MANCHESTER 1824
The University of Manchester

The University of Manchester Research

Exploring the Relationship between Web Accessibility and User Experience

DOI:
10.1016/j.ijhcs.2016.03.008

Document Version
Accepted author manuscript

Link to publication record in Manchester Research Explorer

Citation for published version (APA):
Aizpurua, A., Harper, S., & Vigo, M. (2016). Exploring the Relationship between Web Accessibility and User Experience. *International Journal of Human-Computer Studies*, *91*, 13-23. https://doi.org/10.1016/j.ijhcs.2016.03.008

Published in:
International Journal of Human-Computer Studies

Citing this paper
Please note that where the full-text provided on Manchester Research Explorer is the Author Accepted Manuscript or Proof version this may differ from the final Published version. If citing, it is advised that you check and use the publisher's definitive version.

General rights
Copyright and moral rights for the publications made accessible in the Research Explorer are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

Takedown policy
If you believe that this document breaches copyright please refer to the University of Manchester's Takedown Procedures [http://man.ac.uk/04Y6Bo] or contact openresearch@manchester.ac.uk providing relevant details, so we can investigate your claim.

OPEN ACCESS

Download date:15. Oct. 2026

Exploring the Relationship between Web Accessibility and User Experience

Amaia Aizpurua[a,b,*], Simon Harper[b], Markel Vigo[b]

[a] *Faculty of Informatics, University of the Basque Country, UPV/EHU, Donostia-San Sebastián, Spain*
[b] *School of Computer Science, University of Manchester, Manchester, United Kingdom*

Abstract

Understanding the interplay between the user experience (UX) and Web accessibility is key to design Web sites that, beyond access, could provide a better UX for people with disabilities. In this paper we examine the relationship between UX attributes and Web accessibility. We measured accessibility in two ways: the perceived accessibility as reported by participants and accessibility in terms of conformance to guidelines. Findings uncover that perceived Web accessibility is significantly correlated with 27 of the 35 UX attributes analysed, suggesting these two qualities are closely related. The relationship between UX and conformance to WCAG 2.0 is more elusive: we only found significant correlations between the hedonic attributes *original*, *innovative* and *exciting*.

Keywords: Blind users, Screen readers, Web, Web accessibility, User Experience

1. Introduction

The World Wide Web has an incredible potential to make our lives better due to the wide range of services offered through it. The Web can be specially helpful for people with disabilities, as barriers to communication and interaction that many people face in the physical world are removed. While the Web was

*Corresponding author
Email address: amaia.aizpurua@manchester.ac.uk (Amaia Aizpurua)

designed to be universally accessible, in practice this does not always happen (Lopes et al., 2010) mainly because Web sites are often designed without considering human diversity. This leads to poorly designed Web sites which can potentially exclude significant segments of the population. Since the Web is a mainly visual environment, navigating the Web is particularly challenging for blind users. Although assistive technology such as screen readers have been an incredible breakthrough, blind users still face a wide range of difficulties on the Web. In fact, blind users face not only more challenges than sighted users (Bigham et al., 2007), but are also disadvantaged when compared to other groups of users with disabilities (Petrie et al., 2004).

The World Wide Web Consortium (W3C) through the Web Accessibility Initiative (WAI) published the Web Content Accessibility Guidelines (WCAG) (Chisholm et al., 1999; Caldwell et al., 2008) to promote the design of accessible Web content. While guidelines are an invaluable starting point, prior empirical research (Power et al., 2012) indicates that WCAG 2.0 only cover around half of the problems that blind users encounter on the Web. This implies that a Web site may have an adequate level of accessibility in terms of conformance to guidelines, but still not be sufficient for users. Our experience, which is informed by a series of studies with blind participants, corroborates that a Web site with a significant number of WCAG 2.0 success criteria violations can be perceived to be accessible; on the contrary, a Web site which is compliant to guidelines may not be always perceived to be accessible (Aizpurua et al., 2013).

Research on the behavioural aspects of blind users on the Web has been mainly focused on the analysis of performance in terms of efficiency, errors committed and satisfaction (Leuthold et al., 2008), and on examining the strategies employed to overcome the barriers they encounter and the situations that trigger the use of coping tactics (Vigo & Harper, 2013). These works have provided a valuable knowledge about how blind users behave and navigate on the Web although they say little about the 'intangible' aspects of the experience. In other words, since behaviour is accompanied by subjective experience, in addition to assessing objective qualities such as performance-related aspects of the interac-

tion, the interaction with Web sites should be explored in a more holistic way. In this respect user experience (UX) provides a framework to understand how users may perceive an interactive artefact from diverse facets including aesthetics, affect or trust (Law et al., 2009). We claim that having a better understanding of blind users' subjective experience on the Web cannot be disassociated from an analysis of how this experience affects the perceived accessibility.

To shed some light on this association we examined the relationship between the UX and Web accessibility by comparing the subjective experience reported by users, with the perceived Web accessibility and with conformance to accessibility guidelines. User experience scores were collected by means of questionnaires and semi-structured interviews based on the UX model proposed by Hassenzahl (2005). In Section 4.1 we examined the relationship between UX and *perceived Web accessibility* after-use and found that perceived Web accessibility (PWA) is significantly correlated with most of the UX attributes, suggesting the close relationship between these qualities. Secondly, we investigated how UX attributes are related to different Web *Accessibility Indicators* (AIs), which were measured using different accessibility evaluation methods. The outcomes of this analysis reveal in Section 4.2 that compliance to WCAG 2.0 guidelines is significantly correlated to three UX attributes that belong to the hedonic quality: *original*, *innovative* and *exciting*. In Section 4.3 we analysed the interviews with participants in order to provide possible explanations for these relationships. Finally, results and implications are discussed in Section 5. This work is not only novel due to the number of covered UX attributes, but also because we study the experience of blind users with regard to a more holistic view of Web accessibility, as the subjective perception of participants and a more normative assessment of accessibility have been considered.

2. Background

2.1. The Importance of the Experience

Usability is a clearly defined concept: the ISO 9241-11 (ISO, 1998) defines usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". However, Web sites are much more than interactive artefacts for accomplishing specific tasks. Individuals find the Web as a mean, not only to achieve informational goals, but also for activities related to communication, leisure, social networking or contributing to building the Web (Lindley et al., 2012). Users value interactive artefacts on the basis of how well they satisfy their needs in a particular situation, beyond the objective features that derive from design choices including content, style or functionalities. Therefore, the success of a Web site may not only depend on its actual characteristics, but also on how well these are perceived by users (Hassenzahl, 2005). This highlights the importance of considering the subjective aspects of the interaction in order to understand the actual experience of users. Because the HCI community has acknowledged the importance of these non-instrumental aspects, several works have focused on defining and setting the scope of UX: according to a survey, UX is considered dynamic, context-dependent and subjective and therefore, difficult to agree upon (Law et al., 2009). Similarly, Bargas-Avila & Hornbæk (2011) found a lack of consistency in the methods employed to evaluate different UX attributes. This is a symptom of not having a common framework that allows researchers and practitioners to understand the UX attributes and the relationships among them. So far, only a few models have been proposed, for instance, the most comprehensive ones are the UX model (Hassenzahl, 2005) and the CUE model (Thüring & Mahlke, 2007). Both models share the same foundations, as both include instrumental and non-instrumental qualities, the emotional reactions of users and their appraisal of interactive artefacts.

