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Beyond web content accessibility guidelines: Design of enhanced text user interfaces for blind internet users

Stefan Leuthold, Javier A. Bargas-Avila*, Klaus Opwis

Department of Psychology, University of Basel, Missionsstrasse 60/62a, CH-4055 Basel, Switzerland

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Abstract

Websites do not become usable just because their content is accessible. For people who are blind, the application of the W3C's Web Content Accessibility Guidelines (WCAG) often might not even make a significant difference in terms of efficiency, errors or satisfaction in website usage. This paper documents the development of nine guidelines to construct an enhanced text user interface (ETI) as an alternative to the graphical user interface (GUI). An experimental design with 39 blind participants executing a search and a navigation task on a website showed that with the ETI, blind users executed the search task significantly faster, committing fewer mistakes, rating it significantly better on subjective scales as well as when compared to the GUIs from other websites they had visited. However, performance did not improve with the ETI on the navigation task, the main reason presumed to be labeling problems. We conclude that the ETI is an improvement over the GUI, but that it cannot help in overcoming one major weakness of most websites: If users do not understand navigation labels, even the best user interface cannot help them navigate.

Keywords: Accessibility; Blind users; Graphical user interface; Interface for the blind; Screenreader; Text interface; Usability for the blind; User interface; WAI; WCAG

1. Introduction

The graphical user interface (GUI) is the most widespread user frontend for applications today and the dominant user interface for websites on the internet. But graphical elements like windows and buttons are designed for sighted users; blind people can neither perceive nor use them (Kieninger, 1996). To compensate for this disadvantage, several countries have passed laws to enforce accessibility of websites for handicapped users. In the United States, these laws are being published as Section 508 of the Rehabilitation Act (Section 508, 1998), which prohibits discrimination against people with disabilities in all aspects of daily life, including education, work and access to public buildings. Since 2004, a Swiss act has required the government to provide access to all internet services for people with disabilities. Namely, communication and transaction services are to be made accessible for visually impaired people. In this context, websites compliant to a certain standard of accessibility are referred to as barrier-free-websites (BehiG, 2002; BehiV, 2003).

To bolster laws like Section 508, the World Wide Web Consortium's Web Accessibility Initiative (WAI) developed guidelines known as the Web Content Accessibility Guidelines (WCAG, 1999). Application of these guidelines ensures that HTML code is readable by screenreader software like JAWS, supporting handicapped users to access the website. Nowadays, the WCAG are the de-facto standard when it comes to accessibility of websites. The above-mentioned Swiss act explicitly refers to them.

Currently, the WCAG are mainly a result of ideas and discussions in the WAI working group, since by nature, working toward standards is different from empirical research. An overview of guidelines, standards and style guides for human–computer interaction (HCI) is provided by Stewart and Travis (2003). No empirical studies are referenced on the WAI website that would support the

*Corresponding author. Tel.: +41 61 2673522; fax: +41 61 2670632.
E-mail address: javier.bargas@unibas.ch (J.A. Bargas-Avila).

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WCAG's normative character, demonstrating positive impact on user behavior. Whereas HCI research has yielded many sets of user interface design guidelines (Nielsen, 1994; Shneiderman and Plaisant, 2004), to date, it has solely focused on accessibility and technological aids for perceptually impaired people (cf. Section 2.1).

The vast majority of the WCAG contain checkpoints and core techniques to improve the *programming* of websites to render them accessible for all users and all devices, and only the three guidelines stated in Table 1 contain advice for user interface design in the sense of *conceptual* design, comparable to Shneiderman's and Nielsen's work cited above. This illustrates that, regarding websites, the situation for blind and visually impaired users resembles the situation for sighted users in the mid-1990s: Content on websites is often accessible, but not consequently usable.

According to Nielsen (1993), a website is usable if it satisfies the five criteria shown in Table 2. This definition is context-independent. It needs to be conceptualized into concrete, applicable guidelines on the user interface level to be of practical value in real design contexts. This has been demonstrated for sighted users by Agarwal and Venkatesh (2002) or Venkatesh and Agarwal (2006), as they were able to determine the success of e-commerce websites from their empirically researched set of the Microsoft Usability Guidelines (Keeker, 1997).

This research sheds light on what influences usability from a blind person's point of view. It also shows how a new set of guidelines leads to a new kind of user interface, that will be called enhanced text user interface (ETI), because it relies only on text and not on graphical representations of content and navigation items. ETI can be regarded as an extension of the WCAG insofar as the guidelines can be associated to the last 3 of the 14 WCAG, explicating them for blind internet users. Thus, it could be a first step toward an exhaustive set of empirically researched guidelines that may be used to ensure usability, and not only accessibility, of user interfaces for blind users.

Table 1
The three non-technical WCAG

No.	Guideline
12	Provide context and orientation information
13	Provide clear navigation mechanisms
14	Ensure that documents are clear and simple

Numbering corresponds to numbering of WCAG (WCAG, 1999).

Table 2
Nielsen's five usability criteria

Factor	Explanation
Efficiency	Users accomplish their tasks quickly and without much cognitive effort
Errors	Users commit only few errors and are able to recover quickly
Satisfaction	Users are satisfied with how the website works
Memorability	Returning users do not have to relearn the use of navigation items and functionalities
Learnability	Novice users of a website get productive quickly, finding information and using the website's functionality

2. Theoretical background

This section starts with a brief overview of relevant research in HCI regarding accessibility and the conception of guidelines for user interface design. It then summarizes current research which shows that, as of today, the WCAG are rarely used, and if they are used, their impact is not as originally intended. The end of the section contains a short overview of approaches that go beyond the WCAG to support blind or visually impaired people.

