11

Distance Learning: New Opportunities for the Blind

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1. Introduction

The rapid growth of the Internet has created extraordinary opportunities for distance learning, further enhanced by the diffusion of mobile learning systems. Students especially appreciate the portability and overall ubiquity of electronic content, but they also value legibility, presentation and good design (Wilson et al. 2002). Furthermore, smart searches and other dynamic features (such as tag clouds and semantic data navigation) make content exploration quicker and easier. In this context, quality and enhanced facilities that are unavailable in paper format will fuel the future of electronic learning material.

Chats, blogs, Wikis, collaborative environments, assessment SW, podcasting, games, voting systems and more can be accessed on a laptop, palm device or cell phone—anywhere, anytime. Collaborative and cooperative technologies offer a particular contribution to the learning process. The trend is to create a Virtual Learning Environment (VLE) where students can collaborate and cooperate. Thus, to allow all users to enjoy these services, accessibility and usability principles should be applied when preparing materials and developing the interactive environment. Unfortunately, accessibility and usability have not progressed at the same pace as technology, and special-needs users risk missing out on this great educational opportunity. In particular, visually-impaired students still encounter difficulties when using e-Learning content, both on desktop computers and on mobile devices.

Accessibility and usability are fundamental when designing any user interface, but they are crucial for e-Learning systems, since technological barriers can hinder learning. Technology can support learning if it does not require additional effort on the part of the user. Specifically, the interaction environment should be transparent for users in the sense that it should not interfere with learning, or else the benefits of distance learning risk becoming worthless. When designing electronic learning materials (i.e. Learning Objects) and delivery systems (e.g. Learning Management Systems) it is crucial to identify the needs and requirements of the target community to create a system geared to the individual; based on user profiles, learning objects are delivered according to user ability.

In this chapter we focus on the needs of blind persons who interact via screen reader with voice synthesizer. For effective, efficient and satisfactory design (i.e. usable according to ISO 9241-11), developers must be aware of all the obstacles encountered by users aided by assistive technology and should map accessibility and usability criteria in e-Learning systems from the very earliest stages of the design process.

The chapter is organized as follows. First, the background is introduced: the main problems encountered by blind people when interacting by screen reader, basic accessibility and usability principles, and an overview of studies in this field. Next our discussion focuses on specific guidelines related to e-Learning methodology and systems, also showing two examples of using standard technology for enhancing the experience of the visually impaired. Last, the conclusion discusses future research trends and opportunities.

2. Interacting via Screen Reader: user needs and requirements

A screen reader is an assistive technology used by the visually impaired to interact with a computer or other electronic devices, such as mobile phones. The screen reader interfaces the user with the operating system and the applications. It interprets the user interface (UI) content which is read aloud sequentially by means of a voice synthesizer, or written using a Braille display. However, Braille output is extremely slow and is rarely used (by less than 10% of the blind population, Lee 2004).

Popular screen readers are: JAWS for Windows (http://www.freedomscientific.com/), Windows Bridge (http://www.synthavoice.on.ca/), Windows eyes (http://www.gwmicro.com/) and Hal for Windows (http://www.dolphincomputeraccess.com/). In the following we refer only to JAWS for Windows. Henceforth, we will use the term "screen reader" to indicate a screen reader with voice synthesizer.

Web navigation is still quite difficult for blind persons using a screen reader, as pages are read sequentially one line at a time, starting from the top left-hand corner of the page, losing all layout, style and font information (Goble et al., 2000). In particular, interaction with e-Learning environments is even more difficult due to the complexity of their interfaces, rich in functions and options, and the time it takes to perform even a simple action. More precisely, non-visual perception can lead to many problems:

1. Content serialization. The screen reader reads contents sequentially, as they appear in the HTML code. This process is time-consuming and annoying when part of the interface (e.g. the menu and/or the navigation bar) is repeated on every website page. As a consequence, blind users often have to halt the screen reading at the beginning, and they prefer to navigate by Tab Key, from link to link, or explore the content row by row via arrow keys.
2. Content and structure mixing. The screen reader announces the most important interface elements such as links, images, and window objects as they appear in the code. For the blind user, these elements are important for figuring out the page structure. However, the actual reading process can overload the user, requiring considerable cognitive effort. If the table's content is organized in columns the screen reader (which reads by rows) announces the content of the page out-of-order, and consequently the information is confusing or misleading for the user.
3. Lack of context. When navigating by screen reader the user can access only small portions of text and may lose the overall context of the page; thus it may be necessary to reiterate the reading process.
4. Lack of interface overview. Blind people do not perceive the overall structure of the interface, so they can navigate for a long time without finding the most relevant

content. To resolve this problem it is necessary to structure the HTML code appropriately (for instance using ARIA regions as discussed in the following), add hidden labels, and apply other features to improve navigation.

5. Difficulty understanding UI elements. Links, content, and button labels should be context-independent and self-explanatory.
6. Difficulty working with form control elements. For instance, the order in which the user visits form elements (e.g. via Tab Key) should reflect the logical order in which the user fills out the form. If possible, make the user able to jump to a group of homogenous elements (for instance, using ARIA regions as discussed in the following).
7. Lack of visual perception. For accessing multimedia content such as video streaming or video conferencing, appropriate educational-equivalent textual alternatives should be provided.

Designers of e-Learning systems must consider three crucial factors: usability, accessibility, and educational effectiveness. Consequently, the challenge is to design systems that are accessible to everyone and simple to use while maintaining pedagogical and educational efficacy. In particular, blind students may fruitfully utilize e-Learning systems if educational materials are accessible and learning paths can be tuned to the "rhythm" of the individual student.

When designing for blind users, it is necessary to consider the three main interacting subsystems of the Human Processor Model: the perceptual, motor and cognitive systems (Card et al., 1983). Sightless persons perceive page content aurally and do not interact using a mouse or other pointing device since they only navigate via keyboard. This can make the "reading process" time-consuming, difficult and frustrating, if the content is not designed with special attention to their needs. Analyzing the cognitive part of the interaction is important, since many learning techniques are only relevant for sighted people. Thus, alternative ways to deliver the same content should be provided. Furthermore, a blind person may develop a different mental model of both the interaction and the learning processes, so it is crucial to provide an easy overview of contents.

