Univ Access Inf Soc (2012) 11:359–373
DOI 10.1007/s10209-011-0253-9

LONG PAPER

An evaluation of web-based voting usability and accessibility

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Published online: 27 September 2011

Abstract Several countries are considering web-based voting as an alternative to, or a replacement of, traditional voting methods. It is argued that electronic voting could increase voter participation and help strengthen democracy, as e-voting would increase accessibility for large sections of the population, particularly with regard to groups that previously have experienced difficulties with the traditional voting setup. With a focus on usability and accessibility, this paper reports on a study evaluating several electronic voting prototypes in Norway, involving technical aspects as well as expert evaluation and user testing in the field, with users from a wide range of disabled user groups participating in the study. Technical testing regarding accessibility standard compliance, testing with the personas method and user testing revealed that many rather basic universal design principles were either not fully understood or not prioritized for implementation by the solution providers. However, despite various accessibility difficulties, the participants generally showed a positive attitude towards web-based elections. Through the findings of this study, the authors highlight factors that are important to consider in the development and testing of web-based voting systems.

Parts of this work were presented at the Unitech2010 conference, see Halbach et al. [1].

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Keywords e-Inclusion · Universal design · e-voting · REVS · Accessibility · Disabled · Democracy

1 Introduction

1.1 The Norwegian e-voting project

The Norwegian authorities have been preparing for e-voting trials as an additional feature to be incorporated into their paper-based traditional voting system. The project, called E-vote 2011, is governed by the Norwegian Ministry of Local Government and Regional Affairs (KRD) [2]. The primary objective of the project is to plan, specify and procure a complete administrative system for online elections, with the testing ground being the 2011 municipality elections. Trials with web-based voting was conducted in selected municipalities in 2011.

According to the system requirements developed by the E-vote 2011 project, the e-voting solution should simplify voting and provide better accessibility than the current paper-based system [3]. The e-voting solution will act to supplement existing paper-based voting. The project owners argue that electronic home elections can strengthen democracy via an increased participation in the elections. Long-term savings are expected through the lower costs involved in electronic elections—in terms of premises, equipment, inventory and automatic counting, etc.—as compared to paper-based voting. Another anticipated advantage is seen in the concurrent development of the appropriate infrastructure that needs to be in place for the effortless execution of these public electronic polls.

An important aspect of the new e-voting system is the requirement for the solution to be accessible and usable in accordance with the relevant laws. The Norwegian

Discrimination and Accessibility Act of January 2009 states that new Information and Communication Technology (ICT) aimed at the general public must adhere to the principles of universal design from 2012. Universal design is understood as the design or accommodation of the main solution with regard to physical conditions, including ICT, so that it can be used by as many people as possible [4]. Thus, some of the most important challenges of the project, besides security and privacy matters, are connected to these usability and accessibility features.

1.2 Development process of the election system

During the autumn of 2009, the E-vote project team had to decide upon an appropriate system supplier from a choice of five different initial applicants. The decision was based on a procurement process utilizing a competitive dialogue procedure including, among other aspects, the evaluation of prototype software implementations.

The assessment of the solution's usability and accessibility aspects was addressed by the authors of this article, alongside other researchers at the Norwegian Computing Centre, due to it being an interesting industry case. As such, a financial constraint for the entire evaluation was given, which, in turn, limited the choices regarding the number of users involved in the testing process.

Another constraint was that two rounds of prototype evaluations were required by the project owners. While the evaluation in the first iteration consisted of five prototypes from different providers, a shortlist was drawn up of the three partly improved prototypes in the second iteration. The aim of the conducted work was in short to uncover usability and accessibility problems and to evaluate, compare and rank the prototypes with regard to usability and accessibility. Any changes were attributed to the first iteration's assessment and feedback of problem areas to the suppliers.

1.3 Accessibility and usability requirements of the E-vote solution

The E-vote 2011 project provided the usability and accessibility requirement specifications for the development process. These requirements are grouped into the following main categories:

Functional requirements [3].

W3C's Web Content Accessibility Guidelines (WCAG) 2.0 [5]. The prototypes were required to meet all AA and parts of AAA conformance level requirements.

ELMER (Easier and More Efficient Reporting) 2.0 [6].

Other requirements (see below).

ELMER is a comprehensive set of principles and specifications for the user interface design of web-based forms. The Norwegian Ministry of Trade and Industry decided that all public governmental forms in Norway shall be based on the ELMER guidelines as of 2008 or later. ELMER mainly covers usability issues. When it comes to accessibility, it states that the form must comply with current conventions relating to web accessibility for all, including WAI requirements and general W3C conventions.

Regarding the other requirements, a set of fourteen other accessibility and usability requirements were developed by the E-vote project team with input from the project reference group. The most important requirements among those address the topics of (a) cross-platform independence of the e-voting client, stating that the solution must work well in all popular browsers and operating systems; (b) logical structuring of HTML code such that the information-flow order on a page is identical for users with various user agents, including users with assistive devices; and (c) providing the users with the possibility to change the text size, contrast and the language for all content.

In this paper, experiences concerning the evaluation of e-voting prototypes are shared, and the most prominent usability and accessibility issues are described. Some aspects relating to privacy, trust and attitude that came up during the user investigations, and which may influence user behaviour and, thus, election results, are also described. The paper also contributes with a discussion of whether web-based elections can provide increased accessibility for disabled people. This is an explicit goal of the Norwegian E-vote project because of the Norwegian Discrimination and Accessibility Act of January 2009.

This paper is organized as follows. Related work is presented in Sect. 2. Section 3 covers the applied method. The study's findings are presented and discussed in Sect. 4, and relevant conclusions are drawn in Sect. 5.