2.2. Web Accessibility, Usability and UX

There is little agreement when it comes to defining web accessibility, which causes some tensions between the community of users, researchers and accessibility advocates (Yesilada et al., 2012). Moreover, while it cannot be denied that accessibility and usability are two qualities that interact with each other it has always been difficult to define the scope and extent of this relationship. In fact, if accessibility and usability are not properly integrated, Web sites can turn out to be either accessible but barely usable, or usable but barely accessible (Leporini & Paternò, 2008). In a study run by Petrie & Kheir (2007) it was found that sighted and blind users have in common 14% of the problems they encounter, suggesting this figure as the overlap between accessibility and usability.

There are few reliable research works about the relationship of UX and Web accessibility. One exception is a study about the relationship between aesthetic features and accessibility (Mbipom & Harper, 2011). The authors found that there was a relationship between the *visually clean* dimension of aesthetics and conformance to Web accessibility. It must be noted that even if Web accessibility evaluations were carried out following the barrier walkthrough method (Brajnik, 2006), the aesthetic judgements were made by sighted users. This suggests we require a more comprehensive understanding of the relationship between Web accessibility and UX as experienced and reported by blind users. In addition, the experiential and subjective aspects of Web accessibility remain largely unexplored. In previous work (Aizpurua et al., 2015) it was uncovered that experiential aspects such as prejudices, evoked memories, expectations can influence on how blind users experience the accessibility of a Web site.

2.3. The Experience of Blind Users on the Web

In order to understand the experience of blind users on the Web, previous work has focused on identifying the problems they encounter (Theofanos & Redish, 2003; Murphy et al., 2008; Power et al., 2012), analysing their performance (Leuthold et al., 2008), examining their navigation behaviour and the coping

strategies they use (Vigo & Harper, 2013). Works about the subjective aspects of the interaction of blind users with the Web are scarce: Lazar et al. (2006) conducted a study that examined the frustrating experiences and mood changes of 100 participants with visual disabilities when browsing the Web. One of the main findings showed that frustration causes individuals' mood to deteriorate. More specifically, the factors that had the strongest negative impact on mood were those related to the ability to complete the work.

3. Method

3.1. Participants

Eleven participants (4 females and 7 males) took part in the study, as shown in Table 1. The median age of participants was 43 years, with a range of 21–64 years. Expertise varied among participants: 2 were experts, 2 beginners, 4 intermediates and 3 advanced. In an interview which took place before the navigation tasks we asked participants to rate their expertise on the Web on a four-item scale: expert, advanced, intermediate and beginner. Due to the observed lack of reliability of self-reported values, Web expertise was also assessed based on external observation of the navigation skills shown by participants. The first author looked at the strategies employed and the confidence of participants when carrying out the proposed tasks. These assessments were corroborated by the facilitator in charge of the computer training facility at the National Organisation of Spanish Blind People (ONCE), who had trained the participants. In line with the findings of van der Geest et al. (2014), who found that self-rated competence of visually impaired users is not always related to their actual performance, Table 1 shows that self-rated and observed skills do not necessarily match.

3.2. Apparatus

All participants were legally blind and utilised screen readers to navigate on the Web: ten participants were Jaws users (version 10, except for P01 and P03

Table 1: Demographic data and characterisation of Web expertise

part. id	gender	age	Web familiarity	frequency of Web use	expertise	
					self-reported	observed
P01	f	29	>7 years	daily	advanced	expert
P02	f	29	>7 years	daily	advanced	expert
P03	m	39	>7 years	daily	advanced	advanced
P04	m	54	4–6 years	daily	intermediate	intermediate
P05	m	43	1–3 years	weekly	beginner	intermediate
P06	m	21	1–3 years	weekly	beginner	beginner
P07	m	64	>7 years	daily	intermediate	advanced
P08	m	58	>7 years	daily	intermediate	intermediate
P09	f	54	4–6 years	daily	intermediate	advanced
P10	m	64	4–6 years	daily	beginner	intermediate
P11	f	42	>7 years	weekly	intermediate	beginner

who used version 12) on Internet Explorer and Windows XP and Windows 7 respectively, while just one participant (P02) was a VoiceOver user on Safari over MacOS. The first three participants were observed in the research facility of the HCI laboratory at the School of Computer Science of the University of the Basque Country, where they brought their own laptop. Remaining sessions took place in a room at the ONCE delegation in Donostia-San Sebastián, where these eight participants used the same laptop and keyboard, which were provided by the ONCE.

3.3. Stimuli Selection

We recruited local participants and selected Web sites of restaurants that were popular in the area where participants lived in order to let the subjective dimensions emerge. We focused on one type of Web site for two main reasons: 1) to establish analogous tasks across different stimuli; and 2) to minimise potential confounding factors resulting from different types of Web sites.

In order to select the final set of Web sites we first listed 25 Web sites of local restaurants of different styles. We then analysed their homepages, using four automated Web accessibility evaluation tools: AChecker (Gay & Li, 2010),

EvalAccess (Abascal et al., 2004), TAW [1] and WAVE[2]. Using the WAQM metric (Vigo et al., 2007) we evaluated again the homepage and two more Web pages. Based on the results we classified the Web sites into 2 groups: highly accessible and poorly accessible sites. Within each group we separated Web sites into two other groups considering the style of the restaurant: traditional and innovative. Then we performed manual accessibility evaluations: we applied the Barrier Walkthrough (BW) inspection method (Brajnik, 2006) in three Web pages of each Web site. Based on the results, we finally selected the two most and least accessible Web sites for each type of restaurant.

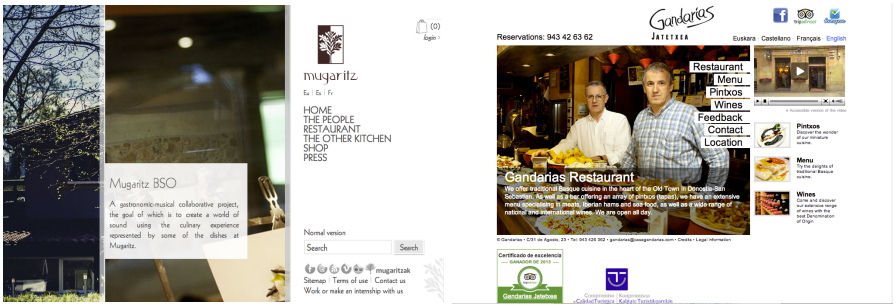
We evaluated the final four Web sites against the AA conformance level of WCAG 2.0[3]. The selected Web sites contained different features and problems: in general, W1 and W2 satisfied more AA level success criteria (SC) than W3 and W4. The homepages of W1, W2, W3 and W4 satisfied respectively 73%, 69%, 52% and 36% of the SC for the AA level of WCAG 2.0. The most severe accessibility problem of W3 was that the seven links that conform the navigation menu, all of them have the same text which is 'image'. In the case of W4, the main accessibility problem is about Flash content which is not accessible using a screen reader.

Regarding the above-mentioned selection criteria with respect to branding, W1 and W3 represent internationally well-known restaurants with an innovative character and a culinary style based on research and creativity. In contrast, W2 and W4 Web sites correspond to restaurants that are locally popular and their style is based on traditional Basque cuisine. The visual design of the Web sites is in line with the style of the restaurant. The Web sites of the internationally well-known restaurants (W1 and W3) have more stylised visual layouts, as they have had their typographies designed and make use of high-quality close-up pictures. In contrast, the Web sites of the traditional-style restaurants (W2

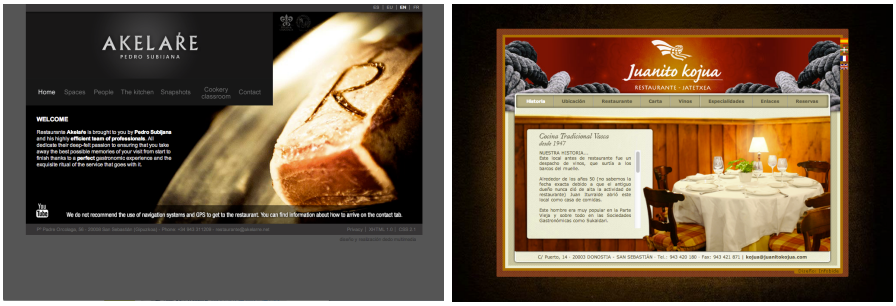
[1] `http://www.tawdis.net`

[2] `http://wave.webaim.org/`

[3] Both VoiceOver and Jaws screen readers were used on BW and WCAG 2.0 evaluation.



