Understanding users with reading disabilities or reduced vision: towards a universal design of an auditory, location-aware museum guide

L Pareto and U Lundh Snis

Laboratory for Interaction Technology, University West
P.O Box 795, SE-45126 Uddevalla, SWEDEN

lena.pareto@hv.se, *ulrika.snis@hv.se*

ABSTRACT

We present ongoing work on the design of an information system for users with reading disabilities and users with reduced vision. The design target is a portable, auditory, location-aware information system, to complement visually displayed information in exhibitions. Applying a user-centred, we identify non-typical user-groups' specific requirements, which are turned into a design. The first design-iteration, which includes a formative evaluation, using a mock-up prototype, with dyslectic and visually impaired participants, is completed. The evaluation indicates that the user-group's specific aspects we have identified are relevant, while designing for these groups.

1. INTRODUCTION

Many public places are information intense with several, sometimes large, displays of various kinds, e.g., museums, libraries, train stations, and airports. Information in such environments is not accessible to people with *reading disabilities* (people with minor comprehension disabilities, and dyslexics) or *reduced vision* (elderly people, and people that are visually impaired). According to the International Dyslexia association (International Dyslexia Association, online) 15% of the US population has a reading disability; according to the American Foundation for the Blind (American Foundation for the Blind, online), 2-4 % of the US population is blind or visually impaired. The National board of Statistics in Sweden reports 8-10% of the Swedish population to be diagnosed as dyslexics and 1-2% as visually impaired (Statistics Sweden, online).

This paper takes the point of departure from the design of information systems for these two groups. The two user groups have distinct needs both with respect to *information content* and with respect to the *technical device* providing the information; to design a usable system we must investigate these needs and understand which implication they have on the design. Although their respective needs are different, both groups benefit from having auditory information compensating, augmenting or complementing visual information.

Rather than solely providing assistive technology solutions (Liffick, 2003), the aim ought to be on *universal* design solutions according to Schneiderman (2000) and Law et al, (2005). Mainstream products with universal usability are attractive to a larger population and therefore more cost-effective, an important aspect for most organisations. In alignment with this reasoning, we argue that a suitable strategy for approaching universal design solutions is to identify non-typical user groups and to focus on their respective needs in the design process, without excluding the rest of the population as potential users of the designed system. Hence, we will focus on two non-typical user groups during the design, i.e. people with reading disabilities or reduced vision, respectively, but the aim is to provide auditory complement to visual information for hearing individuals in general.

The case we consider in this work is an auditory museum guide, dedicated to our two user groups. The case study was carried out in collaboration with a regional museum in Sweden, with exhibits reflecting the local culture, local handicraft and artworks. Most exhibits are organized around visual objects accompanied by displays of text. Objects and information is distributed over several rooms and floors. The typical visitor wanders around and experience objects as they appear along the route. The information is distributed (scattered around) and often tied to the location where it occurs. Typically, a person wanders around in the museum; the actual situation triggers the desire for information. Therefore, we are considering portable, context-dependent devices, which provide auditory information to the user at the location, when desired − just as visual displays do. Information systems of this kind need to be location-aware, as well as interactive.

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The purpose of this paper is to support the design of systems involving portable, auditory, context dependent information devices to be used by people with reading disabilities or reduced vision. We do this by

- Identifying aspects which are relevant for our respective user groups, and specific to these.
- Eliciting system requirements guided by these aspects for a particular case. (A museum system.)
- Turning these requirements into a conceptual design.
- Evaluating the design with representatives from both our user-groups.

2. UNDERSTANDING THE USER GROUPS

The get a better understanding of the users groups, we undertook the following: We studied literature about dyslexia and visual impairments. We visited a school for adult dyslexics, to perform interviews with the teachers. (To involve knowledgeable persons from communities around a user group—a method discussed in Sullivan and McGrenere (2003)—is often a more effective way to get general information about a group rather than to involve users.) The interviewed teachers' experience, collected during 14 years of teaching, gave valuable information of common problems among dyslexics and insights into methods and equipment used. We interviewed a woman with severe dyslexia who also has a dyslectic son. We contacted the national organization of visually impaired in Sweden (National Association of visually impaired, online), and interviewed the chair of the organization, who also works with rehabilitation of visually impaired people.