3. Accessibility and Usability

A Learning Management System is accessible if everyone, including the differently-abled, can access and use all its contents. Designers must be aware of "technical barriers" that a disabled user may encounter when interacting with the system. Specific examples of web barriers for the blind are:

- non-textual content without an equivalent alternative text, for instance video, complex graphs, charts, diagrams with poor or no description (see Fig. 1)
- active elements that do not receive the focus (e.g. dynamically created widgets)
- dynamic applications (Ajax, Asynchronous JavaScript and XML) that change only a portion of the UI and are not announced by screen reader
- graphical alert boxes that are not perceived by screen reader (no alternative text).

Accessible design is not only for the differently-abled but benefits every user. For instance, a person may experience temporary disability due to a medical condition (for instance, after an accident or suffering a medicine's side effects) or may experience reduced perception due to distractions or to performing activities simultaneously (noisy environment, using a cell phone while driving a car, etc.). Furthermore, as the age of the user population rises, accessibility becomes even more critical.

However, accessibility alone does not guarantee satisfactory use: removing obstacles to access on-line content or services is a prerequisite, but usability completes the design, making a system simple to understand and easy to use. Usability addresses multiple aspects of the interaction including the application domain and user tasks.

Usability principles are extremely important in the educational field where students need to concentrate on the learning process without spending time and effort orienting themselves on the user interface. With an e-Learning system, the same content still has to reach every user. For instance a learning object may be delivered by different media according to student ability, taking great care that textual information (of non-textual content) is educationally equivalent to the original version.

In 1993, five general usability criteria were proposed by Nielsen (Nielsen, 1993):

- Efficiency in carrying out tasks (speed and cognitive effort)
- Errors (few easily recoverable errors)
- User satisfaction
- Memorability of visited items and functions (next time the user accesses the system)
- Learnability, the ability to be proficient quickly, which impacts on performance of novice users.

Compared to interaction with stand-alone applications (with homogenous UIs), the Web poses another difficulty due to interconnections between different sites. In fact, links enable the user to move in one step (mouse click or enter key pressing) from one site to another where the logical organization of the content may be inconsistent, and no guidelines are provided for ensuring inter-application coherence (Scapin et al., 2000).

If taken into account early during the design and development phases, applying accessibility and usability principles requires much less effort than doing so later. However, to be effective, abstract principles need to be expanded into specific guidelines in order to be concretely applied to web sites or systems.

Usability is only one important aspect of a website; also important are content, functions, and popularity. However, usability is crucial in the decision to choose/discard a website: even when the same services are provided, a user will choose one that is most effective, efficient and satisfactory (Nielsen, 2001).

For evaluating accessibility and usability different techniques are commonly used including:

- Automatic/semiautomatic inspection of web content (for instance Markup, CSS and accessibility validators). However, the validator output requires a human control for problems not automatically verifiable.
- Usability inspection (Nielsen, 1994) refers to evaluators (usability experts) analyzing the interface to verify its conformance to a set of principles of usable software design (such as heuristics and cognitive walkthroughs). This approach detects a high percentage of problems and it is easy to implement. However, general principles need to be embedded in the design context. For instance, Squires and Preece (Squires & Preece 1999) embedded usability heuristics proposed by Nielsen in the socio-constructive theory and specified criteria ad hoc for e-Learning .
- Usability testing with users is an efficient method for identifying interface issues. Objective and subjective user tests are possible. Integration of these techniques improves accuracy of results.

Objective usability testing relies on measuring user performance when carrying out a set of tasks. It may be costly since it requires HW/SW for carrying out the test in the lab, collecting and analyzing log files server/client-side and/or recording user actions. An alternative, which considerably reduces the cost, is remote evaluation. The validity of remote testing vs classic laboratory usability testing is a widely discussed topic in literature. Recent studies have shown that during remote testing, users take a bit longer to complete tasks due to the communication overhead, but that results are just as effective as, if not better than, traditional testing in the laboratory (Thompson et al., 2004).

Subjective usability testing measures user satisfaction, for instance by means of questionnaires and interviews.

3.1. Accessibility guidelines

The main objective of the World Wide Web Consortium (W3C, http://www.w3.org/) is to "Bring the Web to its full potential…" while allowing satisfying access to anyone "anytime, anywhere, under any condition, regardless of any disability". Unfortunately accessibility barriers seem to increase over time while websites become more and more complex (Hackett et al. 2004). To counteract this trend two ingredients are necessary:

- accessibility and usability must evolve on the base of the definition and evolution of new protocols, languages and standards
- Web designers must incorporate accessibility and usability into their web systems.

The first point is addressed by the WAI group of the World Wide Web Consortium which define guidelines for web content, authoring tools, and user agent design.

Web Content Accessibility Guidelines (WCAG) version 2.0 are general principles for making Web content more usable to people with disabilities (W3C, WCAG 2.0). The guidelines are grouped into four categories: perception, interaction, comprehension and robustness, as shown in Fig. 1. Unlike the previous version (1.0), criticized by several authors (Sloan et al., 2006), (Leuthold et al., 2008) for addressing only web accessibility, WCAG 2.0 consider the full interaction and navigation paradigm, thus including usability principles for guaranteeing effectiveness, efficiency and user satisfaction to all.

1. **Perceivable**
   1.1 Provide text alternatives for any non-text content so that it can be changed into other forms people need, such as large print, Braille, speech, symbols or simpler language
   1.2 Provide alternatives for time-based media
   1.3 Create content that can be presented in different ways (for example simpler layout) without losing information or structure
   1.4 Make it easier for users to see and hear content including separating foreground from background
2. **Operable**
   2.1 Make all functionalities available from a keyboard.
   2.2 Give users enough time to read and use content.
   2.3 Avoid designing content in a way that may cause seizures.
   2.4 Provide ways to help users navigate, find content, and determine where they are.
3. **Understandable**

3.1 Make text content readable and understandable.
3.2 Make Web pages appear and operate in predictable ways.
3.3 Help users avoid and correct mistakes.
4. **Robust** (consistency, inter-operability)
Maximize compatibility with current and future user agents, including assistive technologies.

