Web Portal Usability Tests for the Nevada Climate Change Portal

Ivan Gibbs, Sergiu M. Dascalu, and Frederick C. Harris, Jr.
Department of Computer Science and Engineering
University of Nevada MS-171
Reno, Nevada 89557 USA
Email: igibbs, dascalus, fredh@cse.unr.edu

***Abstract*—Web technologies have proven to be very helpful to users and have proliferated. As web technologies evolve rapidly, the runtime environment for web user interfaces is constantly changing. Unique web portals have been created to deliver climate change related information and data. One of these portals, discussed in this paper, is called the Nevada Climate Change Portal. Currently, there are questions regarding how to develop this portal while it is still in its early stages of development. In an attempt to answer some of these questions, usability testing has been performed to assess the fitness of this web portal for its stated requirements. The usability tests are described herein, which employ the methods of accessibility testing and competitive testing.**

***Keywords*-accessibility, usability, website**

I. Introduction

This project is a compilation of usability tests for a web portal. Due to the current emphasis on climate change in the world today, many organizations have developed climate portals to provide climate related data to scientists and other interested parties. Some of these sites also have educational information related to raising the awareness of the general public about the implications of climate change on our environment. The University of Nevada, Reno (UNR) is developing the Nevada Climate Change Portal (NCCP), shown in Figure 1, to deliver data about Nevada's environment to users through a web based interface [1], [2]. A project of this size takes a lot of time and money to complete and in order to avoid the possible late-stage problems we are performing usability testing throughout the project. Usability tests provide us with feedback during the development of the web portal in order to help guide developers to create a more useful and more accessible end product.

This testing project's focus is on assisting the development of the NCCP to determine what directions to take with regards to the final version of the web portal. Since the web portal is actually in a prototype state at this moment, we did not have to design the entire system from scratch and there was available a sufficiently evolved artifact to actually test with. The goals [3] of this testing were to:

1) Increase the accessibility of the NCCP
2) Evaluate the NCCP with respect to other portals

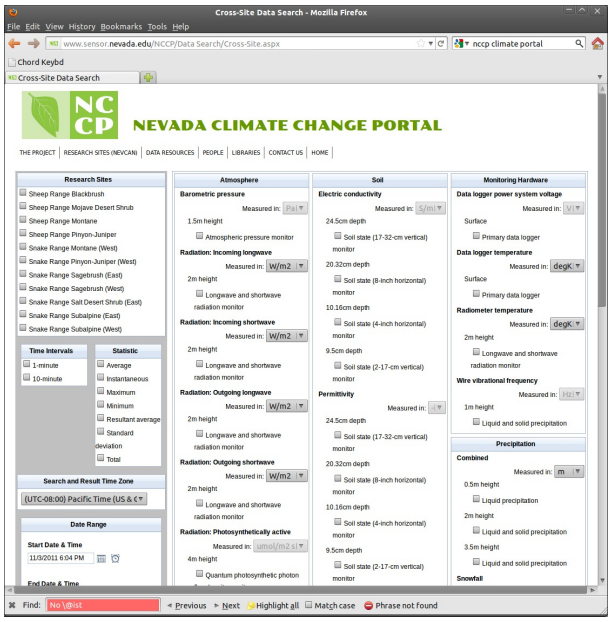

Figure 1. The data searching page of the NCCP

3) Enable the maintainability of the NCCP with regards to accessibility

Though the web portal is intended for a multitude of potential users, due to its current early state of development, the focus of this study was on scientific researcher usage of the portal. Climate change researchers should be able to run simulations with the climate data they choose. The key usability goals here are to ensure that these users can easily access the data they want, when they want it, and in a way that they desire it [4]. With regards to running simulations, the portal will provide the ability to create scientific workflows consisting of different climate models in order to run experiments on data [5]. A tool will be provided to allow the users to design such scientific modeling workflows and to run them. The usability goal is to verify that this is is done in a way that makes it easy for the users to access this feature. The main characteristics of the web portal are that it enables access to climate data, is web accessible, provides

web services, and provides a scientific workflow creation tool.