2.1 Reading Disabilities

Of the population with reading disabilities, 85% has what is called dyslexia (International Dyslexia Association, online). Dyslexia is a language processing disorder with many different symptoms and combinations of symptoms. Some dyslexics have problems translating language to thought (i.e. reading or listening), others translating thought to language (i.e. writing or talking), yet others have problems with both. Dyslexia is characterized by inefficient information processing. This includes difficulties with phonological processing, the working memory, rapid naming and with automation of basic skills. Contrary to an occasional misconception, it is not a problem of vision: people with dyslexia do not "see backwards". The symptoms for each individual vary, but there are common symptoms related to reading or listening: lack of awareness of sounds in words; difficulties with decoding words,; difficulties with sequences of letters (left-felt); problems with reading comprehension; confusion about directions in space; imprecise or incomplete interpretation of spoken language (International Dyslexia Association, online; Ross-Kidder, online).

Language processing in any form requires an effort for most dyslexics. Many have problems retaining the contextual information while reading or listening. Therefore, material is only comprehensible if it consists of short sentences in short paragraphs. Meta constructs in languages such as metaphors or irony adds a layer of interpretation—as the text cannot be understood literally—further reducing comprehensiveness.

Many dyslexics perceive audio-books and other auditory material as more comprehensible than texts. In auditory material there are distinct pauses between paragraphs, and sometimes relaxing music to indicate and stimulate pause and rest for the listener. Many, however, have problems interpreting auditory material too: specialized tape-recorders with additional controls to change the speed of the narrated text, controls for treble and bass and a button for pause are sometimes used by dyslexics. Since the language processing is demanding and the phonetic interpretation is less clear for many dyslexics, it is harder for dyslexics to mask out the desirable information from the surrounding noise. To some dyslexics, background noise and conflicting sources of sound is very disturbing.

2.2 Reduced Vision

There are many variations of reduced vision, with diverse effects on how the viewer experiences the target. Reduced vision can have effects such as seeing a blurry picture, seeing a grey spot while trying to focus (but clear and sharp around it), seeing only light and dark, or seeing the world through a small camera (reduced area of vision) (National Association of visually impaired, online; Tiresias, online).

Some visually impaired have experienced a normal vision earlier in life, whereas some are born with their impairment. To compensate for a reduced function, humans tend to take advantage of other senses more effectively than others. People with reduced vision can compensate their lack of seeing by developing their listening skills and by using their hands to "see with", for instance. Blind or almost blind people use their hearing to a much greater extent than seeing people do, which indicate that they are trained listeners.

Visual impairment is used as an umbrella term to describe a broad spectrum of individuals and abilities, and particular attributes of a person's disability will make assistive solutions more or less appropriate (Fraser, and Gutwin, 2000). For instance, magnifying is not appropriate for users with limited field of view; change of colour or high contrast is helpful for some types of impairment, but not all; people who retain central vision have other needs than people with limited central vision do. However, complementary auditory information ought to be beneficial for most users with reduced vision, unless they also suffer from reduced hearing. Since many elderly people suffer from both, it is important to make the auditory device compatible with hearing aids.

3. REQUIREMENTS ON AN AUDITORY INFORMATION SYSTEM SUPPORTING BOTH USER GROUPS

Our approach is to study needs and derive requirements from non-typical user groups, as a strategy to achieve more universal, mainstream products. Therefore, we continue by analysing the user groups' respective needs and how these can be combined into one solution. As a result of our user studies, we have identified the following requirements on information systems for users with reading disabilities or reduced vision. The requirements are organized in technology requirements and information requirements.

3.1 Requirements on the Technology:

Since a reading disability often originates in a language processing deficit, functionality that supports these users' language comprehension processes should be provided. The ability to alter the narration speed of speech is important. Due to problems of discriminating sounds within words, dyslexics are often more sensitive to the level of treble and bass, so these parameters ought to be controllable. The possibility to pause is necessary. Possibility to repeat the last sentence (i.e., to back up a semantic unit, rather than a time unit) is desirable. As background noise is an issue for many dyslexics, it should be possible to filter out conflicting sources of sound by, for instance, using isolating headphones.