2 Related work

It has been claimed that web-based voting could increase voter participation and help strengthen democracy because e-voting solutions are potentially more accessible for large sections of the population than conventional methods [7–9]. At the same time, there have been examples to show that usability can have an influence on voters' ability to vote as they wish [11].

Electronic voting systems (EVSs) have been studied and discussed for at least four decades. In 1970, Stiefel outlined the potential application of electronic data processing and data transmission techniques in voting and election processes [7]. The foreseen advantages were to allow greater participation, to make voting practices more efficient and economical and to support democracy through more reliable, more accurate and more frequent reports of people's opinions. The same arguments have been used with regard to web-based voting or remote e-voting systems (REVSs).

Qadah and Taha [9] define a "remote" e-voting system as a system that allows voters to cast their votes from any computer or digital device connected to the Internet or to a private network, typically from home or at work. Devices such as personal digital assistance units, mobile phones and even game machines may access these systems (ibid.). While REVS has the potential of increasing voter participation, other concerns arise. Surveys of citizens' attitudes to web-based voting show that people are concerned about the security and integrity of such systems [10]. Another concern is that the introduction of REVS could change the socio-demographic and ideological composition of the voters, because it would be the younger, well-educated and liberal citizens who would be the most positive about such systems [10, 11].

Yao and Murphy [12] convincingly argue that people's perception of voting technology is likely to affect their intention to use it and thus possibly their decision to vote. It is, therefore, of value to learn more about what characteristics of REVS could affect a person's intention to participate in elections. Based on established models of the adoption of technology, Yao and Murphy [12] developed and tested a model of participation intention, which consisted of five main characteristics: availability, mobility, accuracy, privacy protection and ease of use. They found that mobility and accuracy strongly affected people's intention to participate, although differently for men and women. Mobility is connected to flexibility, i.e., to eliminating location, time or schedule restrictions, and accuracy is connected to security and trust issues. Smith [13] conducted a survey among (semi-) professional and well-educated Internet users. He found that the most important factors influencing people's willingness to vote online were the ease of access and their level of confidence in these technologies. These results seem to relate well with the results from Yao and Murphy.

It is generally agreed that usability is a very important aspect of web-based voting systems [11, 14–16]. Problems with usability were a central issue in the controversy surrounding the US presidential election in 2000 [15]. An electronic voting system was piloted in the Finnish municipal elections on 26 October 2008. Usability problems with the voting machines meant that re-elections had to be held in three Finnish municipalities [17]. Allowing people to be able to vote independently is essential, not only for voters with disabilities, but also for all voters [18, 19]. However, research into accessibility for the disabled and other vulnerable user groups is scarce when it comes to web-based voting systems.

Bederson et al. [15] review some studies in the area, but these refer primarily to voting machines at a public voting locale. Conrad et al. [16] argue that previous studies of Internet elections devoted very little attention to usability and then report a laboratory study of the usability of electronic voting systems. Many usability problems were revealed in this study, and the authors argue that most of the problems are easy to fix, provided that manufacturers incorporate usability design and testing into the development process.

Smith et al. [19] explore the impact of graphics on the usability and accessibility of web-based voting systems. They discuss graphical elements such as photographs, party logos that indicate specific candidates, or political parties and informational icons such as arrows, alert symbols and animations and videos. It was pointed out that voter errors due to poorly designed ballots can be difficult to detect, but can be significant enough in number to affect the outcome of an election. The authors conclude that basic usability concepts, such as the use of plain language, solve many of the issues of a cognitive nature and are also helpful to all voters. However, the use of graphical elements is controversial, and specific research is needed to establish whether graphics will indeed contribute to an improved usability of voting systems.

Little et al. [20] conducted focus group interviews to uncover the social aspects of the use of ubiquitous technology. Before the interview, participants looked at a video based on an e-election scenario. Findings from this study include that electronic voting is influenced not only by trust, privacy and usability, but also by other aspects such as context, type of device used and individual factors for each user.

To summarize, voting technology can influence the voter population and thus the election outcome, how voters feel about their ability to exercise their right to vote, as well as people's willingness to participate in elections and their willingness to accept the results of an election as legitimate. Moreover, poorly designed voting systems can result in voting errors or obstacles when using the technology, which, in turn, can affect the outcome of an election.

When it comes to usability and accessibility testing methods, these may be divided into three main approaches (a) automated/semi-automated testing with regard to accessibility guidelines (b) expert reviews and (c) testing with users. A main advantage of utilizing (semi-)automatic accessibility testing tools is the limited resources required with regard to time and resources [21].

Expert reviews with heuristics are another common method employed in usability testing. Using this method, one will often be able to uncover several local problems and many problems in total [22], but it may be difficult to determine the severity of the problems [23]. Also, the choice of heuristics is important, and it seems that current accessibility heuristics have a number of shortcomings [24, 25].

When based on and combined with user research, the personas method can be another useful technique to bring in new perspectives and highlight the diverse characteristics of users [26]. A persona is a hypothetical archetype of a real user described in detail and refined by their goals and needs, rather than just being based on pure demographics [27, 28]. Zimmerman and Vanderheiden [28] give a comprehensive description of how personas and scenarios can be used in accessibility testing. The description of a persona should include the use environment and any assistive technology that the user needs. The personas method is often used as aid for designers and developers to make accessibility requirements more tangible, concrete and reasonable [28].

User testing with a minimum of six participants has proven to be a good and cost-effective way to uncover unique, important and serious usability problems [22]. Kopackova et al. [21] note that non-skilled and non-disabled people can be very effective in testing for motion disabilities (browsing without a mouse), in testing low-resolution browsers and alternative browsers and in the evaluation of screen-reader outputs.