There are currently other climate related data portals on the World Wide Web (WWW) offering data and information. Though some are very extensive, they do not all have the same features. This study includes a comparison between the NCCP and other similar portals. It is hoped that some things done by other portals may be useful in the NCCP and that the benefits of the NCCP may become more apparent from such an analysis. We attempted to answer interesting questions in this analysis about ease of use, accessibility of sites, and features of sites.

This paper is structured as follows. Section 2 describes current standards regarding web user interfaces. Section 3 gives the details on the particular package of usability tests that were used. The results of the tests are presented in Section 4. Conclusions and future work are detailed in Section 5.

II. Standards

Two important areas of standardization are important for this testing. The WWW has particular technical standards to abide by; some of these are to support interoperability of web sites, others are to support disabled users, and still others deal with Human Computer Interaction (HCI) factors such as brightness contrast.

A. Web Standards

Accessibility has a wide range and there are few definite boundaries to necessarily focus on because most of them exist along a spectrum of steady diffusion between two criteria. In addition to a lack of definite boundaries, accessibility is fractured into different areas for any one criteria. For example, if we focus on color then we can talk about clarity, number of colors, color contrast, compatibility of color palettes, distinguishability, or even others. As this domain of accessibility is large and not easily defined, it makes pragmatic sense to find a standard in which someone else has already done the work of ferreting out what to measure regarding a web site and accessibility. Therefore, most of our tests have to do with the use of specific standards and testing conformation of the web page to that standard.

In this project, we concentrate on widely recognized standards that are assumed to be relatively free from conflicts of interest. The point of paying attention to conflicts of interest is to help support a single standard for the WWW, rather than disparate standards that may be proposed by some groups who might like to control some particular web technology. In doing this, we believed that the accessibility of the web portal has been evaluated in a way to support multiple computer platforms and future developments. As new web technologies arise, standards will likely also be made to accommodate those new technologies which can then be used as part of our accessibility testing. Therefore, hewing to standards allows us to focus on implementing tests and meeting the standard rather than spending a lot of extra time determining how to create our own standard for accessibility, or detrimentally relying upon our development tools to automatically incorporate relevant standards for us.

Although there are many standards organizations, this usability study has focused on standards that are promoted by the World Wide Web Consortium (W3C). The W3C offers accessibility guidelines in the form of the Web Content Accessibility Guidelines (WCAG), which are derived from Section 508 of the Rehabilitation Act of 1973; published by the United States Access Board (USAB).

III. The Test Package

The tests that we performed are separated into two categories, acceptance tests and competitive comparison. The acceptance tests are based on determining if the web portal conforms to some standard and the competitive comparison compares and contrasts the NCCP with other web portals of similar size and focus. The particular methods employed for testing are described next.

A. Acceptance Tests

The acceptance tests used here are generally evaluated using automatic tools. These tools provide an easy and reusable way to evaluate the web site at any stage of development. The metrics used in this study were the following:

1) Hardware and software accessibility overview
2) Compliance with W3C HyperText Markup Language (HTML) standards
3) Compliance with W3C Cascading Style Sheets (CCS) standards
4) Compliance with W3C standards for mobile web viewers
5) Disabled user accessibility overview
6) Compliance with W3C WCAG
7) Readability of the text

Hardware accessibility refers to the ability of different types of computers to actually access the site. Disabled user accessibility refers to the ability of the portal to deal with users of varying disabilities. The second and third metrics allow us to be reasonably confident that the web site is displayed correctly on different web browsers. If, for some reason, the site is found to not be viewable using some specific browser, we can be reasonably assured that that specific browser does not support the current W3C standards for HTML or CSS on the web. The fourth metric allows us to become more aware of how to design for the increasing numbers of mobile devices which can access WWW content. Therefore, the first four of our metrics specifically deal with the technical accessibility of a web site to be viewed via different technologies. The disabled user accessibility refers to the ability of the portal to deal with users of varying disabilities. The last three metrics focus on determining how

well the web site may be used by users who are disabled in some way.

