Alexa ranking	0.28**	1.00	0.32**
PageRank	0.15	0.32**	1.00

** Correlation is significant at the 0.01 level (2-tailed).The complete results data set is included as a data supplement with this article.

Table 4-4 lists the Spearman correlation coefficient in WAB score, Alex ranking and Google's PageRank. The Spearman correlation test indicates a statistically significant, though modest, correlation between the WAB score and the Alexa™ traffic ranking (r=0.28, $p < 0.01$). However, no statistically significant correlation exists between the WAB score and the PageRank of websites was found ($p = 0.111$).

4.6. Discussion

Awareness of Web accessibility issues is increasing among developers of health information websites due to law enforcement and prospective commercial benefits. Even though many evaluation tools are now available to developers intending to improve the accessibility of their websites, the status of Web accessibility, especially among health information websites, is largely unknown. Compliance with the specifications of Web content accessibility is necessary to narrow the digital divide between the information affluent and digitally underserved people, in this case, those with disabilities. Ours is the first study to address the issue. It provides a relatively comprehensive evaluation of the Web accessibility of consumer health information websites, and proposes a metric for measuring the accessibility of a website that takes into account both Web accessibility violations and the complexity of the website presented as potential violations of accessibility checkpoints. This approach provides a more accurate and impartial measurement about the level of accessibility barriers than using only the absolute number of violations as employed by most other evaluations. Additionally, the study investigates the relationship between the level of Web accessibility and function, importance, and popularity of a website.

4.6.1. State of Web Accessibility

None of the consumer health information websites satisfied all of the Web accessibility requirements, which may be attributed to website developers knowing little about Web accessibility standards, lack of effective and efficient evaluation and repair tools, and pressure to update information on the website quickly. The fact that Web accessibility, if ever considered, is often an afterthought once Web content design is finished implies that program tools producing efficient, effective post-hoc repairs of Web content accessibility violations or an accessible proxy server transforming and filtering inaccessible online content for persons with disabilities may be more accepted by both the developers and website visitors.

4.6.2. Web Accessibility across Different Categories

Of the sites providing health information, government sites followed by education sites are the most accessible. This compliance may be attributed to Section 508 since it is mandatory for all federal agencies and any federal-funded entity [97]. High compliance among sites which fall under this mandate also indicates that legal activities would facilitate the removal of accessibility barriers for persons with disabilities.

None of the tested websites, including the most accessible government sites, passed the WCAG guideline priority 1 checkpoints, even though the five most frequently violated checkpoints have technically uncomplicated solutions if designers pay attention to them. This may imply that the website editor simply overlooked the errors, and, for such editors, an automatic website monitoring program could be very helpful in identifying and correcting these errors on their website.

The education websites are the second most accessible category of the websites. Section 508 is not strictly mandatory for the information technology available on educational websites, but high awareness of WCAG rules and legal requirements on most campuses may contribute to better Web accessibility among the education websites. Furthermore, although Section 508 does not mandate all education websites, it does apply to educational programs and projects that receive federal funding, as many do, which may explain the high compliance to WCAG rules among education sites.

4.6.3. Web Accessibility and Popularity or Importance

The accessibility of a website also correlates with its popularity, possibly implying that persons with disabilities are more likely to visit websites that contain fewer or no barriers to them. Search engines use programs called Crawler to access Web pages on the Internet and store web page indexes in database for fast Web information retrieval. Web crawlers works similarly to blind Web user using screen reader program [98]. Accessible Web pages will have better opportunities of being indexed by Web crawler. Subsequently the overall popularity of the websites increase since they attract a group of visitors who have difficulties accessing other sites containing more Web accessibility barriers.

4.6.4. Limitations

Please note that there are several limitations of this study. First, although this study attempts to comprehensively assess the Web accessibility of a website, it is not practical for some websites, especially those with large amounts of archived documents. The Bobby program used in the study often freezes when check all layers of a website, resulting in the decision to check only a manageable two layers of Web pages in the study. A more robust tool needs to be adopted or developed in future studies.

Secondly, only the checkpoints of Web accessibility that can be examined automatically by a computer program were studied. Many other checkpoints require a manual check of pages to ensure the compliance of the content with the guidelines of Web accessibility. WAI proposed a comprehensive framework for evaluating Web content accessibility which requires multiple steps involving several evaluation tools to ensure the accuracy of the evaluation results. Although this type of evaluation is important for quality assurance of individual websites, the cost of such a large operation makes it impractical for an evaluation study involving many websites. This study assumes that the checkpoints that can be automatically evaluated will strongly correlate to the manual checkpoints and can be used as a surrogate assessment for the Web accessibility of a website. Future studies might explore the agreement between these two groups of checkpoints.

Furthermore, the traffic ranking information provided from Alexa may skew towards users of Internet Explorer on Windows operating system, underestimating the traffic to sites that are disproportionately accessed by people using other browsers or operating systems. The site most likely to suffer from this bias is AOL (American Online) since their members commonly use AOL browsers to access the site.

4.6.5. Conclusions

This study evaluates the current state-of-accessibility of consumer health information websites to persons with disabilities. Accessibility barriers are present in all categories of the sites, especially commercial websites. Government and education websites show better performance than websites among other categories. Accessibility of a website may have an impact on its popularity because persons with disabilities will feel comfortable visiting websites with fewer accessibility barriers than other inaccessible websites. This study attempts to increase awareness of Web accessibility among the designers of consumer health information websites.

Chapter 5 BEYOND WEB ACCESSIBILITY: WEB USABILITY FOR BLIND WEB USERS VIA A WEB TRANSCODER SERVER

5.1. Introduction

From Chapter 2 and Chapter 4, we learn that the Web is still inaccessible to persons with disabilities despite efforts to apply guidelines and legislation on accessible Web design [15, 32, 60, 98-100]. Chapter 4 suggests that Section 508 has been successful in making federal government websites relatively accessible, just as the WAI standard is successful in making educational websites accessible [101]. The same study, however, also reveals that other categories of websites, namely corporation, community, e-commerce, and portal websites, remain inaccessible. As the complexity of websites increases due to new technology, the problems of inaccessibility worsen [102].

Efforts in making the Web accessible take place at three interconnected fronts: the server side, the client side, and through transcoding intermediaries [3]. Efforts on the server side include guidelines for writing accessible websites [8, 14, 103]. Efforts on the client side include the development of screen readers with enhanced ability to render Web pages [104]. The other front to make the Web accessible is the transcoding intermediary [47, 48]. In considering the size of the Web, especially the size of inaccessible Web pages, this approach has great potential in supplementing the other two approaches. The number of unique Web pages was estimated at 2.1 billion pages as of July 2000, growing at a rate of 7.5 million pages per day [62]. The total number of deep hidden Web pages, Web connected back-end databases, is estimated at 550 billion invisible Web documents [63]. The Web is not only characterized by its sheer enormity but also by its fluidity; websites constantly expand and change. The average lifespan of a Web page today is estimated at 100 days [64]. Moreover, the ambiguity of the Web accessibility guidelines leaves room for self-interpretation during the implementation of these guidelines. Web developers also complain about the lack of available tools that integrate well into their daily business process. All of these contribute to the production and existence of inaccessible Web pages on the Web. Some of these pages are no longer anyone's responsibility but still contain useful information. An intermediary approach can retrofit these pages to an accessible status in real time if any inaccessible barriers exist on them.

Many researchers, including ourselves, have developed different designs of Web intermediaries [46, 49, 105-107]. Our accessibility transcoder server differs from other approaches in several ways. Firstly, in addition to use generic Web accessibility checkpoints to define the transformation guidelines, we also employ participatory design to generate rules for transformations. Secondly, we made our server benefit not only persons with disabilities but also others whose access to the Web is under functional constraints. Thirdly, we developed and implemented several novel algorithms to clean HTML and detect spatial context on a page. This chapter and the next report usability studies conducted on blind Web users and PDA users.

We developed the accessibility transcoder server primarily to serve the community of persons with disabilities trying to access the Web. As discussed in Chapter 1, it will also benefit other Web users with situational or device limitations. The majority of the transformational rules used in our Gateway are in conformance to the guidelines of WCAG 1.0. Therefore, relying only on the WAB scores described in Chapter 3 to measure the outcome of the gateway server may lead to exaggeration of the effectiveness of the server. We need to employ other measurement methods to triangulate the assessment of the outcome. In this chapter, I will utilize usability testing to measure the performance enhancement of the Web accessibility gateway server on persons with disabilities, especially blind Web users. In chapter 6, I will evaluate the usability of the transformation by the server for persons accessing the Web under constraints, especially the PDA Web users.

5.2. Methods

5.2.1. Pilot Study and Participatory Design

Prior to the usability study, we conducted a pilot study on similar but different groups of participants. We adjusted several implementations of our initial Web accessibility transformation rules based on the feedback from the pilot study. During this pilot study, we asked the participants to list the features that they liked or disliked during the debriefing period. The experimenter shadowed the participants visiting websites and took notes of interesting findings. The following is the list of observations from the pilot study:

Later versions of JAWS (> version 4.02) have a feature that can retrieve all HTML headings (h1 - h6) in the HTML file after it is loaded, blind Web users usually rely on this feature to navigate directly to the destination. They also utilize this feature to circumvent the repetitive and tedious navigation menu. Navigation menus usually are placed at the top or right side of the page that will appear first from the JAWS readout. Because of this finding, we implemented preliminary heuristics to ascertain possible headings at different sections of a Web page.

Although some pages may provide blind Web users with a “skip to the main content” at the beginning of the navigation menu for better navigability, it may not be practical for novice users of screen readers. Our participants let the screen reader read out a page for them. By the time they hear the “skip to the main content” link, it is usually too late to press the “ENTER” key to follow the link, especially for novice users of screen reader. Therefore, in addition to the “skip to the main content” hyperlink, we also add an implicit heading coded as “<h1 title=”main

content"></h1>" to indicate the starting point of the main content. The usability of this approach needs further exploration.

From version 4.5, JAWS allows users to choose different levels of verbosity. If the user selects "read out links," JAWS can add a readout "link" after each hyperlink. This eliminates the initial problems presented by adjacent links as required by WCAG 1.0. We suppressed the implementation of adding brackets between adjacent links to accommodate newer versions of JAWS. However, whether this approach is universally accepted by all assistive technology users is uncertain.

WCAG 1.0 defines "Until user agents handle empty controls correctly, include default, place-holding characters in edit boxes and text areas."[14] Although JAWS 4.5 still does not have the ability to handle empty controls, putting default characters inside a text field or area as hints may cause usability problems for novice users of screen reader. For example, our pilot testers often forget to remove the default text before inputting any character in the text input or area. As long as the label of the form element is closely bound to the element itself, it is not necessary to put default text inside an input field. We removed our original implementation of putting default text in input areas as a reminder to accommodate novice users of screen readers or voice browsers.

One common theme from our observations is that blind Web users place more emphasis on usability than accessibility itself. For example, a page can be free from accessibility violations, but it may still be difficult to use by a blind user if it does not provide contextual support or shortcuts. On the contrary, if a page provides screen reader-friendly contextual information such as informative headings and hyperlinks, it would be more usable for the blind user even though it may contain syntactical violations of the Web accessibility guidelines. Many participants make such statements as "I don't care whether the image has alternative text or not. I only care whether the site can help me find the information I am interested in." This indicates that Web accessibility guidelines are only useful to a certain extent while the usability for persons with disabilities should be the top priority when designing accessible websites.

5.2.2. Study Design

The study design is a within-subject crossover study. Each participant accessed both original websites and the websites transformed by our gateway server. Half of the participants accessed the original website first, then the transformed website. Half of the participants accessed the websites in the opposite way. The benefits of the crossover design are the elimination of between subject variance, decrease in the sample size needed, and the discovery of possible learning effects. Learning effects occur when participants rely on experiences obtained in the first leg of study to implicitly improve their performance in the second leg. Because listening to the synthesized speech from a screen reader may cause fatigue easily for blind Web users, we asked participants to take a break between the first and the second leg of the study. The break also serves as a washout period to reduce the learning effect on the performance in the second leg.

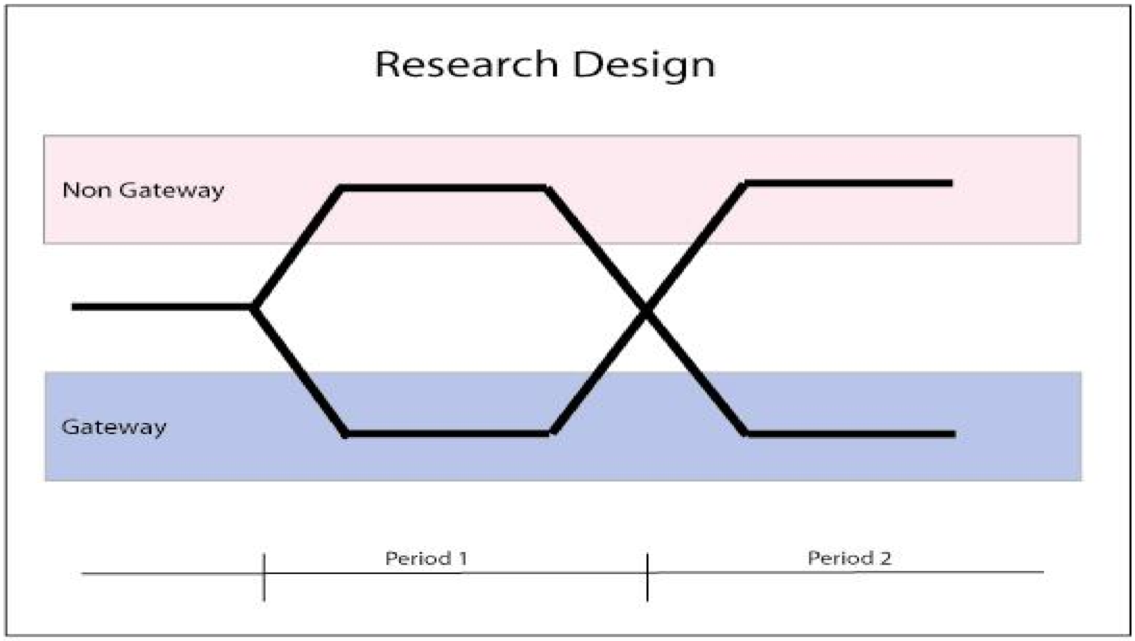

Figure 5-1: Research Design

We conducted the usability study to explore the effectiveness of our gateway server for blind Web users. The study was conducted at participants' houses or their offices with their preferred setting of computer and screen reader. By observing the participants working in their natural environments, we gain not only ecological validity but also insight into how the participants use their computers in daily life.

