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Accessible Web Page Design for the Visually Impaired: A Case Study

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Section 508 of the Rehabilitations Act of 1973 states that federal agencies are required to maintain accessible web-based information for persons with disabilities, namely, visual impairments. Studies spanning over 1 decade conducted by The American Foundation for the Blind and Towson University's Universal Usability Lab investigated federal home pages for Section 508 violations. Both studies concluded that numerous university, corporate, federal, and federal contractor websites are largely inaccessible to people with disabilities—specifically in terms of clarity, consistency, and fidelity to standards. Due to inconsistencies across federal agencies, constant website updates, and webmaster turnaround, there is a need for practical guidelines for web page design compliant with Section 508, the Americans with Disabilities Act, and the World Wide Web Consortium's Web Content Accessibility Guidelines, with particular focus on the visually impaired.

1. INTRODUCTION

Despite the existence of the accessibility rules and guidelines of Section 508 of the Rehabilitation Act of 1973 (with revision in 1998), the Americans with Disabilities Act (ADA) of 1990, and the Web Content Accessibility Guidelines (WCAG) created by the World Wide Web Consortium (W3C) Web Accessibility Initiative (WAI; Henry, 2012), their implementation is deficient.

The investigation "Usability Research with Computer Users who are Blind or Visually Impaired," conducted by the American Foundation for the Blind (Gerber, 2013), revealed (a) in general, websites (i.e., a collection of web pages under one domain) lack clarity, consistency, and fidelity to standards, that is, properly labeled forms, precise text description of images, and so on, and (b) technically compliant web pages are not necessarily truly usable. In 2011, the Universal Usability Laboratory of Towson University found that 96 of 100 federal websites exhibit accessibility violations, and on average 2.27 Section 508 guidelines were violated per home page (Olalere & Lazar, 2011). The causes of web inaccessibility are likely due to the constant and rapid change of information (Olalere & Lazar, 2011), necessitating rapid upkeep of websites, the turnover of web designers within agencies and institutions (Olalere & Lazar, 2011), the lack of compliance checks by the Department of Justice (DOJ), and most important the absence of a technically relevant web-accessibility guide for use by both federal and nonfederal entities.

In addition to federal agencies, 41% of university websites do not meet the Web Accessibility in Mind (WebAIM) standards (Schmetzke, 2001). Eighty-four percent of corporate and 83% of service/retail websites are inaccessible to people with disabilities (Loiacono, 2003; Loiacono & McCoy, 2004). Considering that people with disabilities control more than $175 billion (Loiacono, Djamasbi, & Kiryazov, 2013), there are more than just societal implications (Fuchs & Obrist, 2010; Hochheiser & Lazar, 2007) to address these issues. Common violations of Section 508, ADA, and WCAG include no alternative text on images, inaccuracies with screen readers, meaningless alternative texts, and illogical header organization.

We do not attempt to amend these guidelines, as that is obviously beyond our purview. For the purpose of this case study, we report on generically applicable, practical implementation guidelines for enabling full accessibility and rapid upkeep of websites, with particular focus on the visually impaired, including the various definitions ranging from partially sighted to completely blind (Prougestaporn, 2010). Prougestaporn (2010) already performed research to improve the accessibility of ELearning websites in particular. ELearning—the concept of online education—could give those with visual impairments a chance to learn at their own pace, providing better results than in a traditional classroom. Similarly, Loiacono et al. (2013) identified website designs that would appeal to users with audio-visual impairments.

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2. GUIDELINES FOR ACCESSIBLE WEB PAGE DESIGN

This chapter is meant to clearly explain "how" to implement accessible coding that is consistently applicable across all web pages while surpassing technical compliance with Section 508, ADA, and W3C's WCAG. Although there have been several proposals for accessible web page design (e.g., ELearning: Prougestaporn, 2010; audio-visual: Loiacono et al., 2013), what is commonly lacking is how to technically apply all of the policies of WCAG and Section 508. Such factors that must be addressed while designing an accessible web page include general formatting such as appropriate widths and resolutions, text fonts and color schemes, and page headers and footers; inclusion of accessibility statements; and explanation of how accessibility is checked.