Users with reduced vision are often accustomed to technical aids, since many depend on these for their everyday activities. Possibility to receive human assistance is considered important among visually impaired. The device's controls should be operable without visual attention: this may be achieved by tactilely distinguishable controls (for instance buttons with relief-symbols), or by auditory feedback when operating the controls. Since users may carry a blind stick or use the other hand for it should be possible to operate the device with one hand only. Users with reduced vision are likely to be accompanied by others, so social interaction is likely to co-occur and must be supported. If headphones are used, they should be compatible with hearing aids, and allow for social interaction.

Differences between the two groups include the ability to hear and comprehend auditory information, and the ability to handle simultaneous sources of sound. This can be solved by providing different alternative sound transmission devices (e.g., headphone, speakers) allowing for private, immersive reception of the information, as well as reception in a more social setting.

Only minimal functionality should be considered when designing for disabled according to Dickinson et al, (2003). Necessary functionality for this system is to provide context-dependent, appropriate information to the user, when the user wants to hear it. The system must provide the possibility to interact with the information (pause, stop, forward, backward, control speed, and perhaps repeat the last sentence, and change treble or bass). The device should be robust, context-sensitive, discrete, and have controls distinguishable with reduced vision (tactilely or with auditory feedback), which is a feature often appreciated even for seeing users. It must allow for listening to information as well as communicating with others and must be compatible with hearing aids. Finally, the system should provide help instructions, and perhaps the possibility to contact human help.

3.2 Requirements on the Information:

In general, the use of simplified language is needed for users with reading disabilities. Avoid difficult and long words as well as complicated grammatical structure. Avoid metaphors, ambiguous use of pronouns and words that are ambiguous by their pronunciation, since they require contextual understanding to interpret. Keep sentences and paragraphs short, to allow frequent rests. Make pauses in between paragraphs longer than normal, and use music to indicate pause. Quality of the audio output is important for dyslectics, in particular the articulation of words. It is preferable to use human, recorded speech, since it is less intelligible and less preferred (Tiresias, online) and easier to perceive for dyslexics than synthetic speech (Blomert and Mitterer, 2004).

The purpose of auditory information for users with reduced vision is, in addition to provide information, to convey environmental aspects (e.g., description of the room, light circumstances, placement of objects in the room) as well as navigational aid. Visual aspects of objects of interest such as size, colour, and main impression, should be explained. A suggested principle is to always explain the "big picture" first, and continue with details after. It is important to avoid referring to visual impressions without explaining them (which seeing people tend to do all the time). To use vivid, metaphorical descriptions is a natural way to explain visual sensations; for this user group, such descriptions are preferable to plain descriptions.

The two user groups have different information needs, regarding the type, amount, and level of information, e.g., information to support navigation is relevant for users with reduced vision only. Users with reduced vision typically appreciate colourful, metaphorical descriptions, whereas dyslexics typically find such descriptions incomprehensible. A strongly simplified language may be considered indigent by the visually impaired, who wants to compensate their lack of vision by descriptive information. Thus, the information must be adapted to each group, respectively.

4. DESIGN APPROACH

In our search for design solutions, we have not found any existing system fulfilling all requirements above. The location-aware, auditory handheld museum guide in Ciavarella and Paternò (2004) is ruled out since the user must choose the object of interest from a visual display on the PDA which is not appropriate for visually impaired people. The Audio-Augmented Reality prototype in Bederson (1995) is a location-aware, fully automated digital tape-recorder, which provides information in the visitors' headphones as soon as the user approaches an object. According to Dickinson et al. (2003) this is in conflict with the need of our users: automated actions tend to be confusing and intrusive to the users, so user-initiated and user-controlled systems are more desirable (Aoki and Woodruff, 2000). The audio-based, location aware system, Ec(h)o (Hatala et al., 2004) are based on general user models and is therefore not suitable for non typical users. Other systems are more concerned with augmenting the museum experience by adding features rather than striving for universal usability, for instance the system in Terrenghi and Zimmermann (2004) provides personalized sound illustrations based on movement and gestures, and the Discovery Point system (Berkovich et al., 2003) encourage social interaction between visitors by initiating short stories about the artefacts in front of the visitor. Thus, we see a need for a new system to be designed differently.