(a) W1: high accessibility and innovative (b) W2: high accessibility and traditional



(c) W3: low accessibility and innovative (d) W4: low accessibility and traditional

Figure 1: Screenshots of Web sites.

and W4) have a more basic and less elaborated visual aesthetic designs (see a snapshot of their homepages in Figure 1).

3.4. Procedure

Each session was conducted with one participant at a time. Once the participants were informed about the objectives of the study and the procedure of the session they signed a consent form. In order to reduce bias in the obtained answers we told participants that we had no conflict of interests with the Web sites, and that we had only selected those Web sites for the purpose of the study. We let the participants know that we were interested in their personal opinions in order to let them play the role of testers rather than tested subjects. We also made it clear that there were no right or wrong answers. Thus, they would feel free to respond as honestly as possible.

Then, we asked each participant questions about demographics, and their Web expertise, including their familiarity with the Web and the frequency of access to the Web. After that, each participant was interviewed about his previous experiences and expectations regarding restaurant Web sites. Once the interview had finished, the participant could start to navigate the first Web site. Following a within-subject design, each participant was asked to complete the same three consecutive tasks within each Web site (more in Section 3.5). Repeating tasks on all Web sites did not introduced a potential learning effect bias as each Web site structured its content in a different manner. In order to minimise order effects, Web site navigation order was counterbalanced. Once they finished the tasks or withdrew from them, participants were asked to rate the items of the questionnaires (more in Section 3.6). Then they were interviewed about their browsing experience. Each session, including the navigation on Web sites and interviews, was video and audio recorded to enable subsequent analysis.

3.5. Tasks

The three tasks were: 1) freely navigate on the Web site in order to become familiar with it; 2) find information about the gastronomic offer; and 3) find the means offered by the Web site to make a booking. The idea was to let the users explore the Web site through real tasks, which would induce a more naturalistic behaviour. Even if tasks were set in advance, they were not very specific and were kept open, as participants were not given explicit clues or directions to follow in order to find the information. This allowed the participants to explore and browse each Web site with ample opportunities. Participants were told that the time estimated for each task was between 5-10 minutes. However we insisted on their freedom to spend more time or withdraw from navigating if they wanted. For this reason completion times were irrelevant and not useful for the scope of our study.

3.6. Data Collection

We used existing instruments to capture the UX of participants in order to focus on their perception of the Web sites and the emotional reactions they had. The instruments we selected after reviewing the literature were: Attracdiff 2 (Hassenzahl, 2008) and the emotion word prompt list (EWPL) by Petrie & Precious (2010) both in Table 2. Attracdiff 2 was used for collecting the insights from participants about the Web sites. This questionnaire consists of a set of 23 word pairs reflecting opposite adjectives that can be rated on a 7-point scale to assess perceptions of users about an interactive artefact on pragmatic quality (PQ) and hedonic quality (HQ) attributes also including judgements on beauty and goodness. PQ refers to the usability of the artefact, and focuses on task-related aspects. In contrast, HQ refers to more subjective quality attributes in terms of stimulation, identity communication (identification) and valued memories. The emotions that emerged during the interaction with the Web sites were obtained by means of the emotion word prompt list (EWPL). The EWPL consists of 11 emotional words: *annoyed*, *bored*, *confident*, *confused*, *disappointed*, *frustrated*, *happy*, *interested*, *hopeful*, *pleased* and *unsure* that can be rated through 7-point Likert items where 1 means low intensity and 7 high intensity. We translated both questionnaires into Spanish.

Information about the Web accessibility perceptions of participants was obtained by asking participants to rate the accessibility of each Web site in a 7-point Likert-type question, from 1 (very inaccessible) to 7 (very accessible). We also used semi-structured interviews to gather deeper insights on the aspects collected by the questionnaires. Some of the prompts we gave them aimed at knowing more about the moment and the reasons for their emotional reactions, the problems they encountered while navigating, the positive and negative aspects of the Web sites, etc.

The accessibility indicators (AIs) were obtained applying the different evaluation methods described in Section 3.3. As a result, we computed 37 accessibility indicators that derived from four main sources: the TAW online automated

evaluation tool[4] (*tool*), the metrics from the WAQM software (m) and those obtained through inspection methods: conformance to WCAG 2.0 (sc) and the Barrier Walkthrough method (bw). These four main AIs were broken down into more specific indicators resulting in a list of 37 AIs: the automatically detected problems (e), warnings that require manual verification (w); the four accessibility principles of the WCAG 2.0 guidelines: perceivable (p), operable (o), understandable (u) and robust (r); the conformance level (a, aa) and the number of satisfied (sat) and not-satisfied ($nsat$) success criteria (sc). For instance, m represents the average accessibility score computed by WAQM, $tool_w_p$ refers to the number of warnings reported by the tool for the p principle, $tool_e_u$ corresponds to the number of errors reported by the tool for the u principle, sc_sat_a represents the number of satisfied sc for the A conformance level, $sc_nsat_aa_p$ indicates the number of not satisfied sc for the AA conformance level for the p principle, and bw corresponds to the number of barriers found using the Barrier Walkthrough method.

3.7. Data Analysis

We run analyses of statistical correlation to observe the relationships between: 1) UX attributes and perceived Web accessibility (PWA) as reported by participants; and 2) UX attributes and accessibility indicators (AIs) as generated by tools and inspections by experts. The statistical software used was R[5]. We also analysed data from the interviews in order to better understand the importance of the identified relationships and the reasons why they emerged.

[4] We chose the TAW online tool because it provides a straightforward way to discriminate automatically reported violations and warnings that require human verification.

[5] http://www.r-project.org/

4. Results

4.1. UX and Perceived Web Accessibility

Table 2 shows that most correlations between PWA and UX attributes (27 out of 35) are statistically significant when we compute Kendall's Tau test[6]. We found strong significant ($\tau > 0.5$ and $p < 0.001$) correlations between PWA and six attributes of the hedonic quality-identification (integrating, professional, valuable, inclusive, brings me closer to people, presentable), one attribute of the hedonic quality-stimulation (creative), five attributes of the pragmatic quality (simple, practical, direct, clear, manageable), goodness, appeal, annoyed, disappointed, frustrated, happy, interested and pleased. We also found significant and moderate correlations ($0.4 \geqslant \tau \geqslant 0.5$ and $p < 0.001$) between PWA and one attribute of hedonic quality-identification (classy), three attributes of hedonic quality-stimulation (original, exciting, new), beauty, bored and confused.