2.1. Relevant HCI research regarding accessibility and guidelines for user interface design

Both Jacko's and Brewster's summary of recent HCI research make it clear that most researchers dealing with perceptually impaired people have devoted their time to investigate the *accessibility* of information and/or functionality via computers in order to enable or enhance usage for diverse user groups (Brewster, 2003; Jacko et al., 2003). However, they have not focused on usability or user interface guidelines, leaving a theoretical gap to address. Edwards' exemplary work on the Soundtrack user interface illustrates this point: The aim of the research was to adapt a mouse-based interface into an auditory form, i.e. make it accessible for blind users, and not to conceive user interface guidelines for the blind (Edwards, 1989).

Many researchers have contributed to the development of user interface guidelines for sighted users (see e.g. Nielsen, 1994; Shneiderman and Plaisant, 2004), and the International Standards Organization (ISO) has published a vast body of work on them as well (as described in Stewart and Travis, 2003).

2.2. WCAG are rarely used

The WCAG certainly do lead in the right direction. However, Sullivan and Matson (2000) found that if content accessibility is defined in a continuous, rather than dichotomous manner, 29 of 50 of the Web's most popular sites can still be classified as inaccessible. Klein et al. (2003) examined 157 websites of public high schools in Iowa with different methods, including Bobby, an automated engine for checking WCAG compliance. They found that 94.3% of these pages did not pass the Bobby priority 1 check (e.g. provide alternative text for all images) and 98.1% did not pass priority 2 check (e.g. do not use fixed font size). These studies indicate that although the WCAG have existed since 1999 and there are corresponding laws demanding their application, there have been few consequences or advancements in this field. Hackett et al. (2004) even found that the accessibility problems seem to have worsened in the last few years. They used the Internet Archive's Wayback Machine to analyze the accessibility of random websites from 1997 to 2002 and found that websites became progressively inaccessible, whereas their complexity increased over the years. Lazar et al. (2004) found, in a survey conducted with 175 webmasters, that 73.7% of respondents were familiar with the Section 508 laws and that 56% thought that their website was accessible. Most respondents (78.9%) were also aware that there are software tools to check accessibility. These results suggest that missing knowledge is not the main reason for the lack of development of accessible websites.

One problem area could be financial aspects. Developing an accessible website requires a substantial amount of work. In consideration of the relatively small number of handicapped users, decision makers could often opt against implementation of WCAG. Richards and Hanson (2004) addressed this problem. They claim that most approaches to the implementation of accessibility standards are based on unrealistic economic models in which web content developers spend too much and receive too little. This is due to the narrow definitions given to both those who benefit from enhanced access to websites and what is meant by "enhanced access". To the knowledge of the authors there is currently no further research in this direction.

2.3. WCAG are not enough

Compared to sighted users, navigation behavior of blind people is completely different. Anyone who has ever witnessed a blind person surfing a web page with a screenreader and a braille terminal has noticed instantly that the blind person's strategies of accessing an information space cannot be compared to visual navigation (Savidis and Stephanidis, 1998).

However, the WCAG show how to tweak the visual interface to make web page content accessible for handicapped users. For users with visual impairments this may be sufficient, but for blind people it is not enough. Petrie et al. (2004) showed that of all impairment groups, surfing the web is most difficult for the blind. Only 53% of the blind succeeded in their tasks, while 75% of partially sighted, 83% of dyslexic and 85% of physically impaired and hearing impaired succeeded. In their test with 51 disabled users, they collected 585 problems of which only 55% were related to WCAG checkpoints; 45% could be present on any WCAG-conforming site. Due to this kind of phenomenon, Powlik and Karshmer (2002) noted that making a resource accessible does not necessarily make it usable.

2.4. Beyond WCAG

Why do blind people still have many problems even if a page is fully WCAG-compliant? We believe that this is partially due to the GUI itself. This interface, even if tweaked, still remains an interface for sighted users. The graphical interface elements are designed to serve as visual input.

2.4.1. Crossmodal output

One way of solving this problem is enhancing the visual elements of the existing interface with crossmodal output aimed at the blind (audio or haptic cues). Hardwick et al. (1998) developed a browser capable of generating force-feedback from a VRML file. Using this browser it is possible to use haptic displays to communicate three-dimensional images to blind users. Yu et al. (2002) developed web-based multimodal graphs designed for visually impaired and blind people. The information in the graph is conveyed through haptic and audio channels.

Unfortunately, these ways of enhancing the interface are often tied to special hardware and require a considerable amount of work on the website. Additionally the main bulk of the visual interface is not altered, so many problems remain.

2.4.2. Dual user-interface paradigm

Another way of addressing the problems beyond the WCAG goes back to Savidis and Stephanidis (1998), proposing that blind and sighted users need different interfaces (dual user-interface paradigm). We believe that this idea deserves further consideration. If blind people navigate differently, they need another kind of interface. GUI elements have no value for them. They only generate audio-clutter on the screenreader output. This leads to the idea of altering the nature of the user interface instead of just tweaking the visual elements. This would provide the blind with a stripped-down and clean interface containing the same information, but structured in a different way.

2.4.3. Extension of screenreader capabilities

Web page content is being described with HTML code which is rendered into a user interface. All user interface elements correspond to HTML elements. Both sighted as well as blind users must be able to perceive the same navigation and content elements. But, whereas a sighted person scans the layout of a website, using visual cues to focus on interesting elements, blind and visually impaired users have to deal with a screenreader's linear narration of all HTML elements: A screenreader cannot know whether an element is simply used for layout purposes and could be left out, it just reads aloud all objects encountered in the exact sequence they are contained in the HTML code. Thus it often happens that blind users need to extract structure, navigation and content from a quite chaotic audio babble, even if the page is fully compliant with the WCAG. This problem was recognized by Fukuda et al. (2005). They claimed that the traditional way of evaluating accessibility by automated tools does not lead to usable websites for the blind. To solve this problem they proposed that important elements of navigation and structure as well as factors contributing to readability must be included in the accessibility measurement. Their evaluation measures are navigability (how well structured the web content is) and listenability (how appropriate the texts are).

