User Interfaces for Persons with Deafblindness

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Abstract. This paper examines problems persons with deafblindness have when using computers and it analyses how we can approach these problems in the redesign of a communication tool. A qualitative interview and observation study was conducted with 12 participants. The results indicate that future systems must improve simplicity, flexibility, and feedback. Our redesign employs a use flow for the screen reader that provides precursor cues for reading on a Braille display. This is intended to aid users getting an overview of the program and its functions. We discuss the advantages and problems that arise when implementing this concept to operate both on a visual display and a Braille display.

Keywords: Deafblind, accessibility, usability, inclusive design, total communication

1 Introduction

Persons who are deafblind often experience difficulties managing their daily life. Computer applications could provide a great aid and can let this group live more independently. Most tools are, however, usually designed for people who have at least partial vision and/or hearing still intact. People who cannot employ any of these senses have considerable difficulties to use computer-based tools. To improve these applications and provide a design-for-all the designer has to carry out a detailed analysis of what a broader range of people need and involve users in every stage of decision making [10].

In this article, we examine the problems persons with deafblindness meet when they are using computers. We analyze what can be done to avoid these problems and provide examples on how a communication program can be redesigned to fit the needs of this user group. Our application focuses on users who are either totally deafblind or totally deaf and visually impaired. Hence, our discussion does not include the use of speech synthesis.

1.1 Deafblindness

Deafblindness is a severe combination of hearing and visual impairment. Some people who are deafblind are both deaf and blind, while others have remains from both seeing and hearing. A common misunderstanding is that deafblindness can be seen as a combination of deaf- and blindness and that this group therefore can gain from services designed for deaf and blind persons. However, deafblind people are unable to use one sense to fully compensate for the impairment of the other sense, in similar ways that, for example, a deaf person can compensate lost functions with their vision. Hence, persons with deafblindness have two sensory impairments that intensify the impact of each other and create a severe disability that is unique.

One cause for deafblindness is the genetic disease Usher syndrome. Persons with this syndrome constitute approximately half of all deafblind persons in the world. People with Ushers are born deaf or with impaired hearing and with or without balance signals from the ears. Later in life, people with Ushers acquire an eye disease called retinitis pigmentosa and this illness causes night-blindness, limited field of vision and in some cases total blindness.

1.2 Communication and Deafblindness

People with deafblindness can find their disability handicapping in many social situations. When it comes to communication, persons who are deafblind can, according to The Swedish Association for Persons with Deafblindness (FSDB), roughly be divided in three different language groups: sign language users, spoken language users, and persons without language. Not very many are totally without language, but some cannot use spoken language due to dementia or unspecific intellectual disabilities. The spoken language users are usually born blind and become hearing-impaired or deaf later in life. Some of them learn sign language as a second language.

For people who are born deaf, visual sign language is a natural way to communicate even if their vision is reduced. When communicating via sign language with people with impaired vision it is essential to create high contrast between hands and the background.

People with deafblindness, who do not have enough vision to perceive the hand signals, can perceive the sign language tactically. When people employ tactile sign language, there are two different conversation positions; the monologue and dialogue positions. In the monologue position, both signers' hands are held under the hands of the listener. In the dialogue position, both participants hold the right hand under the other person's left hand and the left hand on top of the other person's right hand [9].

According to FSDB, persons who become deafblind in later life and are used to written and spoken language, can have difficulties learning tactile sign language. In those cases communication with hand alphabet can be an alternative. The hand alphabet is a part of the sign language and it is much easier to learn but slow to use. Naturally, another possibility is to be accompanied by a contact person who assists with guiding and communication.

1.3 Communication Tools and Deafblindness

Communication can often be a great challenge for persons who are deafblind, and challenges that are too great can cause anxiety [1]. Communication tools can however strengthen their skills. Below follows a list of such tools:

- *Braille* is blind persons' alphabet that can be used in most languages. The Braille code is physically presented as raised dots, usually arranged in cells with up to six dots.
- *A contact machine* is a computer connected to a Braille display. The contact person/interpreter writes what is said and the deafblind person can read it on the Braille display.
- *Text telephony* makes it possible for people with hearing impairment, deaf- or deafblindness and speech impairment to call and receive phone calls using text. Via an interpreter at a relay service users can communicate with hearing.
- *Video telephony* offers a possibility to use sign language, lip reading, and facial expressions.
- *Instant messengers* (ICQ, MSN Messenger, AOL Instant Messenger, Jabber, Yahoo! Messenger etc.) can be useful for persons with deafblindness.
- *Total conversation* is a multi-modal concept in which video, text and speech can be used simultaneously. In other words, this service combines the functionalities of text, video and ordinary telephony in one program. The International Telecommunication Union has also standardized and defined the concept [6].