2.1. General Formatting

A universal approach toward an accessible web page comprises a structurally "lean" (i.e., simple layout) and compact design to accommodate the content on the screen. W3Schools, a web developer's portal, reported in its browser statistics that although 98% users use a display resolution of 1024 × 768 or higher, 1% of users still have only 800 × 600 screens as of January 2012 (W3Schools, 2014). More important, the use of web-accessing mobile devices such as smartphones and tablet computers has increased. Most of these devices display screen resolutions of less than 1024 × 768. Therefore, a centered "graphics safe area" of 800 pixels maximum width should be implemented such that users can view an entire webpage with vertical scrolling only. Cascading Style Sheets (CSS) should be implemented as well to enable the highest level of accessibility across various devices, especially for smartphones (Zhang & Lai, 2011). CSS improve content accessibility by providing flexibility and control in the presentation of characteristics, as well as shared formatting across multiple pages (i.e., separating all formatting from the content).

A "flat" hierarchy (i.e., only up to two click levels) in website structure should be used for direct access to its web pages. To ensure clear and consistent navigation, rows of all navigational links should always be placed in the same location on all web pages and in the same sequence, which will help avoid user disorientation. For example, rows of links can be positioned in and directly accessed from the header and footer sections of the website (Figure 1).

2.2. Text Fonts and Color Schemes

The use of standard sans serif fonts, such as Arial and Helvetica, are important for alphabetic clarity for low-vision web users (W3C Web Accessibility Initiative, 2014). WCAG Guideline 1.4.4 states that all text should remain legible after being resized 200% without assistive technology (Caldwell, Cooper, Reid, & Vanderheiden, 2008). Therefore, it is highly recommended that font size should be around 12 and never

FIG. 1. Guidelines applied to the official website of the Visual and Autonomous Exploration Systems Research Laboratory (http://autonomy.caltech.edu) with (a) clear and consistent link arrangement at the top and at the bottom of each page, (b) complete header with basic information about the institution in which the display of photos is changed upon page-refresh, (c) complete footer showing the date of the last update and accessibility icons, (d) "Skip Navigation" link, (e) Accessibility Statement, (f) Access Keys, (g) Site Map, and (h) Google Accessible Search.

drop below 9. Moreover, to offer the best contrast to visually impaired users, the strongest contrast in any color system, namely, black and white, is preferable for the display of content as it is considered "web safe." Although 98% of modern computers contain 24-bit or 32-bit color displays (W3Schools, 2014), high-contrast color schemes, especially for textual content, are essential to low-vision accessibility. Moreover, artificial vision implants, predominantly used for people who are blind due to age-related macular degeneration or retinitis pigmentosa, are currently not capable of stimulating well-defined gray-scaled vision let alone color vision. Therefore, black and white are still preferred for the display of web page content to visually impaired users.

2.3. Page Headers and Footers

One standard header and footer should be utilized throughout the entire website.

- The *header* needs to provide basic information about the institution, including its name and logo (Figure 1). Header display photos can be utilized to characterize the field of the institution/agency. Header pictures may change upon page refresh (Figure 1), but all pictures should contain text equivalents. Random image swapping should be implemented by means of JavaScript, a separate scripting language (see http://www.javascriptsource.com/). Navigation links should be provided in the header using a "flat" hierarchy. In addition, a "skip" link should be implemented in the header, which allows those who use screen readers to move past these "flat" hierarchy links and straight into the main content of the web page.
- Akin to the header, *footer* information is essential for giving provenance to the page, as users need assurance that a given page is up-to-date (Figure 1). Therefore, every web page should include a footer with the date of the last update in standard international format yyyy/mm/dd, as advised by the International Organization for Standardization (2004). The footer should also include the "flat" hierarchy links as in the header.

2.4. Accessibility Statements

A general statement of accessibility compliance should be included in plain text on the website. Although accessibility statements are not required by law, an understanding of the accessibility of any given web page would be helpful to users, especially to those with impairments (Olalere & Lazar, 2011). Moreover, the statement brings awareness of regulations to the web designers and should incite extra caution when it comes to maintaining violation-free sites. Even for nonfederal websites that are not legally required to follow Section 508, ADA or WCAG, an accessibility statement can be educational to those who use and maintain the web page.