This structural problem was addressed in several studies (Donker et al., 2002; Pontelli et al., 2004). Ramakrishnan et al. (2004) developed HearSay. This screenreader is based on a novel approach: It automatically partitions the web document through tightly coupled structural and semantic analysis, which transforms raw HTML documents into semantic structures to facilitate audio browsing. In fact this method tries to mimic the screening behavior of sighted users, so the structure of the website is communicated to the blind in a more efficient way. The work of Ramakrishnan et al. seems very promising. Unfortunately the evaluation they present is still on a very rudimentary level, tested by only five blind users.

Most approaches of developing a new user interface for blind users pursue promising ideas, but lack quantitative empirical evaluation of the benefits for the blind. In this study we will provide a direct quantitative comparison between two interface types.

3. Necessity of an enhanced user interface

In order to successfully use a navigation, users first have to form a mental model of the underlying navigation space. In order to form a mental model, users have to make sense of the grouping and labeling of navigation items. This sense-making is based on cognitive processes coupled to sensory input. Many models follow this train of thought (e.g. Spence's framework for navigation: Spence, 1999).

The sensory input leading to mental model formation is completely different for sighted and for blind users: For sighted users, visual grouping and non-audible attributes (such as text size, color and formatting) yield a great deal of insight into the intended grouping of navigation items and hence communicate the intended structure of the navigation space. Blind users have to form their mental model of the navigation space based solely on the linear representation of navigation items and audible cues added to visually represented content.

Some qualitative insights and examples from exploratory studies we conducted explain blind users' problems with a GUI:

- Blind users cannot guess relationships between primary and secondary navigation items if they are expressed visually. The website used in the first exploratory studies had a tab navigation on top with navigation items "News", "Weather", "Stock Exchange", "Money", etc. The "News"-tab was highlighted, and there was a subnavigation consisting of five groups with a total of 26 navigation options on the left. Blind users often could not make a connection between the highlighted "News"-tab and the corresponding second-level-navigation on the left.
- Blind users often only learn by chance which navigation options are recurrent on every page. Again, consider the tab navigation mentioned in the first example. The "News"-tab was always shown on top of every page, although users could not make sense of it. In the worst case, it took a user almost 30 min to execute a task, and when he was near completion, he mistook the "News"-tab for a navigation option in the subnavigation which brought him back to the homepage where he had to start over.
- It takes blind users a lot of time to explore navigation options: Whereas trial and error is a valid navigation strategy for sighted users, we never observed blind users applying this strategy. It seems to be too much effort to navigate back and forth between different web pages just for the sake of exploration.

Thus, theories of navigation and qualitative insights from our exploratory studies demonstrate the necessity of a user interface that is enhanced regarding navigation through and interpretation of the linear representation of content, using user interface elements especially designed for the blind. The next section shows how such an interface could be conceived.

4. Goals, guidelines and requirements for the ETI

4.1. Introduction and construction of the ETI

The GUI has been introduced to make use of human perceptual abilities in order to reduce demands on working memory: Instead of learning hundreds of commands by heart, users could see all available commands for a selected object and reserve their cognitive resources mainly for decision making. The only reason sighted users can instantly use a computer program or website without training is their ability to see data objects represented on the screen together with the corresponding commands.

Blind users need representations that enable them to hear or feel data objects and available commands. Preferably, an enhanced user interface for the blind would make use of auditive cues to communicate structure, since Lee (2004) showed that only 10% of the blind population uses Braille.

Our proposal therefore, is to use a text-only interface in order to free blind users from having to listen to auditive clutter from visual user interface elements, and impose a structure consisting of auditive cues. For the construction of this text-only user interface, we surveyed existing HCI research about guidelines (cf. Section 2.1) as well as user interface approaches beyond the WCAG (cf. Section 2.4). We then decided to follow the dual user interface paradigm (cf. Section 2.4.2), focusing on the application of two of

Shneiderman and Plaisant's *Eight Golden Rules of Interface Design* (Shneiderman and Plaisant, 2004):

- *Strive for consistency.* This guideline applies to labeling, order and effects of user interface elements.
- *Reduce short-term memory load.* At any given moment, users should not be required to handle more than Miller's famous seven plus/minus two chunks of information (Miller, 1956) in order to successfully use the interface.

We focused on these two guidelines because we believed them to be a reasonable starting point considering the effort of programming experimental test settings and conducting experiments with dozens of blind internet users. Furthermore, Norman's (Norman, 2001) emphasis of mental models as the source of errors has also led us to pay special attention to consistency, as only the consistent use of user interface elements enables users to make successful predictions of interface behavior, based on the inspection of their mental models.

We call the resulting text-only user interface the ETI because it contains enhancements which should make it superior to a regular text-only user interface that conforms to the WCAG.

4.2. Goals of the ETI

If the ETI supports the usability factors in Table 2, our goals with the ETI can be directly related to those factors: It should take blind users less time to complete tasks, they should commit fewer mistakes and show greater satisfaction surfing the website. These goals will be the criteria for the empirical evaluation of the interface, stated in our hypotheses in Section 6. Table 3 shows which guidelines are expected to affect which of Nielsen's usability factors. The reason for omitting memorability and learnability is explained in Section 6.

4.3. ETI guidelines

This set of nine guidelines was constructed based on the two guidelines stated in Section 4.1, as well as qualitative insights from exploratory studies and interviews with blind "power users" (referred to in Section 3). In building these guidelines we followed the approach for human-centered design laid out in ISO 13407 (as explained in Stewart and Travis, 2003): *Users were actively involved* in interface conception; the two guidelines mentioned above were used to *allocate function according to proper use of human skill*; and the *design solutions were iterated* before the experiments started.

An overview of all nine guidelines is provided in Table 4. The first group of guidelines deals with context and orientation information (WCAG no. 12 in Table 1). The second group addresses navigation (WCAG no. 13 in Table 1), and the last guideline is included to keep the user interface as clear and simple as possible (WCAG no. 14 in Table 1).