Mankoff et al. [29] compared several methods for finding accessibility problems for people who are blind, namely a laboratory study with blind users, an automated tool, expert review by web designers with and without a screen-reader, and remote testing by blind users. While developers using a screen-reader were quite successful in revealing accessibility problems, remote testing with blind users was found to be a less effective evaluation method. However, all of the techniques had different complementary strengths and weaknesses. To achieve accessible design, it is recommended that the three main approaches mentioned above are combined, i.e., utilizing automatic testing tools, expert reviews and user testing [28].

3 Method

Since this work was part of an industry case, it was limited by tight financial and time constraints. Particular guidelines were given that limited the choices regarding, for instance, the number of prototypes, the number of development iterations, the selection of user group characteristics and the number of users. These constraints had implications on the test design. The selected testing methods are detailed in the following.

3.1 Testing scenarios

First, three testing scenarios were developed based on the use case descriptions mentioned above and with assistance from a subject matter expert from the E-vote project. The objective was to cover the most frequently used and most important functionality involved in casting a vote. In order to compare the prototypes, each user had to go through each testing scenario with all the competing prototypes in one test session. In a pilot testing phase, the three test scenarios were employed, but it was found that this was too time-consuming and exhausting for the user, so the number of scenarios were reduced from three to two:

1. County elections—cast a simple (party) vote without any changes;
2. Municipality elections—cast a party vote, vote for two particular candidates of this party and add two candidates from other parties.

In general, the user/tester was allowed to decide what party and candidates to vote for, but suggestions were provided in case the participant had not made up her mind, or did not want to expose any political sympathies. The test scenarios were utilized in the technical, expert and user testing arenas. In order to be able to compare the prototypes, all the prototypes were tested based on these scenarios.

To make the scenarios more realistic and at the same time test the requirement of interoperability (in a cross-browser and cross-platform manner), a number of combinations of browsers and platforms were tested, as specified in Table 1.

3.2 Evaluation metric

The definition of the evaluation metric was given as a fixed requirement by the project owners.

For each particular requirement, one or several tests were defined that had to be passed to satisfy the corresponding part in the aforementioned requirement specification. The technical accessibility was measured in a quantitative manner, as detailed in the following. The testing, involving expert and persona testing, deployed a credit score system ranging from zero to three points for each part of the requirement specification, where three

Table 1 Overview of combinations of browsers and platforms, with an “X” for each combination

Browser	Platforms		
	Windows	Mac	Linux
Internet Explorer	X		
Firefox			X
Chrome	X		
Safari		X	
Opera		X	
Lynx			X

denoted excellent conformance and two points were given for a plain "pass" of the test.

The average score per testing topic–WCAG, ELMER etc.,– as described in the following, was determined as the weighted average of credit points of each single test. A prototype's overall score could then be calculated as the average over the weighted testing topic average scores.

3.3 Technical evaluation

The conduction of technical testing was given as a constraint by the project owners. More specifically, the following topics were to be tested: markup (HTML 4.01), style (CSS 2.1), accessibility (WCAG 2.0 Level A and AA, and parts of AAA), compliance to guidelines for electronic forms (ELMER 2) and JavaScript interoperability. Some other technical matters such as page size (in KByte), page width (in pixels) and responsiveness (in seconds) were also tested.

Partly automated tools were used to check the extent to which the prototypes met the technical accessibility requirements, namely various add-ons to the Firefox browser, such as the Web Developer, Contrast Checker and Firebug. The degree of WCAG conformance was controlled with Achecker, the only tool available at the time of the study that claimed to support WCAG 2.0 [30], while HTML and CSS conformances were checked with W3C's validator tools [21]. The conformance to ELMER was checked by manual assessment due to the lack of automated testing tools for these requirements. Since testing for WCAG 1.0 or 2.0 compatibility alone would reveal at most 33% of all identified accessibility problems of a web page [31], manual testing was also employed, as explained in the following.

3.4 Expert evaluation

The E-vote project owners set requirements on the types of user groups that should be included in the testing. The user testing needed to include users with visual, hearing, cognitive and motor impairments. In order to detect as many potential flaws as possible within the given constraints, it was chosen to combine expert evaluation and user testing, the latter of which is discussed later.

For the expert evaluation, the personas method was chosen along walk-through with respect to the total list of requirements from the project owners. As the authors conducted the expert testing themselves, they were able to become acquainted with the prototypes in order to prepare for user testing. Through previous projects, they had quite extensive experience from user testing with various user groups, such as with the visually impaired, elderly and people with cognitive disabilities [32–34]. It was also important to get an indication of whether the selected test scenarios were practically feasible for user testing within the given time limits. According to previous experience, one to one and a half hour of testing per participant is an appropriate time frame for user testing. Based on the persona profiles developed for accessibility testing purposes in other research projects, six personas with different impairments or disadvantages were developed: vision impairment, hearing impairment, dexterity problems, movement impairment, difficulties related to concentration and memory, an elderly person with a combination of impairments and a non-native speaker. The description of each persona included any assistive technology that the persona needed, their familiarity with technology and their attitude to e-voting.

These six personas were simulated by three researchers from the authors' research group, i.e., the researchers acted as a fictive character while walking though each prototype and scenario, taking notes as if the persona had performed a *think aloud* commentary on it. Even though the persona description is fairly detailed, it is important that the person who impersonates a particular persona has some experience with regard to the particular disability in question. This is a prerequisite in order to be able to do a realistic persona performance. It can be assumed that an evaluator, who has never experienced how a disabled person, e.g., a blind person with a screen-reader operates a web page, would be a poor actor. Therefore, the personas were distributed among the researchers so that each researcher got a persona with a type of disability with which they had ample previous experience. To summarize, the persona testing served several purposes at the same time: getting to know the prototypes, doing cross-platform and browser testing and preparing for the user testing by functioning in a piloting phase. The latter resulted in some adjustments and improvements to the detailed test plan and the materials provided for it.