2.5. Accessibility Verification

Establishing and maintaining web accessibility has become increasingly difficult in light of the vastly growing amount of Internet-based information. Verification that a web page is free of accessibility violations can be accomplished either manually or automatically. The most accurate method to check a page for violations is to listen to various screen readers and check all code for proper "alt" texts. Proper "alt" text will convey the basic, essential information that is displayed by the respective multimedia or image object. Using just one screen reader may miss web design flaws due to variation in how they interpret a web page. One caveat with using a screen reader is that it works only if one can see the screen to verify if what one is hearing matches what is on the screen. Due to time constraints of such "manual" checking, there is a variety of automated web- and software-based compliance checkers available, such as Web Accessibility Checker, RAMP, InFocus, and WAVE (replacement of "Bobby (WebXACT)"; Olalere & Lazar, 2011). However, the challenge with automated checkers is despite being much faster they will only catch roughly 25% of the issues (Groves, 2011). It is difficult for any automated system to evaluate content value; therefore uninformative "alt" text will not be caught as an issue. In consequence, a mix of manual and automated verification will likely provide the most reliable results.

2.6. Usability Verification

Takagi, Asakawa, Fukuda, and Maeda (2004) pointed out that there is too much focus on the compliance with guidelines and not enough on actual usability, too much relying on syntactic checking, and no paying attention to time-oriented aspects of users. They devised an accessibility checker for web designers, the Accessibility Designer (aDesigner). aDesigner is a disability simulator that helps web designers ensure that their content and applications are accessible and usable by the visually impaired. It uses tools such as "Blind Usability Visualization" to help designers create more accessible websites. Blind Usability Visualization allows designers to see how the visually impaired navigate through their website, including how long it takes to reach each section based on the proper use of skip links. aDesigner also possesses an automatic error detection to screen for things such as inappropriate "alt" text and redundant texts. A caveat of aDesigner is the fact that one has to download the Windows-only application and cannot run it directly off the web, that is, in a web browser.

By analyzing the ease of use for the visually impaired, web designers can take the accessibility of their website to the next level. With the rapid increase of online shopping, businesses are doing whatever they can to keep users coming back to their websites. Emphasizing that people with disabilities control more than $175 billion (Lociacono et al., 2013), more attention should be given to usability for the visually impaired. Tonn-Eichstädt (2006) developed an improved Goals, Operators, Methods, Selection rules, or GOMS, method using aDesigner. This allows designers to address areas that are tough to access and provides quicker access to desired areas, such as purchase pages.

Usability testing can be taken one step further using a behavioral model that predicts behavioral intention to use a given website. Loiacono et al. (2013) modified and tested the Technology Acceptance Model to accurately predict what factors will encourage a visually impaired person to return to a website. If information on the web is to become truly universal, higher usability for persons with sensory impairments must become a priority.

3. PRACTICAL EXAMPLE IMPLEMENTATION OF GUIDELINES: A CASE STUDY

The aforementioned guidelines were applied to the official webpages of Caltech's (2013) Visual and Autonomous Exploration Systems Research Laboratory (http://autonomy.caltech.edu; see Figure 1). The Laboratory conducts research in ophthalmology with emphasis on visual prostheses, thus making it of particular interest to the visually impaired. While the website was designed, many preexisting accessibility concerns were raised and subsequently addressed. The following section is meant to detail common technical accessibility issues and their appropriate solutions for webmasters in charge of Section 508 compliance (see also Table 1).

The website contains only text-labeled graphics (Figure 2). An alt-attribute of maximum length of 50 characters is defined in a tag, such as img, area, and so on, with a clearly identified native language (WCAG 1.0 Checkpoint 4.1). An empty alternative text is assigned to purely decorative elements to signal the screen reader to skip the image (WebAIM, 2013). When necessary to describe complex graphics, such as diagrams, detailed

TABLE 1
A Case Study Overview of Technical "Do's" and "Avoids" for Accessibility Compliance

Do	Avoid
Only text-labeled graphics	Longdesc for critical information
< 50 characters in a tag	Using text-only pages
Empty text alt for decorative images	"D-tag" descriptions
Ensure information is visible in black and white	Server-side image maps
Use CSS for design control	Frames
Provide links to plug-ins	Animated flashing of 2–55 Hz frequency
Label forms with tags	Repeating list navigations
Add title attributes to acronyms and abbreviations	
Provide a quick link to access keys	

Note. CSS = Cascading Style Sheets.