(1) *Communicate menu structure through numbering*

Scope: Every menu item is numbered, and the total number of menu items is announced before the menu.

Rationale: We assume that blind users navigate with higher levels of certainty and efficiency if they can use working memory for either of two possible strategies:

- In the case of navigation menus with many items, they know they must focus their attention and remember only a few items to come back to after they have aurally scanned the whole menu. This navigation strategy should lead to a one-by-one evaluation of navigation items: Users are likely to follow one of the first navigation items that seems to fit their goal. Of

Table 3
Usability factors and ETI guidelines

	Efficiency	Errors	Satisfaction	Memorability	Learnability
Guideline 1	Yes[a]	Yes	Yes	Yes	Yes
Guideline 2	No	Yes	No	Yes	Yes
Guideline 3	No	Yes	No	No	Yes
Guideline 4	Yes	No	Yes	No	No
Guideline 5	Yes	Yes	Yes	Yes	Yes
Guideline 6	Yes	Yes	No	No	No
Guideline 7	Yes	No	Yes	No	No
Guideline 8	Yes	Yes	Yes	Yes	Yes
Guideline 9	Yes	Yes	Yes	Yes	Yes

[a]Yes: respective guideline expected to affect the corresponding usability factor, No: expected not to.

Table 4
ETI guidelines overview

No.	Guideline	Basis (cf. Section 4.1)
Guidelines concerning context and orientation information, WCAG no. 12		
1	Communicate menu structure through numbering	Working memory
2	Label all user interface elements	Mental models
3	Place buttons after options in forms	Qualitative[a]
4	Do not use unnecessary words to create context	Qualitative[a], working memory
Guidelines concerning navigation, WCAG no. 13		
5	Frame every page with the same elements	Consistency, mental models
6	Add navigation menu on all pages, except pages at the end of the page hierarchy	Consistency, mental models
7	Place generic navigation and continuative links at the bottom of the page	Consistency
8	Place search on top of the homepage to facilitate task initiation	Qualitative[a], consistency
Guidelines concerning clarity and simplicity, WCAG no. 14		
9	Eliminate all visual elements used solely for layout and branding	Qualitative[a], working memory

[a]Based on qualitative insights from our exploratory studies with blind users.

course, there is only need to remember more than one navigation option because labels are ambiguous. If no navigation item could be mistaken to be an option except for the navigation item really leading to the desired content, users could always rely on a simple one-by-one evaluation of navigation options until the right navigation item is found.

- In the case of navigation menus with few items, they can listen to the whole menu without restricting their attention to single items, because they can remember all navigation items. The second strategy should result in users' taking the time to get an overview of all navigation options first, which would be desirable according to many guidelines (see e.g. Shneiderman and Plaisant, 2004) because users then feel more in control over the user interface.

This guideline is based on the body of research around human information processing (Card et al., 1983; Byrne, 2003), and uses the short-term memory guideline referred to in Section 4.1: Users have to compare their current navigation goal to navigation items in their working memory and decide how to behave. This is a tedious task if the number of possible navigation items exceeds the working memory span.

(2) *Label all user interface elements*

Scope: Examples for user interface elements include grouping, menus, links and images.

Rationale: For blind users to be able to form a mental model, they need auditive cues to understand what the interface consists of and what relationships exist between interface elements. Similarly, users with sight use visual hierarchy, nearness and other principles from gestalt theory as a starting point to form relationships between elements (see e.g. Palmer, 2002). Of course, for trivial cases like link labels, the label itself becomes even more important: Blind users often use a function which displays all links contained on the page they are on. If link labels are not self-explanatory, they cannot know where a link leads (e.g. any link labeled "more").

This guideline is based on research about mental models (Norman, 2001; Yoshikawa, 2003).

(3) *Place buttons after options in forms*

Scope: Place all form options after the label of the form but before the submit button, and place the link to extended search before the submit button.

Rationale: In many GUIs, designers use an input field for text entry, place the submit button next to it and put additional options below the button. This serves the need of most sighted users, who do not require options like language or document type restrictions to be included in their search. As long as these options are visible somewhere near the locus of attention (Raskin, 2000), users are able to find and use them. Blind users, on the other hand, can only guess whether there are further options after the submit button, and would have to explore the area aurally, continuing after the button in order to find them.

This guideline is based on empirical observations in our exploratory studies and not derived from the guidelines in Section 4.1.

(4) *Do not use unnecessary words to create context*

Scope: Context must not explain everything explicitly, but contain hints to form a mental model of the navigation space.

Rationale: As a web page loads in the browser window, sighted users determine whether they have navigated to the right page by looking at cues like the page title. Our first set of ETI guidelines for the exploratory studies added auditive clutter with the intention of creating context: The user interface read location labels in plain German and announced as well as explained all page elements. For example, at the beginning of each page, the screenreader read: "You are on page [path]." Although users welcomed the idea of labeling every object to create context (cf. Guideline 2), they wanted it to be shorter: Enough context to decide what to do and form a mental model, but not more.

This guideline can be viewed as an explication of WCAG no. 14 (cf. Table 1) and can thus be associated with Shneiderman and Plaisant's working memory guideline (cf. Section 4.1).

(5) *Frame every page with the same elements*

Scope: Always clearly indicate the beginning and end of a web page. Order and format menus similarly on all pages, so that they sound alike. Include page title, but do not display path to page.

Rationale: As visual structures of different pages within a website should look alike, auditory structures of different pages should sound alike so that blind users may rely on a single overarching structure to direct their attention to appropriate areas of a page. In the exploratory studies, users indicated that they do not need to hear the whole path to the page they are on since a good page title, in most cases, renders that information useless (cf. Guideline 4). Instead, they wanted an indication of where exactly a page started and ended so they could verify that they began certain tasks at the beginning of a page and ended their search for certain information or functionality at the end of the page.

This guideline is supported by the consistency principle stated in Section 4.1 and based on research about mental models (Norman, 2001).