1) HTML and CSS Compliance: In a world of organizations with possibly conflicting goals, standards emerge as a way to enforce fairness among different entities. One of the accessibility criteria is the conformance with one of the HTML [6] and CSS [7] standards for the web. These standards are formally defined by the W3C. For this study, we have used a publicly available tool provided by the W3C called the Unified Validator [8].

2) Mobile Web Compatibility: Technology changes rapidly with new solutions that are developed to solve problems or remove limitations of older technologies. In recent years, wireless communication has become widespread. When wireless capabilities are combined with the increasingly powerful and smaller computer chips, we emerge with smart phones, personal data assistants, and other mobile devices. This trend is likely to increase in the future and it behooves those who offer data over the web to think about how they might deliver content in the newer environments which involve smaller screens and more limited input abilities [9]. The W3C offers a standard tool called W3C mobileOK Checker [10] that can check a web page for conformance to their proposed standards for this new mobile paradigm of WWW viewing.

3) WCAG Compliance: The WCAG are not as easy to automatically verify compliance with. Specific guidelines [11] are designed to make a web page more accessible to people with disabilities. They do not address every single disability, but focus on a wide swathe through this area to improve the understanding of the needs for these types of users. To verify compliance, both human testing and automated tests are important. In this paper we focus on the automated tests for the WCAG. The tool we have used is called EvalAccess 2.0 [12] and is available from the Universidad del Pais Vasco.

4) Readability Evaluation: Another accessibility criterion used is related to the ability to read text on the web site. Though books are quite standard in that they present black text on a white background, the same format has not been a standard for web sites. Unfortunately many web sites use colors other than black and white, to give some artistic flair, which can make the text on a site difficult to read. The metric used for this [13] is listed by the W3C [14] and measures the color contrast between the background and the text to ensure that an adequate amount of color difference exists. A second metric used is the compilation of readability indexes [15]. Though these sites are targeted for a scientific user, the readability of the text can give insight as to how easy a site is to read for some segment of the population. Three indexes of readability are provided; the Gunning Fog Ease index, the Flesch Reading Ease index, and the Flesch-Kincaid Grade index.

B. Competitive Comparison

The web sites investigated were providers of climate data to users. Since there were many web sites, we specifically narrowed this study to a few of those sites (denoted Portal A to Portal E) that were regionally defined in a small locality as that of a state in the United States; in addition, Portal E's site was provided to get a more international scope. The specific sites studied for this testing are; Portal A, Portal B, Portal C, Portal D, Portal E, and the NCCP [2]. To preserve their anonymity, we have chosen to use generic names instead of their actual names.

Comparisons can be made using many different types of criteria. A general comparison is made for the stated usability metrics that were previously mentioned such as HTML standards and the others. In addition to these general usability metrics, we assessed some qualitative criteria related to the particular goals of a user. Most of the qualitative criteria measured relate to the portal's current goal of providing data to researchers. Besides comparing the usability metrics stated earlier, specific comparisons have addressed the following criteria:

1) Can data be downloaded?
2) Is the data provided in multiple formats?
3) Is the data searchable?

In addition, we incorporated a statistical comparison of the different web sites consisting of comparing items such as:

1) The number of web pages
   This provides us with a way to compare the amount of resources that have gone into a web site and therefore provide a basis for comparison between two sites.
2) The size of the site
   The size of the site gives us another measure regarding the number of resources that went into the development of the web site.
3) Data path lengths
   Data path lengths describe the number of clicks a user must make to get to a part of the web site that actually offers data. It is calculated using the home page of the site as a starting point.

It was hoped that, by gathering this information, some correlations between usability and these statistical metrics may become more salient and thus enable new directions in further studies. At the very least, we aimed at obtaining more information when considering differences among web sites.