FIG. 2. WAVE 5 Accessibility Tool – Icon view of web page http://autonomy.caltech.edu/research.html (http://wave.webaim.org/report?url=http%3A%2F%2Fautonomy.caltech.edu/research.html).

photos, and so on, "D-tags" (a link to the textual description represented by [D] within [D]) are not recommended due to fact that most users do not recognize the convention. Instead the similar technique of *overt caption links*—a "D-tag" denoted by an apparent link, for example, "[Click link here]"—should be used. If text descriptions were only necessary to reach those using screen readers (i.e., visually impaired users), a long attribute "longdesc" would be most effective (Chisholm, Vanderheiden, & Jacobs, 2000). A longdesc attribute specifies a URL to a page that contains a long description of an image (not universally recognized and supported by all screen readers, such as MacOS VoiceOver). This would, in particular, apply to images for which the descriptions are apparent from viewing them.

An "image map" permits assigning a specific action to each region of an image, for example, "open a new webpage" or "retrieve a document" (graphical header of the website). A client-side image map is accessible because an alternative text (alt-tag) may be assigned to it. For a server-side image map, however, active regions in the image only display a set of coordinates. After clicking on a particular area of an image, the client browser sends the coordinates of the mouse click to the server where calculations are made and then appropriate action is taken, such as opening a new link. Because this process depends on both vision (i.e., cursor placement) and mobility (i.e., mouse movement), server-side image maps are generally inaccessible and should not be implemented (Thatcher, 2011b). If server-side image maps are implemented, redundant text-links should be provided for each active link to ensure accessibility (in particular with screen readers; Thatcher, 2012).

Text-only versions of a web page can be used to comply with accessibility guidelines. A text-only web page conveys exactly the same content as a graphical web page. Images are replaced by their descriptions, and instead of audio or video, textual transcriptions are provided. Instead of adding a text-only version to every web page, accessibility compliance may also be accomplished by properly using alternatives to, for example, multimedia or image objects. The text-only version of such a webpage would then be viewed in a text-based browser (e.g., Lynx; Delorie, 2004) and its contents compared with the contents of the same web page displayed in a multimedia browser (Figure 3). The use of a text-only web page is indicated, in accordance with Section 508 (Even Grounds, 2013), when all other accessibility options are essentially impractical, for example, for the blind.

To ensure all information is visible without color, web pages are viewed in a browser with black/white mode engaged, and printed in black and white. CSS (Thatcher, 2011a) are used because they allow for more precise design control. Layout, positioning, fonts, colors, and style information for an entire website are contained in a single file to be downloaded once by the user's browser and then referenced by all web pages of a website. Only this file needs to be modified to change the website appearance, therefore guaranteeing consistency. Web page content may be viewed with CSS turned off to