Fig. 1. WCAG 2.0 Guidelines - Source W3C

To overcome problems of navigation via screen reader and interaction via keyboard, the Web Accessibility Initiative (WAI) group of the World Wide Web Consortium developed ARIA, the Accessible Rich Internet Applications (WAI-ARIA) Suite (W3C, ARIA), which enhances usability and accessibility for the blind. ARIA makes dynamic content such as AJAX (Asynchronous JavaScript and XML), (X)HTML and related technologies more accessible to the disabled, especially people interacting via screen reader and keyboard (W3C, ARIA).
We do not discuss the WCAG 2.0 Guidelines in detail, as they are available online (W3C, WCAG 2.0). Each guideline is general and can be applied to more than one element. To conform to WCAG 2.0, developers should refer to the "Techniques for WCAG 2.0" document, which contains techniques and failures grouped in general (applicable to any technology) and specific (i.e. Plain Text, (X)HTML, CSS Client/Server-side Scripting, SMIL, ARIA) Techniques.

3.2. Accessible Rich Internet Applications

As discussed in the ARIA best practices document (W3C, ARIA), ARIA offers the following advantages for navigation via screen reader:

- Quicker and easier page navigation. Using standard (X)HTML code, blind users are forced to press the Tab key many times to access active elements (e.g. form elements, links). To simplify interaction and allow easy jumping to main interface regions, developers usually create a link to the main content or use heading levels to structure the page (since the screen reader has a command for showing a table of headings). However, headings have a different purpose and their use to mark sections is not consistent across web sites (W3C, ARIA). Instead, ARIA allows marking sections with standard specifying XHTML landmarks (main, navigation, search, banner, contentinfo, etc.) or defining customized regions, if they do not appropriately reflect the aim of the region (e.g.: <div role="main" title="Chemistry Experiments">).
- using landmarks/regions the user is able to get a page overview ("Ctrl+Ins+;" command in JAWS v.10). This also allows simplifying navigation via keyboard since the user may jump from one region to the next by pressing a key (in JAWS v.10 the ";").
  Furthermore, the developer using the attribute "flowto" defines the order in which regions should be visited. For example <div role="region" title="Chemistry Lab" flowto="Exercises" >
- reduces user overload, since it is possible to select sections be announced (reducing the amount of unnecessary text announced). Specifically, the use of an (X)HTML element (such as a table) as layout may be silently ignored by the screen reader if it is tagged with the presentation role.

4. Related Work

In recent years e-Learning has become an important research topic. E-Learning is a great opportunity for visually-disabled people, provided that both the interactive environment (created by the LMS) and the learning objects are properly designed and delivered.
Numerous user studies suggest that totally blind people encounter more difficulty than those with other sensorial disabilities (e.g., low vision, motor or hearing impairments) when executing specific tasks (Petrie et al., 2004), (Craven & Brophy 2003), (Ivory et al., 2004). Petrie et al. (Petrie et al., 2004) presented the results of accessibility testing of 100 websites with users who had either visual, motor or perceptual disabilities, showing that websites that are accessible for differently-abled users can also be visually pleasing. Specifically, 100 websites spread out over five sectors were tested with automated verification and user testing, involving 51 differently-abled users, 10 of whom were totally blind. Results showed a mean task success rate of 76% that fell to 53% (the lowest score of all the user categories) when considering only the totally blind. Likewise, regarding user satisfaction, the authors recorded that the blind users encountered more difficulty than other differently-abled users (4.2 on a 1-7 Likert scale, the lowest score of all the user categories). Researchers at Manchester Metropolitan University (Craven & Brophy 2003) highlighted issues of non-visual access by studying a sample of blind and visually-impaired users who performed four information-seeking tasks, including the use of search engines. Visually-impaired users searching the Web for a specific piece of information took an average of 2.5 times longer than sighted users. The efficiency gap was further quantified by Ivory et al. (Ivory et al., 2004); when blind subjects carried out a set of tasks, they took twice as long as sighted users to explore search results and three times as long to explore the corresponding web pages.
An interesting study on improving interaction for the blind was proposed by Leuthold et al. (Leuthold et al., 2008) who defined nine specific guidelines for building "enhanced text user interfaces" (ETI). With a user test involving 39 blind users, authors evaluated efficiency, errors and user satisfaction of a web UI developed according to ETI guidelines with respect to WCAG 1.0-compliant GUIs. Results showed that ETI guidelines enhanced experience for the blind in the search task while a similar result was not found in the navigation task. However, authors did not provide users with a page overview, the main feature for orienting and guiding users in the navigation.
Today developers use two strategies for enhancing interaction via screen reader: (1) inserting a link to skip at the main content and (2) using heading levels to provide an interface overview. Heading levels improve interaction since screen readers have special commands for showing the headings list (f.i. Insert+F6 JAWS command) and moving from one heading to another. Brudvik et al. present an interesting study on how sighted users associate headings with a web page, observing very different results depending on factors such as whether the page has a hierarchic structure, how users identify sections, etc. (Brudvik et al., 2008). Furthermore, authors applied techniques of information retrieval (i.e. training data and a classifier), developing a system for automatically inferring from the context (font, size, color, surrounding text, etc.) whether a phrase "works semantically" (and may function) as a heading, and dynamically adds the heading level using Javascript. The system called HeadingHunter was evaluated using human-labeled headings gathered from the study and showed high precision (0.92 with 1 the max). However today ARIA may perform the same functions (i.e. structuring the interface for a page overview and rapid

section navigation) allowing a kind of inter-website coherence, if standard landmarks are applied in different websites (see section 3.2).