5.2.3. Participants

Sixteen participants were recruited from the local Pittsburgh area via local vision services and blind computer user groups. Six out of the sixteen participants are female. The participants range from 30 to over 65 years of age. On average, they have 5.8 years of experience using screen readers, 4.6 years of experiences with the Internet, and 4.1 hours of daily usage of the Internet. All participants use the JAWS screen reader with about thirteen of the sixteen (81.25%) using version 5.0 and the rest using version 4.5. Because JAWS provides integrated functions with

Internet Explorer, all participants used Microsoft Internet Explorer as their only Web browser. The participants are involved in many online activities: 100% use email, browse the Web, and use the Web to search for information; 62.5% listen to online radio or music; 50% did some online shopping before; 31.3% played online games or mentioned reading books online; 12.5% did online chatting.

5.2.4. Tasks

Table 5-1: Tasks of the usability study

LEGS	WEBSITES	TASKS
1	http://www.post-gazette.com	Read the top headline news in the **local** news section. Find the name of the reporter who wrote the news.
	http://www.booksamillion.com	Locate the No. 1 bestselling **fiction** book, find the different formats of the book available, and put one copy (in any format) in the shopping cart.
2	http://www.post-gazette.com	Read the top headline news in the **U.S.** news section. Find the name of the reporter who wrote the article.
	http://www.booksamillion.com	Locate the No. 1 bestselling **non-fiction** book, find the different formats of the book available, and put one copy (in any format) in the shopping cart.

The study includes two different types of tasks. The first is online browsing and information gathering. The participants visited a local newspaper website, read the headline news of different sections, and found the names of the reporters who wrote the articles. The second is conducting online shopping. The participants visited a bookstore website to locate the No.1 bestselling book. They also needed to find out the different formats the book comes in and put their favorite format into the shopping cart. Table 5-1 describes each task in detail. Although the same website appears in both legs, the tasks performed on the website are slightly different to reduce the learning effect. The similarity of the tasks from the same website at different legs will minimize the performance difference caused by task variation.

5.2.5. Measurement

The current study used usability testing methods to evaluate the performance of Web Transcoder Gateway server for the blind to access the Web. International Standard Organization (ISO) defines usability as "the effectiveness, efficiency, and satisfaction with which specified users achieve specified goals in particular environments" [108]. Subsequently, effectiveness is "the accuracy and completeness with which specified users can achieve specified goals in particular environments." Efficiency is "the resources expended in relation to the accuracy and completeness of goals achieved." Satisfaction is "the comfort and acceptability of the work system to its users and other people affected by its use." From these definitions of usability and its components, it is possible to develop explicit measurements that, in turn, provide a framework for empirical studies.

5.2.5.1. Objective Measurement

Three variables – time, success, and number of errors made on each task – were employed to measure the performance of the participants finishing each task. The time on each task was measured beginning after participants finished loading the Web pages into their screen reader and ending when participants finished all the requirements in each task or decided to give up. For each task, the time limit to finish is set as 20 minutes. We classified the success of each task into three levels: "0" when the participant cannot find the answer and withdraw or the time is over the 20 minute limit; "1" when the participant gave the wrong answer; and "2" when the participant gave the correct answer. The number of errors the participant made is the number of task-unrelated webpages they had visited during the study. The researcher explained the details of each task to the participant until the participant fully understood all the requirements. The researcher provided no help or suggestions to the participants for their performance, but he repeated the requirements occasionally to the participants if they asked for clarifications during the study.

5.2.5.2. Subjective Measurement

The participants answer three subjective questions – satisfaction, frustration, and confidence – in a 7-point Likert scale. These three questions are phrased as follows:

- Could you indicate the degree of your satisfaction with the websites using a 7-point scale – one is the least satisfied, seven is the most satisfied?
- Could you indicate the degree of your frustration with the websites using a 7-point scale – one is the least frustrated, seven is the most frustrated?
- Could you indicate the degree of your confidence with the websites using a 7-point scale – one is the least confident, seven is the most confident?

5.2.6. Debriefing

The experimenter held a debriefing session with each participant at the end of study session to acquire feedback from the participants. The participants were free to ask any questions, express their opinions on the gateway server, or describe their experiences with Web content accessibility.

Study sessions were video recorded with the informed consent f the participants. Private information of each participant was kept confidential by the researcher.

5.2.7. Data Analysis

For all data analysis hereafter, an alpha value for statistical significance is set at 0.05 and statistical power is set at 0.80 (beta value is 0.2).

Descriptive statistics were conducted on the demographic and outcome variables of the participants. A mixed model analysis was employed to analyze the statistical significance of the effects of design, period, and intervention. Mixed model analysis is a linear model that takes both random and fixed variables as input variables. The design variable is a random variable that represents whether the participants were randomly assigned to different path. The period variable is a random variable that represents the different period of the study. The intervention variable is a fixed variable that represents the effect of the intervention – gateway or no gateway. The outcome variables are time, error rate, and the subjective score respectively.

5.3. Results

5.3.1. Time

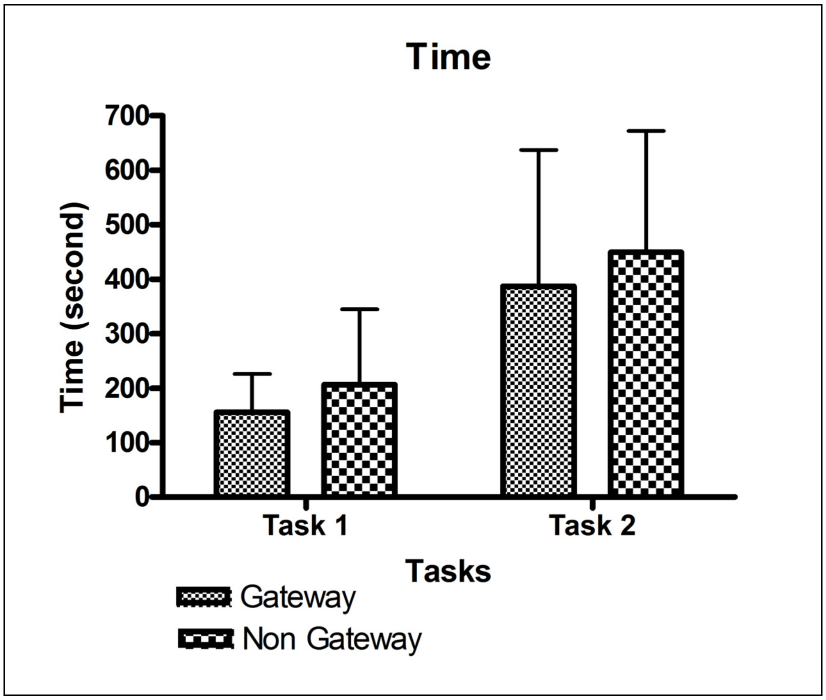

Figure 5-2: Time on each task via gateway or non gateway

Figure 5-2 depicts the mean and standard deviation of the time participants spent on each task through the gateway server or the original websites. On average, participants spent less time finding information through the gateway server than accessing the websites directly in both tasks. They spent less time on task 1 than on task 2, which is proportional to the level of the complexity of the tasks.

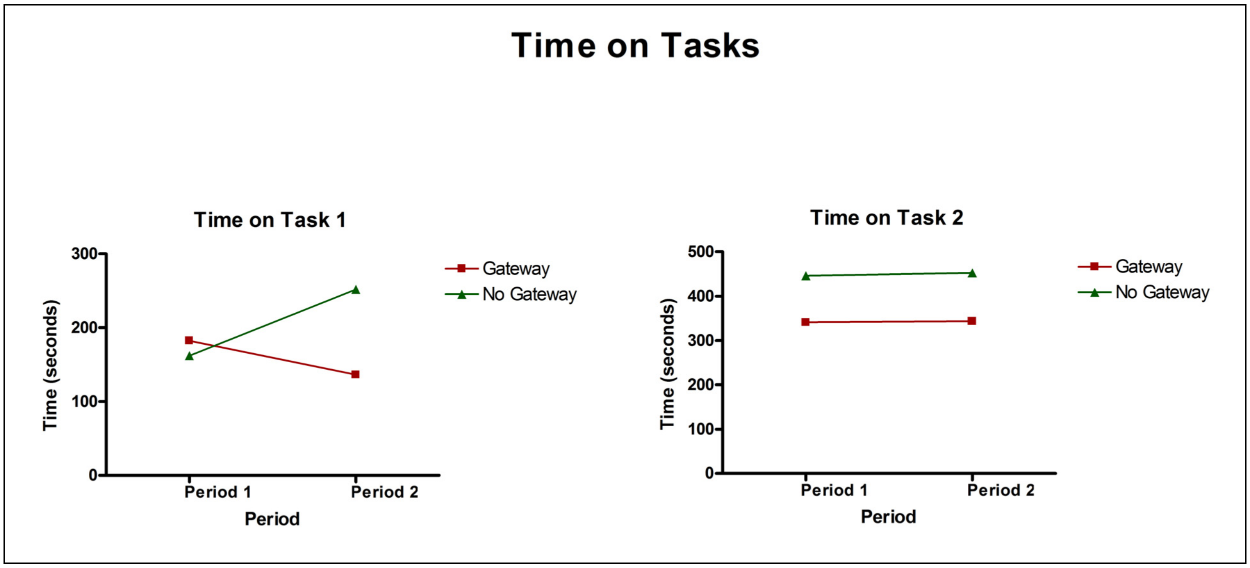

Figure 5-3: Time on each task at different periods

Figure 5-3 breaks down the mean time during the different periods. For task 1, participants spend less average time accessing the original websites than the transformed ones during period 1, but they spend more time on the original websites than the transformed sites during period 2. The gap of time between using the gateway and not using the gateway is larger in period two than in period 1. For task 2, participants always spent less time accessing the transformed websites than the original websites at any period.

5.3.2. Success Rate

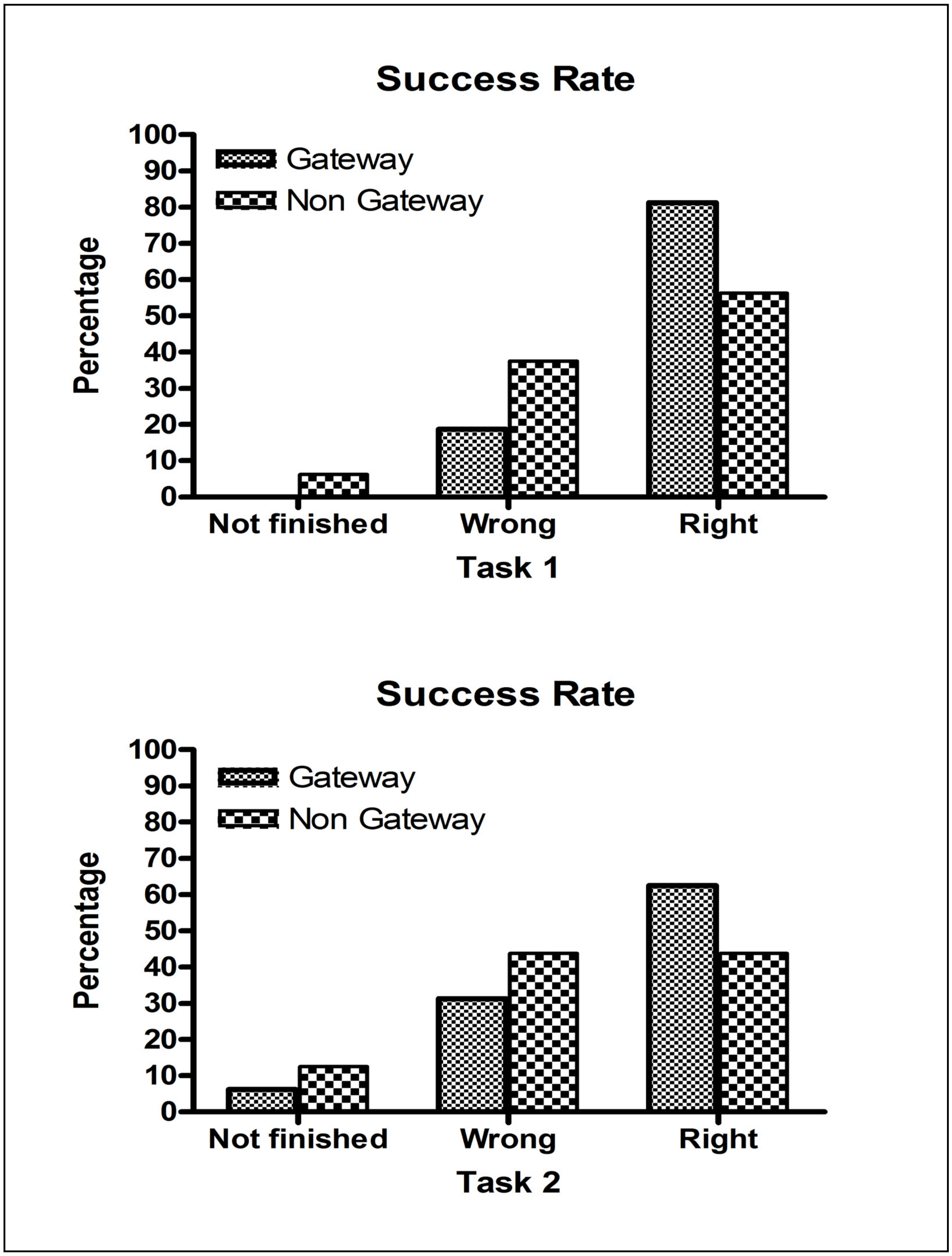

Figure 5-4: Percentage of success level for each task via gateway or non gateway

Figure 5-4 shows the percentage of different success level – not finished, finished but wrong, and finished with correct answer – of each task via the gateway server or not. In task 1, 81.25% of the participants can find right answer via gateway server, while 56.25% of them find correct answer via non-gateway. In task 2, 62.5% of the participants can find correct answers via gateway server, while 43.75% of them can find right answers accessing original websites. It indicates that participants tended to find more right answers via the gateway server than by visiting the original websites. It also indicates that participants were more likely find the right answer for task 1 than task 2, which also matches the level of complexity of each task.