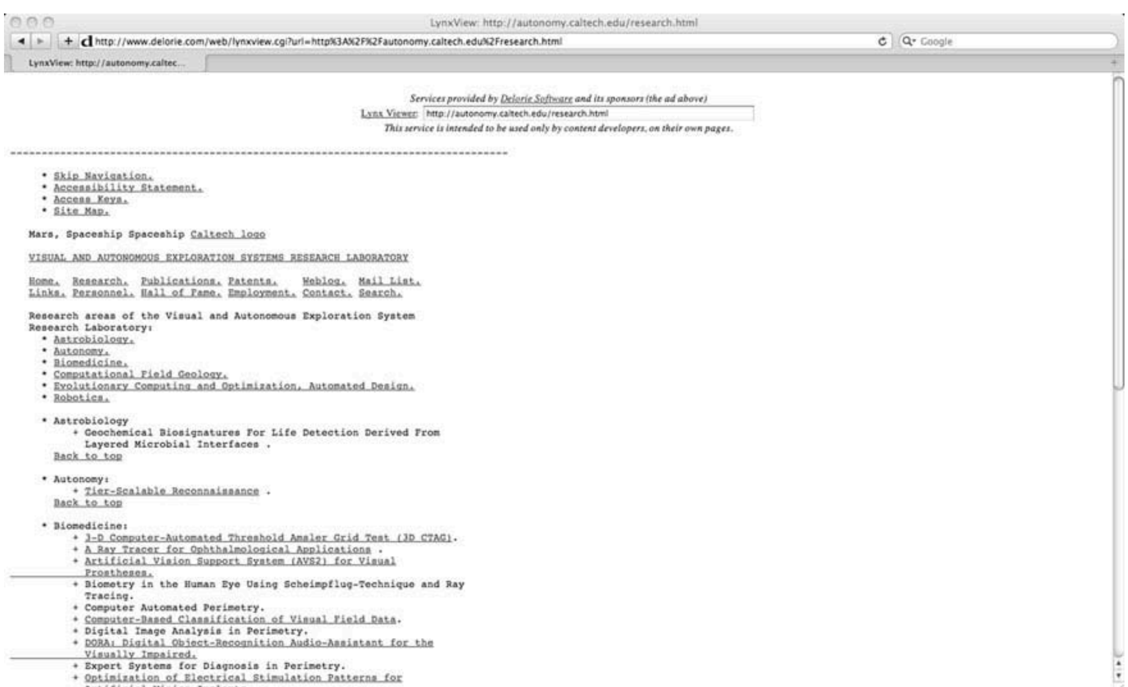

FIG. 3. Lynx – text-only version of web page http://autonomy.caltech.edu/research.html (http://www.delorie.com/web/lynxview.cgi?url=http%3A%2F%2Fautonomy.caltech.edu%2Fresearch.html).

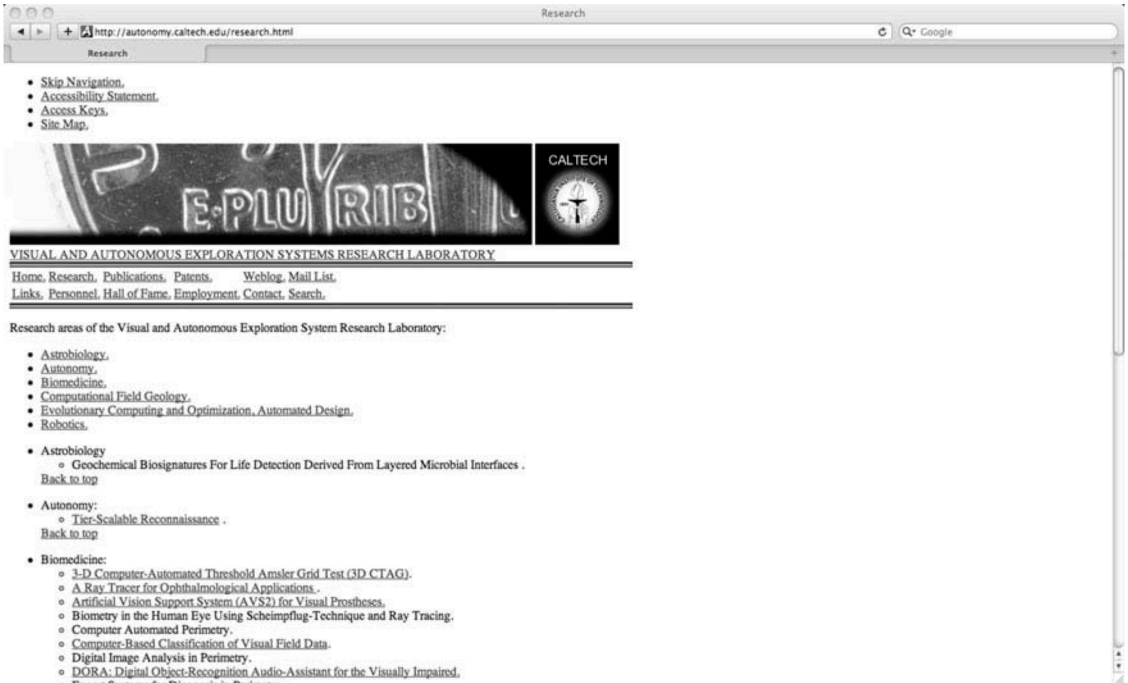

FIG. 4. Web page http://autonomy.caltech.edu/research.html with Cascading Style Sheets (CSS) turned off.

remove formatting (Figure 4). This benefits impaired people who may want to override existing style sheets with their own, for example, having a different font size.