To design technology for users with reduced functionality is challenging for at least two reasons: First, for most designers, it is more difficult to understand these users' situations and needs, since most designers have little own experience and knowledge of disabilities. As described in Dickinson et al (2003): "Developing systems for "non-typical" groups meant that in some cases a "logical interface" in the developer's sense of the term was not a solution." And thus, secondly, standard solutions are not always appropriate, which calls for creative, new solutions which must be tested by representative users. Hence, a user-centred, iterative approach to design which involves users is crucial when designing for disabled. This conclusion is also supported by Dickinson et al (2002), Dickinson et al (2003), and Wattenberg (2004).

The overall methodology we used is a user-centred approach to interaction design (Dix et al, 1998; Preece et al, 2002), in a contextual setting (Beyer and Holzblatt, 1998). So far, we have completed the first cycle of iterations: analysis, design, prototyping and evaluation. In this first iteration of the design work, we have conducted user and task analysis, set up requirements and design implications, constructed a mock-up prototype simulating the system, and performed user tests in the museum with potential users from the target groups.

To evaluate the conceptual design, two sets of user tests were conducted: one with each target group. The test was performed in the museum, in a particular exhibition of paintings, which was the preferred choice of the museum for this study. For the purpose of these tests, a mock-up prototype was constructed, which simulated the device and the main functionality of the system. Auditory information related to 4-5 paintings was developed, following directions from our user studies. The evaluation consisted of (1) users testing the mock-up prototype according to an arranged scenario in the chosen exhibition, (2) observations and logging of their interaction and their reactions when interacting with the device, (3) interviews with the participants directly after the test, and (4) analysis of the texts carried our by teachers from a school of adult dyslexics. The group of dyslexics consisted of 7 and the group of visually impaired of 5 participants. Test groups sizes were determined on the basis of the tests' purpose: the tests were intended as formative evaluations to get input to further design. Such tests motivate small test groups (Nielsen and Landauer, 1993). In accordance with Dickinson et al (2003), we will perform tests continuously during the development, to assure the usability of the device and the content.

5. DESIGN SOLUTION

As a consequence of the different needs regarding information content of the studied user groups, the design solution is split in two parts: a generic infrastructure consisting of a location-aware, context-dependent technology, and specialized content which provide the user-groups with adapted information, respectively.

5.1 Infrastructure: Location-Aware Technology

The infrastructure consists of a portable device together with a headset for auditory information, and an environment in which objects and information displays are equipped with identification tags. The location-awareness in our prototype is provided by IR (InfraRed light) tags on objects, an IR transmitter in the device, and a database with object-related information. The RFID (Radio Frequency Identification) technology (Das Raghu, 2004) was considered, but it turned out to have too many technical limitations for now. The current IR solution is flexible as new tags can be added to the environment; new information can be added or changed in the database and since the context-dependent information is any auditory information. The same infrastructure can be used for various applications. The system includes a hand-held device to interact with, and different kinds of headsets to support different needs: isolating headphones, ear plugs, or small speakers for group interaction.

5.2 Content: User-Group Adapted information

The information is organized in a database, coupling the pieces of information to the identification of the corresponding objects or displays. Content must be provided and adapted to the target groups. For this purpose, guidelines of adaptation to the user groups are provided. The content can either consist of sound files to be transmitted directly, or by text that is transformed into synthesized speech. For the first evaluation with the mock-up prototype, example texts were produced by the museum and recorded in our studio. For each painting, the museum produced information adapted to visually impaired and to dyslexics, following the directions from our analysis. This procedure was time consuming, and is not reasonable in the future. Therefore, to be practical in a commercial application, software for producing content must also be provided.