5.3.3. Errors

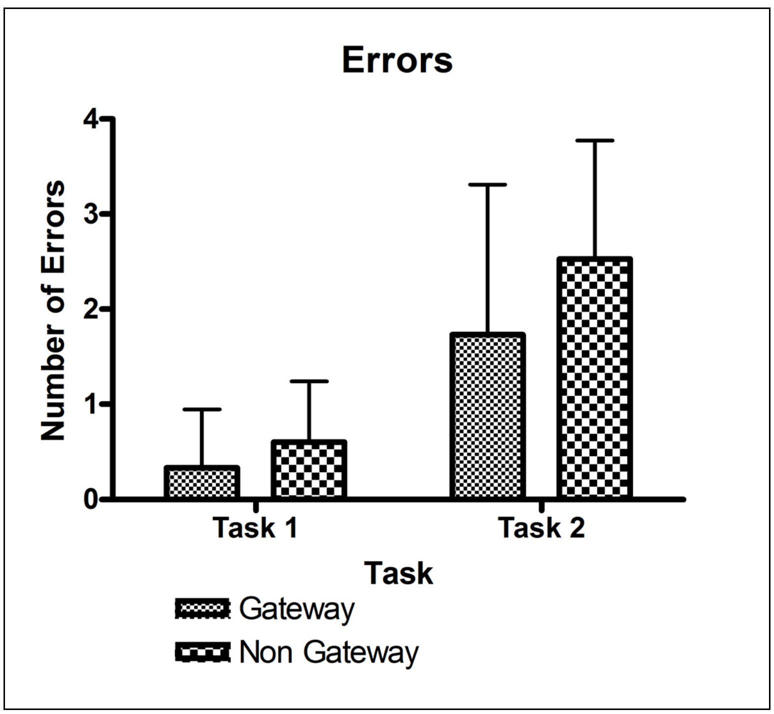

Figure 5-5: Number of errors of each task via gateway or non gateway

Figure 5-5 illustrates the mean and standard deviation of the number of errors that participants made in each task via the gateway or non gateway server. It shows that the gateway server can help participants make fewer erroneous visits to unrelated webpages than does the original website. It also shows the number of errors increases when the complexity of task increases.

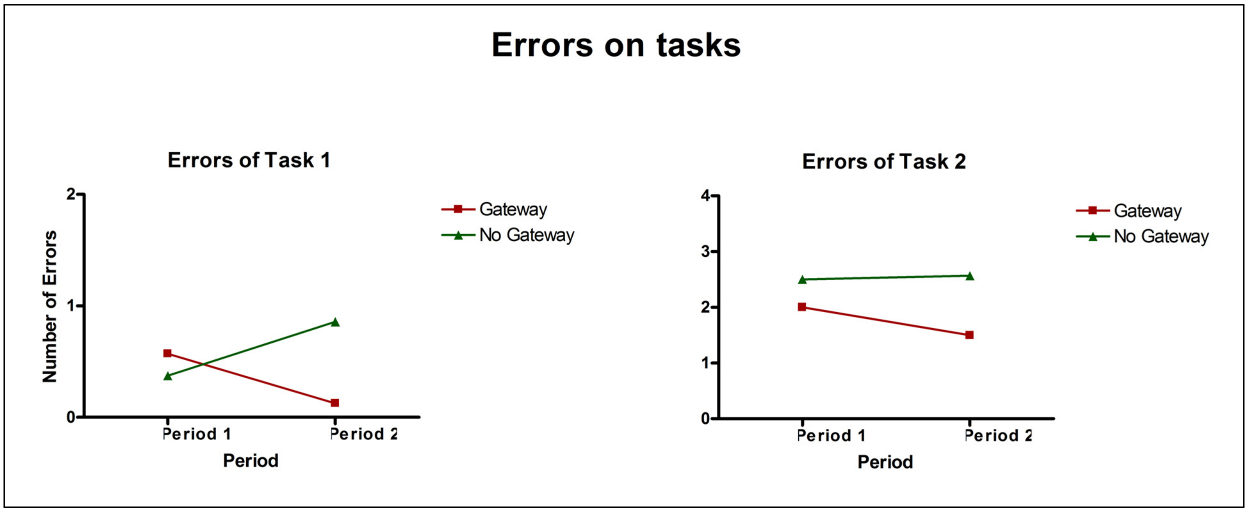

Figure 5-6: Number of errors of each task at different period

Figure 5-6 breaks down the mean errors during the different periods. For task 1, participants averagely make fewer errors accessing the original websites than the transformed one at period 1, but they make more errors on the original websites than the transformed at period 2. The gap of number of errors between using the gateway and not using the gateway is larger in period two than period 1. For task 2, participants always make fewer errors when accessing the transformed websites than the original websites at any period.

5.3.4. Subjective Measurement

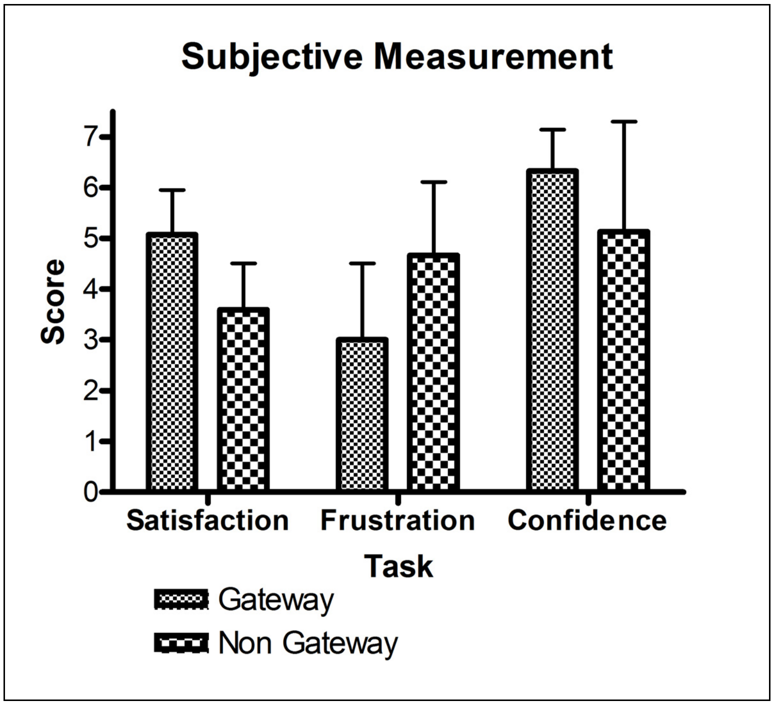

Figure 5-7: Score of subjective variable

Figure 5-7 displays the mean and standard deviations of each subjective variable—satisfaction, frustration, and confidence—after finishing the performance test through the gateway or non gateway server. On average, participants feel more satisfied, less frustrated, and more confident when using the gateway server than the original websites.

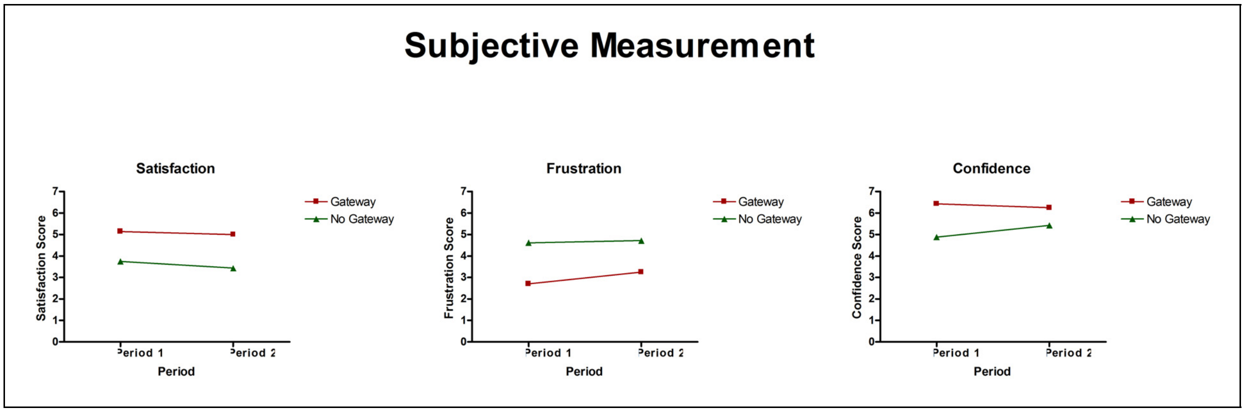

Figure 5-8: Subjective measurement at different period via gateway or non gateway

Figure 5-8 shows the average score of each subjective variable during the different periods. Participants always feel more satisfied, less frustrated, and more confidence about the gateway server approach than the original websites regardless of the period.

5.3.5. Mixed Model Analysis

Table 5-2 lists the *p* value of design (the sequence of the study), period (period 1 or 2), and intervention (gateway or no gateway) from the mixed model analysis of the time on the tasks. The outcome of the mixed model analysis is the time of each task. For each task, the design variable does not have a statistically significant effect on time. This indicates that each participant is randomly assigned to different sequences. The period variable also has no statistically significant effect on the time the participant spent on task. The intervention variable is the variable indicating the effect of our transcoder server. It is the only variable that has a statistically significant effect on each task.

Table 5-2: ***p*** **value of mixed model analysis of time on each task**

	TIME ON TASK 1	TIME ON TASK 2
Design	0.1780	0.6165
Period	0.3162	0.8028
Intervention	0.0356	0.0168

Table 5-3 lists the *p*-value of the design (the sequence of the study), period (period 1 or 2), and intervention (gateway or no gateway) variables from the mixed model analysis of the number of errors on each task. The outcome of the mixed model analysis is the number of errors in each task. For each task, the design variable does not have statistically significant effect on the number of errors. This indicates that each participant is randomly assigned to different sequences. The period variable has no statistically significant effect on the number of errors participants made during the study. The intervention variable is the variable indicating the effect of our transcoder server. It is the only variable that has a statistically significant effect on each task.

Table 5-3: ***p*** **value of mixed model analysis of errors on each task**

	ERRORS ON TASK 1	ERRORS ON TASK 2
Design	0.1042	0.6994
Period	0.9125	0.3556
Intervention	0.1166	0.0038

Table 5-4 lists the *p*-value of the design (the sequence of the study), period (period 1 or 2), and intervention (gateway or no gateway) from the mixed model analysis of each subjective variable. The outcome variables of the mixed model analysis are the subjective variables in the study – satisfaction, frustration, and confidence. For each task, the design variable does not have a statistically significant effect on any of the subject variables. This indicates each participant is randomly assigned to different sequences. The period variable has no statistically significant effect on how the participant feels about the websites. The intervention variable is the variable reflecting the effect of our transcoder server. It is the only variable that has a statistically significant effect on each subjective variable.

Table 5-4: *p* value of mixed model analysis of the subjective measurements

	SATISFACTION	FRUSTRATION	CONFIDENCE
Design	0.1780	0.6165	0.6313
Period	0.3162	0.8028	0.6858
Intervention	0.0356	0.0168	0.0212

5.3.6. Observational and Anecdotal Findings

From the quantitative data, we found that accessibility oriented online transcoding could improve the usability – effectiveness, efficiency, and satisfaction – for blind Web users. However, the Web, despite efforts to enhance the accessibility, still presents a challenge to blind Web users. The following sections list our observational and anecdotal findings when we conducted the usability study with participants.

- Accessibility means being accessible to both assistive technology and persons with disabilities. Almost all of our participants use JAWS (only one uses WindowEyes). The functionality of JAWS and WindowEyes to render Web pages changes drastically from old version to new version. For example, before version 4.02, JAWS was not well integrated with Internet Browsers. It could only read out the content of Web pages without sufficiently supporting navigation and quick "scanning." A more serious problem is the lack of consistency between different versions. In JAWS 4.0, Insert+F6 simply means close the browser, while in JAWS 5.0 it is read out the headings. If a user uses an earlier version of the JAWS program, the same Web page will be less accessible to them than users who use the latest version. In our study, we had to exclude one participant because she uses JAWS 4.0 that does not have much of a Web browsing functionality.

- Visual and aural perceptions are different when processing Web information. The visual perception is high bandwidth, two dimensional, and is capable of taking a "snapshot" of the entire Web content. The aural perception, on the other hand, is low bandwidth and primarily one-dimensional. In addition, the limitation of short memory of human information processing makes it hard for blind Web users to obtain a quick overall impression of the pages. Since information on a Web page is accessed linearly, spatial and contextual information that is useful for sighted persons lost its meaning for blind users. Blind users prefer a page that is simple, short, and provides immediate feedback. Aural perception has limitations in dealing with homonyms. One participant could not differentiate "cache" and "cash" when she heard "Cached Page" from the Google output. Participants are more interested in the information points that are important than understanding the page. They usually overlook images since they do not provide much understanding for the page even with alternative explanations. Unlike sighted users, aesthetical factors do not have any impact on whether a blind user finds a page useful.

- Users experience and knowledge with assistive technology plays an important role in determining how successful they can finish the task. All users know how to let the JAWS read page for them. Almost all users use the link list to navigate between different pages. Fewer than half of the users use headings. Only one users use the Internet Explorer search functions to search the pages. The more skills the user can master, the quicker he will find information online.

Table 5-5: Different screen reader operations used by participants

SKILLS	NUMBER OF USERS (%)
Let JAWS read the page automatically	16 (100%)
Use Link List to navigate page	15 (93.8%)
Tab through Links to find target link	16 (100%)
Use Headings List to browse within page	7 (43.8%)
Use Internet Explorer Search to find information on a Page	2 (12.5%)
Use Find next text element ('N' key)	5 (31.3%)

- The ability to find information is more important than information completeness. For blind Web users, Web pages are like a string of information pearls. They have to listen to the content linearly to find the information they are interested. Many of them rely on the functionality of the screen reader – the link list, heading list – to quickly "skim" the page. It is hard for them to find information embedded deep into the audio output of the screen reader. Moreover, careless design can complicate this issue more. For example, on the BooksAMillion website, many links have the same text content on a page. When the blind Web user hears a link twice, he is uncertain if he has already finished listening to the whole list or if the link has been repeated.
- Blind Web users strive to obtain desired information as quickly as possible. Usually they will bring up the link list after they listen to the first several lines of the pages. They use first key letters to pick up possible hyperlinks. For example, they would use the letter "b"

to locate the link for “bestseller.” They will feel frustrated if they cannot find the link for “bestseller” after they have exhausted all the hyperlinks that start with “b”. They will then try to use the heading list to find any clue of the targeted information. If it is still not successful, they will use the “n” keystroke to access the next non-text element to start listening to the page. If the page is too long, they will keep pressing “PageDown” to reach the next section instead of listening to it sentence by sentence.