4.2. UX and Accessibility Indicators

We examined the relationship between the UX attributes rated by participants and the accessibility indicators corresponding to Web sites. Since Likert scales can actually be considered somewhere between an ordinal and a true interval scale (Maxwell, 2006), it has been a subject of debate for years how these scales should be appropriately analysed (Carifio & Perla, 2007; Norman, 2010). Due to the exploratory nature of our research, we decided to apply both parametric and non-parametric tests including Pearson, Spearman and Kendall correlation tests. If we focus on large effect sizes (above 0.5) the Pearson and Spearman test yielded some significant correlations, while the Kendall test did not. Table 3 shows that, predominantly, *conservative–innovative* (HQS_4) and *lame–exciting* (HQS_5) attributes are the ones with more strong and significant correlations. We observe that these correlations correspond to those criteria in which conformance to WCAG 2.0 guidelines was evaluated by human testers,

[6]Kendall's Tau is preferred to Spearman test because it performs better with small sample sizes (Clark-Carter, 2004).

Table 2: Correlations between PWA and UX attributes for the Kendall test [N=44, 11 participants x 4 Web sites]. Significance of tests are reported at $p < 0.05$ (*), $p < 0.005$ (**), $p < 0.001$ (***).

UX attributes	Kendall's Tau (τ)
Attracdiff – Hedonic quality-identification	
HQI_1 isolating–integrating	0.63***
HQI_2 amateurish–professional	0.64***
HQI_3 gaudy–classy	0.44***
HQI_4 cheap–valuable	0.62***
HQI_5 noninclusive–inclusive	0.68***
HQI_6 takes me distant from people–brings me closer to people	0.66***
HQI_7 unpresentable–presentable	0.67***
Attracdiff – Hedonic quality-stimulation	
HQS_1 typical–original	0.43***
HQS_2 standard–creative	0.55***
HQS_3 cautious–corageous	0.18
HQS_4 conservative–innovative	0.29*
HQS_5 lame–exciting	0.47***
HQS_6 easy–challenging	-0.19
HQS_7 commonplace–new	0.45***
Attracdiff – Pragmatic Quality	
PQ_1 technical–human	0.37**
PQ_2 complicated–simple	0.52***
PQ_3 impractical–practical	0.64***
PQ_4 cumbersome–direct	0.53***
PQ_5 unpredictable–predictable	0.39**
PQ_6 confusing–clear	0.55***
PQ_7 unruly–manageable	0.60***
Attracdiff – Evaluational Constructs	
beauty	0.48***
goodness	0.68***
appeal	0.61***
EWPL	
annoyed	-0.56***
bored	-0.46***
confident	0.10
confused	-0.47***
disappointed	-0.58***
frustrated	-0.58***
happy	0.59***
interested	0.54***
hopeful	0.41**
pleased	0.54***
unsure	-0.26*

and specially the ones related to the number of satisfied and non-satisfied success criteria for the Perceivable principle.

Table 3: Correlations between Accessibility Indicators and UX attributes for the Pearson test [N=88, 11 participants x 4 Web sites x 2 Web pages)] for p <0.001. Values between brackets correspond to the Kendall test.

	HQI_1	HQS_4	HQS_5	PQ_2	PQ_7
	isolating	conservative	lame	complicated	unruly
AI	integrating	innovative	exciting	simple	manageable
m_u			0.54		
tool_w_u	-0.50			-0.50	-0.50
sc_sat_aa		0.52 (0.54)			
sc_sat_aa_p		0.50			
sc_sat_aa_o		0.50			
sc_sat_aa_u		(0.50)			
sc_sat_a_p			0.51 (0.53)		
sc_sat_a_u		(0.50)			
sc_nsat_aa		-0.50 (-0.51)			
sc_nsat_aa_p		-0.52 (-0.52)			
sc_nsat_aa_o		-0.50			
sc_nsat_a_p		-0.52 (-0.53)	-0.51 (-0.52)		

Figures 2, 3 and 4 show the correlation matrices corresponding to the coefficients obtained from Pearson, Spearman and Kendall tests respectively, providing a general overview of all the correlations in addition to those with large effect sizes in Table 3. Matrices show that the more and stronger correlations are between *typical–original* (HQS_1), *conservative–innovative* (HQS_4) and *lame–exciting* (HQS_5) attributes and those AIs generated through the expert evaluation of Web site compliance to WCAG 2.0, particularly again to those success criteria belonging to the Perceivable principle.

In order to check the consistency and robustness of the results we performed Pearson's correlation test using sampling with replacement. We applied the bootstrapping technique for different numbers of bootstrap replicates (R=100, 500, 1000, 1500, 5000, 10000) for the same confidence level (0.95). We obtained

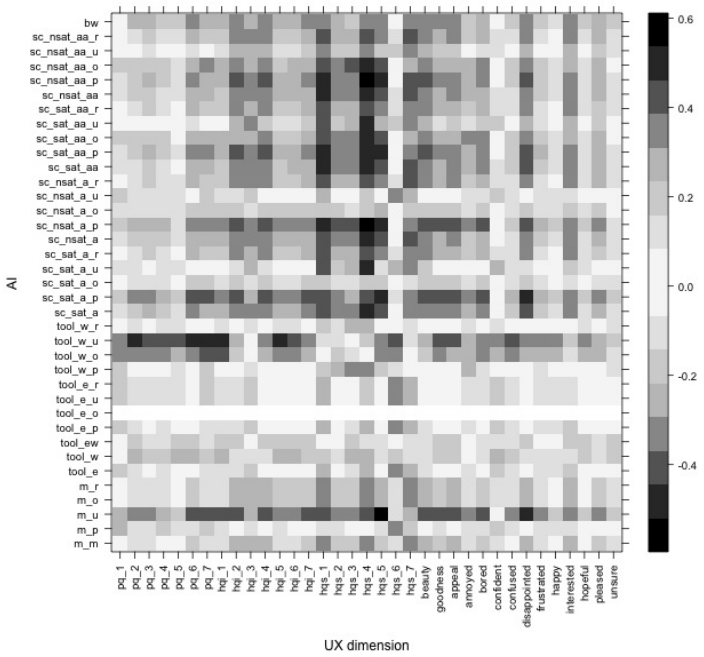


Figure 2: Correlation matrix for the AIs and UX attributes, using the Pearson test [N=88, 11 participants x 4 Web sites x 2 Web pages, $p < 0.001$].

the bias (the difference between the mean of the R bootstrap samples and the original estimate), the standard error (the standard deviation of the R bootstrap samples) and the confidence intervals for R samples. We did not observe big differences on the confidence intervals depending on the size of R. On the other hand the bias and the standard error are very low, which suggests the similarity with the original estimate. For instance, if we take the bootstrap results for the correlation between the HQS_5 attribute and the sc_sat_aa AI, the obtained minimum and maximum values for the bias and the standard error were [-0.0094, 0.001], [0.066, 0.071] respectively. We also applied the bootstrapping technique by relaxing the confidence level (0.90, 0.92). In this case the confidence intervals kept stable even when increasing alpha. As the bias and the standard error obtained as a result of applying the bootstrapping technique is very low, none of the confidence intervals include the zero value and the range of the intervals

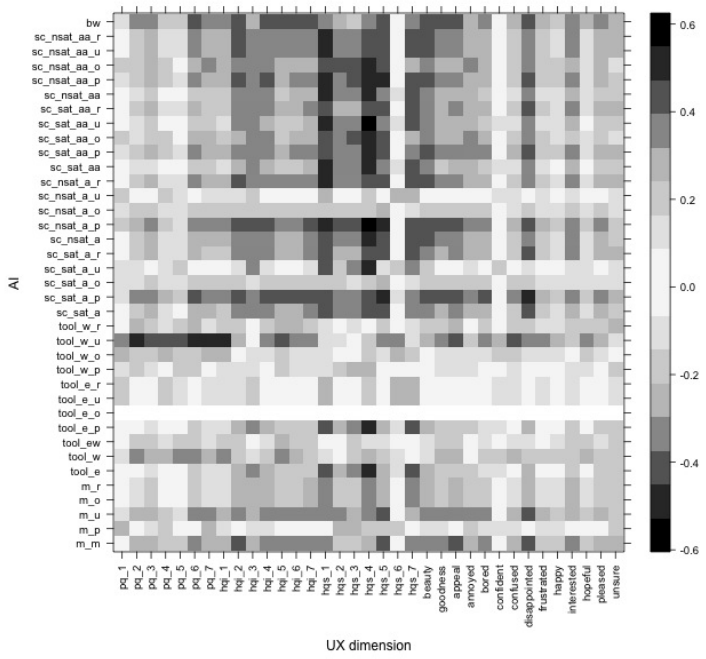


Figure 3: Correlation matrix for the AIs and UX attributes, using the Spearman test [N=88, 11 participants x 4 Web sites x 2 Web pages, $p < 0.001$].

is not very wide we conclude that the correlations are robust.