C. Pilot User Tests

Actual users were tested in a pilot test. As always, we faced a challenge in determining the proper users to perform in such a study. The study has focused primarily on scientific researchers as the users. Various timing tests were conducted, including:

1) Access data for the average amount of rainfall, in inches, during 10-minute intervals for the Sheep Range Montane. The data needed is for the time span of 2010-08 to 2011-08.
2) Access data for the amount of solar radiation, in $W/(m^2)$, during the time span of 2010-01 to 2011-01.
3) Access data for the maximum soil temperature, in degrees Celsius, during 10-minute intervals from the Sheep Range Mojave Desert Shrub research site. The soil depth we are concerned with is at 9.05 centimeters. The data needed is for the time span of 2010-05 to 2011-05.

Users were observed in order to establish a good understanding of potential problems for task completion. Users were asked to fill out a questionnaire after they completed each task, identified as the After Scenario Questionnaire (ASQ)[16]. The questions for the ASQ were:

1) Overall, I am satisfied with the ease of completing tasks in this scenario.
2) Overall, I am satisfied with the amount of time it took to complete the tasks in this scenario.
3) Overall, I am satisfied with the support information (on-line help, messages, documentation) when completing the tasks.

The answers were given on a 7-point Likert scale from "strongly agree" to "strongly disagree." An option of "not applicable" was also given, and a last item specified for the users to add any additional comments which they may have.

After all of the tasks were completed, users filled out another questionnaire, called the System Usability Scale (SUS) [17]. The questions for this questionnaire, listed below, were on a 5 point Likert scale, from "strongly disagree" to "strongly agree."

1) I think that I would like to use this product frequently.
2) I found the product unnecessarily complex.
3) I thought the product was easy to use.
4) I think that I would need the support of a technical person to be able to use this product.
5) I found the various functions in the product were well integrated.
6) I thought there was too much inconsistency in this product.
7) I imagine that most people would learn to use this product very quickly.
8) I found the product very awkward to use.
9) I felt very confident using the product.
10) I needed to learn a lot of things before I could get going with this product.

One last part of the questionnaire asked the users to freely write additional comments if they like.

Subsequent to the SUS, users were interviewed by asking a series of abstract associations to determine a possible theme that may be implicit in the site design. This is denoted the Abstract Association Interview (AAI) and it is an experimental test designed by this paper's authors. The AAI consists of a series of questions as follows:

1) If this web site were a car, what kind of car would it be?
2) What is the sound of this web site?
3) What type of weather best describes this web site?
4) If this web site were a building, what kind of building would it be?
5) What type of person would this web site be?
6) If this web site were a feeling, what kind of feeling would it be?

The objective was to attempt to get an abstract description of the NCCP. It was hoped that there might be some type of similarity between the answers of all of the users that could give an indication of the type of mental environment that is created by this web site. The analogous situation in the real world would be the effect of a building's architecture on its inhabitants. Though large buildings were quite an engineering accomplishment, when they first began to be built there were some problems with the building's achievement of engineering efficiency but poor productivity of inhabitants. Another example is the typical appearance of a church, which is very well defined and conveys a specific feeling to its inhabitants. A set of abstract questions might give us more information related to an architectural feeling that might exist in web site design as well.

IV. Results

During the process of designing this usability test package, significant effort has been invested into creating actual tools for evaluating some of the metrics used. This section details metrics that have been collected to date.

A. Acceptance Test

1) Hardware and Software Accessibility: The information provided in Table I provides a classification of the NCCP and its current capabilities to be used on different computing platforms. The display designation for Small displays are those of resolutions 1024x768 pixels and smaller. For the Mobile display designation, the sizes are 480x800 pixels and smaller.

2) HTML and CSS Compliance: The results of tests done for HTML validation are shown in Table II. The overall validity for the HTML of a site is shown in a yes or no format where a site was judged to have passed if 75% of the pages for that site comply with W3C standards for HTML. Though there are different levels of compliance, here we assume that if no errors were detected by the validator [6], then the web page was compliant with the standard. The procedure used for CSS compliance [7] follows a similar pattern.