1.4 Special Input and Output Devices

When it comes to input and output, persons who are deaf but have enough residual vision to read large print, can make use of large font displays. Another alternative to read text visually is to use a Braille display, which uses small pins that are raised or lowered to form the Braille characters. There are usually 40, 65, or 80 characters per line of text, depending on the device. A screen reader program translates from the information on the visual display to the Braille display or to large font. In general, deafblind and blind people use keypads for input, with or without tactual indicators on the keys.

1.5 User Interfaces and Deafblindness

Generally, persons with deafblindness that are unable to employ computer aids communicate via their contact person or interpreter [3]. This means that computer technology can open up new doors for this user group and make them less isolated and dependent on others.

When designing any user interface, there are some basic usability considerations that must be met. Significant qualities are learnability, effectiveness, attitude, flexibility, relevance, efficiency, and satisfaction [11, 8, 5]. A designer should always have the user's perspective when designing a user interface. Design principles like suitability for the task, self-descriptiveness, controllability, conformity with user

expectations, error tolerance, suitability for individualization, and suitability for learning may also have differing relative importance in different situations [5]. Furthermore, the tradeoffs between these design principles may also vary with the situation of use. For users with special needs the tradeoff effects are especially important to consider.

User interfaces for persons with deafblindness need to be straightforward so that there are few things to memorize [7]. Many deafblind do not have strong writing skills and this is why pictures and icons could be an appropriate alternative in some situations. However, this is not an appropriate option for those who use Braille, since it is solely a textual medium where graphical images are not easily represented. Moreover, for users who rely on tactile output there is an additional problem. They receive information from their hands, but they must also employ the hands to type in information. This means that it is difficult to receive and type information at the same time. With the hands doing both input and output special care must be taken to allow the user to correct mistakes.

Following the considerations above, Ladner et al. [7] developed a system called DBNet. This system is extensive and includes an email client and provides means to read news and to chat with others people. The user interface is based on a simple hierarchal model, which allows its users to perform hundreds of distinct tasks that takes just a few actions. The conceptual model of the system is a hierarchical list with entries that can themselves be lists. Each entry in the list has a textual label associated with it.

After implementing the DBNet system, Ladner and colleagues evaluated it with six users with deafblindness. They wanted to see if the conceptual model was comprehendible and how easy the system was to use. Their result was that five out of six participants understood the conceptual model in less than an hour of use. Thus, it can be concluded that the hierarchal model of the DBNet system is well within reach of deafblind people and it can easily be learned with little teaching effort.

In a similar study by Fisher and Petrie [3] thirteen persons with deafblindness were interviewed about their current use of communication and information tools. Their results are similar to the results of Ladner's and colleagues. They found that users must be able to access different functionalities with a minimum of steps. Moreover, they found that it is important to provide system status feedback at each interactional step. Tools that provide vibration is a common form to alert users, for example, for doorbells and telephones and this modality could also be used as feedback from the system. Ladner and colleagues also pointed out that there is a urgent need of portable systems that includes Braille displays and other aids for this user group.

1.6 Focus of Current Study

The focus for our research project is the design of functional communication tools for people with deafblindness. The approach of *total communication* has not been studied in relation to user interface design for persons with deafblindness while it seems promising and it is therefore worthwhile to explore further. The specific aim of this study is to describe the interactional problems deafblind meet when they are using

computer-based communication tools. Moreover, we seek to find new designs and we exemplify them in a total communication tool.

2 Method

An interview and observation study was conducted with nine deafblind persons and three informants with experience from working with persons who are deafblind. Semi-structured interviews and e-mail interviews were conducted to get a deeper understanding of how persons with deafblindness employ computer applications, what problems they encounter and what can be done to avoid the problems.

Semi-structured interviews were chosen because of the flexible design of the method, which allowed the interviewed person to suggest new approaches to given topics. E-mail interviews were used in two cases when face-to-face interviews were not possible. Observations were used to add to the information gained from the interviews.

2.1 Design Case

The design case in this study is a re-design of the total conversation program Allan eC. The name is an acronym for "All Languages electronic Conversation" and the system is developed by Omnitor AB in Sweden. Total conversation is a standardized concept in which video, text and speech can be used simultaneously (see Figure 1).