Despite numerous accessibility and usability studies, even today various researchers perceive the lack of accurate studies in the e-Learning field (Ardito et al. 2006), (Zaharias 2006), (Kelly et al., 2005). Specifically, Ardito et al. outlines a methodology for the rigorous evaluation of e-Learning applications, but accessibility for special-needs students is not analyzed. Furthermore, Zaharias critically examined the usability of e-Learning applications and proposed a new usability measure: the student's intrinsic motivation to learn. Developing a usability evaluation method based on a questionnaire, he carried out two large empirical studies showing the reliability of this approach (Zaharias 2006). For Sloan et al. the goal of universal accessibility on the Web is inappropriate and instead it is necessary to explore multiple routes to provide equivalent experiences (Sloan et al., 2006). As Kelly et al. argued, rather than demanding that an individual learning resource be universally accessible, it is the learning outcome that needs to be accessible (Kelly et al., 2005). Based on user profiles, metadata and dynamic connection to resources, the user's experience can be customized to match his/her abilities.

De Marsico et al. (De Marsico et al. 2006) defined methodological guidelines involving users with disabilities as well as pedagogical experts in the development process, believing that input of different kinds of know-how would enrich the quality of e-Learning applications and provide a more satisfying learning experience. They also include two examples of building and providing learning objects that are accessible to visually- and hearing-impaired students respectively.

Rodriguez et al. describe a project aimed at improving the e-Learning experience for the visually impaired, based on ethnomethodology and taking into account psychosocial issues, user context and experience (Rodriguez et al., 2006). Next they created different learning object formats suitable for the blind, including DAISY (Digital Accessible Information SYstem). However, although the authors describe the methodology used to improve learning materials, no general guidelines are offered to the reader.

Within the framework of a project aimed at providing an accessible e-Learning platform for disabled and adult learners, Santos et al. (Santos et al. 2007) illustrate a methodology for developing standard-based accessible courses using two-step evaluations. However for the totally blind, more specific UI features are necessary, such as providing a page overview, full control of interface elements and easy and rapid navigation via keyboard.

Furthermore, the rapid evolution of communication technologies has also led to the widespread diffusion of mobile devices (especially cell phones) in developing countries. For this reason mobile learning (m-Learning) promises to help narrow the educational digital divide in rural or economically depressed areas. M-learning denotes the use of learning systems from mobile devices which have reduced resources such as screen, keyboard, and connectivity bandwidth. Debevc et al. (Debevc et al., 2008) provided basic guidelines for designing and structuring accessible m-Learning applications for people with special needs (including the blind), taking into account basic human-computer interaction factors. Arrigo et al. describe a mobile learning environment, AMobiLe, designed for social integration as well as collaborative learning among all students regardless of type of disability. The authors argued that it is necessary to take a broader view of communicative and social needs as well as consider the overall capacities and knowledge of disabled users instead of only focusing on technological barriers and assistive technology (Arrigo et al. 2008). Last, Glavinić and Granić investigated the adaptivity of knowledge representation, interaction style and mobility support within the framework of an e-Learning research project, including usability evaluation methods, techniques and results. The main hypothesis of this work is that intelligent interaction as an adaptation to users' individual characteristics and needs, as experienced through her/his behavior during interaction, can lead to a more efficient, effective and humane ICT-supported education (Glavinić & Granić 2008).

5. Accessibility and Usability of e-Learning systems

The e-Learning system itself as well as the content should be adapted to the users' abilities.
Pedagogically speaking, we should remember that the learning process itself is the main focus of e-Learning-based education methodology. Students should be able to concentrate on content and educational activities. If system components are suited to the user's capabilities, difficulties interacting with the virtual environment can impact on student performance.
An e-Learning environment basically consists of: (I) the integrated system (i.e. the container, which provides the content and interactive activities) and (II) the Learning Object (LO) - the educational content provided through the e-Learning interactive systems.
Consequently, when designing an e-Learning environment two important aspects should be kept in mind:

- Accessibility and usability of the system, i.e. the "container" providing content and activities for the participants should be easy to use
- Accessibility and usability of content, that is the texts, documents and interactive tools used for didactic purposes should be created according to the various users' abilities.

If either of these two aspects is unavailable, interactive distance education methodology is ineffective for people who must interact using assistive technology. This is particularly significant for blind users who interact by screen reader.

5.1 Learning Management Systems

A Learning Management System (or LMS) is a software package that enables the management and delivery of on-line content to learners. Most LMSs are web-based to facilitate "anytime, anyplace, any pace" access to learning content and administration. Typically an LMS provides student registration, access to learning activities, and evaluation and assessment in an on-line environment. Both commercial and free platforms are developed. Open source and Web-based LMS software solutions are growing rapidly in the education and business worlds, offering:

- Quality, thanks to the collaborative effort of many people in designing, developing and maintaining the system
- Use of standards and thus interoperability
- Portability in different platforms.

In addition to managing the administrative functions of on-line learning, Learning Management Systems also provide tools for delivering instructor-led synchronous and asynchronous on-line training (Learning Content Management Systems). An LCMS provides tools for authoring content as well as virtual spaces for learner interaction (such as discussion forums and live chat rooms).

Often, when considering accessibility issues only disabled students are considered, and only LMSs are taken into account. Instead, people with disabilities may also be teachers, who must be able to create and manage the materials used in distance courses. Thus LCMS authoring functionalities should also be accessible to and usable by assistive technologies. In the following we discuss accessibility and usability features referring to both kinds of platforms (LMS and LCMS).

Since the user interface of an e-Learning system is usually based on Web technologies, at first glance it may appear sufficient to apply web accessibility guidelines. Actually, regarding the most widespread e-Learning platforms, some considerations can be made concerning technical aspects:

- Student tracking: provides information about individual use patterns of the participating students. Scorm-based platforms use javascript technologies for tracking activities. Since most e-Learning systems – such as Moodle (http://moodle.org/), aTutor (http://www.atutor.ca/), and so on – are scorm-based (implemented with javascript), the use of ARIA is thus crucial to assure the accessibility of these systems.
- Hidden frames: several e-Learning platforms use hidden frames for storing data to communicate to the Web server. Although according to usability principles frames should not be used, appropriate design suggests using a few hidden frames and positioning them after the frames containing the learning objects. In order to further simplify interaction, it is useful to give appropriate names to all the frames.