4.3. Analysis of the Interviews

We looked into the transcriptions of the interviews in order to better understand the practical importance of the identified correlations and the reasons why they emerged. For this analysis we only focused on those three UX attributes *typical-original* (HQS_1), *conservative-innovative* (HQS_4) and *lame-exciting* (HQS_5), which showed stronger and more consistent correlations across the three statistical tests we performed.

We queried the transcripts using the synonyms and antonyms of the word-pairs of the identified UX attributes. Then we annotated and coded the excerpts

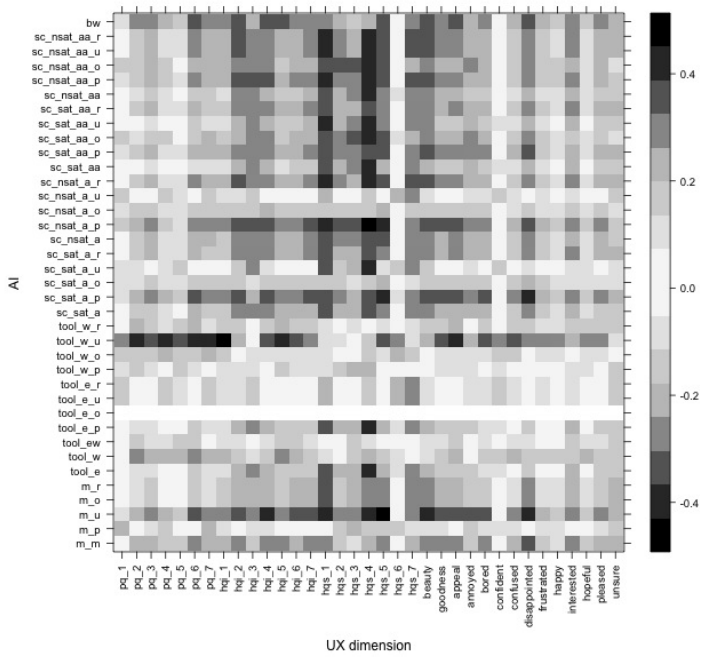


Figure 4: Correlation matrix for the AIs and UX attributes, using the Kendall test [N=88, 11 participants x 4 Web sites x 2 Web pages, $p < 0.001$].

we retrieved. We used the Merriam-Webster online dictionary[7], the Collins online dictionary[8] and the qualitative data analysis software NVivo 10 for this analysis.

4.3.1. Hedonic Quality-Stimulation: Typical–Original (HQS_1)

Typical can be defined as being or serving as a representative example of a particular type, characteristic, having the qualities associated with the members of a particular group or kind. We looked up synonyms (such as archetypal, standard, model, normal, classic) and opposites (including unique, unusual, unexpected, exceptional) in the transcripts. The majority of comments were observations about situations that occur regularly such as coming across non-

[7]http://www.merriam-webster.com/thesaurus/

[8]http://www.collinsdictionary.com/dictionary/english-thesaurus

accessible Web sites. Two expert users (P01, P02) said that finding accessible sites is still uncommon, particularly when it comes to restaurant Web sites: "*Restaurant Web sites are those that I find especially non-accessible (P01)*". P05 said that he would not spend much time on W3 if he was not participating in the study: "*This is the typical page I say – out! [snap of fingers]*".

If a Web site provides an accessible version, the link pointing to it, is often located at the bottom of the Web page and thus, not easily reachable: "*Normally the buttons for the accessible version are at the bottom (. . .) normally I cannot get to the accessible version (. . .) it always happens (P02)*". Since not all Web sites have an alternative version, it is not very usual to find one: "*It's assumed that the most suitable for us is the accessible one, because the 'normal' one is the one that everyone uses (P07)*".

Original is related to something unusual, novel, not known or experienced before. We looked up synonyms (new, novel, different, unusual, unknown) and opposites (old, standard, traditional, normal, usual, ordinary). Most excerpts about originality and accessibility have to do with content (i.e. textual information) and a few refer to the layout of the Web site (i.e. how the information is arranged). Regarding textual content the uncommon name of the dishes on W1 drew the attention of participants. Unlike ordinary restaurants, this one organises cultural events like live music or plays to enhance the gastronomic experience: "*I found the Web site funny and very interesting. It called my attention that the guy is in the artistic wave. The mix with culture, theatre, music (. . .) (P05)*".

Regarding unconventional layouts, the gastronomic information on W2 was conveyed through links in a hierarchical multi-level layout, instead of providing the information on the same page, which was not expected by P09: "*The menu, I was expecting a document, right? and then of course, it was not a menu as such, it was like a bunch of links"*. P02 said that it was unusual to find the link to the accessible version of the Web site quite at the beginning of the Web page on W1: "*No, it's not usually the case (. . .) it's quite at the top*". The fact that the content was placed before the navigation menu on W1 attracted P03

participant's attention.

Apart from the aspects related to Web content and layout, some participants valued the novel experience of visiting a restaurant Web site for the first time: "*First time I visit a restaurant Web site, I didn't know what it could contain and I really liked it because it was non-accessible but if you try, you get to know new things (P06-W1)*". Many participants praised and linked originality and the accessibility of W1 and W2 Web sites although this was not always the case: "*It's not original, it gets to the point and is very professional, it is not arty (. . .) the page lacks an artistic touch (P05-W2)*". This suggests that not only the accessibility of a Web site, but the quality of the textual content provided on the Web site influences the perception of originality: "*The text meets the objective of informing, and the more interesting the better, we ignore all the visual part of about the venue and the dishes so textual explanations are interesting for us (P10)*".

4.3.2. Hedonic Quality-Stimulation: Conservative–Innovative (HQS_4)

This attribute is closely related to the previous one (*typical-original*, HQS_1) as many comments coded as *original* were also coded into the *innovative* category. Nevertheless, there is a subtle but important difference about the meaning: unlike HQS_1, HQS_4 deals more with conservatism and innovation, which are somehow related to progress and evolution.

Conservative represents a tendency to favour the preservation of established ideas, conditions, values or institutions, opposing innovation. Some synonyms are traditional, conventional, moderate, cautious and reactionary. While liberal, radical, progressive, innovative, and imaginative are some examples of opposites.

We found few examples of comments which relate both *conservative* and inaccessibility: "*The feeling is that the page hasn't served me for anything (. . .) in addition to annoying me I feeling the site is totally conservative, it has no innovation, it is not accessible at all (P04-W3)*". P05 goes further and suggests that the lack of accessibility is an indicator of non-evolved society or country: "*I think they haven't thought much about people who are not able to see, right?*

Regarding accessibility, nowadays it should already be there (. . .) I'm sure that in the Netherlands these non-accessible Web sites aren't developed any more . . . (P05-W3)".