(6) *Add navigation menu on all pages, except pages at the end of the page hierarchy*

Scope: Make a website accessible like a file navigation system, stating all options to move further down the hierarchy and provide a back function to go one level up in the hierarchy.

Rationale: Some blind users have been observed to load the appropriate web page for their task, but instead of looking for the page's content, they followed a link in the page's navigation menu and never even noticed there was content. The proposed guideline prevents users from following links if they are at an end node of the page hierarchy.

This guideline is based on the consistency principle stated in Section 4.1 and research about mental models (Norman, 2001).

(7) *Place generic navigation and continuative links at the bottom of the page*

Scope: Place all generic navigation items as well as continuative links that are believed to help users continue browsing after they are done with a page, at the bottom of the respective page.

Rationale: On most websites, generic navigation links (e.g. help, contact) are placed somewhere in the top corners. For sighted users, scanning the page and learning that they just have to look in the corners to find those items is enough to work with it. However, for blind users a screenreader reads these elements aloud every time they are being encountered. Therefore, by placing them somewhere else than at the bottom of the page means there will always be content on a web page that is separated by these links. Users expect generic navigation items to exist and they will most certainly search for them if they need them, e.g. blind users can use the find-functionality and type in ''help'' to find the help-link.

This guideline is based on the consistency principle (cf. Section 4.1) and on research about design and layout of different types of navigation as reported in Rosenfeld and Morville (2006).

(8) *Place search on top of the homepage to facilitate task initiation*

Scope: Search should be easily accessible and therefore be placed at the top of the homepage, but can be left out on every subsequent page.

Rationale: Because tasks with a website can be divided into navigation and search tasks, it seems reasonable to design the ETI in a way to facilitate the initiation of either task type. Search should be placed on top of the homepage to be perceived as being of equal value to main navigation. To reduce audio output to a minimum, however, search should not be included in subsequent pages: If it were placed on top of every page, it would be rather annoying, if it was at the bottom of every page, it might as well only be on the homepage. Users in the exploratory studies did not indicate problems with this.

This guideline is based on the consistency principle (cf. Section 4.1), although we recommend *not* to include search on *every* page: Simply repeating user interface elements on every page of a website is not, per se, helping users achieve their tasks. Making the very prominent search functionality accessible only on the homepage is consistent and avoids search functionality in locations where users are focused on navigation tasks.

(9) *Eliminate all visual elements used solely for layout and branding*

Scope: Blind users' working memory should not be overloaded with audio clutter.

Rationale: Considering that blind users are not able to process visual cues, the enhanced user interface for the blind should not contain any elements that pollute the screenreader's linear audio reproduction of the content. Audio clutter stems either from structural layout elements (such as those used to enforce exact spacing between layout elements) or from elements that are used for branding purposes. Attention should be paid to not leaving away too many elements since, in the exploratory studies, blind users indicated they did not want to be patronized and feared getting incomplete information (cf. Section 4.4.1).

This guideline is based on the fact that graphical elements for branding are designed for sighted users; blind people can neither perceive nor use them (Kieninger, 1996). Therefore, the audio output should not be polluted with useless information stemming from these elements, thus supporting the working memory guideline (cf. Section 4.1).

4.4. Requirements for reasons of feasibility

Advocating the need for an alternative interface like the ETI is a sensitive issue. Blind users could fear they are not getting complete information because some HTML elements are no longer included in the ETI. Decision makers could fear high implementation and maintenance costs in building not only a GUI, but also an ETI in the future. Hence the ETI has to fulfil two requirements to be feasible, as explained in the next two sections.

4.4.1. Completeness of information

In the exploratory studies we conducted to develop the ETI, blind users expressed severe concerns: They were worried about being discriminated against with a ''crippled'' interface and that they would be deprived of vital information. One user reported asking sighted colleagues to describe images discovered in the content, advising us not to leave images away simply because *he* could not perceive them. If we provide blind users with an alternative interface that suits their navigation behavior better, it is crucial that this interface contains the same information as the visual interface.

4.4.2. Implementation with a content management system

The population of blind internet users is very small and of little economic importance for most companies. Thus, available funding to make websites accessible is often limited. If we want an ETI for blind users to have any chance of success, the implementation has to be simple and must not require a huge amount of manual work. Most websites of bigger companies use powerful content management systems (CMS) that allow usage of different standard templates. These templates define the location of navigation and content as well as layout aspects like font types and colors. To make the implementation of the ETI feasible, a CMS must be able to generate it automatically. The authors believe this to be possible if the guidelines from Section 4.3 are integrated in the CMS.

5. Experimental design

5.1. Objects of evaluation

The experiment was conducted with the current website of the University of Basel (http://www.unibas.ch). This website contains the usual information about the University, its departments and personnel. At the time of evaluation, the website was partly compliant with the WCAG. To avoid changes to the website during the experiment, a copy of the relevant eight pages necessary to conduct the tasks was used.

Three interfaces were examined as explained in Table 5 (see Figs. 1 and 2).

5.2. Participants

This study was conducted with 39 blind participants. They were recruited with the help of organizations for the blind and corresponding newsletters. To participate in this study, they had to be considered totally blind (less than 2% remaining vision), and made use of Freedom Scientific's screenreader JAWS to surf the Internet for at least 1 year. The average age was 36 years ($SD = 14.72$; Range: 18–64) and the gender distribution was 72% male and 28% female.