Allan eC can be used in different ways depending on how the users communicate. Persons who are sign language speaking can communicate with other sign language speaking persons in their own language. Hearing persons can make use of the advantages that video telephony brings and persons who have impaired hearing can use lip reading to understand the other person. Allan eC can also be used as a text telephone, where the two users have a real-time text conversation. This is a good way to communicate if one of the users is deaf and the other does not speak sign language. It can also be used to support voice or sign language communication. A deaf person who wants to contact a hearing person, who does not have a total conversation terminal, can call the IP-video interpreter service. Then an interpreter dials the number asked for and then translates the conversation.
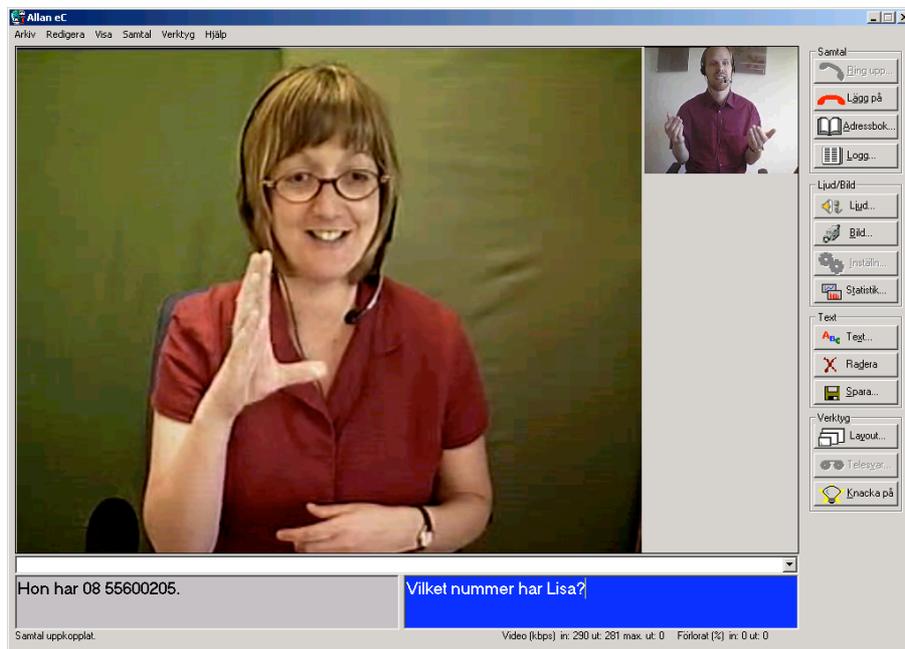
Fig. 1. The total conversation program Allan eC

2.2 Participants

Twelve participants have taken part in this study and nine of them have some degree of deafblindness. The remaining three has experience from working with persons who are deafblind. Of consideration for the participants they are presented by numbers and not by names.

Participants who are Deafblind. Participant 1 was born deaf and uses sign language to communicate. He has a visual impairment that narrows his field of vision to around 10 degrees. He has Retenitis Pigmentosa and will in the future totally loose the vision. He works with education and lives an active life. He has a large interest in computers and uses it for mail communication and also for MSN video communication. He uses an enlargement program. The participant was interviewed at his work with help from two interpreters.

Participant 2 has the Usher syndrome. She was born deaf and has sign language as first language. Her visual impairment was discovered when she was young and today she has tunnel vision and is dependent on good lighting conditions. The participant works at a small company and uses different computer programs such as Allan eC and ICQ to communicate per distance. She uses an enlargement program and both mouse and keys. She is also learning to use Braille and sometimes uses it to interact with the computer to rest her eyes. The interview was carried out at her work with help from an interpreter.

Participant 3 was born deaf and has sign language as first language. He has a visual impairment that slowly gets worse. The participant works with computers at a company and uses an enlargement program to his computer. To see better what is on the screen he has a special lamp behind the computer. He is an expert user of the Allan eC program and the interview was carried out via the text function in Allan eC. No interpreter was needed.

Participant 4 was born deaf and has sign language as her first language. Eight years ago she went totally blind and now she communicates with tactile sign language. She runs her own company and is often out traveling. She uses Allan eC and SMS on a mobile phone with a 20-character Braille display. Two interviews were carried out; one interview was made via the text function in Allan eC and one interview was made in her home. The participant was also observed when using Allan eC in her home. The second interview and the observation were made with help from an interpreter.

Participant 5 is both deaf and blind and has sign language as her first language. She uses tactile sign language. She writes on computer with a Braille display and uses a text telephone program for communication per distance. The interview was made at her school with her assistant interpreting.

Participant 6 is deaf and blind and has Swedish as her first language. She communicates through talking and tactile sign language. She uses the computer with Braille display for mail and for searching for information on the Internet. An interview and an observation were carried out. She looked at the interface of a, for her, new program for text telephony. Her assistant helped with interpretation during the interview/observation.

Participant 7 is born deaf with a visual impairment. He has a large interest in computers and uses them for surfing the Internet and communication via an e-mail program. An enlargement program makes it possible for him to see information on the computer screen. The interview was carried out through e-mail contact.