Innovative relates to showing a noteworthy use of the imagination and creativity especially in creating new things and inventing. Synonyms include novel, new, original, different, fresh, unusual and unfamiliar. Most comments who link innovation and accessibility refer to the W1 Web site: "*Seeing a different design has aroused my curiosity (. . .) what I have liked most is its innovative character. . . (P10-W1)*".

4.3.3. Hedonic Quality-Stimulation: Lame–Exciting (HQS_5)

Lame means falling short of a standard, painful or weak, unconvincing, not effective or enthusiastic, conventional or uninspiring. Synonyms include defective, unconvincing, poor, inadequate, weak, insufficient and unsatisfactory. Most comments were about the W3 Web site, where we found at least one comment for each participant about W3: "*It is not easy to handle. The information is quite hard to find with a screen reader, unspecific (. . .) It's too much effort, you waste a lot of time, the information you get is not very reliable. The messy links were not very clarifying, they do not give an idea of the content in each link (. . .) it was like a labyrinth, too complicated (. . .) to get something specific you would have to invest much time, effort and I'm not sure if one would get to anything concrete (. . .) it forces you to have to do all the tour of the entire page. It's like to get a room in a hotel you would have to go through the 360 rooms it has (. . .) is the most difficult one of the four Web sites, for a screen reader user is unsatisfactory (P07)*".

We only found comments from one participant who would stress the lameness of W4: "*Disappointed, confused in many moments, completely bored and very annoyed (P02)*". We also found a few comments about the most accessible Web sites, W1 and W2: "*It's not a very clear content as to the presented links. It's promising, it seems it will provide information, but the information that exposes is very literary. Very literary and very repetitive for a screen reader (P07-W1)*".

Exciting is related to causing great emotional or mental stimulation. Synonyms for exciting would be stimulating, inspiring, thrilling or sensational while opposites include boring, dull, dreary, monotonous, uninspiring. Most comments are about the accessible Web sites, W1 and W2: "*I found the Web page attractive (...) a desirable place to go (...) a Web site with very specific and clear information, and very attractive content (P03-W2)*". Some participants suggested the possibility to revisit the Web site and other even showed their willingness to go to the restaurant: "*I'll check it at home, maybe I'll write them an email telling them that the Web site is perfect (P06-W2)*".

5. Discussion

5.1. On the Relationship between UX Attributes and Perceived Web Accessibility

Results suggest that perceived Web accessibility is associated to most UX attributes. The strong and moderate significant statistical correlations found between PWA and the attributes belonging to the hedonic quality-identification (i.e. inclusive, presentable, brings me closer to people, professional, integrating, valuable and classy) indicate that participants may feel closer or more identified with Web sites they experience to be accessible. And the other way around: they may feel more distant from Web sites perceived as non-accessible, as if these Web sites were foreign artefacts that are not designed for them.

We found a relationship between PWA and pragmatic quality, which represents the usability perceived by participants. A Web site that participants considered accessible is related to aspects such as practical, manageable, direct, clear and simple and predictable; whereas a non-accessible perception of a Web site is related to aspects like impractical, unruly, cumbersome, confusing complicated and unpredictable. Results for the relationship between PWA and the hedonic quality-stimulation attribute indicate that Web sites experienced as accessible are related to perceptions such as creative, original, exciting and new. In contrast, Web sites considered to be non-accessible are related to perceptions like standard, typical, lame and commonplace. Findings also support that a

positive accessibility perception is related to appraisals of goodness, appeal and beauty. This suggests that a Web site which is experienced to be accessible is perceived as good, appealing and beautiful, while a non-accessible Web site is considered as bad, repelling and ugly. In summary, participants perceived positive qualities on Web sites experienced as accessible, and the opposite effect happened, in Web sites perceived as non-accessible negative qualities were predominant.

We also found strong and moderate correlations of PWA with emotion-bearing words. PWA is positively related to emotional words with positive valence (i.e. happy, pleased, interested and hopeful) and negatively related to emotional words with negative valence (i.e. disappointed, frustrated, annoyed, confused and bored). Accessible Web sites are related to positive emotional reactions, while non-accessible ones are correlated to the negative ones. This indicates that participants may feel better on a Web site they experience as accessible than when navigating on a Web site perceived as non-accessible.

These results show that the experienced accessibility of participants is not only associated to perceptions on task-oriented aspects, but also to even more subjective and experiential ones like hedonic aspects, emotional reactions or appraisals on beauty, goodness and appeal. While these outcomes are not surprising, we provide empirical evidence indicating that perceived accessibility and user experience could be understood as interchangeable qualities for blind users. A practical implication of these findings is about informing the design of instruments and protocols to be used in studies involving users. Because we know the UX attributes that are strongly correlated to PWA, UX terminology could be used as an indirect way to elicit information about how users perceive or experience the accessibility of a Web site on questionnaires, questions on focus groups and interviews. Participants will probably be more familiarised with terms representing UX attributes (e.g. emotional reactions such as disappointment and frustration) than with technical terms about the Web, assistive technologies and accessibility. The identified attributes do not only serve as proxies for perceived Web accessibility, but they can also facilitate the commu-

nication during user studies, leading to a better understanding of the experience of blind users with a Web site.

5.2. On the Relationship between UX Attributes and Web Accessibility Indicators

We found evidence to support the relationship between the UX attributes corresponding to the hedonic quality-stimulation *typical-original* (HQS_1), *conservative-innovative* (HQS_4), *lame-exciting* (HQS_5) and AIs representing the conformance to WCAG 2.0 guidelines. We observed a slight predominance of AIs corresponding to the *Perceivable* principle of WCAG 2.0. Accessible Web sites (in terms of a higher number of satisfied SC or fewer number of non-satisfied SC) are perceived to be original, innovative and exciting, whereas non-accessible ones (in terms of a lower number of satisfied SC or higher number of non-satisfied SC) are perceived as typical, conservative and lame.

Comments of participants during the interviews provided additional evidence to support the correlations found between compliance to guidelines and three hedonic quality-stimulation attributes: original, innovative and exciting. Participants may consider accessible Web sites original because they still find many non-accessible Web sites on the Web. Expert users claimed there are still many non-accessible Web sites (especially restaurant Web sites) and coming across an accessible Web site is considered a novelty. In line with this, some users appreciated the uncommon event of encountering alternative and theoretically more accessible versions of Web sites. We also learned that the perception of originality is not only influenced by the Web site's accessibility: the quality of textual content and its arrangement boosted the perception of originality. Nevertheless, we are cautious about this statement as user expertise and familiarity with the domain seem to play the role of moderator variables.

Accessible Web sites were considered to be innovative and related to progress and evolution, while non-accessible ones were regarded as conservative. A clear relationship between *lame* and lack of accessibility as well as between *exciting* and accessibility was observed. With regard to *lame*, participants gave some

illustrative metaphors which reflect how it is like to navigate on a Web site with serious accessibility problems: "*a labyrinth, a loop going nowhere, trying each room of a hotel to select just one, a fortress for the accessibility, a bunker...*". Conversely, participants were strongly motivated on accessible Web sites, which led to Web site revisitation or even to physically go to the restaurant featured on the Web site. The experience of accessing a different type of Web site for the first time may have contributed to some extent to the motivation of participants. This suggests that the hedonic quality-stimulation is not only driven by the characteristics of the stimuli, but by other experiential aspects, such as expectations and previous experiences on the Web.