- Several guidelines defined in the WCAG are obsolete or not favored by blind Web users. Some examples are vertical bar between hyperlinks and text within text fields as hints. Two reasons can contribute to the mismatch. One is the increasing functionality of Screen reader. Screen reader can decide the level of verbosity; therefore, blind Web users will know that a link is a link from Screen reader. Vertical bars put between adjacent hyperlinks can irritate users from listening it too repetitively. The other reason is that form entry is one of the hardest tasks for blind Web user. They have to switch to the “Form Entry” mode by pressing “Spacebar” after they hear there is a text field. It does not provide feedbacks that indicate the existence of the default text. After they input their own phrase and press the submit button, they will definitely get the wrong answer for their query. These two examples are highlighted here because many Web accessibility evaluation and repairing tools are still using these rules as reminders to Web developers.
- Familiarization with the websites and pages is important for blind Web users to understand a page and navigate a site. Many blind users ask sighted friends to help them go through a website. After they learn where the barriers are for them to navigate around, they can figure out a way to go around them. This is similar to the physical world where blind individuals can navigate a site once they are familiar with the place. Familiarity with the place can sometimes help overcome serious barriers. For example, one

participant can remember a long gibberish URL for a link shown as an icon "Put in Shopping Cart" on Amazon.com.

- The Internet brings independence and pleasure to persons with disabilities despite all the barriers. Although they blame (sometimes curse) the inaccessibility of the website for making the Web hard to use, they admitted the Web has brought them unprecedented independence and fun. Many blind Web users listen to online radio and music. Several of the participants can order food and other products online. Many of them read online newspaper and e-books that would otherwise be inaccessible to them. The Web also provides a novel medium for community integration and for social networking. Two of the participants play online games and chat with other players. One of the participants used Google to locate one of her long time friends in Texas.

5.4. Discussion

We have developed a flexible and scalable gateway transcoder to handle various user preferences and limitations. The results of our usability study are very encouraging; users can accomplish tasks more efficiently, make fewer errors, succeed more, have higher satisfaction, feel less frustrated, and feel more confident when using the gateway. The study on the gateway confirmed the common belief that accessibility is a necessary but not sufficient condition for the Web to be usable for persons with disabilities. Our study, however, also found that usability should precede accessibility. Sometimes, it might not matter whether a website follows accessibility guidelines as long as it follows usability rules. Other research also supports the precedence of usability over accessibility [109]. Relationships between accessibility and usability need further investigation.

To implement usability rules, a transcoder should be able to understand the structure (template) of the Web page and apply appropriate transformation rules to the template. We have implemented a preliminary version of the novel template-matching algorithms. We will refine the algorithms for future versions of the gateway.

We designed the study as within subject, repeated measurement to control the variance among different participants. Consequentially this design requires fewer participants than between group comparison. We designed isomorphic tasks for each participant using and not using the gateway server to overcome the learning effect because of the familiarity with the tasks. We also ask each participant to take a break between each period to reduce the learning and fatigue effects. From the statistical analysis, the period variable does not have an effect on the outcome variables, which indicates the minimized learning or fatigue effect.

The majority of the participants (93.75%) use JAWS as their screen reader, which is much higher than the normal market share of JAWS. One reason for this unusual distribution is that one local vision service acquired and installed computers and software for most of the blind Web users. JAWS is the default screen reader with the installation. In the future, we may need to recruit participants using other types of screen readers or voice browsers to evaluate their performance and attitude.

Chapter 6 ELECTRONIC CURB CUT: WEB USABILITY FOR PDA USERS VIA A WEB TRANSCODER SERVER

6.1. Introduction

Handheld devices provide computer processing handy to people who are willing to use them at any time and in any place. Handheld devices users use their device to manage their personal information, process data, and conduct many other computing activities. One related development, a boom in wireless networks, has made it possible for people to access the Internet without being confined to wired connection. The marriage of the PDA and wireless connection provides new possibilities for accessing and processing information to accomplish tasks from anywhere at anytime. The PDA has evolved from a stand-alone personal device into a mobile networked device with an increasing availability of Internet access. About 15% of PDAs offered this wireless connection functionality in 2002, and the percentage is expected to grow to 75% by 2007 [110]. In addition to modems installed on PDAs, wireless and communications functionalities will also increase on PDAs. Users will have a choice of a Wi-Fi connection for a variety of usage models. Another strong trend that will boost the usage of handheld devices to access the Internet is the convergence between PDAs and cell phones, often called smart phones. About 13 million smart phones are expected to ship in 2003, an amount expected to grow about 86 percent annually until 2007 [111].

Although the PDA is attractive to mobile computer users, compared to desktops or laptops, it has several inherent drawbacks: a small display, low resolution, limited memory, slow processor speeds, and problematic data input. However, in time, all of these drawbacks, except the problem of the small display, will be solved with better technology. This is the reasons why research on the mobile human-computer interface (HCI) primarily concentrates on presenting information on a small display.

Because the PDA serves different purposes than those of desktop computers, PDA users behave differently than desktop users when they access the Internet. Weiss [112] summarized the following differences in Internet use between desktop and PDA web users.

1. PDA Web users "hunt" for information. Because of the aforementioned limitations with handheld devices, PDA users usually will go to a website with a specific purpose in mind and are not easily side tracked.
2. PDA users usually have to pay for service to access the Internet via a cellular phone. They have to consider the cost per minute or per byte when they access the Internet. However, with the widespread availability of wireless hotspot connections (Wi-Fi), this difference may decrease.
3. PDA users have limited choices of information resources. In addition to the limited resources tailored for a mobile display, other information resources are relatively inaccessible to PDA users due to formatting barriers. Weiss refers this phenomenon as a "walled garden."
4. PDA users may have concerns with privacy and security because the device is so small that it could be easily lost or stolen.

Regardless of the limitations exhibited by PDAs, they are still predicted as the next "killer" application on the Web [113]. Currently, the approaches to assist PDA users in accessing online information fall into three categories:

1. Providing static replicated information to mobile devices users. Many popular websites such as Google maintain a set of different Web pages for mobile device users. These pages are well structured and re-authored to fit the small display of the PDA. AvantGo is an information-portal service for mobile information access. The Web crawler from AvantGo accesses websites and stores the information on their Web server. All Web pages are reformatted for better presentation on the PDA or cell phone. Users need to subscribe to the service to access these reformatted pages. The usability of Web access from this approach could be optimized because the reformatted pages are tailored for PDAs. However, the resources needed to maintain and update the pages are enormous. The portal service might consider Web pages of PDA users' interests unimportant, and they may not be included on the server. The users only have access to the information available by AvantGo subscriptions.

2. Providing adapted Web pages to PDA Web users using a Web intermediary. The Web intermediary approach evolves from the idea of the Web proxy server. They intercept the user's request, and the server responds by reformatting the HTML page to a format appropriate to the device. IBM's transcoding publisher server is an example of such an approach. It can work as a proxy server that transforms HTML pages to other types of markup languages for different devices. It also supports human interventions by providing tools for Web page annotations [107]. Palm also provides a proxy service for Palm Pilot PDA users. Apart from syntactically reformatting Web pages for PDAs, other intermediary approaches can also support content summarization, contextual understanding, and structural reorganization [114]. This approach may not provide the best organization of the Web pages for the PDA screen, but the flexibility and scalability of the approach makes it an attractive solution.

3. Rendering Web pages using specialized browsers for PDAs. Manipulating Web page to fit in small display can also be accomplished at the client side. For example, Microsoft Pocket PC Internet Explorer can fit the page to the screen and hide images. Some specialized browsers provide manipulations such as zooming, focusing, and other Web page adaptation [115, 116].

6.2. Significance

Although research in Web transcoding has been very active in the last few years, no study has been done on the usability of Web transcoding. Previous studies on the usability of PDAs for Web browsing used only simulated Web pages to investigate the impact of different Web formats on PDA users. In this study, we use real-world websites to investigate the usability of a transcoding gateway for PDA users. Because these websites were originally designed with no PDA Web user in mind, they may cause usability difficulties if the Web pages are simply shoehorned into a PDA display format. The transcoding gateway used in the study was originally designed for Web users with visual impairments. We are interested in evaluating whether the same transcoding technology can benefit PDA Web users.

6.3. Materials and Methods

6.3.1. Design

The study uses a two-level within-subject design. The participants accessed both original and transformed Web pages in different sequences. The experimenter randomly assigned the sequence in which they accessed the Web pages when they signed up for the study. Figure 6-1 shows the design of the study.

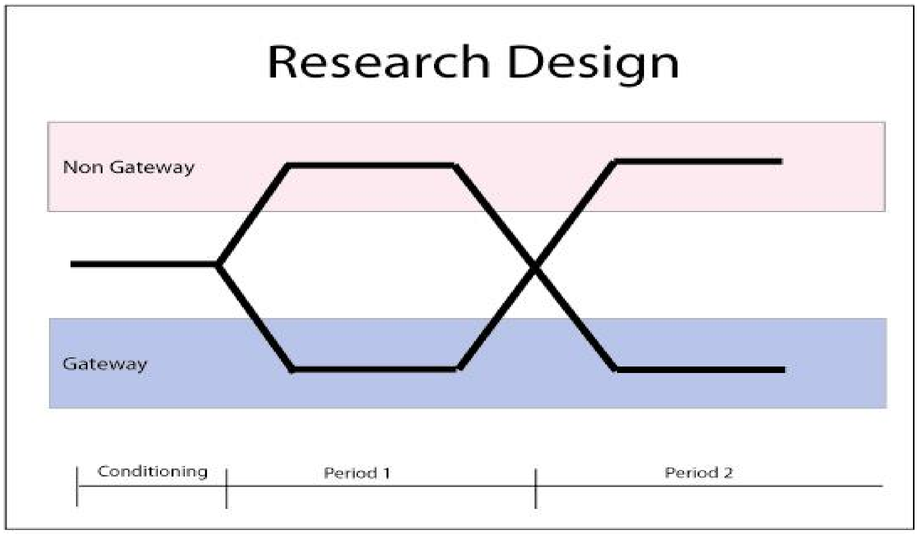

Figure 6-1: Research Design of the PDA study

6.3.2. Participants

Twenty undergraduate students were recruited from the School of Health and Rehabilitation Sciences at the University of Pittsburgh via email announcement and flier distribution. The majority (90%) of the participants' ages fall between the range of 20 and 30. Eighty percent of the subjects are female, matching the distribution of the student population at the school. Participants obtained monetary compensation after they finished all requirements for the study. Although prior experiences with a PDA was not a prerequisite for the study, we excluded students who did not have Internet and computer experience. Thirty percent of the participants had experience with PDAs. None of the participants had experience using a PDA as an Internet device. Therefore, using an Internet browser on a PDA was a new experience to all of the participants. The participants were tested individually with an experimenter. The test was conducted in a quiet room with comfortable seating and lighting.

6.3.3. Device and Web Browser

The device we used in the study is Dell Axim X3i with Microsoft Windows Mobile 2003 for Pocket PC as the operating system. It weighs 4.9 oz with 400 MHz processor and 64MB ROM installed. The screen resolution of the device is 240 × 320 with 16-bit color support. It has embedded IEEE 802.11b wireless connectivity. The default Web browser for the device is the Internet Explorer for Pocket PC. We retained all of the browser's default settings with the menu items "Fit to Screen," "Show Images," and "Address Bar" checked. A NetGear MR814v2 wireless router was used to provide IEEE 802.11b wireless connectivity with a maximum connection speed of 1.5Mbps.

6.3.4. Materials

An early survey of Web usage found that the four most popular online activities are information gathering, browsing, searching, and shopping [117]. Information gathering is an activity in which people obtain specific information from websites to fulfill their specific purpose. Browsing is when people explore websites by simply following the hyperlinks. Searching is an activity involving the use of user-defined queries to search engines to find information, and shopping involves a transaction to purchase goods or services from an Internet store. For each of these categories of activities, we designed representative scenarios. The websites and scenarios are summarized in Figure 6-1.

Table 6-1: Tasks for usability testing

CATEGORY	WEBSITE	TASK
Information Gathering	http://www.accuweather.com	Find the highest temperature tomorrow.
Browsing	http://www.cnn.com	Find the last sentence of the day's headline news.
Searching	http://www.yahoo.com	Find the first three non-commercial websites using assigned query phrases.
Online shopping	http://www.booksamillion.com	Locate a bestselling book. Find other formats of the book. Find similar books. Put the bestseller in the shopping cart

6.3.5. Web Transcoder Gateway Server

Web Transcoder Gateway (WTG) server is an ongoing project at the University of Pittsburgh. The server works as a proxy server that intercepts users' HTTP requests to URLs and returns an optimized page to them. The initial targeted population is people with disabilities, especially Internet users with visual impairments. The transformation rules deployed in the WAG server are extracted from the Web Accessibility Initiative's Web Content Accessibility Guidelines (WCAG 1.0). However, the Web content design for people with disabilities is very similar to the designing requirements for making a Web page accessible to PDA users [3]. For example, both design principles encourage the usage of standard HTML code. In addition, the coding burden was reduced since we already implemented several such rules in our work with transcoding for blind Internet users.

The following sub-sections describe the re-authoring and transformation rules used by the Web Transcoder Gateway Server.

6.3.5.1. Page Standardization and Cleaning

The page standardization process includes cleaning non-standard HTML tags from the intercepted Web pages. We use a page standardization program named Tidy to clean up pages that are not well-formatted and turn them into pages following XHTML standard 4.0. Although Tidy is able to syntactically restructure Web pages, it is often mistaken when dealing with HTML form tags if they are not well-structured. About half of the forms lose the semantic correctness after being processed by Tidy, subsequently causing functioning problems of certain pages. We developed an algorithm that regroups mistakenly processed HTML form elements to remain the semantic integrity. We also removed advertisements from Web pages by simply inspecting specific HTML code segments to determine whether the link is to advertisement websites.

6.3.5.2. Table Detection and Layout Transformation

It is common for Web page developers to use an embedded HTML table to organize the spatial information on a Web page, not as a real table. Such practice is discouraged by Web design guidelines because it can confuse client devices. It is impossible to separate tables used for the purpose of layout from tables used for presenting real data from the HTML code itself. We implemented a HTML table classification algorithm that can differentiate these two types of HTML tables based on the table's location, information content, and hyperlink density.