5.2 Learning Objects

A Learning Object (LO) may be defined as any entity, digital or non-digital, that can be used for learning, education or training (IEEE/LTSC). A Learning Object can be as small as a paragraph or as large as a complete online course and come in the form of HTML/Text files, simulations, JAVA, Flash, QuickTime movies etc. Depending on the format and complexity of an LO, guidelines and principles should be applied to make them accessible and usable as well.

Apart from technical accessibility, we think that another issue should be considered when developing a Learning Object. Since the main goal of e-Learning methodology is education, a LO should be designed to best exploit the user's abilities. For instance, for a sighted child an image or animation is probably more effective than a descriptive LO whereas for a blind child an audio object is much more effective than a textual one. Thus, the way a Learning Object is designed and structured is very important. In this case it could be made more effective by using different LOs for different users' abilities and skills. Further study is needed to define the best approach for developing accessible and usable LOs.

Moreover, we believe that most difficulties arise from simulation activities. Simulation systems and LOs can present various technical accessibility problems, and a target study in this direction could prove useful.

6. Application domain: Design principles

For blind users to benefit fully from distance education in a collaborative and cooperative manner, e-Learning systems must be made both accessible and usable. Both the interactive environment and the educational materials must be adequately developed, so appropriate guidelines, requirements and suggestions should drive the design phase.

The main objectives of the accessibility and usability principles contextualised for e-Learning are (1) to remove or minimize the potential negative effects deriving from interaction with the UIs through assistive technologies, to avoid compromising the learning process and (2) simplify user interaction.

6.1 Requirements

First of all, the designer should keep in mind how blind users interact with the system: that is, via screen reader and with a keyboard. These interaction modalities mean that various issues should be considered when developing and structuring interfaces and content. Furthermore, in order to move quickly around the page content, a blind person prefers to use the Tab key to jump from one interactive element to another, rather than explore content via arrow keys.

Objective difficulties can be reduced or eliminated by presenting the same content in aural form and providing multiple ways to navigate faster. To guarantee better navigation around the content, the interface and functionalities should be developed so that user interaction is simplified or minimized. Thus, some information could be provided automatically in aural format so that the screen reader is informed about the UI changes. Audio or vocal feedback, as well as the new ARIA suite, could improve perception of some announcements or messages. Particular attention should be paid to multimedia content and interactive activities (e.g. exercises, collaborative work, editing, and so on). Generally speaking, accessibility and usability principles aim to ensure that the content and all didactic tools are also available for students who are obliged to interact via screen reader.

The following principles attempt to be as general as possible, i.e. applicable to both systems and content. However, since Learning Objects can be prepared using several modalities and techniques and can refer to various kinds of materials they may require specific analyses and targeted criteria. Proposed criteria only express general principles; to provide more specific indications, further studies and evaluations should be conducted.

6.2 Basic general principles

In the following, we first discuss the main interaction properties, then we suggest some general principles, taking into account the main features that an e-Learning system should have. However, specific and more detailed criteria can be provided in order to define certain important issues precisely.

6.2.1 Interface Overview

The first problem is that the blind person does not perceive the overall structure of the interface, so they can navigate for a long time without finding the most relevant content. To reduce this gap, the UI (source code) should be structured defining logical sections of the interface so that the screen reader is able to provide this overview. For web-based systems or Learning Objects, defining logical sections and/or areas of the interface can meaningfully increase usability. For instance, by using ARIA regions the UI can be split into several content areas that can be explored quickly. This approach can improve interface structure perception.

Specifically, it is possible to group and structure (by landmarks) sets of homogenous text and elements in order to give the user the idea of the interface immediately, and enable him to jump rapidly from one section to another. Landmark tags, if appropriately applied, are particularly useful since they are captured by screen reader and listed as an index, helping the user to "navigate" the areas of the interface (see section 3.2).

6.2.2 Order of Content Blocks

Main content should be placed at the beginning of the interface in order to facilitate sequential reading. Indeed, the position of the most important content is crucial for a blind user who usually wants to explore the least amount of information necessary. ARIA attributes can affect the order of the content blocks. Navigation of the container may become an obstacle to learning, so it is very important to place the most important element of the interface at the top of the content read by screen reader in order to access relevant content quickly. Instead, the graphical interface must conform to the usual HCI criteria, arranging the content in a more appropriate way for visual elaboration. For instance it is possible to change the order of the <div> block (corresponding to the main content) in the HTML source code, by using "absolute position" in the CSS styles.

6.2.3 Rapid Comprehension of the Most Important Events

When certain basic events occur, such as positive or negative responses, a specific mechanism for immediately informing the user should be applied. In this sense, aural feedback is very useful for blind users since it associates a specific sound with a given situation (e.g. different tones may be associated with the success or failure of an operation) and simplifies interaction with form control elements.

A similar approach should also be used for other important events, such as when specific portions of the page change due to various operations or updates. ARIA specifications can overcome this kind of issue.

The designer may include these features in the e-Learning system interfaces, adding tones in some cases, or implementing appropriate ajax/javascript functions exploiting ARIA functionalities (e.g. role attributes etc.).

Some examples of when aural feedback – i.e. short sounds or brief messages -- could be applied:

- When the interactive form elements (edit field, radio button, or checkbox) receive the focus
- When a lesson module is finished or a new module is started
- When a new user joins a forum or a new message is added.

In other cases, ARIA properties can be more effective than a short sound or message. Here are some examples:

- To immediately inform the user of the success or failure of an operation (for instance the result of a self-assessment)
- To read a new message added to the forum community, the virtual class, the chat room, etc.
- To announce content portions changing due to user interaction (e.g. when expanding items or carrying out certain operations which give out different contents according to the user's choice.