6. EVALUATION OF THE CONCEPTUAL DESIGN

We have conducted two sessions with formative evaluations: one with each user group. For this purpose, a mock-up prototype simulating the system was constructed. The evaluations consisted of a test with the mock-up prototype, observations during these tests, followed by interviews with the participants. The tests were performed in the museum context, in a dedicated room with paintings. General information about 5 paintings was available, in two versions: one for the group of dyslexics; one for the group of visually impaired. The purpose of the user tests was to evaluate the functionality of the system, the interaction with the (mock-up) device, the appropriateness of the content, the quality of the sound, and the overall experience as perceived by the participants.

7.1 The Mock-up Prototype

Our first mock-up prototype was a simulation of the system and its main functionality. It consisted of a device, two wireless headphones, a laptop, and an operator simulating the system's behaviour. The device we used was a so called Daisy-player (see Figure 1)—a special device developed for dyslexics. The Daisy-player was suitable as mock-up device, since it has all the functionality and controls that are considered for the design. Moreover, there is an option to have the device give auditory feedback when a control is used (such as "Lower the volume"). This feed-back was sent wirelessly to the operator's head-phones, so that the operator could act accordingly. Similarly, auditory information was sent wirelessly to the test user's headphones from the laptop according to the operators commands. On the laptop, an mp3 player was playing the files according accordingly. Test user's could, thus, move around freely, operate the device, and receive auditory information in headphones in the very same way as the system is going to function (see Figure 2).

Interaction commands are sent wireless to operator's headphones Laptop sends sound information wireless to user's headphones Our first attempt to balance user- and system-initiated transmissions in the prototype was to alert the user by a sound, but then expect the user to initiate information playback by pressing "play". This was simulated by the operator playing a special sound when the user came close to objects with available information. In this way, the user was made aware of the presence of information, and was allowed choose to listen to it at will.

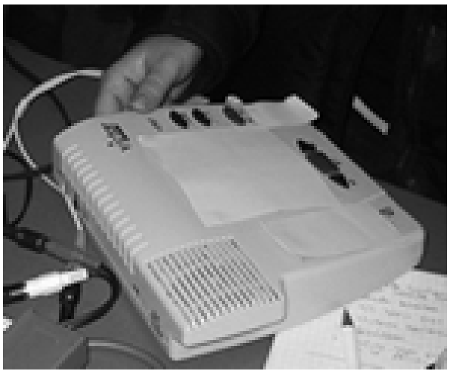

Figure 1. *Mockup device.*

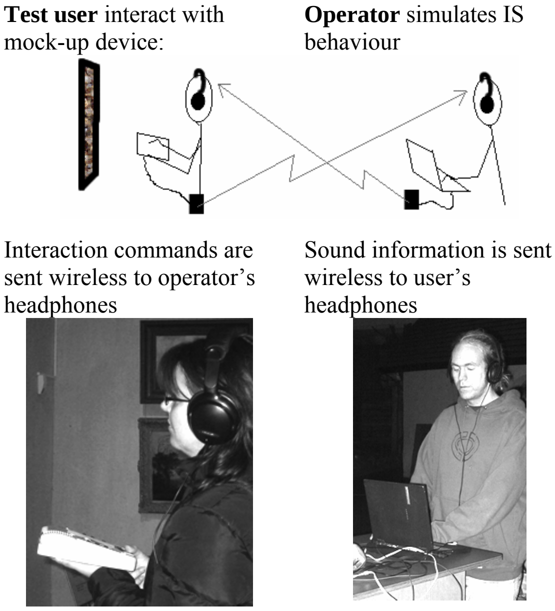

Figure 2. *Prototype simulating the system.*

Figure 3. *Test situation.*

Figure 4. *Test users.*

7.2 The User Tests

The tests proceeded as follows: The participants were introduced to the mock-up prototype, and we explained which functionality it had and how to operate it. They were told to walk around in the room, looking at the paintings as they wished, and trying to act normally (see Figure 3). We carefully explained that the purpose of the test was to test the system, not to test individuals; this was essential, as people in these user groups are often subject to tests considering individuals. We encouraged our participants to be as critical as possible to the system. While they were wandering around listening to the information and handling the device, we tried to observe what they did with the device and how they reacted to the response they got. That information was used in the interview following the test, as points of discussion.