Participant 8 has hearing and vision impairment. He uses speech synthesis and enlargement when using the computer. He also learns how to use Braille, to be able to use a Braille display in the future. He is used to computers and uses both total conversation and mail to communicate. He can also use telephone to communicate.

Participant 9 was born with a hearing impairment and speaks Swedish as her first language. She also knows sign language. Today, she is blind and hearing impaired and uses a hearing devise. At her work she uses the computer to write and to communicate via mail. She is familiar with Allan eC, but due to technical problems she does not use it. She uses Braille display and speech synthesis with a hearing device connected. The interview was carried out at the work of the participant. No interpreter was needed.

Participants who are Not Deafblind. Participant 10 works as a teacher at a school for persons with deafbindness. Among other things he teaches his students how to use computers, Braille displays and different computer-based programs.

Participant 11 works with accessibility on websites. He has experience from working with disabled persons in general, such as persons with deafblindness.

Participant 12 works with persons with deafblindness and among other things she teaches them how to work with different computer programs. Allan eC is one of the programs that she teaches.

2.3 Procedure

When interviewing participants who are deafblind every interview was adjusted to that specific user and situation. In two cases that meant interviews via e-mail, and in two other cases it meant communication via Allan eC. The rest of the interviews with the deafblind participants were conducted with help from an interpreter. The participants were asked general questions about their situation, how they communicate with others, what is difficult when using computers and what they wish for in future products. Every interview became a specific example of how the everyday life can be for a person with this disability. A majority of the participants have experience from using Allan eC and in those cases more specific questions about this program were asked. In those cases where the participant did not have experience from using Allan eC, questions about other communication programs such as mail and text telephone programs were asked.

The three interviews with persons with great experience from working with persons who are deafblind gave information on how people with this disability communicate, what can be problematic with the tools for communication today and what can be improved in future products. The persons interviewed looked at, and tested the Allan eC program, commented the interface and possible problems.

A problem when designing programs for people who use Braille display is to understand how they actually use it and what kind of information they receive in this interaction process. This can be difficult to explain in an interview and therefore two observations with two persons who use Braille display to interact with the computer were conducted. One of the participants was observed when using a mail program and a text telephone program, and the other participant when using Allan eC. During the observations the participants were given tasks to perform and they were commenting everything that happened in the interaction between them and the computer. The situations were filmed and the observer and the participants communicated with help from an interpreter.

2.3 Analysis

The gathered material was categorized to analyze information and to create meaning (see for example [2] for further information on categorization). Categories were identified by asking: "What categories can help me organize the most important aspects of what my interviews have given me?"

The analysis was iterative and the first step was to learn about the material. The interviews and observations were transcribed. All quotations concerning the research question were organized under different categories, which focus on how the users interact with computers. The different possible input and output methods are: Braille, short keys, enlargement program, mouse and keys.

The next step in the process was to re-organize the material and to create new categories. This time the information was structured under categories describing different issues deafblind users encountered in the usage of communication tools. Altogether it became a list of seven categories (simplicity, flexibility, adjustment, feedback, independence, motivation and information. These were considered in the redesign of the Allan eC user interface. The core categories focused on in this paper are: simplicity, flexibility, and feedback.

2.4 Prototyping

The results from the interviews and observations were put to use in prototypes showing what consequences the encountered usage issues have on the Allan eC interface and how it can be re-designed to manage those issues. Having the issues in mind, possible ways to create the prototypes were explored. In total, three prototypes were developed. The prototyping started with a stated problem, for example how to give enough feedback to persons using Braille. Different alternatives were put together and carefully considered. Many of them were thrown away and the design was changed many times.

2.5 Use Flow Diagramming

In the design of one of the prototypes, a variant of the use flow diagram technique [4] was used. For each function, all choices possible are shown, leading to a good overview of the program's functionalities. This method also gives a good picture of how a person using Braille will perceive the program functions. The Braille only shows information one row at a time, and cannot present graphic information. The use-flow diagram presents the information exactly as it will be presented on the Braille display, making it possible for the designer to construct a usable flow. The visual prototype was designed after the use flow diagram, resulting in a prototype usable for both persons using Braille and vision.

3 Results

The results show that for a system to fulfill the needs of this group, usage issues of simplicity, flexibility, and feedback need to be resolved. Below, we describe what these issues mean in the specific situation of user interfaces to communication tools for users who are deafblind. The quotations are translated from Swedish to English by the authors. Every quotation in the results is marked with a number that refers to a specific participant.