3.5 User testing

The purpose of the user testing was to assess which of the prototypes worked best for users with various disabilities, as well as uncovering problems and issues that needed improvements.

It is argued that testing in the user's natural environment provides the most realistic setting for web-based elections. Therefore, in the conducted evaluation, the participants were allowed to decide at what location they preferred to conduct the test: at their home, workplace, at a Senior Centre or another suitable location. They were encouraged to use their own or any familiar PC and equipment. Portable test equipment was used for observation, including a camera/microphone on a tripod and a notebook with recording software for the researcher.

In the authors' experience, testing in the field brings up a wider range of issues than a laboratory test. Especially when it comes to user testing with people using assistive technology, field testing is considered as by far the best solution. First, there are a seemingly endless number of combinations of types and versions of computers and set-ups with assistive technology, and each type of assistive technology and its equipment often has many possible settings and configuration options that have to be optimized according to each particular user's needs. It will generally be very time-consuming to achieve the same settings on laboratory equipment as on the users' own equipment. Often, the user does not know or remember what settings they actually use, and researchers need to try and fail to achieve approximately the correct settings. Thus, testing with laboratory equipment will often require adaptation—so diverting attention away from the test application and scenario. In some cases, it is not possible for the user to use unfamiliar equipment and to participate when in unfamiliar settings. By visiting the user, the testing is not limited to the setups that are available in the test laboratory. Moreover, many users may be reluctant to bring their own machines to a test laboratory, at least those who mainly use stationary equipment. Additionally, travelling to a testing laboratory may be perceived as a barrier in itself for many users, not least for some disabled or less resourceful users.

In summary, it is easier to gather meaningful test results with a wide range of users and ICT equipment by having the opportunity to visit the user. Additionally, it is believed that this method has the potential to bring up a wide range of important issues, at an early stage in the development process.

3.5.1 Participants

The testing participants were recruited through different Norwegian non-governmental user organizations, such as the Norwegian Association of the Blind and Partially Sighted, Dyslexia Norway, the Cerebral Palsy Association, the Norwegian Federation of Organizations of Disabled People and Senior Centres.

The organizations invited their members to take part in the accessibility and usability evaluation. A detailed information letter about the test procedure, expected duration, the needed equipment, such as PC, software, telephone and the need for magnifiers, was sent to the volunteers.

There was a budget for conducting nine user evaluations in the first iteration and fifteen evaluations in the second iteration. Participants with a varied background with regard to ability/disability, age, gender, ICT and voting experience were selected from the volunteers. The participants were given a monetary compensation (of 500 Norwegian kroner). Nearly half of the participants were women, i.e., respectively four and seven in Iterations I and II. The distribution of participants by age in the two iterations is shown in Table 2.

Three participants in Iteration I and seven participants in Iteration II used assistive technology, including a head mouse, a screen-reader with a Braille display and text-to-speech software, a hearing-aid headset, screen-magnification software and alternative keyboards and pointing devices. The distribution of participants by type of impairment in the two iterations is shown in Table 3.

Participants were asked to report their ICT experience on a scale from 1 (inexperienced) to 5 (expert), as shown in Table 4. Some familiarity with ICT, i.e., being able to read web pages and send e-mails, was a condition for participation.

Participants also accounted for their voting experience by means of three categories: None—no voting experience; Simple—have given votes to parties; and Advanced—have changed the order of candidates or added names from other parties. This is shown in Table 5.

In Iteration II, the distribution was skewed towards more experienced participants both with regard to ICT experience and with regard to voting experience. Whether it was by chance that fewer inexperienced persons were interested or whether there is any other reason for this is hard to say. Due to a very tight time schedule, it was necessary to settle on the range shown. The fact that several of the participants were relatively experienced makes the findings of usability and accessibility problems even more severe. One would expect that disabled people with less ICT and voting experience would encounter at least as many, and probably more problems than the participants in this study did.

3.5.2 Detailed test procedure, data collection and analysis

Conventions on ethics and privacy in user testing were followed. At the beginning of each test session, the researcher made sure that the user had been informed about

Table 2 Count of participants by age group

Age groups (no. of years)	<20	20–29	30–39	40–49	50–59	60–69	70–79	80–89	Total
Iteration I	2		2	2	1		2		9
Iteration II	1	2	3	2	3	2	1	1	15

Table 3 Distribution of participants by type of impairment

Type of impairment	Iteration I	Iteration II
No impairment, first time voter	1	
Low vision	4	3
Blind	1	2
Dyslexic	2	2
Hard of hearing		4
Deaf	1	1
Dexterity problems		3
Total	9	15

Table 4 Number of participants per category of experience using ICT

ICT experience	Iteration I	Iteration II
Inexperienced (1)	0	0
(2)	2	2
Intermediate (3)	3	4
(4)	2	6
Expert (5)	2	3

Table 5 Number of participants per category of voting experience

Voting experience	Iteration I	Iteration II
None	2	0
Simple	4	4
Advanced	3	11

the test procedure and their rights. The researcher offered to read the information letter to the participant, and after any questions were answered, the participants were asked to sign a consent form that acknowledged that their participation was voluntary and that the session could be video-taped (alternatively voice-recorded).

The researcher was seated next to the user and tried as far as possible to act as a silent observer. The participants were asked to provide demographic and background details, such as age, gender, occupation, ICT experience, voting experience, impairment and use of assistive technology (AT) with their PC. Depending on voters' experience, the users were briefed in the voting procedure with regard to casting personal votes and adding candidates from other lists. The researcher then logged into a restricted area on the Web, with links to the different prototypes.

The prototypes were presented to the different participants in a different order. This was done in order to avoid skewed results due to the possibility of a user's learning curve. The task scenarios were repeated for each prototype, and each user had to test all prototypes. For each prototype, necessary information such as voter cards with a virtual user name, password and instructions was provided. While doing the tasks, the candidates were asked to think aloud.