7.2.1 Test users with Reading Disabilities. The first test session was performed with dyslectic people. There were 7 participants, with various degrees and symptoms of dyslexia; all were women of age 20-35. Their interest for art varied; none was a frequent visitor of the museum, but some had been there before. The results from the tests with dyslexics were as follows:

Technology: For most, interacting with the device was unproblematic. However, the use of the Daisy-player as a mock-up device may have affected this result, since the participants were already accustomed to it. Most test users tried to interact with the information by pausing, rewinding, forwarding and stopping. The way the backward button was handled in the prototype, did not correspond to all users anticipation. Some expected it to rewind (as a tape recorder) when hold and others pushed it several times to achieve the same effect. The function to get to the start of a text was a function that several users wished to have. A few adjusted the volume; none adjusted the treble and bass. All participants appreciated the isolated headphones; none considered it a problem to wear them.

Information: The text adapted to the dyslectic participants, was considered reasonable, but too simplified: more colourful descriptions were asked for. After the tests, the teachers who we had interview, analyzed and commented the texts that we had produced. The quality of sound was considered good, but parts of the reading were considered too monotone, even though the texts were read by a professional museum guide.

The overall impression of the dyslectic test group was that they liked the idea: at least they really appreciated that they were put in focus for the development. Some of them said they would consider visiting the museum (which most of them had not done before) and use such a system if it was available.

7.2.2 Test users with Reduced Vision. The second session of the evaluation was performed with visually impaired people. There were 5 participants: all elderly women (see Figure 4). Their degree of vision varied: some could only identify light and dark, and they had various kind of visual impairment; one could only see parts of a painting simultaneously, one could not see in the focus spot and the others had general reduced vision. Their interest of art varied, but several of the participants used to be frequent visitors to this museum; they had, however, stopped visiting as their ability to see was too restricted for a visit to be meaningful. They were all used to various kinds of technological equipments, since they all depended on that for their everyday activities. The results from the tests with visually impaired were as follows:

Technology: The device was a bit difficult to handle, for most of the participants. This can partly be explained by that the buttons did not have enough tactile information on them to be able to identify easily. The buttons also needed to be more visually distinct from the rest of the device. Most of the test users were not as eager to explore the functionality of the device, so after listening to the information, they just continued. However, several participants said they wanted to repeat the description, or parts of it, and listen to the information again. All participants chose and appreciated the isolating headphones, even though smaller alternatives were present. The relation between the stop, start and pause buttons and the actions were not clear (in particular, the difference between stop and pause was not apparent).

Information: The adapted information was much appreciated; they considered the descriptions to be involving and interesting. However, most of the participants wanted more information of the same kind: about the artist, for instance. The quality of sound was considered good. There were requests of more instructions regarding navigation, such as obstacles or where places to sit and rest were to be found. Instructions of available choices, was asked for. On-line help instructions was not provided in the test, only manual description before the test, which apparently was not enough.

The over-all impression of the visually impaired was positive: 3 out of 5 said that they gladly would visit the museum again, if such a device was available to them.

7. CONCLUSIONS AND FUTURE WORK

The evaluation gave valuable input for the next iteration of the design process—which was its main purpose. None of the design aspects we identified have shown to be unnecessary, but some may be of less importance such as the ability to alter treble and bas. The concrete device and the interaction with the device must be specified in detail, prototyped, and evaluated in test with users again.

The two user groups—users with reading disabilities and users with reduced vision—have been in focus throughout the development, and will remain in focus. However, the information system can be beneficial for any museum visitor, since non-typical user groups often have higher, but not necessarily different demands than others. Hence, to focus on several non-typical users groups during design is a good strategy to aim for main stream products with universal usability (Shneiderman, 2000; Law et al, 2005), rather than particular assistive technology (Liffick, 2003).

Future work includes developing and testing more and diverse types of content; testing the first running IR-based prototype, with more and different user groups; experimenting with sound manipulation and sound recording, and developing practical support for content production.

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