3.1 Simplicity

For a person who is deafblind it takes an enormous amount of time and effort to learn a new computer program or system. No matter what combination of deafblindness the user has, it will take a long time to learn how to navigate, where to look for information and how to use different functionalities. Participants express their experience of this complicatedness:

> "One must know what it looks like. I haven't really figured that out. What does the information look like, where to walk, where to go? Get the entire picture. It's really hard to know. It takes time to learn." #9

The observations clearly show the significance of reduced complicatedness in a program for this user group. One of our participants was asked to start a program, which she has very limited experience from. The most difficult thing for the user was to get an understanding for possibilities in the interface and she had trouble knowing what actions to perform. This shows both the importance of having information logically structured and to have an interface with less complicated functionality.

Many participants report that pictures and graphics are disturbing when using Braille display. The display only shows one row at a time and is therefore unable to interpret graphics. This means that the user misses the information presented and it makes it hard to navigate. Graphics can also be disturbing for persons who use enlargement programs. The pictures get too big to be seen in a context and that makes it confusing and hard to navigate for those users.

According to several of our participants, many persons who are deaf and deafblind have difficulties to fully understand complicated written text, and therefore it is important that information is presented in simple language. Also text lines with more then 40 characters cause trouble since they do not fit into a Braille display.

The observations indicate that for persons who have a narrow field of vision, it is important that information is not spread out over the screen. Then the user does not have to search a big area to find the right information.

Some of the participants use keys to navigate, either as input for a Braille display or as an alternative to the mouse. An interface, where important functions are placed late in the hierarchy, can be frustrating for the user to use.

3.2 Flexibility

Persons with deafblindness is a diverse user category. It would therefore be impossible to create one interface that is perfect for all those persons. Instead, possibility to adjust and individualize the interfaces is important. The most important features that have to be adjustable are size and color on objects at the interface. Most of our participants with impaired vision want a high-contrast interface. Suitable colors also vary between persons. Sometimes you furthermore need to make adjustments depending on the situation. For example, our participants say:

"I use a larger interface and when I get tired I make it even bigger. It's good to be able to vary." #1

"I think it is good with both because sometimes it is hard to use vision too much and then it can be relieving to use Braille, but then it goes very slowly and that becomes another problem." #2

Another thing that varies is whether our participants find text preferable to icons or not. For persons using Braille, information definitely has to be text based and some persons who use their vision find it easier with text as well. Others think icons are preferable and easier to handle.

For persons with deafblindness it is quite common that the vision gets worse and worse until it disappears and blindness occurs. To support the user during this process the program interface should have the flexible features described above.

3.3 Feedback

A problem for persons who have impaired vision, and especially for those who are blind, is to get feedback on system status and to know what should be done in every step. Sometimes information presented on the screen does not show on the Braille display and this can be extremely frustrating:

"A problem for deafblind persons who use computers is: How do I know that the computer is on? That I don't know until the Braille program has started and you can read what's on the screen. If there is, for example, a floppy disk in the computer when it starts and information shows on the screen and tells the user to take out the floppy disk, the person using Braille cannot see this. The person doesn't know what's wrong. It could be something wrong with the Braille display or something else." #10

During the observations it happened that the user gave a command and the program gave feedback visually but not on the Braille display. The user waited for information, without knowing when or even if the right information would appear. In one occasion during the observations information about the system status was shown visually in the middle of the screen, and this information was not translated into Braille. The user tried over and over again to use the call function, which was out of function at the time. Frustrated not knowing what to do, the user restarted the computer. The problem still remained and the user was still not given any information on what to do.

In some cases we observed that feedback was given, but not in a self-descriptive way. When starting Windows one of the users waited for the clock in the Windows program to show on the Braille display. When it did, the user knew it was okay to continue. When using the calling function in Allan eC the users must wait for the program to connect. While doing this the information "close" is shown on the Braille display. This may not be the best way to tell the user to wait while a connection is made. The users, however, looked satisfied because they have learned what the

feedback stands for. They are used to illogical feedback and they are happy to receive information telling them that something is happening. However, irrelevant feedback makes the program hard to learn and more complicated to use.

Sometimes it was also hard for our participants to know what to do in a certain part of the program. Using vision a person can get a quick overview of what possibilities the program offers. The blind person cannot get this kind of overview. To handle this, the participants have somewhat different strategies.

One of the participants has learned the order of some keyboard commands by heart, and follows it strictly. If she for example wants to check for her mail she presses the Window-button to go into the menu, presses the down arrow three times to find the mailing program and presses enter etc. She tends to start the process from the beginning, rather than start in the middle. If she for example wants to send a new e-mail when she is done reading old ones, she does so by pressing the Window-button, use the down arrow and so forth. It is as if she follows a path and has learned how many steps to take before making a turn. If she is not sure on how far she has gotten on the path and where to turn, the easiest thing is to start from the beginning. This strategy may very well work for basic tasks, but it soon become hard to learn many steps by heart when, for example, surfing on the Internet.