Currently we present the content in the layout table linearly when we keep the original structure of the data table. The linearization of the layout table follows the sequence from the top down and from left to right. A one-cell layout table with the width of 100% of the window's size restrains the Web content within in one screen width. As a result, it eliminates the horizontal scrolling caused by many original Web pages.

6.3.5.3. Image Resizing

Web pages are designed with desktop computers in mind as the viewing devices. Many Web page designers test their page for a screen resolution of 800×600 or higher. Images that look appropriately proportional to the desktop area would be awkwardly large for the small display of a PDA. We calculated the ratio between the modest screen resolution of desktop (800×600) and the resolution of the Pocket PC (240 × 320) to resize the image proportionally.

6.3.5.4. Image Map Transformation

Image maps, which are often used as header or menu bars, represent usability issues for PDA Web users. Usually Web developers use graphic text within image maps to illustrate the meaning of different areas on the image map. Microsoft Windows Pocket PC has a choice of *fit to screen*. Although this choice can squeeze in much more information on one screen, it makes the image map unreadable, especially if the image map contains graphical text. Our approach is to use the alternative text along with each image area to replace the image map. Therefore, image maps are transformed into a list of hyperlinks. Note that this approach also helps the low vision users because they often need to magnify Web pages that will make the image map's graphical text too coarse to read.

6.3.5.5. Annotation

Retrofitting existing Web pages to accommodate PDA users is one of the hardest problems for intermediary technologies. The current Web does not provide semantic information for end users because HTML is a presentation and formatting language. For example, the locations of header, navigation menus, and main content are not clarified in HTML coding. Most PDA users are likely to seek information from the main content area with minor concern about menus. We used some annotations to indicate the locations of these different sections.

Figure 6-2 illustrates the homepage of the AccuWeather weather service (http://www.accuweather.com) before and after being transcoded by our WAG server shown on Pocket PC emulators. Types of transformation seen on this illustration include image resizing, layout table removal, background color removal, and main content landmark insertion.

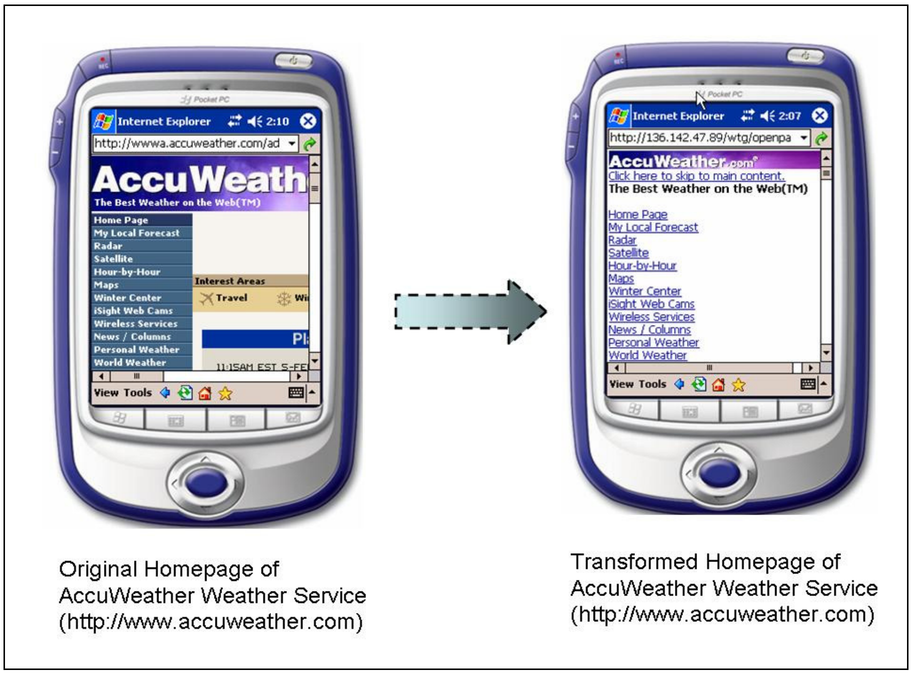

Figure 6-2: Homepage of AccuWeather before and after transformation

6.3.6. Session

Each participant worked individually at a desk in a well-lit, comfortable room, using a Dell Axim X3i Pocket PC. Each participant signed an informed consent form before the study session. The experimenter explained the purpose and procedures of the study to the participants. A time limit of 10 minutes was set for completing the study session. The experimenter demonstrated how to use the device and the browser to the participants. Each participant practiced using the device for approximately 30 minutes at a conditioning session to familiarize themselves with the device and the browser. During this conditioning session, participants had the freedom to visit any websites in which they were interested. The study would not start until the participants felt comfortable using the device and the browser. The experimenter gave explanations to the participants on the purpose and protocols of the study, giving special emphasis to the fact that the experiment is not intended for testing their ability or skills. The experimenter also gave each participant a warm-up task so that they could familiarize themselves with the format of the study. A description of each task was printed on an 8” × 11” sheet of paper and put beside the participants as a cue card. Participants were free to read the description during the study. The experimenter would load the website onto the device before each task. After finishing all four tasks, the subjects filled out a questionnaire about their satisfaction with using a PDA to access websites.

6.3.7. Measurement

6.3.7.1. Objective measurement

1. Time: we used the time that each participant spent on the task as the measurement of the efficiency of the websites. The time starts when the participants start touching the screen using the stylus. The time stops when the participants stop writing answers on the paper. To eliminate the time differences of writing down answers, we asked the participants to write the first five words if the answer was longer than that.

2. Success rate: the experimenter reviewed the answers for each task. Because some of the answers were time sensitive, the experimenters checked the answer immediately after the session. The experimenter also examined the screen before loading Web pages for the next task to make sure the written answer was the same as the one on the screen.

6.3.7.2. Subjective measurements

We adopted the Computer System Usability Questionnaire (CSUQ) from IBM to measure user satisfaction with website usability [118]. The publicly available questionnaire contains 19 questions with a seven-point Likert scale for each answer. The CSUQ has excellent internal consistency with an overall coefficient alpha of 0.97. CSUQ can gauge three factors of satisfaction – system usefulness, information quality, and interface quality, with corresponding coefficient alphas of 0.96, 0.91, and 0.91, respectively. A higher score means higher satisfaction with the system. In addition to the 19 questions from CSUQ, we also asked participants about their preference on transformed or non-transformed Web pages at the end of session.

6.3.8. Statistical analysis

Descriptive statistics were calculated for demographic and usability variables. Mixed model analysis was used to measure the effect of participants, periods, and interventions on each usability variable. All statistical analyses were conducted using the SAS 8.2 package. The alpha level is 0.05, and the beta level is 0.80.

6.4. Results

6.4.1. Previous Experience with Computer, Internet and PDA

Nineteen of the 20 participants (95%) have their own computers. Out of the 20 subjects, two (10%) spend less than 1 hour per day using computers, 14 (70%) spend 1- 5 hours, 1 (5%) spends 5 – 9 hours, and 3 (15%) spend more than 9 hours. Activities using computers include editing (65%), playing games (25%), Internet surfing (85%), programming (25%), and data processing (25%). Of the 20 subjects, 8 (40%) spend fewer than 1 hour per day on the Internet, 9 (45%) spend 1 – 5 hours, 1 (5%) spends 5 – 9 hours, and 2 (10%) spend more than 9 hours. All subjects use the Internet to search for information. Twenty-five percent of the subjects play online games. Eighty percent of the subjects have online chatting experience. Seventy-five percent of the subjects use Web-based email. Thirty percent of the participants had used PDAs before, but none of the participants had ever used PDA as an Internet device to access websites.

6.4.2. Objective Measurements

6.4.2.1. Time

Figure 6-3 shows the mean and standard deviations of the time spent on each task for both transformed and non-transformed websites. On average, participants spent less time on the transformed page of each website. Task 4 (online shopping) took longer for participants to finish than the other three tasks. This pattern matches the level of complexity of the different tasks.

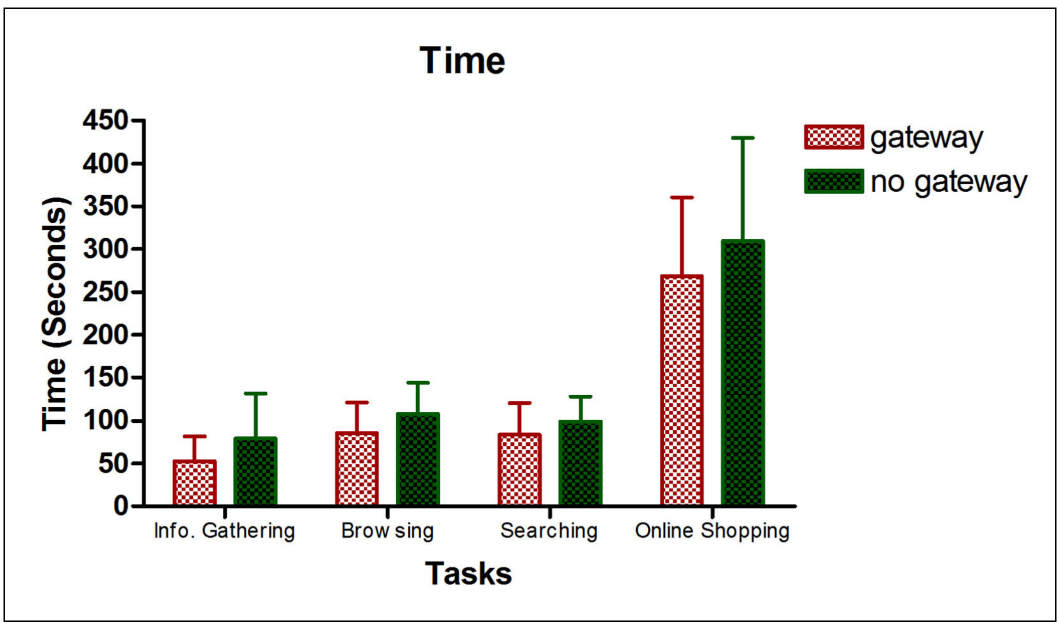

Figure 6-3: Time on each task via gateway or non gateway

Table 6-2 and Figure 6-4 show the mean time and 95% confidence interval in seconds that participants spent on each task at different periods via the gateway server or through the original website. In each period, participants spent an average of less time on each task using the gateway server than they did accessing the original websites. Figure 6-4 also shows that for the sites accessed through the gateway, the average time spent in the second period is less than that of the first period.

Table 6-2: Time spent on each task via gateway or non gateway

		GATEWAY	NON GATEWAY
Task 1	Period 1	54.0 (39.90 – 68.10)	81.7 (41.60 – 121.80)
	Period 2	51.0 (24.26 – 77.74)	76.0 (38.56 – 113.43)
Task 2	Period 1	97.2 (68.15 – 126.25)	106.6 (78.56 – 134.64)
	Period 2	73.6 (53.87 – 93.33)	108.7 (83.08 – 134.32)
Task 3	Period 1	88.8 (64.97 – 112.63)	101.80 (78.34 – 125.26)
	Period 2	78.0 (48.35 – 107.65)	95.7 (76.60 – 114.80)
Task 4	Period 1	303.40 (239.82 – 366.97)	308.20 (206.50 - 409.90)
	Period 2	233.00 (171.74 – 294.25)	310.90 (237.79 – 384.01)

Figure 6-4 illustrates the mean time each participant spent in each period on each task with different levels of intervention – gateway or no gateway. Across all the tasks, on average, participants spent less time with the transcoded pages than with the original ones. It also shows that the time difference in the second period is bigger than that of the first period. The exception is in Task 1, where the gap between the gateway and no gateway page is smaller in the second period.

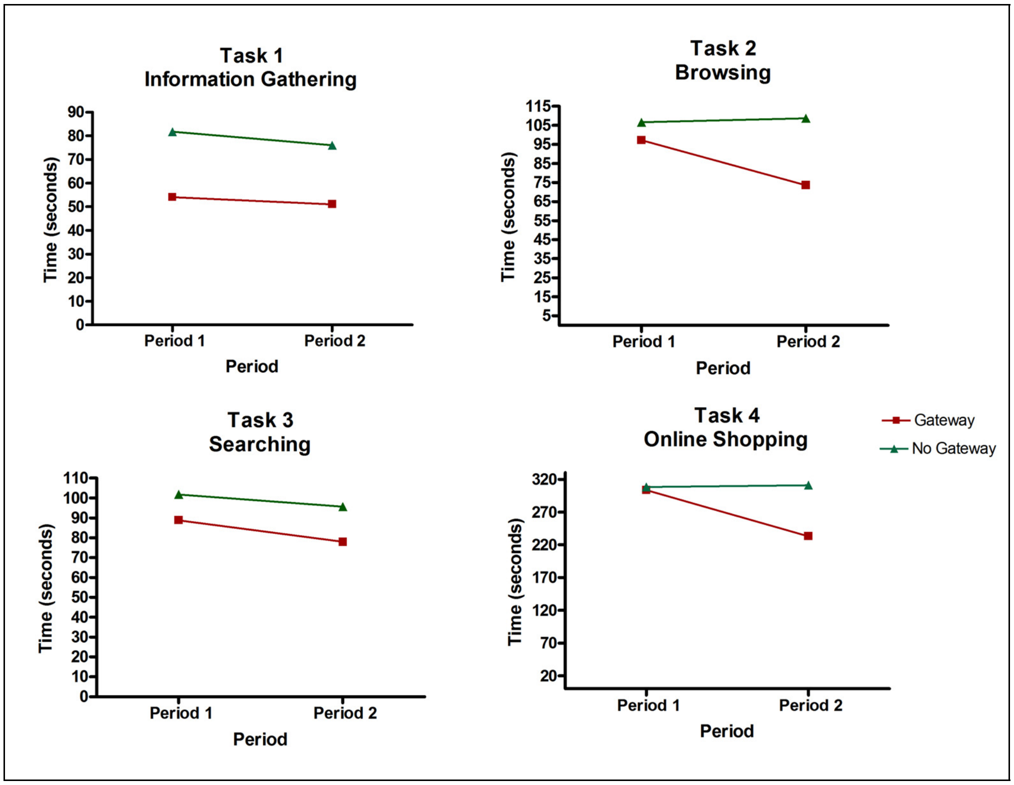

Figure 6-4: Time on each task at different period

6.4.2.2. Success Rate

All the subjects finished the tasks successfully within the 10-minute time limit. In the online shopping tasks, two participants used different approaches from the one we had expected. Nonetheless, they found the correct products. Meanwhile, the time they spent on the task is not an outlier from the other participants' times. Therefore, we regard these two cases as successes and include the results in the final analysis.