Nevertheless, we found it surprising the unbalanced number of comments about the *lame* attribute on the Web sites with low accessibility (W3 and W4). One possible explanation for this is that the severity of accessible barriers may have more impact than their number. For instance, W3 did not have proper text alternatives for the navigational image links, which had devastating consequences on the hedonic quality-stimulation attributes. Even if the content about the gastronomic offer was accessible users were totally demotivated when exploring the homepage. On the other hand, the texts of the navigation menu link in W4 were clear and concise although the content about gastronomic offer was not completely accessible. This can be explained in light of previous works that highlighted the importance of the information architecture and the understandability of the texts in navigation menus. Blind users use them to get an overview of Web sites, which helps them form a mental model of the Web site (Leuthold et al., 2008).

Few works in the literature relate UX attributes and Web accessibility. One exception is the study by Mbipom & Harper (2011) where accessibility indicators were computed using the Barrier Walkthrough method and aesthetic judgements were made by sighted users. They found that Web pages judged on the classical aesthetics attribute as being visually clean showed significant correlations with accessibility. No correlation was found between the expressive aesthetic attributes and accessibility indicating that an expressive design is not

necessarily in conflict with accessibility. In fact, expressive aesthetics (Lavie & Tractinsky, 2004; Hassenzahl, 2008) match with the hedonic quality-stimulation attribute from Hassenzahl's model. Specifically the *original*, *innovative* and *exciting* attributes map to *original*, *creative* and *fascinating* expressive aesthetics attributes respectively. Hence, our findings do not only corroborate that an expressive design is not necessarily in conflict with accessibility, but we provide additional evidence on the interplay between Web aesthetics and accessibility. In this context, we emphasise that web aesthetics should be conceived beyond the visual representation and content of Web sites. In order to increase the aesthetic perception of Web sites the information architecture and the quality of texts should be paid attention.

Whether compliance to accessibility guidelines implies a satisfying user experience is a controversial topic. Our findings suggest that compliance to guidelines benefits the *original*, *innovative* and *exciting* attributes of the hedonic quality-stimulation attribute. It seems reasonable to assume that an accessible Web site is more likely to offer users new impressions and opportunities than a non-accessible Web site. If the content of a Web site is accessible, users will have more chances to be stimulated and motivated to navigate on that Web site than on a poorly accessible Web site.

5.3. Implications for Design

The accessibility problems participants encountered are those covered by previous works and guidelines (Theofanos & Redish, 2003; Leuthold et al., 2008; Leporini & Paternò, 2008). These works provide already a substantial body of knowledge on the design recommendations to build more accessible Web sites. Our findings corroborate how critical information architecture and navigation menus are, how beneficial it is to provide 'skip navigation' links and the effect of text quality of the aesthetic perception of Web sites. As far as design recommendations are concerned, our findings stress the criticality of the mentioned features in that they do not only improve accessibility, but they also boost a positive perception of Web sites.

6. Conclusions

In order to acquire a better understanding of the interplay between UX and Web accessibility, we analysed the relationships between UX attributes and perceived Web accessibility (PWA) and accessibility indicators derived from conformance of Web sites to guidelines (AIs). Results revealed that most UX attributes are significantly correlated with PWA indicating that perceived accessibility is related to hedonic and pragmatic qualities. As concepts that belong to these UX attributes (e.g. interested, disappointed, frustrated and annoyed) are probably more familiar to users than technical terms about the Web and assistive technology, they can be employed to facilitate the communication between researchers and in ethnography, contextual enquiry, focus groups or interview studies. We also uncover significant relationships between three hedonic quality-stimulation attribute pairs (*typical-original*, *conservative-innovative* and *lame-exciting*) and accessibility indicators that represent the number of satisfied WCAG 2.0 success criteria. These attributes can be understood as proxy measures for Web accessibility conformance as far as blind users are concerned. Including these attributes in questionnaires or other sort of enquiry method would be an indirect way to obtain estimates of conformance to accessibility guidelines.

Our findings may be generalisable to the remit of the type, domain and qualities of the Web sites used in the study. The Web sites under test have more hedonic than pragmatic qualities since their main objective is to attract potential customers rather than to provide a service or functionality. Thus, at most, and using the Web site classification framework by De Marsico & Levialdi (2004) we could generalise these results to commercial sites, which target a general audience and with an informative-seductive communication style. Future studies should address the possibility of generalising results to other type of stimuli.

7. Acknowledgements

A copy of the Web sites, the results of their Web accessibility evaluations and the generated datasets can be found in http://sipt07.si.ehu.es/amaia/stimuli. A. Aizpurua held a Ph.D. scholarship from The Department of Education, Universities and Research of the Basque Government when the study was conducted. The work has been partly funded by the same department under the Grant IT395-10 and the Basque Advanced Informatics Laboratory (BAILab) at the University of the Basque Country UPV/EHU (Grant UFI11/45).

References

Abascal, J., Arrue, M., Fajardo, I., Garay, N., & Tomás, J. (2004). The use of guidelines to automatically verify web accessibility. *Universal Access in the Information Society*, *3*, 71–79. URL: http://dx.doi.org/10.1007/s10209-003-0069-3. doi:10.1007/s10209-003-0069-3.

Aizpurua, A., Arrue, M., & Vigo, M. (2013). Uncovering the role of expectations on perceived web accessibility. In *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility* ASSETS '13 (pp. 74:1–74:2). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/2513383.2513411. doi:10.1145/2513383.2513411.

Aizpurua, A., Arrue, M., & Vigo, M. (2015). Prejudices, memories, expectations and confidence influence experienced accessibility on the web. *Computers in Human Behavior*, *51, Part A*, 152 – 160. URL: http://www.sciencedirect.com/science/article/pii/S0747563215003222. doi:http://dx.doi.org/10.1016/j.chb.2015.04.035.

Bargas-Avila, J. A., & Hornbæk, K. (2011). Old wine in new bottles or novel challenges: A critical analysis of empirical studies of user experience. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* CHI '11 (pp. 2689–2698). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/1978942.1979336. doi:10.1145/1978942.1979336.

Bigham, J. P., Cavender, A. C., Brudvik, J. T., Wobbrock, J. O., & Lander, R. E. (2007). Webinsitu: A comparative analysis of blind and sighted browsing behavior. In *Proceedings of the 9th International ACM SIGACCESS Conference on Computers and Accessibility* Assets '07 (pp. 51–58). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/1296843.1296854. doi:10.1145/1296843.1296854.

Brajnik, G. (2006). Web accessibility testing: When the method is the culprit. In *ICCHP, LNCS 4061* (pp. 156–163). Springer Verlag.

Caldwell, B., Cooper, M., Reid, L. G., & Vanderheiden, G. (2008). Web content accessibility guidelines (WCAG) 2.0. URL: http://www.w3.org/TR/WCAG20/.

Carifio, J., & Perla, R. J. (2007). Ten Common Misunderstandings, Misconceptions, Persistent Myths and Urban Legends about Likert Scales and Likert Response Formats and their Antidotes. *Journal of Social Sciences*, *3*, 106–116.

Chisholm, W., Vanderheiden, G., & Jacobs, I. (1999). Web content accessibility guidelines (WCAG) 1.0. URL: http://www.w3.org/TR/WAI-WEBCONTENT/.

Clark-Carter, D. (2004). *Quantitative Psychological Research: A Student's Handbook*. Psychology Press.

De Marsico, M., & Levialdi, S. (2004). Evaluating web sites: Exploiting user's expectations. *The International Journal of Human-Computer Studies*, *60*, 381–416. URL: http://dx.doi.org/10.1016/j.ijhcs.2003.10.008. doi:10.1016/j.ijhcs.2003.10.008.