The researchers noted problems, concerns, bugs and procedural errors, and also the participant's actions and comments. In case the participant was unable to continue on their own, they would get hints from the researcher; however, this was noted as a critical error. Both notes and video recordings were used when summarizing each user session. A fairly detailed set of minutes from each session was written up, although not all parts of each session were transcribed in detail.

Since the number of prototypes to evaluate was small (five prototypes in the first and three in the second testing iteration), the users were asked to rank the solutions according to subjective preferences. While ranking the prototypes, the user was encouraged to elaborate on the tasks and to explore the prototypes again. The participants were also provided with a sheet with screenshots of each prototype as an aid in the discussion.

The researchers registered completion of a scenario with or without success, critical errors versus non-critical errors and subjective evaluations according to the following guidelines:

A scenario was considered completed when the participant indicated that the scenario's goal had been reached (whether successfully or unsuccessfully), or when the participant requested and received sufficient guidance as to warrant scoring the scenario as a critical error.

An error was recorded as critical in the case where a vote was inhibited or when it led to an undesired outcome.

An error was considered as being non-critical when the participant recovered from it by her own means, if necessary, and when it did not result in later problems or an undesired outcome. Such errors were often procedural, i.e., the participant did not complete a scenario in the most optimal way but used, for instance, excessive steps and keystrokes. Minor user confusion was classified as being non-critical. Exploratory behaviour, such as opening and looking through the menu options, was not recorded as erroneous.

Subjective impressions regarding, for instance, the ease of use, possible satisfaction and viewpoints on web-based voting were noted down, based on utterances during the task solving or collected during the brief discussion and comparison of the prototypes at the end.

Each instance of a usability or accessibility issue from the minutes was analysed with regard to a category and its severity and was collected into a table for further analysis. The categories were predefined based on the requirements from the project owners. During the analysis, however, the need for more precise category names occurred and, thus, some new categories or sub-categories emerged. Then, the table was sorted into several categories such as operating system, browser type and version, test participant number indicating type of disability, screenshot number, error severity, error type and prototype name. The table was attached to the usability and accessibility report delivered to the project owners [35]. The findings in the next section are based on this material.

4 Findings and discussion

The prototypes were in an early phase of the implementation process and thus incomplete. However, the findings from Iteration I provided valuable input to improvements before the second iteration. In the following, the most prominent issues revealed by our technical, expert and user testing processes are discussed.

Since this study reports usability and accessibility problems in prototypes, i.e., unfinished systems, it cannot say anything about the magnitude or prevalence of such problems in current web-based voting systems. Usability and accessibility requirements were, however, clearly specified in the system specification provided by the project owners, and the vendors knew that their prototype would be evaluated in this respect. Therefore, it can be argued that the study quite realistically captures some important and relevant usability and accessibility challenges that need to be considered when developing and testing web-based voting systems.

4.1 Technical issues

It was found that basic technologies such as HTML and CSS appeared to be well understood and implemented. The same applied to JavaScript incompatibilities, with which none of the prototypes had problems.

One interesting result found was that all prototypes had been designed with static page layout in mind. Given page widths ranging from 966 to 1,008 pixels, none of the providers had obviously given thought to people accessing their solutions from devices with small screens, such as from smartphones or netbooks. This is in strong contrast to the popularity of those consumer products in the market. This further affects users in need of, or preferring, a high degree of magnification. In case a page extends the available space provided by the browser window, which in turn is limited by the screen resolution, content is hidden and scrolling is needed to access it. This may confuse users and lead to orientation problems. It is also noted that zooming into pages will, with a static page layout, lead to wide pages and hence a higher need for horizontal scrolling.

Concerning WCAG, the requirement specification defines 82 different success criteria from all conformance levels, i.e., A, AA and AAA. While this gives a theoretically maximum credit score of 164 points with the plain-pass condition, the prototypes ranged between 138 and 142 points. In other words, all solutions were at least 15% under a standard compliance of 100% and had, consequently, potential for improvement. While the numbers mentioned may not seem to be significantly low, it needs to be taken into account that the prototypes were incomplete, in particular with regard to the lack of multimedia content, which remained scheduled for implementation. Therefore, the number of issues is expected to rise with the degree of completion of the implementation.

Errors viewed as particularly severe include the following: extensive use of tables as a means for layout, text in (raster) images, low colour contrast (both with text and images) and insufficient handling of keyboard navigation.

Another interesting result was observed in the use of particular web technologies. While neither Java applets nor plugins—both known for their accessibility implications—were deployed in the evaluated prototypes, HTTP cookies appeared to be mandatory (i.e., without a proper fallback) with the majority of prototypes. iframes was used once as an alternative technology to HTTP cookies. However, the use of both appears not to have any accessibility implications (the iframes were invisible). One prototype used XML HttpRequest (XHR), also known as AJAX, extensively, which gave conflicts with particular assistive technologies, as detailed in the following.

Thirty-six check points have been assessed with regard to ELMER 2 conformance. This is below the total number of check points in the ELMER specification but was necessary due to tight time constraints. The most important sections in ELMER were regarded as the ones related to page structure, help text and concluding messages.

The best-performing prototype was found to achieve roughly 70% of the theoretically possible maximum credit score of 72 points with the plain-pass condition. As the performance of the other solutions was below 50%, it can be presumed that ELMER is either not well understood or prioritized by the suppliers. However, it can be argued that the application of the ELMER specifications, which were originally intended for the layout of online forms, may not be wholly appropriate for the process of e-voting. This was also acknowledged by the E-vote decision makers, who stated that suppliers may deviate from the ELMER 2 requirements in certain instances because of, for example, security or accessibility matters. In such instances, however, the supplier needed to document why they have deviated and specify the section(s) of the ELMER 2 standard that they have deviated from.