Table I
ACCESSIBILITY TABLE–TECHNOLOGY PERSPECTIVE

	Platform				Display Size		
Use Case	Mac OS X	Windows	BSD	Linux	Large	Small	Tiny (Mobile)
Get Data	X	X	X	X	X		
Upload Data	X	X	X	X	X		
Search Data	X	X	X	X	X		
Read Article	X	X	X	X	X		
Watch Video	X	X	X	X	X		
Make Simulation	X	X			X		
Run Simulation	X	X			X		
View Sim. Results	X	X			X		

Table II
VALIDATION METRICS

Site	HTML Valid?	Valid Pages	CSS Valid?	Error Count
Portal A	Y	83%	Y	0
Portal B	N	0%	Y	0
Portal C	N	0%	N	22
Portal D	N	0%	N	92
Portal E	N	0%	N	41
NCCP	Y	75%	N	1

3) Mobile Web Compatibility: The tests performed for Mobile Web access were achieved using another W3C validator [10]. The results obtained are shown in Table III.

Table III
MOBILE WEB METRICS

Site	Failures Critical	Failures Severe	Failures Medium	Failures Low
Portal A	0	3	4	3
Portal B	1	3	2	6
Portal C	3	5	2	4
Portal D	0	1	1	7
Portal E	3	3	0	4
NCCP	1	0	1	5

4) Disabled User Accessibility Overview: Table IV provides an overall view of the NCCP for users with different types of disabilities. We know that the portal is accessible to abled users because abled users have used the site. In contrast, we have not had any visually disabled or blind users test the site and have therefore relied on secondary methods such as validating the site against WCAG guidelines as well as using other validators. Though the site does not currently allow automated usage for computer scripts, that is planned for the future.

5) WCAG Compliance: Table V illustrates the results of the test against version 1.0 of the WCAG. In this table, Priority 1 refers to problems that make it impossible for some groups to access a website, Priority 2 indicates that one or more groups will find it difficult to access a web site, and Priority 3 indicates things that make it somewhat

Table IV
ACCESSIBILITY TABLE–USER PERSPECTIVE

	User			
Use Case	Abled	Visually Disabled	Blind	Computer Script
Get Data	X			
Upload Data	X			
Search Data	X			
Read Article	X			
Watch Video	X			
Make Simulation	X			
Run Simulation	X			
View Simulation Results	X			

difficult for some groups to access a web site. All the sites in our study have problems on various levels, but Portal B apparently is the only site with Priority 1 problems. The sites vary quite a bit on Priority 2 issues, but obviously all could be improved.

Table V
DISABILITY METRICS

Site	WCAG 1.0 Priority 1	Priority 2	Priority 3
Portal A	0	9	2
Portal B	3	16	2
Portal C	0	3	5
Portal D	0	2	1
Portal E	0	58	0
NCCP	0	34	1

6) Readability Evaluation: The results for the readability tests are shown in Table VI. The first uses guidelines for the color contrast between text and background. A low contrast can affect the users' ability to read the text easily, which may affect those with poor eyesight more than others. For this test, only Portal A and Portal E passed the test. Other sites had numerous problems. Both Portal B and Portal D had few problems, but problems were greater with Portal C and the NCCP.

Table VI
READABILITY METRICS

Site	CSS Color Contrast	Gunning Fog Ease	Flesch Reading Ease	Flesch-Kincaid Grade
Portal A	Y	10.44	39.5	8.54
Portal B	N	14.14	33.04	10.83
Portal C	N	7.77	45.12	7.35
Portal D	N	10.75	50.71	7.03
Portal E	Y	14.40	28.11	10.76
NCCP	N	13.23	36.43	9.36

Another important distinction of readability was in measuring with the Gunning Fog Ease index which indicates the

number of years of schooling needed to understand the text. Portal B required the most and Portal C the least and this comprises a range of about 6 years of schooling. In addition, the Flesch Reading Ease metric, which uses a 100 point rating scale, measures the understandability of text where a higher score indicates that something is easier to understand. On this metric, Portal B had the lowest score and Portal D the highest. Years after the Flesch Reading Ease metric was created, a new formula for this metric was proposed to give a grade-level score instead of a 100 point scale. This grade-level Flesch metric is called the Flesh-Kincaid Grade metric, of which Portal B scored the highest and Portal D the lowest.