Table 5
User interfaces examined in this study

	Name	Explanation
Interface 1	Unibas	The current website's original interface. The code was not fully WCAG compliant, but it worked flawlessly with the screenreader
Interface 2	WCAG	This interface looked exactly like Unibas, but it contained all necessary changes to reach full compliance with the WCAG: (1) Extension of TITLE-tag to provide a unique page title for every unique page (2) Language attribute "LANG = de" added (3) Re-labeled "more"-links with distinguishable names (4) Abbreviations like "Eng" replaced with whole sentence like "This page in English" (5) LABEL-tags added within forms
Interface 3	ETI	The alternative interface, designed according to the ETI guidelines stated in Section 4.3. The HTML code for the eight pages used was written from scratch

5.3. Procedure

The experiments were conducted in the Department of Psychology's usability laboratory in Basel, Switzerland. The websites were stored on a local server and browsed with Internet Explorer 6.0. Blind participants used the screenreader JAWS 5.1 and if required a braille terminal (ALVA 544 Satellite). The braille terminal was not restricted because only few people really use it, and those who do use it mainly for verification purposes and use the screenreader output all the same. All audio and video data from the sessions were digitally recorded for later analysis.

The blind participants were first introduced to the test setting by the supervisor. They had the opportunity to get accustomed to the test setting and adjust the screenreader to their needs with a short practice task. After a short pretest questionnaire (with some questions regarding their blindness to ensure that the necessary criteria were met, see Section 5.2), half the users started with two main tasks using a GUI (Unibas or WCAG): First, they had to find a specific person working in the library (search task). For their second task, they had to locate the address of the University's social counsel (navigation task). They then repeated the same two tasks with the ETI. After each task execution, they completed a subjective rating of the interface. The other half of the users started with the ETI, using a GUI afterwards. To avoid learning artefacts the interface order was randomized (cf. Fig. 3). The experimental session ended by having them fill out the post-test questionnaire (some demographic questions).

5.4. Tasks and data collected

We focused on three areas:

Task performance: Concerning task performance, certain users were not able to complete some of the tasks within 15 min. Their performance on uncompleted tasks was coded with 900 s, because hypotheses were not helped by cutting times short and findings would still be valid.

Average number of errors: As to the errors committed, 13 different errors were observed during task execution. The eight errors in Table 6 occurred more than once and have been included in the statistical analysis.

Subjective evaluation of the user interface: Three satisfaction measures, "pleasant", "comparison" and "speed", were collected. Due to time constraints we decided against complex satisfaction scales (Brooke, 1996) and used a simple question for each measure:

(1) Pleasant: "How pleasant was it to surf on the University of Basel website?" (Six-point Likert scale; 1 = very unpleasant, 6 = very pleasant).
(2) Comparison: "How do you rate the handling of this website in comparison to other sites you normally visit?" (Six-point Likert scale; 1 = a lot worse, 6 = a lot better).

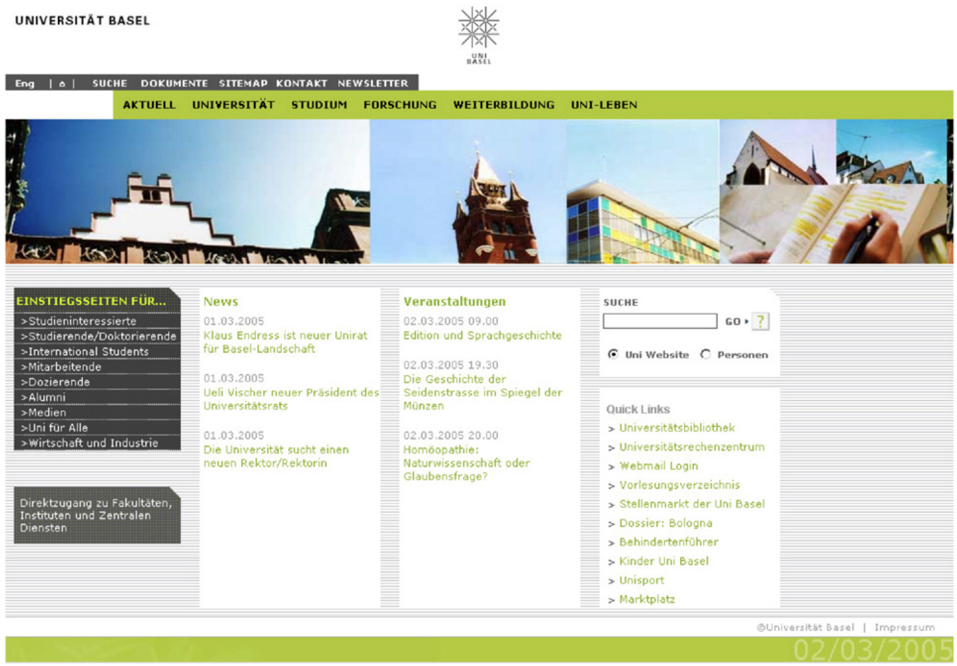

Fig. 1. Homepage of WCAG-compliant website used in this experiment.

Seitentitel

Universität Basel

Suchhilfen (enthält 2 Links)

1. Suche
2. Sitemap

Hauptnavigation (enthält 6 Links)

1. AKTUELL
2. UNIVERSITÄT
3. STUDIUM
4. FORSCHUNG
5. WEITERBILDUNG
6. UNI-LEBEN

News (enthält 3 Links)

1. 03.02.2005
Regenz billigt Verfahren zur Wahl des neuen Rektors

2. 03.02.2005
Antonio Loprieno zum Präsidenten der Planungskommission gewählt

3. 03.02.2005
Gesamterneuerung der Regenz im Sommersemester 2005

Veranstaltungen (enthält 3 Links)

1. 21.02.2005 18.15
'si chiama fagotto' - Zu einer Zeichnung mit Musikinstrumenten von Giovanni Ricamatori, genannt Giovanni da Udine

2. 22.02.2005 18.15
Baustellen im Parlament - eine wirtschaftspolitische Betrachtung

3. 22.02.2005 19.30
Die frühmittelalterlichen Kirchenruinen von Tomils/Sogn Murezi im Domleschg-Kloster, Wallfahrtsort oder Hospitz?

Weitere Links (enthält 5 Links)

Fig. 2. Homepage of ETI website used in this experiment.

(3) Speed: "How would you describe the speed with which you worked on this task?" (Six-point Likert scale; 1 = very slow, 6 = very fast).