Another participant has a slightly different strategy when navigating; she learn short keys by heart. This strategy gives more freedom than the strategy described above, but the user has also in this case trouble navigating in new areas. She also has to depend on standards in short key commands, which are not always followed. This is a usable strategy when doing relatively simple actions, but for more complicated actions all the short keys can be difficult to remember.

Both strategies clearly show the importance of feedback and information in a program. If the user is informed of what actions are possible and in every step knows what happens, the user can be freer to explore the program.

4 Design Case

Given the three core usage issues we identified for this user group, we set out to re-structure Allan eC, to provide an example of how a total communication application can be designed to meet the needs of deafblind users. The principle idea is to design the user interface to be readily used with a visual display by users who have some vision, while being equally optimised to a Braille-display and screen reader used by users who have no vision at all. Given this objective the conceptual design was driven by a use flow diagram. The design work has, however, only begun. We have not yet put our design to test. The design case provided here should therefore be seen as an example of how the results from our field studies can be put to use.

4.1 Screen Reader Use Flow with Precursor Cues

The method used is a variant of the use flow diagram method described in the method section. Here it is used in a slightly different way and we denote it the screen reader use flow method. Inspiration to this method was also taken from Ladner et al. [7].

The need for feedback in the interaction process was evident in interviews and observations. It is also important to get an overview of the program to know its possibilities and limitations. When using vision to navigate, a person can rather quickly get an overview of a program and its functions. Even if the information is spread out over the screen, the seeing user can take in information without much problem. The interviews and observations show that feedback and navigation is a complicated matter for persons using Braille. The difference between navigating with vision and with a Braille display is enormous. The Braille display presents information one row at a time, which makes it more difficult for the user to get an overview of the program and its functions. Only getting one row of information at a time can result in difficulties in finding the right information and knowing where to look for it. This problem mainly occurs because the programs are designed for persons who can see.

Today visual interfaces are created first, and the Braille users have to try to navigate in them as well as they can. This process makes it difficult for the designer to assure that correct and sufficient information is provided to the blind users. To create a program usable for blind users, the designer must think about the consequences of information being presented one row at a time. One way of doing this is to start the design process by figuring out how the program should work. A flow model of the program's functions and interaction should be created.

To give the user information about when to expect functions in the interface, our approach includes what we call 'precursor cues' since their function is to announce or indicate the coming information. The precursor cues are described in Table 1. Using those cues the user does not have to look for non-existing features in the interface.

Table 1. Explanation of the precursor cues.

Precursor cue	Explanation
<	Marks the beginning of a set of functions.
>	Marks the end of a set of functions.
&	Is placed after an information text or a function when there are more information or functions following.
Bold text	Commands made by the user are printed in bold letters.
(text)	Text written in parenthesis describes what happens in the computer.

The visual design is created based on the flow model. If the flow model is wisely created, the designer can feel safe knowing the program will be usable for Braille users. The designer can then concentrate on making the visual design usable for the users with impaired vision.

One part of the redesign of Allan eC is presented below in Figure 2. In the flow model, which follows, the adjustment-function is expanded. Every part in this model

can be seen in isolation, without risking the user to be confused about what actions to do. Each level contains information of what should be done, and what actions the user can choose from. Following the flow in the model should be like following a path with different forks. The user chooses the wanted path and then a new fork appears. This creates a hierarchical menu-based dialogue.
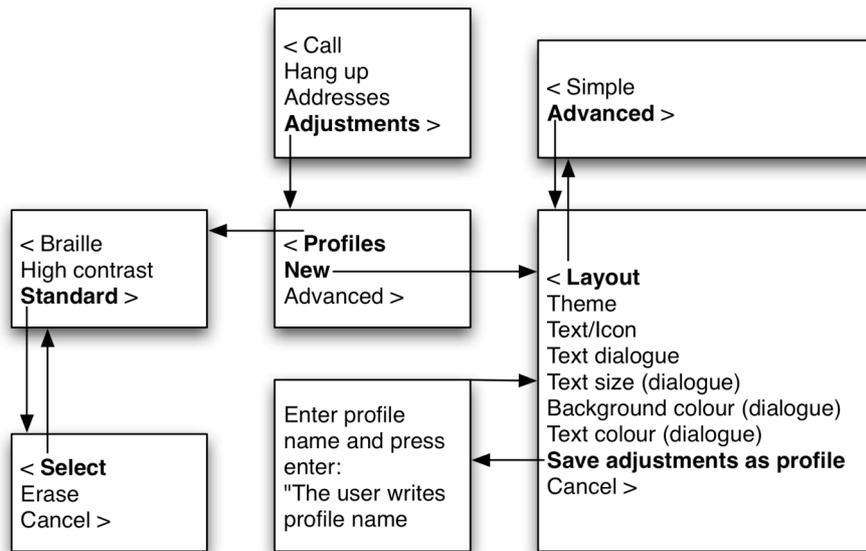

Fig. 2. A screen reader use flow model with the adjustment-function expanded.