B. Competitive Comparison

Qualitative comparisons were done by actually having someone investigate the site manually. The basic checks for this part of the study are presented in Table VII. Statistical comparisons were performed in order to obtain some information from the sites which are actually very difficult for a person to evaluate in a short amount of time. As shown in Table VIII, these statistics give answers to several important questions related to the purpose and capabilities of a particular site. For example, the "Data Path Length" metric gives an indication about how important the data provided is for a site. In addition, this metric could provide information on the ease of use for data collection.

Table VII
QUALITATIVE COMPARISONS

Site	Download Data?	Multiple Formats?	Data Search?
Portal A	Y	Y	Y
Portal B	Y	Y	Y
Portal C	Y	Y	Y
Portal D	Y	Y	N/A
Portal E	N	N/A	N/A
NCCP	Y	Y	Y

Table VIII
STATISTICAL COMPARISONS

Site	Size	Page Count	Data Path Length
Portal A	2.6 G	4137	2
Portal B	616 K	9	3
Portal C	21 G	1425	3
Portal D	2.5 M	17	1
Portal E	355 M	300	2
NCCP	17 M	18	3

C. Pilot User Tests

The user testing has resulted in some useful information about the performance of specific users on the site. The results of the user ASQ after performing tasks are shown in Table IX. We can see that the table displays a reasonably good outcome with respect to the users' satisfaction with the search page. For the overall evaluation of their interaction with the SUS, the results are presented in Table X. Considering the 5-point Likert scale, the cumulative mean of all the results indicates that the search page for the site is adequate for users. The AAI, shown in Table XI, did not yield very conclusive results, but it was noticed that there were differing opinions of the users depending upon their educational levels. It seemed that some of the questions resulted in almost opposite answer types when asked of these differing educational levels. No other conclusions could be drawn from these questions.

Table IX
ASQ RESULTS

	Mean	Std Dev	Min	Max
Q1	5.1	1.7	2	7
Q2	5.5	1.7	2	7
Q3	5.2	2.0	2	7

Table X
SUS RESULTS

	Mean	Std Dev	Min	Max
Q1	3	1.2	1	4
Q2	2.8	1.5	1	5
Q3	2.8	1.5	1	5
Q4	1.5	0.5	1	2
Q5	3.5	1.1	1	5
Q6	1.5	0.5	2	2
Q7	3.5	0.9	1	4
Q8	2.5	1.5	2	5
Q9	3.5	0.9	1	4
Q10	1.8	0.8	1	3

Table XI
AAI RESULTS

	Lower Education Level	Higher Education Level
Q1		low value
Q2		
Q3	sunny	rainy
Q4		
Q5	scientist	
Q6		

V. FUTURE WORK AND CONCLUSIONS

The results obtained present a perspective of how usable the current NCCP is. Using standards and guidelines allowed us to measure the accessibility of a site for different user populations and the automated tools provided an efficient way to perform those tests. Since releasing the results related to the use of automated tools for testing great improvements

to the NCCP have been achieved. Competitive comparisons helped to eliminate the omission of potentially beneficial ideas that others are using in this area. It emerged from our tests that the NCCP corresponds closely and favorably to other sites with a similar purpose. Testing with actual users attempted to get a first hand understanding of the users' perspectives regarding the web portal. Overall the results seem to be positive for the NCCP.

There are several areas in which the NCCP could be improved with usability testing. Increasing the maintainability of software can be aided through unit testing and compliance testing of newer versions. In the spirit of compliance testing, we plan to create a tool for developers to evaluate the accessibility of their current version of the NCCP. The ability to have an accessibility validation tool [18] will give earlier awareness of potential problems with the NCCP and thereby increase the developers' effectiveness at maintaining this crucial feature of a web site [19]. In addition to having automatic tests, the analysis regarding the competitive comparison could be expanded to provide more details and thus inform possible future development directions. Another improvement would be to work on optimizing the search feature of the portal and verify through user testing that this translates into increased user satisfaction.

ACKNOWLEDGMENT

We want to thank Michael McMahon, who was instrumental in providing feedback and details regarding web technologies and later modified the NCCP to comply closely with some of the standards discussed in this paper. We would also like to thank Eric Fritzinger who assisted with several technical aspects of this study.