These questions were asked after each interface used. Six-point Likert scales were chosen to ensure familiarity: In Switzerland the school grades use a six-point scale.

6. Hypotheses

The aim of this research is to develop and validate guidelines to enable construction of ETIs. Our guidelines (cf. Section 4.3) are based on the assumption that accessibility is not enough for the blind. They should lead to significant improvements in all of Nielsen's usability factors (cf. Table 2). This leads to the following hypotheses:

H_1: *Efficiency*. Tasks are completed faster with the ETI than with the GUIs.

H_2: *Errors*. Fewer errors are committed using the ETI than using the GUIs.

H_3: *Satisfaction*. Users are more satisfied with the ETI than with the GUIs.

There are no hypotheses for Nielsen's factors four and five, memorability and learnability, because long-term memory tests were not conducted, and participants took part in only one test. Those factors will have to be addressed in future research projects.

7. Results

7.1. No difference between Unibas und WCAG

We could not detect a difference between the interfaces Unibas and WCAG (cf. Section 5.1) with regard to task completion time, number of errors committed and subjective evaluations, as shown in Table 7.

This is mainly caused through our object of evaluation: The differences between the GUIs Unibas and WCAG, as described in Table 5, stem from only a few modifications. Because no differences were found, the data for Unibas and

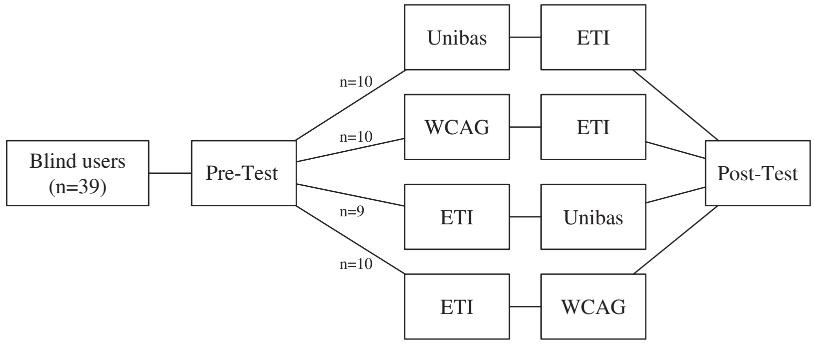

Fig. 3. Procedure.

Table 6
Eight most frequently observed errors

No.	Name	Description
1	Search button	Users do not find or click the search button, respectively. They click a wrong user interface element (e.g. question mark standing for "help")
2	Labeling	Users follow wrong links, either because they do not understand the link label, or because they explore one link after another
3	Extended search	Extended search has three options: website search, Google search and people search. Because people search is third, many users mistakenly searched the website or Google
4	Search option	Users are not able to adjust the search option (from website search to people search)
5	Search results page	Users hear an empty search input box first and start a new search (assuming their search terms did not yield results), instead of looking further down the page where search results were listed
6	Time	Task could not be completed within 15 min
7	Zero results	Users unsuccessfully try to find the desired web page with the search engine (wrong keywords)
8	Page structure	Users find the same main navigation on every page and are not sure whether they are on a new page or on the same page, because there is no indication of where they are

WCAG were merged for all following calculations, comparing the GUI to the ETI.

As expected, no sequence effects were found in any variables (i.e. neither usage of Unibas nor usage of WCAG caused users to perform differently on the ETI).

7.2. Usability factors

The subsequent sections state the results for the three examined usability factors.

7.2.1. Efficiency

It took blind users significantly less time to complete the search task with the ETI compared to the GUI, but there was no difference for the navigation task (Table 8).

7.2.2. Errors

Analysis of the eight most frequent errors (cf. Table 6) yields the same pattern as the efficiency analysis: Regarding the search task, users committed significantly fewer errors with the ETI in comparison to the GUI, but for the navigation task, there was no difference (cf. Table 9).

7.2.3. Satisfaction

Users prefer the ETI significantly more than the GUI and rate the ETI to be significantly better than other websites they visit (cf. Table 10). However, users did not rate their working on the tasks to be significantly faster with the ETI.

8. Discussion

8.1. Summary and interpretation of findings

This experiment demonstrates that the WCAG are not enough for blind internet users. From the nine guidelines, only numbers 4, 5, and 7 are applicable also to sighted users. The other six guidelines cover specific needs of blind users. Thus, the ETI guidelines must be regarded as an extension of the WCAG, producing a user interface more usable than the WCAG-compliant GUI, as our results show for three of Nielsen's five usability criteria in Table 2.

- Efficiency: The search task was completed significantly faster with the ETI. That this is not the case for the navigation task is a strong indicator for the importance of a solid information architecture (Rosenfeld and Morville, 2006) as a necessary precondition for any navigation space: If people do not understand the labels that are assigned to navigation menus and items, if titles and subtitles do not convey information meaningfully, enabling users to form a mental model, the user interface itself cannot compensate for the loss of the resulting inefficiency.
- Errors: In the search task, blind users committed significantly fewer errors using the ETI. As with efficiency, there was no difference for the navigation task—the main problem was presumed to be based on incorrect mental models.

Table 7
Comparison of usability factors for blind users using Unibas and WCAG

	Percentiles						U^a	p^a
	Unibas ($n = 19$)			WCAG ($n = 20$)				
	P_{25}	P_{50}	P_{75}	P_{25}	P_{50}	P_{75}		
Efficiency (s)								
Search	314	518	900	394.5	808	900	140.5	$p = .166$
Navigation	150	365	611	174	385	662	183.5	$p = .857$
Errors (*number of errors*)								
Search	1	2	3	1	2	3	175.5	$p = .687$
Navigation	1	2	2	1	1	2	185.5	$p = .901$
Satisfaction (*rating on six point Likert-scale*)								
Pleasant	3	4	4	3	4	4.75	175.5	$p = .687$
Comparison	3	4	5	3	4	4	172.0	$p = .627$
Speed	2	3	4	2.25	3	4	157.5	$p = .365$

[a]Mann-Whitney test (data not normally distributed), p: two-tailed.