Because different browsers interpret frames differently, the implemented laboratory web pages do not use any frames.

Third party plug-ins, Java applets, and animated (flashing) GIFs may cause the screen to flicker with a frequency in the 2–55 Hz interval. These frequencies are to be avoided, because flickering, flashing, or blinking objects may cause seizure in users with photosensitive epilepsy (Caldwell et al., 2008). Moreover, individuals with visual or cognitive disabilities are unable to follow quickly moving text or graphics. Likewise, screen readers fail to read flickering text. Thus, no animated, flashing, or flickering elements are included in the web page design.

Web pages that include content such as Real Audio, PDF, Flash, Microsoft Office files, and so on, provide a link to the needed plug-ins at the top of the page ("Web-based Intranet and Internet," 2001; e.g., Acrobat Reader: http://get.adobe.com/reader). Moreover, all applets, scripts, and other applications used must be accessible, or an accessible alternative is made available. Users should be able to engage the applet with their mouse and keyboard, and the applet's content must be readable by screen readers.

All forms on the laboratory website, such as a one-line Google Search form (Figure 1), are explicitly labeled with tags used to mark text elements as labels, to then associate a form element with that label ("Web-based Intranet and Internet," 2001). In addition, Google Accessible Search is implemented (Figure 1), because it always prioritizes the most accessible webpages of greatest relevance to a particular query (Google, 2014).

A link at the top left corner of every web page enables users to jump directly to the main content of the respective web page (Figure 1). This "Skip Navigation" anchor addresses (visually impaired) people using screen readers or other types of assistive technologies, to not force them to listen to the same list of navigation links before they reach the actual main web page content ("2.4 Building," 2012).

To enhance document usability a title attribute is added to the acronym and abbreviation elements <acronym title=""></acronym> and <abbr title=""></abbr> tags in XHTML, to provide the expansion of the first occurrence of abbreviations/acronyms in the main body of the document.

The top of every web page has a direct link to the "Access Keys" section, where an access key legend is displayed, showing which keyboard shortcuts are implemented throughout the website. Although access keys are commonly considered to be a poorly implemented tool, any aspect that can bring more accessibility should be included.

4. WEBSITE VALIDATION AND ACCESSIBILITY TESTING OF IMPLEMENTED GUIDELINES

Implementing the guidelines just described, the resulting website is Section 508, ADA, and W3C's WCAG compliant. All generated web pages are tested both for validity and accessibility. W3C has been the driving force behind WCAG

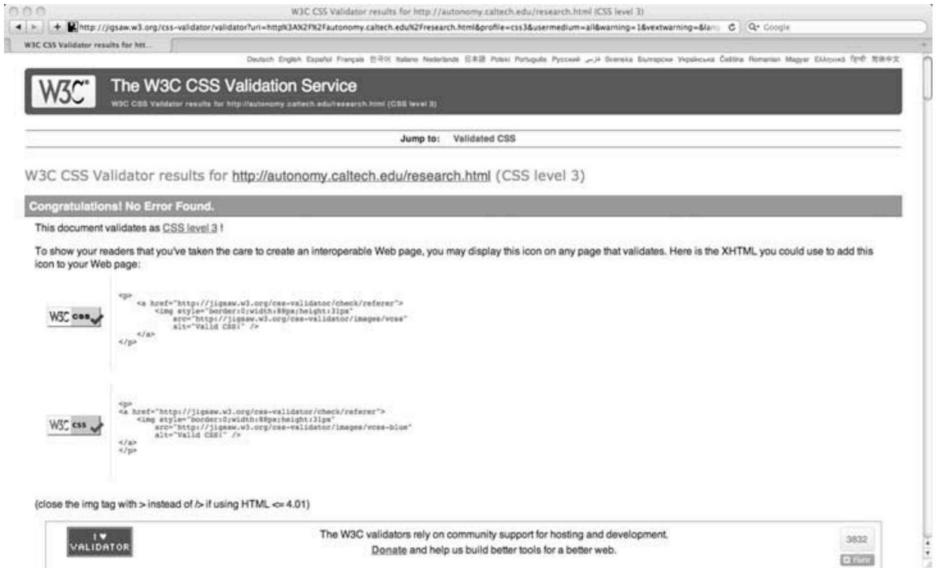

FIG. 5. W3C CSS Validation Test of web page http://autonomy.caltech.edu/research.html (http://jigsaw.w3.org/css-validator/validator?uri=http://autonomy.caltech.edu/research.html).