6.4.3. Subjective Measurements

Figure 6-5 depicts the mean and standard deviations of the score of overall and different categories of the satisfaction measurements. On average, participants feel more satisfied via the gateway than the no gateway approach although the difference is not large.

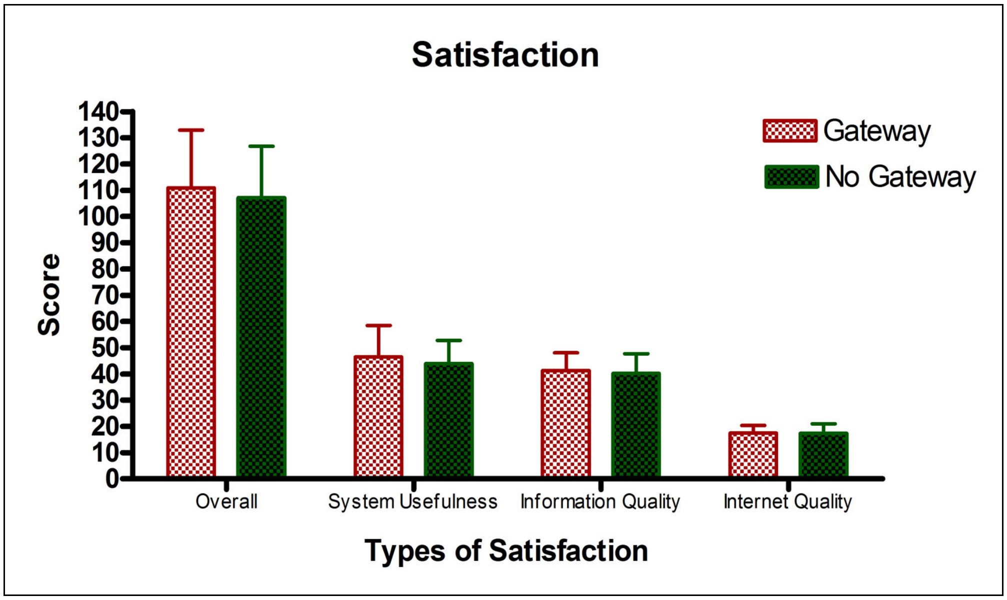

Figure 6-5: Score of satisfaction via gateway or non gateway

Table 6-3 and Figure 6-6 show the means and 95% confidence interval of satisfaction scores that participants gave during different periods via the gateway server or through the original website. During each period, the overall, system usefulness, and information quality scores of the gateway approach are always higher than the scores of the no gateway approach. However, for the score measuring interface quality, each approach was preferred during different periods.

Table 6-3: Satisfaction scores via Gateway or non gateway

		GATEWAY	NON GATEWAY
Overall Satisfaction	Period 1	112.80 (97.88 – 127.72)	109.10 (94.53 – 123.66)
	Period 2	111.36 (92.21 – 126.39)	105.30 (91.26 – 119.34)
System Usefulness	Period 1	48.70 (41.76 – 55.64)	44.30 (36.67 – 51.92)
	Period 2	44.30 (34.21 – 54.39)	43.50 (38.20 – 48.80)
Information Quality	Period 1	41.00 (38.04 – 45.96)	40.80 (35.39 – 46.21)
	Period 2	41.60 (36.56 – 46.63)	39.60 (34.17 – 45.03)
Interface Quality	Period 1	17.30 (14.89 – 19.71)	18.20 (16.24 – 20.16)
	Period 2	17.60 (15.84 – 19.35)	16.50 (13.47 – 19.52)

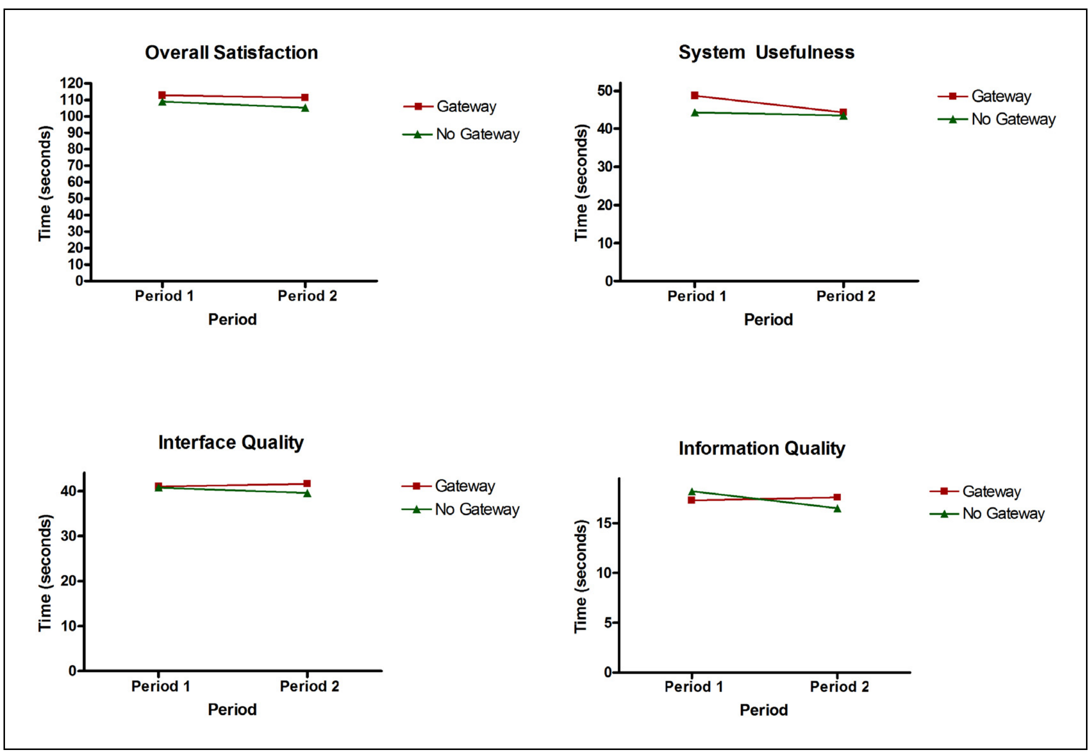

Figure 6-6: Satisfaction scores via gateway or non gateway at different period

6.4.4. User Preference

Figure 6-7 shows the frequency with which participants prefer each format. Fifty percent of the participants prefer the one with the gateway transformation. Fifteen percent of the users feel no difference towards either gateway or no gateway transformation. And 35% of the users prefer the no gateway transformation. The chi-square test shows no statistical significance between the user preference and the different research study sequences (*p* = 0.4164).

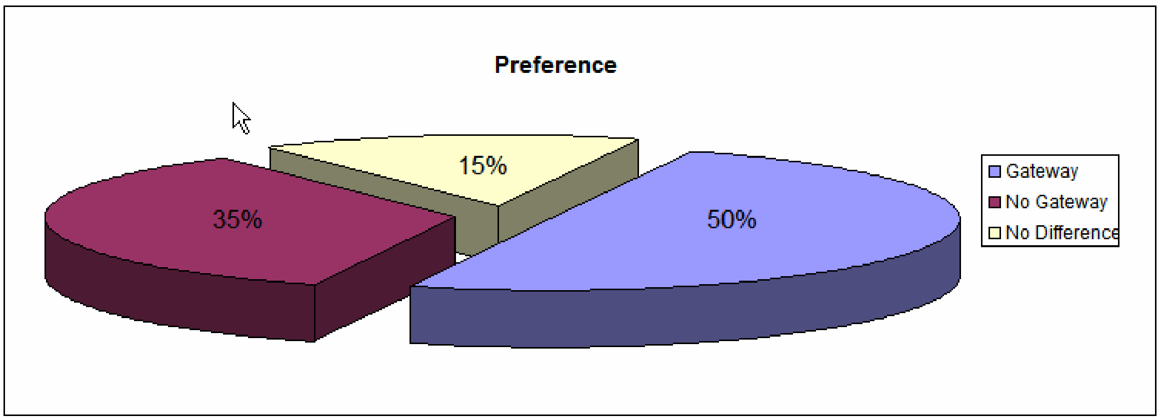

Figure 6-7: Distribution of User Preference to Different Transformation

6.4.5. Mixed Model

6.4.5.1. Time

Table 6-4: *p* values of mixed model analysis of time variable of each task

	TASK 1	TASK 2	TASK 3	TASK 4
Design	0.9308	0.4124	0.8707	0.4341
Period	0.7248	0.0529	0.1299	0.0303
Intervention	0.0440	0.0004	0.0099	0.0102

Table 6-4 lists the p-value of design (the sequence of the study), period (period 1 or 2), and intervention (gateway or no gateway) from the mixed model analysis of the objective measurement. The outcome of the mixed model is time on each task. The mixed model analysis is a linear regression model that considers both random variable (design) and fixed variable (period and intervention) as the input variables. For each task, the design variable does not have a statistically significant effect on time. This indicates that each participant is randomly assigned to different sequences. The period variable has a statistically significant effect on the time participants spent on task 4. The reason for the effect may be that task 4 (online shopping) is a complex task and the learning effect exists in this task. The intervention is the variable indicating the effect of our transcoder server. It has a statistically significant effect on each task at the 95% confidence interval.

6.4.5.2. Satisfaction

Table 6-5 lists the p-value of design (the sequence of the study), period (period 1 or 2), and intervention (gateway or no-gateway) from the mixed model analysis of the subjective measurement. The outcome of the mixed model is the overall and categorical satisfactory score. For each task, the design variable does not have a statistically significant effect on the score of satisfaction. This proves each participant is randomly assigned to different sequences. The period variable does not have statistically significant effect on the satisfaction score given by the subjects. This reflects that period does not change the satisfaction level of the participants. The intervention variable has no statistically significant effect on each satisfaction variable. This is parallel with the finding in section 6.4.4 that participants do not have a strong preference on which format they used.

Table 6-5: ***p*** **values of mixed model analysis of satisfaction variables**

	OVERALL	SYSTEM USEFULNESS	INFORMATION QUALITY	INTERFACE QUALITY
Design	0.9863	0.6949	0.7611	0.3936
Period	0.3686	0.1298	0.8392	0.4516
Intervention	0.3436	0.1298	0.4600	0.9137

6.5. Discussion

6.5.1. Objective vs. Subjective Measurements

The results show that users spent less time on all the tasks when they used the gateway server than they did using the original pages. This implies that the transcoder server is efficient for users to access and interact with the websites. However, the improved efficiency does not translate into better subjective measurements and preferences. Both chi-square and mixed model analyses show no subjective preference for the gateway from the users.

The discrepancy between the objective and the subjective measurements of usability could be attributed to the unfamiliarity of the users to the transformed format of websites. The transcoder transforms page from multiple-column layout to a single-column layout that does not require the rigorous coordination between horizontal and vertical scrolling. However, not all of the users appreciated this approach because they felt that the spatial information or default information distribution on a Web page was distorted. Since the majority of the users had never used a PDA to access the Internet before, the mental model of a Web page they have is the tabular, multiple-column design for desktop browsers. It is possible that the participants would change their preferences if we asked them to use PDA to access the transformed Web pages for a longer time.

However, statistical analysis supports that this approach saves users time finding necessary information by removing horizontal scrolling. The contradiction may indicate that the satisfaction level is not determined by efficiency only. Participants often give comments like "Mainly because it is the format I have become so accustomed to and the first one was not as intuitive for me in locating items I was searching for. Not having to horizontally scroll is nice but it puts the information in an order that I wasn't used to."

6.5.2. Study Design

The study is a within-subject repeated measurement. The participant accessed the same websites under two different levels of transformation. The original websites work as the control for the study. One drawback of repeated measurement is that the participant may obtain experiences during the experiments. To overcome the learning effect, we randomly assign the sequence in which the participants access the websites. Half of the participants access the original websites first while the other half access the non-transformed websites first. The arrangement helps separate the learning effect from the real intervention effect. The assumption is that the learning effect is independent from the study sequence of the participant. The second approach to mitigating the learning effect is to design the tasks of the same category to be isomorphic but slightly different. This design removes the effect of task differences under different conditions while keeping the learning effect to the minimum.

During the pilot study, we found pre-test conditioning is very important to maintain a low level of learning effect from the participants. The reason for the conditioning is that most our subjects did not have enough previous experience with the devices, especially experience using a PDA to access online information. In the pilot study, participants learned to solve the usage problems along with the process of the study. The learning effect actually is maximized by including learning both the devices and the website structure. Therefore, we increased the time of the pre-test conditioning from the 10 minutes used in the pilot test to 30 minutes in the real test. We also required them to master several skills when using the stylus with the PDA before the real test. Meanwhile, we designed a warm up task for them to familiarize the protocols of the study. Overall, we are confident that we have reduced the learning effect to a minimal level.

6.5.3. Limitations

The study employed PDA devices with the Pocket PC operating system as the testing device. Several operating systems currently exist in the handheld device market. PalmOS has been the dominant handheld device operating system for long time. However, Pocket PC has slowly gained a bigger share of the market. Other reasons for using Pocket PC are that it usually has screen with high resolution (240 × 320) and user friendly Web browser. The Pocket PC operating system has similar screen interface to Windows desktop system. We expected the learning curve to master the operating system is less steep than PalmOS.

The sample participants were drawn from the undergraduate students in the School of Health and Rehabilitation Sciences (SHRS). Although typically students in the school are not technologically "savvy," they do spend considerable amounts of time on the Web. This may be the reason for the 100% success rate in all tasks that is very rare in usability testing. Another explanation for the perfect success rate is that the tasks are too easy to fail. This may explain the first three tasks. Nevertheless, the last one is a complex task involving online shopping. Two participants took different paths from the one usually taken by the other participants and finished this task with the same results.

The Web transcoder server is still at an early stage of development. It has already shown promising improvements in the efficiency of Web browsing using PDAs. The transcoding rules overlap with the ones used to transform Web pages for blind Web users. The guidelines for accessible Web design have many overlaps with those for Web page design for handheld devices. The only rule that is specific for PDA browsing in the current study is the one resizing the original image to fit the small screen proportionally. Our developers even had to remove several accessibility specific transformation rules to achieve best transformation for PDA Web users. This implies that the concept of the "Electronic Curb Cut" is practical and applicable in Web development. When you build or transform a website to make it more accessible to blind Web users, actually it will be more accessible to other unconventional devices too.