Table 8
Efficiency comparison between ETI and GUI

	Percentiles						T^a	p^a
	ETI ($n = 39$)			GUI ($n = 39$)				
	P_{25}	P_{50}	P_{75}	P_{25}	P_{50}	P_{75}		
Efficiency (s)								
Search	165	280	774	358	615	900	69 ($n = 32$)	$p < .000$
Navigation	101	323	876	150	365	611	289.5 ($n = 34$)	$p = .891$

[a]Wilcoxon test (data not normally distributed), p: two-tailed.

Table 9
Error comparison between ETI and GUI

	Percentiles						T^a	p^a
	ETI ($n = 39$)			GUI ($n = 39$)				
	P_{25}	P_{50}	P_{75}	P_{25}	P_{50}	P_{75}		
Errors								
Search	0	1	2	1	2	3	79.0 ($n = 31$)	$p < .001$
Navigation	1	2	2	1	1	2	181 ($n = 27$)	$p = .843$

[a]Wilcoxon test (data not normally distributed), p: two-tailed.

Table 10
Satisfaction measures with ETI and GUI

	Percentiles						T^a	p^a
	ETI ($n = 39$)			GUI ($n = 39$)				
	P_{25}	P_{50}	P_{75}	P_{25}	P_{50}	P_{75}		
Satisfaction[b]								
Pleasant	4	5	6	3	4	4	95.0 ($n = 29$)	$p < .007$
Comparison	4	5	6	3	4	5	93.5 ($n = 28$)	$p < .011$
Speed	3	4	5	3	4	4	183 ($n = 33$)	$p = .075$

[a]Wilcoxon test (data not normally distributed), p: two-tailed.
[b]Internal consistency: Cronbach $\alpha = .8027$.

- Satisfaction: Although one might assume that the efficiency and error analysis would lead to users being comparably satisfied with the ETI, because they could not navigate faster and committed the same amount of errors in the navigation task, subjective measures show a huge difference between the ETI and the GUI. In fact, users are more satisfied with the ETI. Aside from the significant difference in scores on an absolute scale, a direct comparison shows that the majority of blind users assesses the ETI to be better than the GUI: 55% of 39 blind users rate the ETI better than the GUI, 30% say that there is no difference and only 15% say the ETI is worse than the GUI.

These results also demonstrate that user interfaces for blind users could be conceived using the same methods of user centered engineering applied to developing user interfaces for sighted users, see e.g. Mayhew (1999). Companies and institutions would be able to rely on worldwide standards for the design of user interfaces for blind users that have been elaborated and tested using proven methods of user interface design.

8.2. *Strengths and limitations of our research*

The obvious strength of our research is the application of the user centered design method according to the ISO 13407 standard: The final user interface used in this experiment was fashioned in several iterations, integrating knowledge about HCI theory and guidelines with insights from exploratory studies (qualitative interviews, observations and usability lab tests with blind users). But the resulting ETI's usability was not only researched qualitatively—unlike most usability lab studies that are conducted with only around 10 participants and thus cannot be used for statistical analysis—it was researched quantitatively with 39 blind users.

The most serious limitation of this study arose from time constraints: Welcoming users to the usability lab, letting them get acquainted with the test setting and recording task execution of two tasks already took well over an hour. We did not want users to work longer during a single test session. We would have liked to conduct the experiment with more than one search task and more than one navigation task, and, ideally, we would have tested the ETI guidelines with different user interfaces, in order to understand the impact of completely different content. Also, rather short tasks were used, because we wanted to make sure participants were able to complete them.

8.3. *Implications for further research*

In the future, empirical studies should be conducted to gain insights into navigation strategies and corresponding navigation guidelines to build new navigations for the blind, because there is at least one crucial difference in navigation strategies: For blind users, trial and error is not a viable navigation strategy, because it takes them too much time to return to the same point once they have taken the wrong direction. However, sighted users can commit errors in order to save cognitive resources. For them, it does not consume a large amount of time if they explore the navigation by trial and error, instead of properly evaluating all navigation options and choosing the one they think is suited best for the task. Further studies might show that due to this difference in navigation strategies, the ETI needs to discern between navigation pages and content pages containing exclusively either navigation menus or content but never both.

The information architecture of a website is even more important to blind than to sighted users, and this is a crucial factor for successful navigation. Further research needs to determine the size of the effect of appropriate labeling of navigation menus and items. There was no experimental condition with changed labels for the GUI as well as for the ETI, but we suppose that labeling was one of the main reasons that the navigation task made no significant difference between the ETI and the GUI.

Our guidelines contribute to three of Nielsen's usability factors (cf. Table 2), leaving at least two open issues for further research to address:

- The two factors our hypotheses did not cover: Learnability and memorability. It would be important to improve the ETI in order to study and improve blind users' learning and usage of website functionality, especially regarding novice users.
- Identification and exploration of *all* factors contributing to usability for blind internet users. Our research focused on guidelines for user interface elements only, and in the future, one could follow the approach of Venkatesh and Agarwal (2006) and investigate which factors make blind users successful in terms of task completion, which factors contribute to user satisfaction and to what extent.

Finally, variations and improvements to each guideline should be considered and researched empirically.

8.4. *Conclusion*

We conclude that, for blind users, the ETI is more usable than the GUI, and our results indicate great potential beyond the WCAG for improving the Internet experience of blind users. Effects from navigation labels should be researched with high priority along with variations of the nine guidelines for different website types. As long as governments and companies are unable to guarantee the *usability* of their websites, they should think carefully before investing in the *accessibility* of the websites' content and functionality.

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Web programming company "aseantic" programmed all needed variants of the website used in the exploratory studies. Stefan Pauwels programmed all needed variants of the website used in the actual experiment.

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