through its Web Accessibility Initiative and has continued to contribute by providing free validation tests (Henry, 2012). These validation tests include the following:

- *W3C Markup Validation Service*, a free service that checks web documents in formats such as (X)HTML for conformance to W3C's recommendations and other standards.
- *W3C CSS Validation Service*, a free service that checks CSS in (X)HTML documents for conformance to W3C's recommendations (http://jigsaw.w3.org/css-validator/).

If a webpage successfully passes a formal validation using an XML parser, it is subsequently checked for validity using the W3C CSS Validation Service. On every successfully XML-validated webpage, W3C icons are displayed (Figure 1, bottom) that are direct links to the respective W3C validation tests, which perform an instantaneous validation test when clicked (Figure 5).

Similarly, all web pages are tested with the freely available online web accessibility testing tool WAVE 5 (http://wave.webaim.org/) before they are officially released (Figure 2). WAVE 5 applies Section 508 rules. WAVE icons, indicating the degree of conformance, are displayed on every web page whose accessibility was successfully verified (Figure 1, bottom). They are direct links to the respective WAVE validation tests, which perform an instantaneous validation test when clicked (Figure 2). Obviously, retesting is required each time the site is updated to justify continued display of the W3C and WAVE icons.

5. CONCLUSION

We have described practical implementation guidelines for accessible web page design for the visually impaired. The main purpose of these guidelines is to enable webmasters to quickly create and update web pages that (a) are sufficiently compliant with Section 508, ADA, W3C's WCAG, and so on, and (b) allow for comprehensive presentation of information that is easily accessible and navigable, especially for the visually impaired. Following these guidelines, we have implemented the rules of Section 508, ADA, and W3C's WCAG and accessibility-tested our Laboratory web pages.

Ultimately, notwithstanding the aforementioned/guidelines, the visually impaired is the ultimate judge as to how accessible and usable web pages really are. As such, real-world testing with blind or visually impaired is envisioned, the results of which will be published elsewhere. Despite its significance, accessible web page design is still widely ignored. We hope this work will contribute to promoting web accessibility by raising awareness of its importance so that universal Internet access becomes a vision for all.

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REFERENCES

Caldwell, B., Cooper, M., Reid, L. G., & Vanderheiden, G. (2008, December 11). W3C recommendation. *Web Content Accessibility Guidelines (WCAG) 2.0.* Retrieved from http://www.w3.org/TR/2008/REC-WCAG20-20081211/

Chisholm, W., Vanderheiden, G., & Jacobs, I., (2000, November 6). W3C note. *HTML Techniques for Web Content Accessibility Guidelines 1.0*. Retrieved from http://www.w3.org/TR/2000/NOTE-WCAG10-HTML-TECHS-20001106/

Delorie, D. J. (2004, October). Lynx viewer. Retrieved from http://www.delorie.com/web/lynxview.html

Even Grounds. (2013). Should sites be accessible or provide a text-only alternative. Retrieved from http://www.evengrounds.com/articles/should-sites-be-accessible-or-provide-a-text-only-alternative (Accessed July 22, 2014)

Fuchs, C., & Obrist, M. (2010). HCI and society: Towards a typology of universal design principles. *International Journal of Human–Computer Interaction*, *26*, 638–656.