6.2.4 Simple Keyboard Interaction

Interaction with the system via keyboard is simplified if shortcuts and navigation by Tab key are provided in order to jump directly to the most important elements or parts of the interface.

- Access keys must be associated with the most important interface elements or functionalities offering a simple shortcut to the desired point (e.g. skip to the beginning of module, go to course index, move on evaluation assessment, etc.).
- Tab index defines an order for visiting UI elements (e.g. links, objects). In this way, the order of "importance" associated with each element of the interface (i.e. the value of the tab access attribute) "drives" the user's navigation by Tab key. A lower tabindex value indicates greater importance. A tabindex value of -1 enables the element to receive the focus programmatically (e.g. via JavaScript). This is used to enable arrow key navigation to elements (ARIA BP).

6.2.5 Multimedia

Multimedia objects are frequently used in e-Learning systems. Indeed, a multimedia object can deliver visually some useful information for learning and understanding specific concepts. Learning Objects (LOs) are increasingly designed using visual and audio modalities. In addition, other important features could be only provided by a video or audio channel. Also in these cases, specific solutions should be considered to provide accessible alternatives. Several studies have been conducted on these specific topics (Ferretti et al. 2007).

Inability to access multimedia content such as video streaming, video conferencing, and captioning may be partially resolved by providing text equivalents, readable by screen reader. For example, supplementary content in an audio presentation can include the exact text presented as well as the description of relevant graphical content.

However to deal with LO accessibility, some precise experiments should be conducted before their use.

6.2.6 Advanced principles for e-Learning systems

When thinking about e-Learning systems, they are often considered as standard Web applications. Indeed, e-Learning platforms are usually Web-based. Therefore, it would seem correct to refer to accessibility and usability principles for the Web. They are suitable for general purposes and kinds of interaction, but to remove all barriers that could negatively affect the learning, specific and targeted principles are needed. Those principles do not refer only to the user interface, but also to the way content is provided to the user so that he/she can receive it in the most appropriate way. Other examples could be considered for the teachers' and tutors' side. Reports appropriately displayed and arranged can help teachers obtain a great deal of information from their students.

Some suggestions of principles for appropriate LMS for blind students and teachers are:

- **Different alternative and equivalent formats**.
  Providing alternative and equivalent contents that can be downloaded in several formats can be useful in several ways. Although not all content can be provided in audio format, at least the main core should be considered. For instance, the content available in text or

html format could also be provided in audio (mp3) format so that it can be listened to using portable mp3 readers or mobile devices.

- **Getting portions of contents**.
  It would be useful to be able to select parts of the content so that they can be extracted and read in different ways. For instance, a student could simply store the selected content so that it can be read very quickly at a later date. In practice, this function allows creation of content by assembling a choice of parts. This might prove very useful when studying or reviewing lessons very quickly. On the other hand, the selected content could be converted into different formats in order to obtain them via other tools and modalities. For instance, parts of selected content could be converted into audio / mp3 formats (as mentioned in the previous point) and it could be read using another software program instead of a text editor. This would allow blind users to use the preferred modality when studying or reading important content.
- **Annotating tools**.
  Another important and useful function would be annotating as well as commenting on content using either voice or written text. Other useful functions could be underlining or highlighting functions, which are similar to using a paper-based format. In order to make these functions useful for blind students, they should be arranged not only to be read visually, but an alternative way should also be available. For example, the user might decide to select a sentence or an entire paragraph. Next, when he/she wants to read the underlined or highlighted contents, a function showing or extracting only those parts would be very useful.
- **Customizable services for content delivery**.
  When adding or modifying content in the LMS, a service informing the users on the updates should be available. This kind of service can increase performance in obtaining new content for blind students or teachers. For instance, RSS (Really Simple Syndication) feed could be one way to inform users.
- **Equivalent alternative concepts**.
  Some content is provided in a graphical or schematic way, and using alternative descriptions may not be enough to deliver the same educational concept. In fact, for educational purposes, some concepts are too difficult to describe solely by means of written text. For instance, if three colored circles – containing a lot of information – are used to illustrate the concept of interconnected/intersected contents, a short description like "three intersected colored circles" is not enough to express the same concept. Another example is an exercise whose goal is recognizing an animal. In this case the alternative description with the name of the animal cannot be used, since the goal of the exercise itself involves naming the animal thus defeating the educational purpose. For cases like these an alternative technique is needed. For instance in the latter example a description could be given of the animal's features (such as genre, family, colors, size,…). In other words, different ways can be found to provide the same meaning for blind users.

7. Examples

As a case study, we refer to two application domain examples: LMSs and wikis. The first example was tracked by analyzing a demo course of Moodle (Buzzi et al. 2009a), and the second was derived from a study regarding Wikipedia, the on-line encyclopedia (Buzzi et al. 2009b).

7.1 Interaction via screen reader: a Moodle Demo course

To show the complexity of interaction via screen reader with a Virtual Learning Environment (VLE), we refer to a study on Moodle (Buzzi et al. 2009a), a popular Open Source LMS., which offers a rich VLE (http://www.moodle.org). The system administrator may enable one or more modules between: assignment modules, Blogs, Chat, Course resources (Moodle pages, uploaded files or web links), Databases, Forums, Glossaries, Interaction, Lessons, SCORM packages, Surveys, Quiz module, Wikis and Workshops. This articulate environment may create difficulties in interaction via screen readers.
To provide an example of interaction we chose the Moodle demo course: the "Higher Education Film Studies Module" (Fig. 2, left side).

Heading level 2 Topic outline
Summary: Layout table
table with 3 columns and 18 rows
Heading level 2 Out of the Digital Dungeon: Exploring Gender and Technology in …
list of 15 items
All Art work on this Course Page: Alex...
...
This topic 1
list of 9 items
Heading level 2 Getting Started
...
Heading level 4 Ice Breaker Activity
...
2
list of 15 items
Heading level 2 Genres, Gender … in context
Art work: Alex Ronald, Judge Dredd & 2000 AD Copyright © Rebellion A/S 2004. All Rights Reserved.
...
8
Heading level 2 **Learning Support Space**
...
Heading level 4 **Continued Support for your** ...
…
List end
...
Table end
Heading level 2 **Online Users**
...
Heading level 2 Activities
Link **Chats**
Link **Choices**
...