Using the screen reader use flow model as a guide, user interfaces usable for both persons using Braille and visual displays can be made. The visual design below is such an example where the screen reader use flow model is visualized in a prototype.

4.2 Visual Design

This prototype is designed for two purposes; to follow the restrictions that were decided in the use flow diagram (Figure 2) and to give an example of how an interface can be made easy to use for users with impaired vision. In other words the prototype is an attempt to design an interface usable for both persons using Braille and vision. Below, the prototype is analyzed from both views. In the prototype, the precursor cues from the use flow diagram are presented visually, to give the reader of this paper an understanding of the relation between the visual user interface and the Braille-based user interface (see Figure 3 and 4).

The interface is similar to the original Allan eC interface, but it is much less complicated. The area for text conversation is placed at the bottom of the interface. The user can choose between text presented in one window, or in two separate windows as in the original interface. The user can choose between four different functions and here the adjustment function will be expanded.
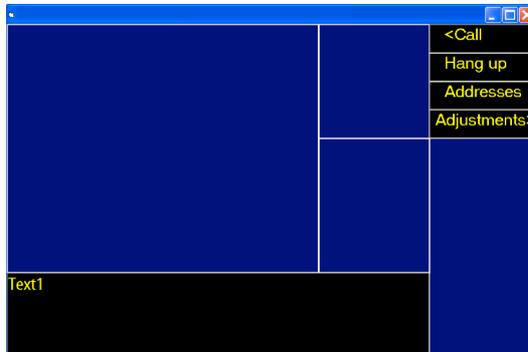
Fig. 3. Main window.

As seen in Figure 4, there is a new function for saving adjustments called Profiles. This makes the program flexible without making it complicated.
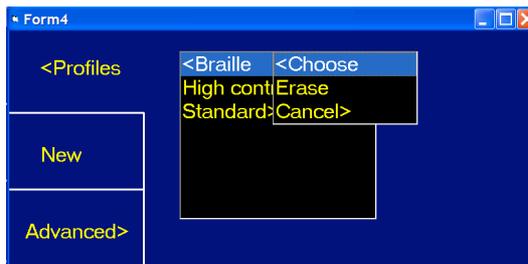
Fig. 4. Choices for the different Profile-alternatives in the adjustment window.

Choosing New, different adjustments can be made and saved as a new profile. Figure 5 shows how the adjustment function can be changed.
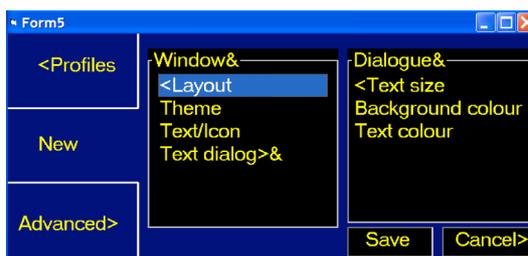
Fig. 5. The New-function.

4.3 Braille Users

This interface follows the conceptual model set up in the use flow and is therefore intended to be more usable for persons using Braille. The different precursor cues

from the use flow model can also be found in this prototype. Among other things the precursor cues inform the Braille user when to expect and look for functions. The interface has reduced complicatedness, which is anticipated to make the time for learning relatively short. Having only one text window also supports the usability for a person using Braille.

Choosing the "<Profiles"-alternative the user gets presented to different profiles including adjustments already made. This function makes the program flexible. A person, who wants to use Braille one day and vision another, may want to change adjustments in an easy way. The adjustments are then saved under different profiles and the user can easily change between for example the "Braille"- and the "High contrast"-profile. This function makes the program both simple and flexible.

To make the program even more flexible short keys are connected to each profile. Profiles can be changed directly from the main window using those short keys.

Choosing the New-alternative in the Adjustment-window the Braille user will be presented to a list starting with "Window&". This is not a function but information that the following functions will be connected to the window. The &-sign informs the user that a set of functions will follow. After the last function in the column, there is another &-sign indicating that there is more information below. The user continues to the next column and receives information that the following functions will be connected to the dialogue.

4.4 Visual Display Users

The prototype is not very complicated for persons with impaired vision, following the demand for simplicity from the results section. The functions in the main window are located at the right hand side in the interface. The buttons are placed just beside the window border, leaving no space in between. In this way the user with impaired vision can find the buttons by following the border of the screen with the mouse. This presupposes a window that fills the whole computer screen.