Chapter 7 SUMMARY AND FUTURE DIRECTIONS

7.1. Summary

The concentration of the current study is Web content accessibility -- making Web content accessible to as many users as possible. Although the main population of the study is persons with disabilities, it also provides insights to people, such as PDA users, with situational constraints. I have performed measurement, evaluation, and usability studies on the topic of Web accessibility. Four major research questions raised by the study are:

1. How can we measure the status of the Web accessibility of a website automatically using a computer program?
2. What is the status of the Web accessibility of websites, especially those providing health information to consumers?
3. Can a Web accessibility transcoder server as an information intermediary improve usability for blind Web users?
4. Can a Web accessibility transcoder server as an information intermediary improve usability for PDA Web users?

I have answered these research questions by:

1. Proposing a normative metric – WAB score – to measure the level of Web accessibility for a website. I also assess the performance of the metric using a Web accessibility logo system as a gold standard.

2. Evaluating the status of the Web accessibility of consumer health information websites. Additionally, I also investigated the relationship between the level of Web accessibility and other properties of the websites.

3. Evaluating the usability of websites before and after being transformed by the Web accessibility transcoder server. I also reported the subjectivist findings from the study.

4. Evaluating the usability of websites before and after being transformed by the Web accessibility transcoder server.

The studies I have described were initial investigations that only addressed some of the questions raised by Web content accessibilities researches. Many questions are still unanswered or unexplored in the area. Based on my findings from my initial studies, I will continue to explore the research and application of information methods and technology in Web accessibility for persons with disabilities.

7.2. Future Directions

I am particularly interested in pursuing four areas of research that originated from the studies in this thesis:

1. Finding a sub-categorical measurement metric to measure Web accessibility for different types of disabilities.

2. Applying measurement metrics to real world projects to assist people with disabilities to access information.

3. Applying machine-learning algorithms to measure Web accessibility of a Web page or website.

4. Investigating the information model of how people with disabilities access the information using limited channels.

7.2.1. Finding sub-categorical measurement metric

Persons with disabilities are a very diverse group. The WAB score proposed in 0 uses accessibility barriers detectable by computer program. Although its performance is acceptable compared to the gold standard logo system, it does not provide any sub-categorical accessibility information for a specific type of disability. Two sites or pages with similar scores may not have the same level of accessibility for a single type of disability. I will analyze the WCAG guidelines and checkpoints for their benefits for different types of disabilities. Future WAB scores will be comprised of sub-categorical scores to reflect the accessibility for a special types of disabilities.

7.2.2. Applying Web accessibility measurements

The measurement method proposed in Chapter 3 is a metric that provides a quick overview of the level of Web accessibility of a website. The benefits of such a measurement are that it can be implemented by a computer program, and it does not hinder the Web developer in creating attractive Web pages. It favors the principles of accessible and universal design. Such a measurement can be implemented as an add-on to many real world applications. For example, this measurement can be integrated into an online search engine. After users query the search engine, the relevant URLs will be returned with a score indicating the accessibility of the site. Persons with disabilities can balance the relevance and accessibility to locate the information that is both relevant and accessible to them. Combined with the sub-categorical measurements planned in 7.2.1, it can provide useful accessibility information for persons with different types of disabilities.

7.2.3. Applying machine-learning methods to measure Web accessibility

Machine learning is studying the design of computer programs able to induce patterns, regularities, or rules from experience. A computer program processes data representing specific experiences and tries to either develop an appropriate response to future data or describe in some meaningful way the data seen. The rules in machine-learning are derived probabilistically from the data, while the rules used in the WAB score are selected from normative Web accessibility guidelines. In chapter 3, a machine-learning program – C5.0 decision tree algorithm – drew rules from the gold standard data. When applying these rules back to the experimental data, we found its performance is better than the WAB score, especially when separating different WCAG priority groups. This may indicate that the machine-learning algorithm is a promising new approach to measuring Web accessibility. Several other classification algorithms, such as the Bayesian classifier, Logistic Regressions, and Support Vector Machine, are available for future investigation.

7.2.4. Information Processing Models for People with Disabilities

In Chapter 5, I described my observations on how blind Web users access online information. The limitations inherited in the aural information processing – linear, low-bandwidth, and missing contextual information – are the psychological reasons why current Web pages are so difficult for blind Web users. Our gateway server can remove syntactical barriers to Web accessibility. However, to totally transform a Web page designed for a sighted audience is like shoehorning a two dimensional page into one-dimensional sentences. This transformation may not fit the psychological model of blind Web users. Blind Web users want a Web page well structured, short, and simple. The challenge is more than simply removing syntactical errors. It may indicate that we need to add "information enhancer" or "navigation landmark" into a page or website. Psychological models of information processing for blind Web users may be the answer to building or re-authoring Web pages that are more accessible to persons with disabilities.

APPENDIX A

Selected Consumer Health Information Websites

Name	URL	Description
CNN Health	http://cnn.com/HEALTH/	Health news, chats and advice from CNN.
Discovery Health	http://health.discovery.com/	Offers news and a variety of health information resources.
America's Best Hospitals	http://www.usnews.com/usnews/nycu/health/hosptl/tophosp.htm	U.S.News & World Report ratings and rankings of the top U.S. medical centers in various specialties.
Healthfinder (tm)	http://www.healthfinder.gov/	Resource for consumer health and human services.
Combined Health Information Database	http://chid.nih.gov/	A database produced by health-related agencies of the Federal Government. Provides titles, abstracts, and availability information for health information and health education resources.
Health A to Z	http://www.healthatoz.com/	Includes a directory of more than 50,000 professionally-reviewed Internet resources, supportive online communities, and a calendar.
National Institutes of Health -- Health Information Index	http://www.nih.gov/health/	Main consumer health information page for the National Institutes of Health (NIH)
WebMD Consumer	http://my.webmd.com/	Frequently updated portal for healthcare, chat forums, health quizzes, news and consumer product updates.
Agency for Health Care Policy and Research	http://www.ahrq.gov/consumer/	Consumer health and patient information on health plans and insurance, prescriptions, conditions and diseases, surgery, quality of care, quitting smoking, and prevention and wellness.
Dr. Koop's Community	http://www.drkoop.com/	Former Surgeon General Koop's resources for health information. A wide variety of topics, an encyclopedia, pharmacopeia, and resources guide.
MCW HealthLink	http://healthlink.mcw.edu/	Features health news and information, produced by the Medical College of Wisconsin.
Apples For Health	http://www.applesforhealth.com/	Weekly consumer news e-zine on a variety of healthcare topics.
Cochrane Consumer Network	http://www.cochraneconsumer.com/	This international group dedicated to the study of evidence-based medicine, explains how to decipher clinical studies and how to use them when making decisions about medical care.
Diseases, Disorders and Related Topics	http://www.mic.ki.se/Diseases/index.html	Karolinska Institutet, Stockholm, Sweden. Comprehensive listings of links to medical information, most reliable, some not.

Name	URL	Description
Accent Health	http://www.accenthealth.com/	Health TV network produced by CNN and delivered to medical waiting rooms across the US. Includes programming guide, articles, and tips for living a healthy lifestyle.
Medicine OnLine	http://www.meds.com	In-depth information on cancer for health care professionals and patients.
Healthgrades.com	http://www.healthgrades.com/	Grades the performance of hospitals, physicians, health plans, nursing homes and other health care providers in the United States.
Laurus Health Information	http://www.LaurusHealth.com	Information on health conditions, pharmaceuticals, medical news, plus profiles of physicians and hospitals. Free registration.
Halls MD	http://www.halls.md/	Clinical calculators of body surface area, breast cancer risk and body mass.
HealthAnswers	http://www.healthanswers.com/	Contains health news and information, including a health encyclopedia.
Mylifepath	http://www.mylifepath.com	Provides information on health and wellness, daily health news and message boards.
Digital City Health	http://www.digitalcity.com/health/	Health resources and providers across the United States.
Internet Pharmacy and Online Pharmacies Verification	http://www.nabp.net/vipps/intro.asp	National Association of Boards of Pharmacy provides searchable listings of approved online pharmacies.
Dr. Gabe Mirkin	http://www.drmirkin.com	Reports on health, fitness, and nutrition news from talk show host Gabe Mirkin, M.D., in text and audio form.
Health Communication Network	http://www.hcn.net.au/	Provides the up-to-date health information on a variety of subjects.
Duke University Healthy Devil On-Line	http://gilligan.mc.duke.edu/h-devil/	Online medical resources and information.
Doctor Healthynet	http://www.doctorhealthynet.com/	Offers diagnosis and treatment of conditions and diseases, medical procedures, preventive health guidelines, and sources of free medicines.
Michigan Electronic Library|Health Information Resources	http://mel.org/viewtopic.jsp?id=13	Extensive resources and links of interest to the health consumer and to professionals.
Health Leader	http://www.uthouston.edu/hLeader/index.html	A webzine produced by The University of Texas Health Science Center, which provides information to help you make better decisions about your health.

Name	URL	Description
McGill Molson Medical Informatics: Student Projects	http://sprojects.mmi.mcgill.ca/	A growing collection of multimedia projects in medical teaching. Developed by McGill medical students under the supervision of the McGill Medical Faculty. Includes a student/faculty forum.
Body1.com	http://www.Body1.com/	Health news and medical information community for consumers.
HealthWindows	http://www.healthwindows.com	A membership healthcare network that helps individuals to become more knowledgeable and active participants in managing their personal health.
Clinnix: Health Care Information	http://www.clinnix.net (No longer available)	Includes daily news, travel information and disease management.
Medicalresourcesusa.com	http://www.medicalresourcesusa.com/	Offers guides to American hospitals, health clinics, medical practices and specialties.
AnswerMed.com	http://www.answermed.com/	Provides basic information on medical conditions and procedures including symptoms, diagnosis, treatment, predicted outcome and alternative diagnoses.
Health Consumer Alliance	http://www.healthconsumer.org	Provides information to consumers and advocates about access to health care for low-income consumers, including consumer education materials in 13 languages.
CountryNurse.com	http://www.countrynurse.com	Includes information on clinics, family wellness, disease prevention, diet, exercise and pharmacies.
Evaluation of English and Spanish Health Information on the Internet	http://www.rand.org/publications/documents/interneteval/	The findings of a large study that describes and evaluates English and Spanish health information on the Internet. Assesses search engine performance and the quality and readability of health information on the Internet, and provides conclusions and recommendations.
Health, Nutrition and Fitness	http://www.health-nutrition-and-fitness.com	Search this extensive directory of sites, focusing on exercise and fitness, nutrition, mental health, depression and therapy, and diseases such as osteoporosis.
Well-aware	http://www.well-aware.co.uk	Provides information on conditions, complementary treatments and expert views, all written by doctors in the United Kingdom.
Health & Family Resource Guide	http://www.noeasytask.com	Personal and professional sites containing valuable information and links.
Health Reserve.com	http://www.healthreserve.com	Offers information on men's, women's, and general health topics.
Ask a Patient	http://www.askapatient.com/	Provides a database of patient opinions and ratings of medicine effectiveness. Also includes weekly consumer opinion polls on healthcare topics, and a health care research assistance section.

Name	URL	Description
MDAdvice.com	http://www.mdadvice.com/	Provides health and medical information, health tips, resources, experts, news, chats, and community support.
Consumer Laboratory Testing Information	http://www.ascls.org/labtesting/index.asp	A thorough guide to medical laboratory tests, why they are performed, and what they might mean.
The Health Resource, Inc.	http://www.thehealthresource.com/	Specialized medical research reports on mainstream, experimental, and alternative treatments, specialists, and support organizations.
HealthLink Plus	http://www.healthlinkplus.org/	Consumer health information on general health, health care providers, medical research, insurance, wellness, mental health, and alternative medicine.
Medidoctor	http://www.medidoctor.com/	A home health guide to diagnosis and treatment, and when to see your doctor or go to hospital.
HealthStatus	http://www.healthstatus.com	Free reports on body fat percentage, body mass index, calorie burning activities, target heart rate and smoking costs. Online health risk assessment which provides resources based on your health risks.
HealthFrontier.com	http://www.HealthFrontier.com/	Offers information including diseases and conditions, nutrition, exercise, mental health, live discussions and a message board.
Patient Protect	http://www.patientprotect.com/en/	Medical consultation devoted to protecting and defend patients. Contributes to reducing health costs, by preventing abuses, negligences, medical errors and incompetence in the health field.
UHealthy Network	http://www.uhealthy.com/	Global health information network and community that integrate every aspect of Health and Fitness in one place.
ProWho	http://www.prowho.com/	Locate health professionals anywhere in the world.
Planetamber	http://www.planetamber.com/	Global International health, medical and disability resources database. Categorized medical condition search for people with disabilities or health impairments, their families and those providing services and support.
Wonderful World of Diseases	http://www.diseaseworld.com/	Catalog of links and information on diseases and human conditions. Includes an online bookstore.
The Medical Information Warehouse	http://www.medfindnow.com/	Offers medical and disease information including poison control and child abuse areas.
eCureMe.com	http://www.ecureme.com/	Identify symptoms to make a self-diagnosis; set up online consultations with physicians and therapists; view online medical dictionary of diseases, treatments, drug information.

Name	URL	Description
A Second Opinion Medical Information Services	http://www.physicians-background.com	Medical treatment options, physician background check service, best hospitals and doctors. (Ft. Walton Beach, FL)[Fee based service |Ed]
Health Forums	http://www.healthforums.com/	Customized libraries of health and well-being information. Log in to access an extensive library of resources.
Health Depot	http://blakkat.com/health.htm	Directory to health and medical sites about diet, fitness, disabilities, diseases, health resources, products and sales.
GetWell.org	http://GetWell.org/	Offers resources for consumers on medical conditions, treatment and research.
Wellness.com	http://www.wellness.com	Includes health resources, discussion and news.
HealthCheck Risk Assessment	http://www.bodybalance.com/hra/start.html	Useful health risk assessment.
Medical Elite	http://www.medical-elite.com/	International medical consulting and information company that specializes in locating medical specialists. Translated into English, Arabic, Chinese, Portuguese, Russian, Spanish, and other languages.
LivingandHealth.com	http://www.healthandage.com	Offers information on topics such as diabetes, irritable bowel syndrom (IBS), hypertension, and epilepsy.
50+Health	http://www.50plushealth.co.uk	Health topics, lifestyle magazine, discussion forum, news and research.
Health Plug	http://www.healthplug.com/	Provides information on prescription drugs and other medications, with a message board and news links.
Medical Consumer Guide	http://www.medicalconsumerguide.com	Medical information pertaining to primary care, elective care, dental care, vision care, and drug and products safety and health.
The Lifestyle Doctor	http://www.lifestyledoctor.uk.com/	Information on lifestyle issues and simple ways to help oneself.
Health-Center.com	http://www.health-center.com/default.htm (no longer active)	Resources on numerous health topics. Includes a bulletin board and discussion forum.
Access Place Health	http://www.accessplace.com/health.htm	Web directory containing links to medical news, specialty sites, and general health information.
C.S.S. Doctor's Credentials Search	http://www.tese.com/css/index.html	Search for a Doctor's Medical School, Board Certification, residence training, licensing, disciplinary action (if any), and other important information.
Health In Depth	http://www.healthindepth.com/	Health information links to newspapers, magazines and internet resources.
Discuss Your Health	http://www.discussyourhealth.com/ (no longer active)	Discussion forums and health information.