Fig. 2. Moodle demo Course: UI (left side), content announced by JAWS (right side) – Source http://demo.moodle.org/

Uploading this course, various elements are detected by JAWS: headings, images, layout table, links. In specific, 32 headings are announced, too numerous to be navigated comfortably. By exploring the heading list (Insert+F6 command) we note that most of them refer to the course, but others are related to the e-Learning tools (e.g. chat, blog, and so on), without any clear separation: the main regions: "menu", "topic outline" and "interacting actions" should be better indicated.
Although headings are used, the page is still too long to be read by keyboard via screen reader, and the use of customized ARIA regions might improve course usability.
To show the Topic outline a table has been used for the layout. Specifically two tables are used, the second nested in the first cell of the first table, but JAWS announces only one table. Although headings are used to split the long content, a table should not be used for the rendering. Moreover, the "summary" attribute of the table is "table layout", totally useless. A more appropriate summary value could be "table of contents"; in this way, by just pressing the letter "t" JAWS will announce immediately "Table of contents". If a layout table is used, at least a meaningful summary should be applied.
Furthermore, the page structure is unclear: it is difficult to understand how many modules compose the course, their titles and contents since the module number has not been included within the <Hn> tag so it does not appear in the headings lists. Thus to obtain this information the user must read the page sequentially. Figure 2 (right side) shows the page content as it is interpreted by the JAWS screen reader.
Although the pages appear to be accessible, our initial testing shows some usability issues: difficulty orienting oneself among different information (i.e. headings and links), as well as in handling conceptual information.

7.2. Application domains and specific guidelines: Wikipedia

To provide an example of guidelines for a specific LMS component, we recall results of a previous study that analyzes accessibility and usability of wiki systems for the blind (Buzzi et al. 2009b). Although these guidelines were derived from studying Wikipedia (see Fig. 3), they are general and thus apply to all Wikis.

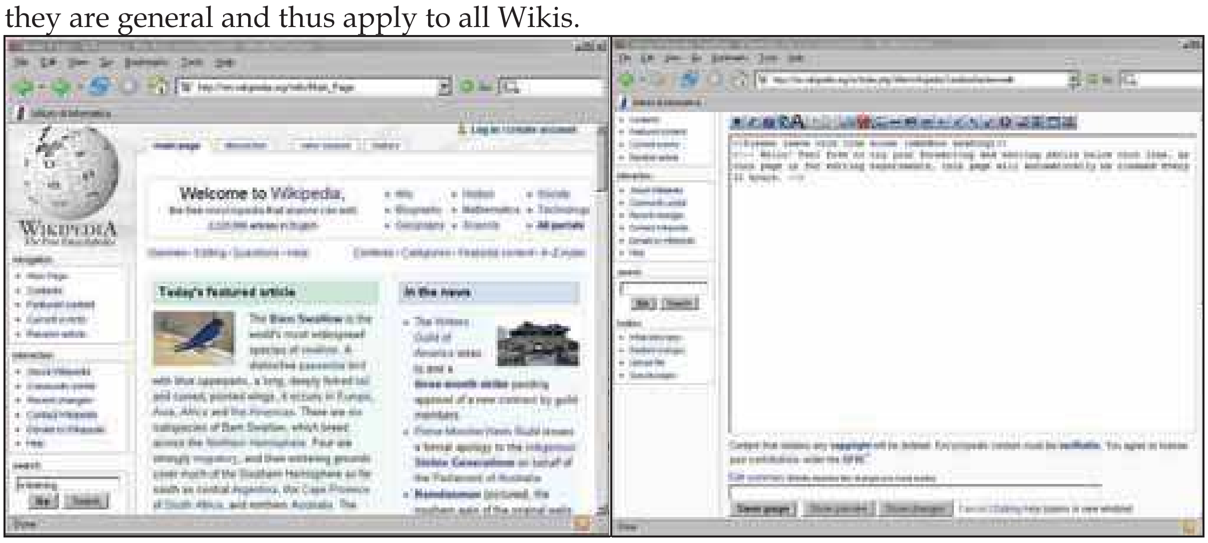


Fig. 3. – The Wikipedia Home (left side) and Editing Pages (right side) – Source http://en.wikipedia.org/

Based on the main difficulties observed when navigating through the search, result and editing functions, we suggest several elements that should be kept in mind when designing a Wiki interface:

- **Make it easy to identify the separate content parts.**

Usually a wiki page is split into several logical sections: navigation bar, header, footer, main content, etc. Each area should be clearly identifiable, both visually and via screen reader, offering a blind user a rapid overview of the main macro topics available on the page (using ARIA landmarks and regions).

- **Make the search box clearly and quickly identifiable.**

The search function is one of the most important features of a portal, so it is essential to find it very easily. Search edit field and buttons should be located at the beginning of the logical flow of the page's main content. Its location early in the content flow should ensure that the screen reader (and thus the user) can identify that important main area almost immediately.
The search box should be easily identifiable and clear labels should be used for edit field and search buttons. Moreover, terminology on the page should be consistent.
Analyzing the Wikipedia Editing page (i.e. selecting Edit this page from the Tab panel) other specific guidelines are:

- **Keep the Editing function simple**.