Gerber, E. (2013). *Conducting usability research with computer users who are blind or visually impaired*. Retrieved from http://www.afb.org/Section.asp?SectionID=57&TopicID=167&DocumentID=1718 (Accessed July 22, 2014)

Google. (2014). Accessibility in Google search. Retrieved from http://labs.google.com/accessible/faq.html (Accessed July 22, 2014)

Groves, K. (2011, June 12). The problem with automated website accessibility testing tools. Retrieved from http://www.karlgroves.com/2011/06/12/the-problem-with-automated-testing-tools/

Henry, S. L. (2012, October 2). Web Content Accessibility Guidelines (WCAG) Overview. Retrieved from http://www.w3.org/WAI/intro/wcag

Hochheiser, H., & Lazar, J. (2007). HCI and societal issues: A framework for engagement. *International Journal of Human–Computer Interaction*, *23*, 339–374.

International Organization for Standardization. (2004). ISO 8601:2004: Data elements and interchange formats—Information interchange—Representation of dates and times. Geneva, Switzerland: Author. Retrieved from http://www.iso.org/iso/catalogue_detail?csnumber=40874 (Accessed July 22, 2014)

Loiacono, E. T. (2003). Improving web accessibility. *Computer*, *36*, 117–119.

Loiacono, E. T., Djamasbi, S., & Kiryazov, T. (2013). Factors that affect visually impaired users' acceptance of audio and music websites. *International Journal of Human–Computer Studies*, *71*, 321–334.

Loiacono, E. T., & McCoy, S. (2004). Web site accessibility: An online sector analysis. *Information Technology & People*, *17*, 87–101.

Olalere, A., & Lazar, J. (2011). Accessibility of US federal government home pages: Section 508 compliance and site accessibility statements. *Government Information Quarterly*, *28*, 303–309.

Prougestaporn, P. (2010, June). Development of a web accessibility model for visually-impaired students on Elearning websites. In *Educational and Network Technology (ICENT), 2010 International Conference on* (pp. 20–24). IEEE.

Schmetzke, A. (2001). Web accessibility at university libraries and library schools. *Library Hi Tech*, *19*, 35–49.

Takagi, H., Asakawa, C., Fukuda, K., & Maeda, J. (2004, October). Accessibility designer: visualizing usability for the blind. In *ACM SIGACCESS Accessibility and Computing* (No. 77–78, pp. 177–184). New York, NY: ACM.

Thatcher, J. W. (2011a, July 30). Cascading Style Sheets. Retrieved from http://www.jimthatcher.com/webcourseb.htm (Accessed July 22, 2014)

Thatcher, J. W. (2011b, July 30). Image Maps. Retrieved from http://www.jimthatcher.com/webcourse5.htm

Thatcher, J. W. (2012, March 19). Side by Side WCAG vs. 508. Retrieved from http://www.jimthatcher.com/sidebyside.htm; http://wac.osu.edu/tutorials/section508/serverimagemaps.htm (Accessed July 22, 2014)

Tonn-Eichstädt, H. (2006, October). Measuring website usability for visually impaired people-a modified GOMS analysis. *Proceedings of the 8th International ACM SIGACCESS Conference on Computers and Accessibility*, 55–62.

2.4 Building in universal accessibility + checklist. (2012, May). *The National Archives*. Retrieved from http://webarchive.nationalarchives.gov.uk/20100807034701/http:/archive.cabinetoffice.gov.uk/e-government/resources/handbook/html/2-4.asp (Accessed July 22, 2014)

United States Access Board. (2001, June 21). Web-based Intranet and Internet Information and Applications (1194.22). Retrieved from http://www.access-board.gov/guidelines-and-standards/communications-and-it/about-the-section-508-standards/guide-to-the-section-508-standards/web-based-intranet-and-internet-information-and-applications-1194-22 (Accessed July 22, 2014)

WebAIM. (2013). Alternative text. Retrieved from http://webaim.org/techniques/images/alt_text (Accessed July 22, 2014)

W3C Web Accessibility Initiative. (2014, March 11). The amazing em unit and other best practices (Chapter 4). Retrieved from http://www.w3.org/WAI/GL/css2em.htm (Accessed July 22, 2014)

W3Schools. (2014, January). Browser display statistics. Retrieved from http://www.w3schools.com/browsers/browsers_display.asp (Accessed July 22, 2014)

Zhang, D., & Lai, J. (2011). Can convenience and effectiveness converge in mobile web? A critique of the state-of-the-art adaptation techniques for web navigation on mobile handheld devices. *International Journal of Human–Computer Interaction*, *27*, 1133–1160.

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