Name	URL	Description
Wellness Hour Medical Informational Talk Show	http://www.wellnesshour.com	A medical talk show aired in over 100 cities throughout the United States.
WoundHeal.com	http://www.woundheal.com/info/infoIndex.htm	Educational information and resources for the non-surgical healing of pressure ulcers, at home.
Mindy Machanic's Change Pages: Wellness and Health Info	http://www.mindymac.com/Health.html	Articles on healthy foods, cancer and breast cancer. Includes comprehensive links to additional resources for health and wellness.
Vital Star Health, Science and Technology Resource Center	http://www.vitalstar.com/	Free online Medical Check up How healthly your are? Test your eye, BMI, carbs, protein, cholestrol, heart, height, calories, depression. Plus articles, news and updates related to health and fitness.
SymptomTracker	http://www.symptomtracker.com	An interactive medical diagnosis and treatment reference that uses brief yes/no questions about a users symptoms to arrive at possible conditions and treatments. [Please note the "Warning" before proceeding
No Frills Health	http://www.nofrillsguide.com/health.htm	An easy to use and useful guide to health sites on the net.
Citypractice.com	http://www.citypractice.com/	Provides information on preventative approaches in physical, behavioural and emotional healthcare.
DoctorInfo	http://www.maxpages.com/doctorinfo (no longer active)	Provides searches for background information on medical doctors or doctors of osteopathic medicine.
Surgery Door Home Healthcare Guide	http://www.surgerydoor.co.uk/hhcg/detail1.asp?level1=Welcome	Symptoms of common illnesses and ailments. From the UK's on-line health service.
iMedNetworks	http://www.imednetworks.com/ (no longer active)	An internet-based healthcare network that connects physicians and patients to each other and to a virtual world of medical information, tools, and services.
Healthy Living	http://www.balmoralfarm.ns.ca/index2.html	A guide with information about mental health, wellness, disease prevention, and family supports.
Internet Health Library	http://www.health-library.com	Searchable index to healthcare sites.
Best Doctors	http://www.bestdoctors.com/	Comprehensive knowledge-based medical referral service.
A Patient's Guide to the Internet	http://www.patientsguide.com	A step-by-step guide for patients seeking medical information on the Internet.
MedicalClub	http://www.medicalclub.com	Provides interactive free health information on Womens, Childrens and Family health concerns. The site also includes extensive information on herbal medicines, supplements and First Aid. Bilingual, English/Spanish.

Name	URL	Description
HealthInk Plus	https://www.healthinkplus.com	Health information including health assessments, quizzes, polls, news, articles, and drug information.
BluePrint for Health	http://blueprint.bluecrossmn.com/	A health and wellness portal which provides health information, personalized newsletters and interactive health tools.
U.S. Food and Drug Administration: Buying Medical Products Online	http://www.fda.gov/oc/buyonline/	Resource for consumers to help them make better buying decisions when shopping online. Includes information on how to determine if a site is legitimate, how to spot health fraud, and how to report fraudulent sites.
Your Health IS Your Business	http://weber.edu/hp/Faculty/molpin/bushea/index.html	Site includes information on health and wellness including primarily links to sites on the internet on health and wellness.
MayoClinic.com	http://www.mayoclinic.com/	Clinical experts provide current medical information and news on health topics.
SciTalk.com	http://www.scitalk.com	Science related resources for the public on health and disease. Discussion boards, chat, news, patents, clinical trials and books.
MDinteractive	http://www.mdinteractive.com/	Providing consumers with healthcare information and resources in every medical specialty. Providing physicians and patients with an efficient way to create and store medical records interactively.
Medical Information Dictionary	http://www.medical-information-dictionary-and-videos.com/	Dictionary with extensive listings on treatments. Current information on new medical procedures and definitions.
MEDLINEplus	http://www.nlm.nih.gov/medlineplus/	The National Library of Medicine's authoritative and current database of health information for consumers and health professionals. Coverage includes conditions and diseases, drug information, dictionaries, physician and healthcare directories, and links to other medical resources.
Beat Your Health Condition	http://www.beat-your-health-condition.com/	Information pertinent to both men and women health
Best Doctors	http://www.bestdoctors.com/en/default.htm	Link consumer to the medical knowledge they need to make the best healthcare choices for themsleves and their loved ones.
Health Center	http://www2.health-center.com/default.htm (no longer active)	An information portal providing links to many health related websites.
Health Windows	http://www.healthwindows.com/healthwindows/index.asp	Health information windows
NetHealthBook	http://www.nethealthbook.com/	Dr. Ray Schilling M.D. medical website with free info on medical conditions, symptoms, diagnostic test and treatment.

APPENDIX B

Usability Testing Script

1. Introduction

Hello,

We are evaluating usability of websites for PDA users, in this study, the Pocket PC users. Your opinions and time here today will help us understand the status of Web usability for Pocket PC users.

In the next one hour, you will be asked to perform several tasks based on different given scenarios and fill out three short questionnaires. We are evaluating the usability of the websites and NOT you in this exercise. Please don't feel being pressed or in a competition.

The websites you will experience today are selected from popular websites from the Internet. You will use Dell Axim X3i Pocket PC to access these websites via a wireless connection. The connection has already been configured, however, we may experience delays, and at times I may have to reconfigure the device to continue our study.

You may pause or end the study at any time if you are feeling uncomfortable

Ask any questions that come to mind, but due to the research nature of this study, we may not be able to answer any question during testing, as it may compromise our results. However, after the study we will be happy to answer any remaining questions you may have.

Please note that we will record time you spend on each task. This is only for internal purpose only. Again, don't feel being pressed or in any competition.

Each task has a time limit, and I may move you from task to task quickly. This is not a reflection on you or on your performance today.

2. Before we get started, please fill out the first questionnaire (give them the questionnaire I)

3. Before we start the tasks, please familiarize yourself with the device we are using today (help the subject "warm up" using the PDA as much as possible. Feel free to help the subject to master basic skills when use PDA to access the Internet.)

- Make sure subjects grasp the following PDA browsing skills before go to next part:
- How to scroll horizontally and vertically
- How to go back a Web page

- How to use on-screen keyboard to input query
- How to navigate by clicking a link (the difference between “tap” and “tap and hold”

4. Test on Scenario 1 – 4 (Record time).

5. Fill out Questionnaire II

6. Test on Scenario 5 – 8 (Record time)

7. Fill out Questionnaire III

Questionnaire I

What is your age?

10 – 20
☐ 21-30
☐ 31-40
☐ > 40
☐ N/A

What is your gender?

Male
☐ Female
☐ N/A

Do you own a computer yourself?

Yes
☐ No
☐ Unknown
☐ N/A

How many hours a day do you use computers?

< 1
☐ 1- 5
☐ 6- 9
☐ > 9
☐ N/A

What do you do when you use computers (select all that apply)?

Editing
☐ Gaming
☐ Internet Surfing
☐ Programming
☐ Data processing
☐ Others
Specify ____
☐ N/A

How many hours a day do you use the Internet?

< 1
☐ 1- 5
☐ 6- 9
☐ > 9
☐ I don't access the Internet at all
☐ N/A

What do you do when you use Internet?

Searching information

□ Gaming

□ Online chatting

□ Email

□ Others

Specify ____

□ N/A

Do you know what a PDA (Personal Digital Assistant) is?

Yes

□ No

□ N/A

Do you have a PDA yourself?

Yes

□ No

□ N/A

What do you do when you use PDA (Select all apply)?

Personal information management

□ Gaming

□ Data processing

□ Web surfing

□ Others

Specify ____

□ N/A

Have you ever used a PDA to access the Internet?

Yes

□ No

□ Unknown

□ N/A

Warm-up Scenario

Let’s get familiarize with the device and browsers using the Pitt website as a warm up site. Go to http://www.pitt.edu. Find the top headline news on the Homepage.

Top headline news on Pitt homepage

Then, go to “find people” section, use your name as the query to find out your information stored in Pitt web server. Is the information accurate?

Scenario 1

Find the highest temperature **tomorrow** at **Pittsburgh (Pittsburgh, PA)** by visiting AccuWeather (http://www.accuweather.com)

Highest temperature ____

Scenario 2

It is 8:00AM in the morning. You have a daily habit of reading news from CNN website. However, today you are on the road. You have to use the Pocket PC to read CNN news via a wireless connection. Go to CNN homepage (http://www.cnn.com), read the first headline news at the section WORLD and answer following questions.

What is the last sentence of that news report?

____

Scenario 3

You recently feel pain on your left knee. You decide to check it up yourself. A good starting place is the Internet. You go to Yahoo (http://www.yahoo.com) and use “Left knee pain” as the query phrase. Please write down the name of the first three Non-Commercial links (hint: the URL with no .com postfix) returned by the search engine.

1. ______________________________

2. ______________________________

3. ______________________________

Scenario 4

You want to buy a book as a gift to your friend Instead of going to local bookstore, you decide to use online bookstore to save a trip. The bookstore you are going to visit is Booksamillion (http://www.booksamillion.com). Please find the **No. 1 BESTSELLER in FICTION** category listed on the homepage and find out the number of different formats that the book has. Also find out other books that other customers may buy if they buy this book. Locate the paperback format of the book and put it into the shopping cart. Make sure it is in the shopping cart (You don't need to start the checkout).

Which books is the No.1 bestseller fiction?

How many different types of format does the book have (e.g. hardcopy, paperback, etc)?

Customers also bought books besides this one.

Questionnaire II

			1	2	3	4	5	6	7	
1.	Overall, I am satisfied with how easy it is to use this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
2.	It was simple to use this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
3.	I can effectively complete my work using this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
4.	I am able to complete my work quickly using this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
5.	I am able to efficiently complete my work using this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
6.	I feel comfortable using this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
7.	It was easy to learn to use this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
8.	I believe I became productive quickly using this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
9.	The Format gives error messages that clearly tell me how to fix problems	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
10.	Whenever I make a mistake using the Format, I recover easily and quickly	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
11.	The information (such as online help, on-screen messages, and other documentation) provided with this Format is clear	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
12.	It is easy to find the information I needed	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
13.	The information provided for the Format is easy to understand	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
14.	The information is effective in helping me complete the tasks and scenarios	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
15.	The organization of information on the Format screens is clear	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
16.	The interface of this Format is pleasant	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
17.	I like using the interface of this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
18.	This Format has all the functions and capabilities I expect it to have	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
19.	Overall, I am satisfied with this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE

Scenario 5

Find the highest temperature **tomorrow** at **New York City (New York, NY)** by visiting AccuWeather (http://www.accuweather.com)

Highest temperature ____

Scenario 6

It is 8:00AM in the morning. You have a daily habit of reading news from CNN website. However, because today you are on the road, you have to use the Pocket PC to read CNN news via a wireless connection. Go to CNN homepage (http://www.cnn.com), read the first headline news at the section U.S. and answer following questions.

What is the last sentence of that news report?
____

Scenario 7

You heard about the recent Hepatitis A outbreak at west Pennsylvania. You want to explore more on the topic. A good starting place is the Internet. You query the Yahoo search engine (http://www.yahoo.com) using "Hepatitis A" as the query phrase. Please write down the name of the first three Non-Commercial links (hint: the URL with no .com postfix) returned by the search engine.

1. ____

2. ____

3. ____

Scenario 8

You want to buy a book as a gift to your friend Instead of going to local bookstore, you decide to use online bookstore to save a trip. The bookstore you are going to visit is Booksamillion (http://www.booksamillion.com). Please find the No. 1 BESTSELLER in **NON-FICTION** category listed on the homepage and find out the number of different formats that the book has. Also find out other books that other customers may buy if they buy this book. Locate the paperback format of the book and put it into the shopping cart. Make sure it is in the shopping cart (You don't need to start the checkout).

Which book is the No.1 bestseller non-fiction?

How many different types of format does the book have (e.g. hardcopy, paperback, etc)?

Customers also bought other books besides this one.

Questionnaire III

			1	2	3	4	5	6	7	
1.	Overall, I am satisfied with how easy it is to use this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
2.	It was simple to use this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
3.	I can effectively complete my work using this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
4.	I am able to complete my work quickly using this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
5.	I am able to efficiently complete my work using this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
6.	I feel comfortable using this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
7.	It was easy to learn to use this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
8.	I believe I became productive quickly using this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
9.	The Format gives error messages that clearly tell me how to fix problems	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
10.	Whenever I make a mistake using the Format, I recover easily and quickly	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
11.	The information (such as online help, on-screen messages, and other documentation) provided with this Format is clear	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
12.	It is easy to find the information I needed	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
13.	The information provided for the Format is easy to understand	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
14.	The information is effective in helping me complete the tasks and scenarios	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
15.	The organization of information on the Format screens is clear	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
16.	The interface of this Format is pleasant	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
17.	I like using the interface of this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
18.	This Format has all the functions and capabilities I expect it to have	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE
19.	Overall, I am satisfied with this Format	DISAGREE	☐	☐	☐	☐	☐	☐	☐	AGREE

Overall, which format do you prefer?
☐ First one

☐ Second one
☐ No difference
☐ N/A

Why?

APPENDIX C

Subject Recruitment Flyer

Research Subjects Needed

Experiment of Web Page Usability

You will be asked to browse Web pages using Personal Digital Assistance (PDA), to finish several tasks online, and to fill out three questionnaires. All will be finished in about one hour and you will receive $15 as compensation.

The whole experiment will be conducted on campus at 6053 Forbes Tower (Health Information Management Conference Room).

Contact Xiaoming Zeng at (412) 383-5101 (email: xizst9@pitt.edu) for more information. Or call (412)383-6861 to leave voice message for participation. Please leave your name and a phone number at which you can be contacted for an appointment.

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