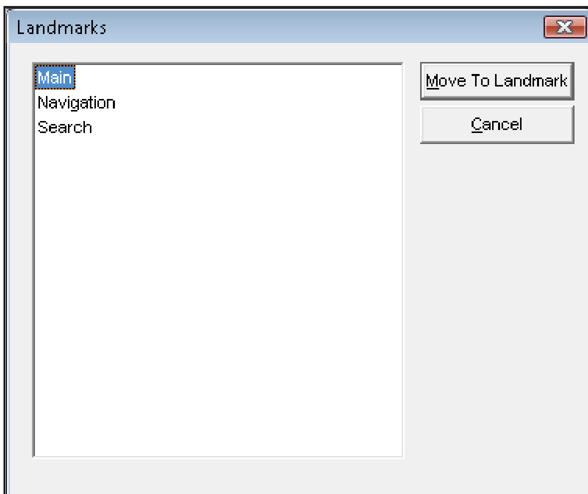
The Editing function is very important in a Wiki system, as in any collaborative environment. Consequently, the Editing commands as well as the Editing page should be easy for anyone to use, independent of the interaction modality used. We offer several suggestions regarding the Editing function:

- Use a separate page for the Editing function.
- Provide a quick way to use formatting functions via keyboard. For instance, if using a graphical toolbar make it accessible via ARIA.
- Provide an alternative textual input that could facilitate formatting for skilled users. To facilitate this modality, two possible suggestions are (1) provide a help page listing all commands with their textual alternative input modalities (2) a very similar HTML syntax could might also facilitate the input process for users who have some experience with HTML.
- Provide a simple way to insert special symbols. In the current version of Wikipedia, to insert a special character a set of over three hundred graphical links is available on the page. Concerning special symbols, two suggestions may be useful:
  - provide a quick and compact way to select a special symbol. Since a great number of links makes interaction via screen reader too difficult, a more effective way should be developed. A list on a separate Web page, or a compact combo-box containing descriptions of all available symbols, are possible solutions.
  - associate a clearer symbol description. Many special chars and symbols are not recognized by the screen reader. A descriptive text would overcome this problem; for instance 'a with circumflex accent' is clearer than the corresponding character (e.g. 'â' is announced by JAWS as 'a').
- Control the edit focus. As in the Editing procedure, the focus is very important and it is necessary to ensure that when interacting with formatting commands or choosing special symbols, the focus goes back to the editing cursor. This feature is fundamental for facilitating the Editing process when using a screen reader -- otherwise, the user

risks losing the Editing position, which makes the composing process difficult or impossible.

As an example of applying the first proposed guideline (make it easy to identify the separate content parts) the XHTML standard landmarks: main, navigation, and search have been included in the Wikipedia editing page source code, as shown in Figure 4 (Buzzi et al. 2009b).

A higher number of regions would facilitate for instance the recognition of important UI parts such as the editing box and the push buttons (save and preview). However, the last JAWS version (v. 10) is unable to detect the 'title' attribute used to customize a region, thus, at the moment, all customized regions are announced by JAWS as 'Region'. This instead of facilitating interaction might make structure unclear and confuse the user. For this reason, at this time we defined only the three XHTML standard landmarks: main, navigation, and search.




```
…
<div role="main" id="main" title="Editing Page"
aria-labelledby="hdr1">
<label title="Editing page"   class="hide">Editing
page</label>
…
<div id="bodyContent">
…
<div role="navigation" id="navigation">
<label title="navigation area"
class="hide">Navigation area</label>
…
<div role="search" id="search" >
<label title="Search Box" class="hide">Search
Box</label>
…
```

Fig. 4. Aria Landmarks of the Modified Wikipedia Editing Page: on the left the landmark lists generated by JAWS, on the right an extract of the HTML code

8. Conclusion

In recent years e-Learning has become increasingly popular, with benefits such as saving time and travel for students and teachers living far from schools or universities, and reduced traffic and environment pollution. Adult education, language teaching, and lifelong learning also profit from the opportunities offered by e-Learning.

Designing e-Learning systems, preparing electronic materials in an appropriate way, and providing content suitable for all end users is a complex task, since three factors must be taken into consideration: usability, accessibility, and educational effectiveness. The challenge is to create a system simple to understand, and quick and easy to use, that delivers effective educational content in multiple formats according to user ability.

E-Learning systems pose new challenges with respect to classic user-centered product design, where the target is a set of homogeneous users. Learner-centered design must fulfil the needs of multiple learner categories with different learning strategies, know-how, experiences, motivation to learn and, not least, user age and ability. If appropriately

designed and implemented, e-Learning systems are more effective and useful than classroom learning (Debevc et al., 2007).
It is important to notice that LMSs can greatly favor the student learning process since the same educational material may be transmitted anywhere, anytime, at any learning rhythm, in a format suited to each individual's ability. On the other hand, since LMSs automatically add a virtual environment to the educational material, if the virtual environment layout is not appropriately designed with a thorough knowledge of accessibility and usability issues, it may induce problems that could spread to the learning objects themselves. This highlights the importance of considering usability issues from the very beginning of LMS development.
Making a virtual learning environment suitable for the abilities and skills of all users offers many challenges. When defining the graphical UI it is fundamental to consider the needs of sighted users, but the needs of blind students should also be kept in mind when writing the UI code. Specifically, the same educational content should be provided through both visual and auditory channels, the design should be optimized for reading via screen reader, the UIs should be easy to use via keyboard and no additional cognitive effort should be required of the blind user.
As technologies evolve new techniques, and standards for assuring quality of the interaction are appearing such as the Accessible Rich Internet Application suite, which enhances usability for the blind in any web-based Virtual Learning Environment. Designers and analysts must be aware of problems of impaired perception, interaction via screen reader, and technological barriers and must know how to apply techniques and standards practically to ensure the quality of the interaction. This requires knowing and sharing best practices that are more accessible than ever today, also thanks to social networks which promote and facilitate human-to-human interaction.
In this chapter we highlighted basic and general accessibility and usability principles for interaction via screen reader when designing e-Learning systems. Future research should focus on analyzing specific Learning Object technologies, showing examples of cases. Another point that deserves special attention is the study of textual-alternative description of multimedia and dynamic contents that are educationally equivalent. This requires a synergic approach involving technical as well as educational experts.
Equal access for all is the basis of our knowledge society. The European Union, with its Communication "Towards an accessible information society" [EU COM, 2008], aims to stimulate Member States to make public websites accessible to and usable by everyone by 2010.

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