The interface leaves space for bigger text, which is needed for many users. The Profile-alternative in the Adjustment-window is useful for a person using vision. Take for example a person with a vision varying from one day to another. Sometimes this person wants the text to be bigger and sometimes it is enough with a smaller text. The user can have two different profiles saved making it easy to change between the two alternatives.

5 Discussion

We have described the difficulties persons with deafblindness have when using computer-based communication tools and we have attempted to find new design solutions to approach this situation. Generally, our interviews and observations indicate that today's communication tools does not provide the necessary simplicity, flexibility and feedback needed by this user group.

Particularly, specialized output methods and a high demand on flexibility in terms of suitability for individualization and adjustment are special user demands from this group. As interface designers, we have to make do with only tactile and haptic output, in some cases in combination with limited visual output. This means that it is sensible to start out to design for the Braille display first. With this in mind, we developed our prototype, which shows that it is possible to design an interface suitable for both Braille users and persons that have vision. The key is to provide *precursor cues* to support anticipation of what to come in each step of the computer dialogue on the Braille interface. This approach facilitates overview of the program, which increases controllability.

5.1 Experts as well as Novices Benefits from Simplicity

It is interesting to compare the result from our study with other research in the same area. Both Ladner et al. [7] and Fisher and Petrie [3] discuss the importance of uncomplicated interfaces, which is one of the main results in this study as well. Ladner et al. states that simplicity is important when designing for this group because most of them are computer novices. This study corroborates this picture with the statement that simplicity is not important just for novice computer users, but for all persons who are deafblind. Computers are designed for persons who have vision, and vision impairment makes the their handling very difficult. It takes a lot of time and effort for people with deafblindness to learn to use a computer program. As discussed in our analysis, simplicity is key to make this process easier.

In terms of the dialogue principles in the ISO 9241 standard [5], reduced complexity will lead to increased suitability for learning. The simplicity will also provide a sense of control for the users since they can overview the complexity of the tool. Making the communication tool simpler may however increase the depth of the interface and this may cause less efficiency and hamper the suitability for task. However, the suitability for learning and the suitability for individualization are here relatively more important than suitability for task.

We also want to note that flexible individualization of a tool may work against the simplicity of the user interface. Many settings can be made, and this can, if not carefully designed, increase the complicatedness of the tool.

5.2 Structuring Use Flow for Feedback

Ladner et al. underline the importance of a clear conceptual model in a program that is easy for the user to understand. This statement is closely connected to the discussion of feedback in this study. The DBNet System [7] is hierarchically structured and the user can easily navigate and receive information. The screen reader use flow with precursor cues in the design section is different in design, but is built on a similar concept. In both systems the user quickly gets an overview of the program structure. The difference is that the screen reader use flow with precursor cues gives the user information of what information to expect in each step.

If we once again use the terms in the dialog principles of ISO 9241 [5], the clear feedback on what the system does and what actions that are available is a means for controllability. It helps the user maintain direction towards the goal and it allows users to abort and undo actions. The flexibility of making individualizations in the system is also a means for control, since it allows users to change the format and type of presentation.

One problem of feedback still remains in our system design. Since we have focused on how to make individual adjustments to the interface we have not yet a clear picture on how to provide feedback on what the communication partner is doing. In a chat with another person the deafblind user does not know if the communication partner have started to writing something. Therefore, one should consider using some kind of indicator to facilitate turn taking.

5.3 Future Research

The suitability of our design remains to be tested. Neither the visual design, nor the Braille display design, or the conceptual model in the use flow has yet been verified. The choice of precursor cues can be further developed. A standard would be interesting to develop. Better use of tactile and haptic feedback can potentially enhance total conversation tools for persons who are deafblind.

Technically, user interface programming has a number of issues to deal with to aid the development of usable interfaces for users with different kinds of impairments. For example, it may be possible to listen when a screen reader starts, as an event. Then an application can listen for it and present appropriate user interface. Another alternative would be to design a different way to start the screen reader so that it sets a state or a flag when it is turned on and off. Applications can then check that flag to see which user interface to present. Today the most pragmatic solution may be to use special characters that are invisible to the eye in the visual display but readable for the screen reader and accordingly presented on the Braille display.

There is also a need for smarter enlargements programs and adjustment functions in operating systems that chooses what user interface objects to enlarge and what objects not to change. The development of such functions is an interesting venue for future research.

5.4 Conclusion

The present study show that much can be done in the area of user interface design for persons with deafblindness, and that knowledge about the users and cooperation with the users is crucial for a successful result. Future systems must improve simplicity, flexibility, and feedback. The concept of a screen reader use flow that provides precursor cues can aid in making systems usable both on a visual display and a Braille display.

The most important learning that we bring from this design case is that creating interfaces for persons with deafblindness is a challenging, exciting and most of all a very important mission, which indeed is not impossible.

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