As already mentioned, the requirements were quite specific about the page structure, and all prototypes had deficiencies related to this. As an example, page headings were missing or not instructive and informative enough. ELMER is also quite specific about having a navigation area, e.g., a menu to the left, instead of at the top of the screen. This leaves less space for the content, though. Several of the visually impaired and elderly made use of zooming to increase the text size on the screen. Left side menus combined with zooming into the page led to the need for horizontal scrolling to see all the content. The issue is generally regarded as a usability and accessibility problem and was again confirmed by the performed testing. Therefore, it was recommended that the decision makers reconsidered ELMER conformance at this point.

In general, the help texts in the prototypes should have been shorter, more structured and divided into smaller segments. Finally, the usability and accessibility of the concluding messages was also of special importance. The strict requirements regarding security and validation mechanisms in the solutions meant that all the prototype providers had implemented some kind of confirmation and validation codes that the user had to consider. However, it was found that the providers had paid less attention to the usability and accessibility aspects of such messages. It would have been advantageous if the providers had looked closer at the ELMER requirements in this area.

4.2 Issues identified in personas and user testing

This section discusses the most prominent usability and accessibility issues of the personas and user testing.

4.2.1 Sequence, page structure and navigation

Regardless of the type of impairment, 14 out of 15 participants in the second iteration had problems with the sequence of actions and page structure in the prototypes. Many participants, 10 out of 15 in the second iteration, had problems with navigation. Several of the prototypes had the option to navigate between pages both by means of a page menu to the left and by means of “Previous” and “Next” buttons at the bottom of each page, which is in accordance with the ELMER requirements. It turned out that the prototype without the left menu, and thus the least number of navigation options, was considered as most intuitive in terms of navigation and sequence. One particular prototype was considered as confusing, as the user was presented with subjectively too many options at the same time and on the same page. Having the menu on the left of the screen also caused wide pages and contributed to the confusion of several of the participants using zooming functionality or magnifiers. They got confused because they missed content such as buttons and help texts, which were “outside” the screen to the right. Some of these users had problems in understanding the concept of horizontal scrolling or simply did not think of it.

4.2.2 Screen-reader usability and keyboard-only navigation

All the prototypes had issues related to poor screen-reader usability, such as ambiguous labelling of buttons, illogical header and section levels and inconsistent ways of selecting items. There were also language inconsistencies, such as Norwegian text on buttons read out load in English by synthetic speech. As an example of poor screen-reader usability, it is worth mentioning the difficulty for users in knowing to which party their vote went. This difficulty was caused by the placement of radio buttons before the party name in text. The user had to move past the button to read the party name and then possibly move back again to the radio button in order to tick it off. Some blind users would have preferred the radio button to be placed after each party name, but this may be discussed in the future, as it also has to do with conventions on the Web and on paper ballots. The use of XHR in one prototype turned out to be entirely inaccessible to the screen-readers used. Several of the prototypes were impossible or cumbersome to use with a keyboard-only navigation. For example, when selecting particular radio buttons, the users expected that they would be able to use the “Enter” button, while the prototype sometimes expected the user to press “Space”.

4.2.3 Layout and text sizes

The user and persona testing revealed many usability and accessibility issues related to too small a text size and a poor contrast of user interface elements in several of the prototypes. In contrast to that, one prototype was positively commented on as easy to understand by several individuals because of its clear and simple layout with good contrasts of buttons and navigation elements (see Fig. 1). However, even this prototype was criticized for a too small default text size and too long and too dense help texts.

4.2.4 Typing of party names

One prototype allowed the selection of additional candidates by typing into a text input field (see Fig. 1). The letters written were expanded to full names, which in turn were shown in a drop-down list right beneath the text field. The user could either pick the candidate of choice from the list or continue writing. This method was viewed by several as more demanding than the other solutions, which were based on lists with full candidate names and check boxes (an example is shown in Fig. 2).