This work was supported in part by an NSF EPSCoR Grant Nevada Infrastructure for Climate Change Science, Education, and Outreach, No. 0814372.

REFERENCES

[1] M. J. McMahon, S. M. Dascalu, J. Harris, C. Fredrick, S. Strachan, and F. Biondi, "Architecting Climate Change Data Infrastructure for Nevada," in *Advanced Information Systems Engineering Workshops CAISE-2011*. Notes in Business Information Processing. LNBIP-83, Jun 2011, pp. 354–365.

[2] R. University of Nevada, "Nevada Climate Change Portal," http://www.sensor.nevada.edu/NCCP/, April 2012.

[3] J. Rubin, *Handboook of Usability Testing*, 1st ed. New York, USA: John Wiley & Sons, Inc., 1994.

[4] M. J. McMahon, S. M. Dascalu, J. Harris, C. Fredrick, and S. Strachan, "S.E.N.S.O.R. - Applying Modern Software Data Management Practices to Climate Research," in *Proceedings of the 2011 Workshop on Sensor Network Applications*, November 2011.

[5] S. M. Dascalu, E. Fritzinger, S. Okamoto, and J. Harris, C. Fredrick, "Towards a Software Framework for Model Interoperability," in *Proceedings of IEEE 9th International Conference on Industrial Informatics (INDIN 2011)*. INDIN 2011, July 2011.

[6] W3C, "Markup Validation Service," Website, April 2012, http://validator.w3.org/.

[7] ——, "CSS Validation Service," Website, April 2012, http://jigsaw.w3.org/css-validator/.

[8] W. W. W. Consortioum, "Unicorn - W3C's Unified Validator," http://code.w3.org/unicorn, April 2012.

[9] A. Leventhal, "Structure Benefits All," in *Proceedings of The 2006 International Cross-Disciplinary Workshop on Web Accessibility (W4A): Building the Mobile Web: Rediscovering Accessibility?*, ser. W4A '06. New York, NY, USA: ACM, 2006, pp. 33–37. [Online]. Available: http://0-doi.acm.org.innopac.library.unr.edu/10.1145/1133219.1133226

[10] W3C, "mobileOK Checker," Website, April 2012, http://validator.w3.org/mobile/.

[11] ——, "Web Content Accessibility Guidelines Overview," Website, April 2012, http://www.w3.org/WAI/intro/wcag.

[12] U. del Pais Vasco, "EvalAccess 2.0," Website, April 2012, http://sipt07.si.ehu.es/evalaccess2/index.html.

[13] AccessKeys, "AccessColor," http://www.accesskeys.org/tools/color-contrast.html, April 2012.

[14] W. W. W. Consortioum, "Complete List of Web Accessibility Evaluation Tools," http://www.w3.org/WAI/RC/tools/complete, April 2012.

[15] J. Studio, "Readability Test," Website, April 2012, http://juicystudio.com/services/readability.php.

[16] J. R. Lewis, "Psychometric Evaluation of an After-Scenario Questionnaire for Computer Usability Studies: The ASQ," *SIGCHI Bull.*, vol. 23, pp. 78–81, January 1991. [Online]. Available: http://0-doi.acm.org.innopac.library.unr.edu/10.1145/122672.122692

[17] J. Brooke, *Usability Evaluation in Industry*. CRC Press, 1996.

[18] B. Leporini, F. Patern, and A. Scorcia, "Flexible Tool Support for Accessibility Evaluation," *Interacting with Computers*, vol. 18, no. 5, pp. 869 – 890, 2006. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0953543806000488

[19] C. C. Shelly and M. Barta, "Application of Traditional Software Testing Methodologies to Web Accessibility," in *Proceedings of the 2010 International Cross Disciplinary Conference on Web Accessibility (W4A)*, ser. W4A '10. New York, NY, USA: ACM, 2010, pp. 11:1–11:4. [Online]. Available: http://0-doi.acm.org.innopac.library.unr.edu/10.1145/1805986.1806002