Gay, G., & Li, C. Q. (2010). Achecker: Open, interactive, customizable, web accessibility checking. In *Proceedings of the 2004 International Cross-disciplinary Workshop on Web Accessibility (W4A)* W4A (pp. 23:1–23:2). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/1805986.1806019. doi:10.1145/1805986.1806019.

van der Geest, T., van der Meij, H., & van Puffelen, C. (2014). Self-assessed and actual internet skills of people with visual impairments. *Universal Access in the Information Society*, *13*, 161–174. URL: http://dx.doi.org/10.1007/s10209-013-0304-5. doi:10.1007/s10209-013-0304-5.

Hassenzahl, M. (2005). The thing and i: Understanding the relationship between user and product. In *Funology* (pp. 31–42). Springer Netherlands volume 3 of *Human-Computer Interaction Series*. URL: http://dx.doi.org/10.1007/1-4020-2967-5_4.

Hassenzahl, M. (2008). The interplay of beauty, goodness, and usability in interactive products. *Human-Computer Interaction*, *19*, 319–349. URL: http://dx.doi.org/10.1207/s15327051hci1904_2. doi:10.1207/s15327051hci1904_2.

ISO (1998). Iso 9241-11: Ergonomic requirements for office work with visual display terminals (vdts). part 11: Guidance on usability.

Lavie, T., & Tractinsky, N. (2004). Assessing dimensions of perceived visual aesthetics of web sites. *The International Journal of Human-Computer Studies*, *60*, 269–298. URL: http://dx.doi.org/10.1016/j.ijhcs.2003.09.002. doi:10.1016/j.ijhcs.2003.09.002.

Law, E. L.-C., Roto, V., Hassenzahl, M., Vermeeren, A. P., & Kort, J. (2009). Understanding, scoping and defining user experience: A survey approach. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 719–728). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/1518701.1518813. doi:10.1145/1518701.1518813.

Lazar, J., Feng, J., & Allen, A. (2006). Determining the impact of computer frustration on the mood of blind users browsing the web. In *Proceedings of the 8th International ACM SIGACCESS Conference on Computers and Accessibility* Assets '06 (pp. 149–156). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/1168987.1169013. doi:10.1145/1168987.1169013.

Leporini, B., & Paternò, F. (2008). Applying web usability criteria for vision-impaired users: Does it really improve task performance? *International Journal of Human-Computer Interaction*, *24*, 17–47. URL: http://dx.doi.org/10.1080/10447310701771472. doi:10.1080/10447310701771472. arXiv:http://dx.doi.org/10.1080/10447310701771472.

Leuthold, S., Bargas-Avila, J. A., & Opwis, K. (2008). Beyond web content accessibility guidelines: Design of enhanced text user interfaces for blind internet users. *International Journal of Human-Computer Studies*, *66*, 257 – 270. URL: http://www.sciencedirect.com/science/article/pii/S1071581907001413. doi:http://dx.doi.org/10.1016/j.ijhcs.2007.10.006.

Lindley, S. E., Meek, S., Sellen, A., & Harper, R. (2012). "it's simply integral to what i do": Enquiries into how the web is weaved into everyday life. In *Proceedings of the 21st International Conference on World Wide Web* WWW '12 (pp. 1067–1076). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/2187836.2187979. doi:10.1145/2187836.2187979.

Lopes, R., Gomes, D., & Carriço, L. (2010). Web not for all: A large scale study of web accessibility. In *Proceedings of the 2010 International Cross Disciplinary Conference on Web Accessibility (W4A)* W4A '10 (pp. 10:1–10:4). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/1805986.1806001. doi:10.1145/1805986.1806001.

Maxwell, K. (2006). What you need to know about statistics. In *Web Engineering* (pp. 365–408). Springer Berlin Heidelberg. URL: http://dx.doi.org/10.1007/3-540-28218-1_12. doi:10.1007/3-540-28218-1_12.

Mbipom, G., & Harper, S. (2011). The interplay between web aesthetics and accessibility. In *The Proceedings of the 13th International ACM SIGACCESS Conference on Computers and Accessibility* ASSETS '11 (pp. 147–154). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/2049536.2049564. doi:10.1145/2049536.2049564.

Murphy, E., Kuber, R., McAllister, G., Strain, P., & Yu, W. (2008). An empirical investigation into the difficulties experienced by visually impaired internet users. *Universal Access in the Information Society*, *7*, 79–91. URL: http://dx.doi.org/10.1007/s10209-007-0098-4. doi:10.1007/s10209-007-0098-4.

Norman, G. (2010). Likert scales, levels of measurement and the laws of statistics. *Advances in Health Sciences Education*, *15*, 625–632. URL: http://dx.doi.org/10.1007/s10459-010-9222-y. doi:10.1007/s10459-010-9222-y.

Petrie, H., Hamilton, F., & King, N. (2004). Tension, what tension?: Website accessibility and visual design. In *Proceedings of the 2004 International Cross-disciplinary Workshop on Web Accessibility (W4A)* W4A '04 (pp. 13–18). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/990657.990660. doi:10.1145/990657.990660.

Petrie, H., & Kheir, O. (2007). The relationship between accessibility and usability of websites. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* CHI '07 (pp. 397–406). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/1240624.1240688. doi:10.1145/1240624.1240688.

Petrie, H., & Precious, J. (2010). Measuring user experience of websites: Think aloud protocols and an emotion word prompt list. In *CHI '10 Extended Abstracts on Human Factors in Computing Systems* CHI EA '10 (pp. 3673–3678). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/1753846.1754037. doi:10.1145/1753846.1754037.

Power, C., Freire, A., Petrie, H., & Swallow, D. (2012). Guidelines are only half of the story: Accessibility problems encountered by blind users on the web. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* CHI '12 (pp. 433–442). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/2207676.2207736. doi:10.1145/2207676.2207736.

Theofanos, M. F., & Redish, J. G. (2003). Bridging the gap: Between accessibility and usability. *interactions*, *10*, 36–51. URL: http://doi.acm.org/10.1145/947226.947227. doi:10.1145/947226.947227.

Thüring, M., & Mahlke, S. (2007). Usability, aesthetics and emotions in humantechnology interaction. *International Journal of Psychology*, *42*, 253–264. URL: http://dx.doi.org/10.1080/00207590701396674. doi:10.1080/00207590701396674. arXiv:http://dx.doi.org/10.1080/00207590701396674.

Vigo, M., Arrue, M., Brajnik, G., Lomuscio, R., & Abascal, J. (2007). Quantitative metrics for measuring web accessibility. In *Proceedings of the 2004 International Cross-disciplinary Workshop on Web Accessibility (W4A)* W4A '07 (pp. 99–107). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/1243441.1243465. doi:10.1145/1243441.1243465.

Vigo, M., & Harper, S. (2013). Coping tactics employed by visually disabled users on the web. *The International Journal of Human-Computer Studies*, *71*, 1013–1025. URL: http://dx.doi.org/10.1016/j.ijhcs.2013.08.002. doi:10.1016/j.ijhcs.2013.08.002.

Yesilada, Y., Brajnik, G., Vigo, M., & Harper, S. (2012). Understanding web accessibility and its drivers. In *Proceedings of the International Cross-Disciplinary Conference on Web Accessibility* W4A '12 (pp. 19:1–19:9). New York, NY, USA: ACM. URL: http://doi.acm.org/10.1145/2207016.2207027. doi:10.1145/2207016.2207027.