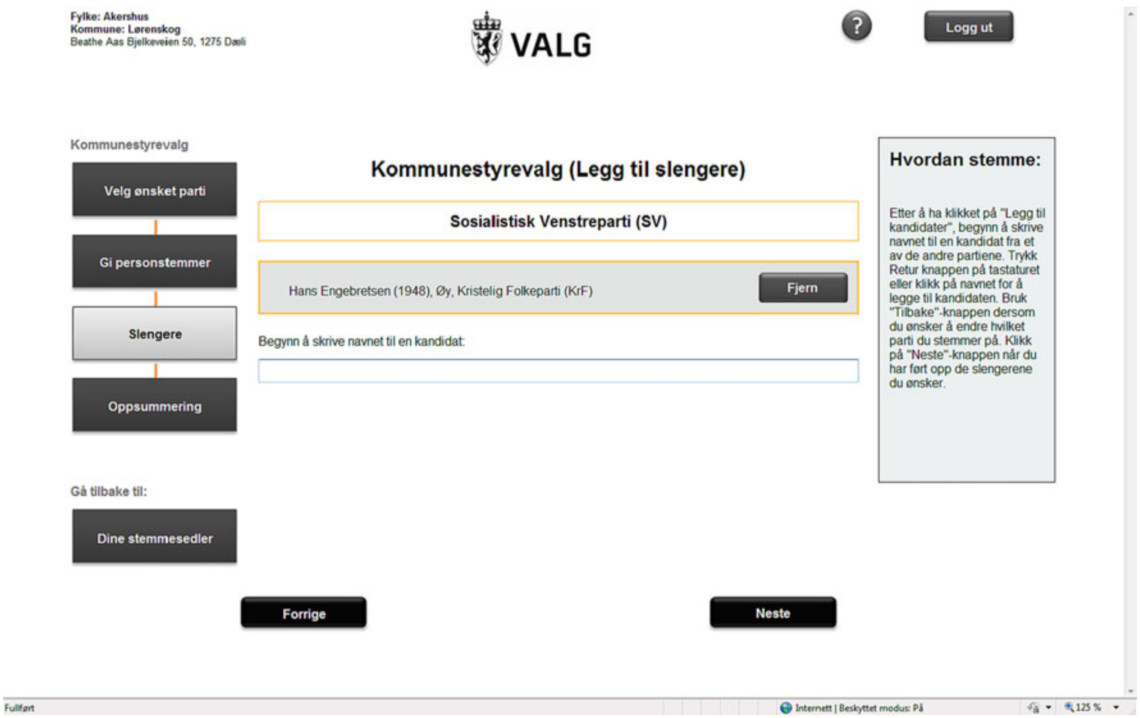

Fig. 1 Screenshot of prototype with appealing layout

Fig. 2 Screenshot of winning prototype's page for selection of candidates

4.2.5 *Party logos*

The use of party logos (icons) as applied in one prototype (see Fig. 3) received positive feedback from several test participants, but not all. Not surprisingly, dyslexics found this especially appealing. However, other research reports that utilizing audio interfaces and standards for legible text may help people with reading difficulties [18], and then party logos may not be necessary. Arguments against party logos include that it is difficult to ensure that graphics will appear similarly on all screens, paper ballots and absentee ballots. Additionally, party logos are not always standardized, and the size of the graphic may be an issue. The graphics or logos may be reduced to small icons in order to limit the total space or number of pages. The problem is that voters who rely on graphical information might have difficulty voting if the images are difficult to see or do not appear as expected. Parties without logos or competing parties using similar symbols may also complicate the issue [19].

4.2.6 *Ambiguous language and missing help*

The button labels, terms and headings were often not precise enough and sometimes ambiguous. Some of these problems may have occurred because of a poor translation from English to Norwegian. Short unambiguous instructions in plain language are important in order to avoid confusion among voters.

Help was, by some users, considered as being too general. Help that is more to the point appears to be necessary. Several participants commented that they would like multimodal help, e.g., in the form of instruction videos. This confirms other research stating that animations can help people learn to use interactive systems quickly and that many people prefer them as compared to explanations without animations [36]. Animations must, however, be used with care. Too many animations or animations that are unclear or imprecise may confuse the user. It is, therefore, essential to carefully review and check every animation that is included in a voting interface to ensure that it conveys its message clearly and concisely, as has also been commented upon in [19].

4.2.7 *Confirmation and validation codes*

All the solutions had a summary page where the voter could check the choices of parties and candidates prior to submission. In addition, there were confirmation and validation codes, which are both of special importance due to the need for security mechanisms. Here, user testing confirmed the expert evaluation's observation that the providers had not paid enough attention to the usability and accessibility of the concluding messages. Usable messages increase the user trust in the system, and usability issues in this part of the e-voting system can render the entire procedure worthless. It was, for instance, regarded as a serious

Fig. 3 Screenshot of prototype with party logos

problem that the participants were not always certain about whether their vote had been submitted or not.

4.2.8 Ranking of the prototypes

At the end of the testing session, the participants were asked to rank the prototypes according to their preferences. In the second iteration, the participants would rank three prototypes. Eight out of the fifteen participants liked the prototype pictured in Fig. 2 best, four preferred the prototype shown in Fig. 1, while three set the prototype in Fig. 3 on top.

It is interesting to note that one particular prototype was preferred by the majority of the participants, and by participants with all types of impairments except dyslexia, as illustrated in Table 6. The dyslexic participants preferred the prototype with party logos (in addition to text) and ranked the winning prototype as number two. This supports the assumption that it is possible to avoid conflicting designs for user groups with different disabilities, and consequently, that it is possible to design systems that are considered usable and accessible across diverse user groups.

4.3 Findings related to privacy, trust and attitude

Some aspects that might not be considered as pure usability or accessibility issues, but which might be interesting in a wider perspective, also emerged during the testing.

A few participants commented that voting in a public polling station is a quite solemn act, and they were concerned about this aspect of voting perhaps disappearing with web-based voting. They felt that the opportunity to vote at home as many times as you like would place less emphasis on the decision and lead to more impulsive voting. It is noted that one of the requirements of the project owners was that the voter should be able to cast a vote any number of times within the voting period [37]. One of the reasons for this requirement was to reduce the possibility of undue influence. If the voter is influenced or pressed in a voting situation, the voter should have the possibility of voting again at a later point in time. For the same reason, the system did not show whether or what the voter had previously voted. Some participants commented that this would lead to doubt as to whether they had managed to cast their vote or not on previous occasions, but they accepted the solution when they received the explanation for this.

Table 6 Subjective ranking of prototypes by type of impairment

Type of impairment	Prototype with appealing layout	Winning prototype	Prototype with party logos
Blind		2	
Low vision	1	2	
Deaf		1	
Hard of hearing	2	1	1
Dyslexic			2
Dexterity problems	1	2	
Total	4	8	3

For one of the prototypes, several participants expressed concern that they were not entirely sure what they had voted for, or they felt less trust because the process was so quick. The particular prototype had, in fact, a quite efficient voting process with very few steps. However, this prototype also had some ambiguous text on the confirmation page, which may have contributed to the confusion and, thus, to these users' concerns.

The system requirements stated that the web-based voting system must facilitate the authentication of all users and that it should incorporate the authentication service of a common public identity provider. However, since the interface specification of the identity provider was not fully defined at the time of the implementation of the prototypes, the authentication functionality was not emphasized by the suppliers. Therefore, the authentication mechanisms were disregarded in the evaluation. There is a risk, however, that the challenge of providing accessible authentication is not taken properly into account. When designing accessible security solutions, one faces additional challenges compared to accessibility and usability in the case where security is not of paramount importance. This is because the security aspects can prevent ordinary use of assistive technology, and because security functions, per se, can be difficult to use. There is minimal literature in the area of accessible and usable authentication, but this challenge is a research agenda in its own right [38] and must be taken seriously in order to come anywhere near equality of access for all.

According to the participants, the main drawbacks regarding e-voting are related to privacy, anonymity and trust. Several participants mentioned the possibility of being unduly influenced by others, e.g., family members. It is clear that the huge variations in possible physical settings, e.g. from a private home or office to a public computer at a library or school, and to a smartphone or netbook at a coffee house, raise new and critical privacy issues compared to the traditional voting booth. However, the majority of the participants in the study argued that these problems would be outweighed by the advantages of web-based voting. The general attitude was that web-based voting could strengthen democracy, as it makes elections more accessible for more people than current conventional solutions do. It seemed that the participants had confidence in that it would be possible to improve the selected solution to an acceptable level with regard to its usability and accessibility.

Several of the disabled participants described bad experiences with existing voting systems in public polling places. Blind participants described the difficulties with regard to finding their way to the polling place and instances of unclear placement of the Braille marking of the paper ballots. For example, the Braille text with party names could be above or below the ballots, and this had, in some instances, led to confusion. Persons in the wheelchair had experienced problems in casting their vote because it was not possible for the person in question to put the ballot into the box on their own. Several participants stressed the importance of being independent of assistance while voting and thought this to be a clear advantage with web-based voting.

Brown and Duguid [39] describe the importance of contextual aspects in design. They claim that users in different ways depend on both material and social characteristics of the artefacts used. When switching from one technology or one medium to another, one may lose or change both the material and social aspects, and therefore the outcome can be unpredictable. Yao and Murphy [12] suggest that one should educate people in how to protect their privacy in remote voting settings. We believe that carefully designed information videos or screen casts, showing and explaining the election procedure, could possibly mitigate some of the challenges related to changing the context and technology.

To summarize, voting through web-based technology alters several aspects of the voting act, and one cannot predict the overall effect on voting behaviour. However, the participants in this study were generally positive towards web-based voting. This must be seen in the light of the fact that they were self-recruited on the basis of our information letter sent out through an organization they were a member of.

5 Conclusion

The prototype candidates for the E-vote 2011 solution were evaluated with regard to accessibility and usability. The report on our findings was used by the project owners as input to the decision-making process for selecting one supplier for the implementation of a system to be piloted in the local elections in 2011 in Norway.

The prototypes were evaluated by means of technical, expert and user testing. Most of the technical testing were carried out using appropriate testing tools. The expert testing was done by deploying the personas method, while user testing involved users with various impairments.

The overall conclusion is that, even though there were clear usability and accessibility requirements for the prototypes and there is an increased focus on usability and accessibility of web-based voting in general, there seems to be a huge potential in improving such systems. This might be caused by the fact that many web developers are still lacking a firm grasp of the necessary techniques to make their solution both accessible and usable, or the lack of available, efficient and usable and accessible tools may be the culprit. Technically, all prototypes still have to fill the gaps towards full WCAG 2.0 compliance. Additionally, better compliance with usability guidelines is recommended, in particular with parts of the ELMER 2 guidelines, which have been adopted by the Norwegian government. However, some parts of these guidelines are not suitable for web-based voting systems, as they were originally meant for electronic forms. It is also argued that parts of ELMER, such as left menus, may lead to accessibility problems and should be improved, also with electronic forms in mind.

The technical testing itself was slightly cumbersome, as the tools involved did not offer a satisfactory degree of automation, and there are currently only a few free and open tools available for the assessment of recommendations like WCAG. Regarding the testing of ELMER, none such tools exist. Next, in particular with XHR in mind, a document-tree validator would be needed, as the existing tools are unable to check the validity of dynamic documents. Hence, better testing tools are needed.

In considering the user testing aspect, the majority of participants had a positive attitude towards the upcoming E-vote solution. However, many usability and accessibility issues were identified, which need to be addressed in such systems. It remains to be seen how future development versions of the solution fill the gaps towards the highest possible degree of accessibility and usability in the e-elections in 2011, and how these features are balanced against security and privacy issues, trust and possible other aspects of importance in terms of the voting behaviour.

Additionally, it is important to study the use aspects of web-based voting systems with a wide perspective and from different angles. Usability testing in the laboratory and testing of accessibility guideline conformance are necessary and valuable, but will not be sufficient to detect as many real-life flaws as possible. Especially for the evaluation of the accessibility for impaired participants using assistive technology, testing in the field has been found to be valuable. The conducted fieldwork also revealed aspects that are interesting from a broader perspective, such as possibly altering the voter's sense of solemnity when voting and increasing some people's independence. This must be balanced against the risk of undue influence. Whether and how these aspects will affect the election results is an open question. Therefore, it becomes particularly important to explore a variety of aspects of web-based voting as a phenomenon in contrast to traditional voting. Social aspects may, in addition to technical, security, privacy, trust, usability and accessibility related aspects, influence voting behaviour.

Acknowledgments We want to thank the E-vote 2011 project for our engagement in this evaluation of the usability and accessibility of the prototypes under consideration. We also acknowledge the help of the user organizations in order to recruit participants for user testing. Our gratitude also goes to the testing participants who provided us with valuable insight. Special thanks to our co-workers and colleagues in the project, Ivar Solheim, Øystein Dale and Trenton Schultz. This paper is partly funded by the Norwegian Research Council, mostly through the e-Me project. Finally, we thank the anonymous reviewers for valuable comments and suggestions, which helped us in improving the paper.

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