Designing Interactive Content with Blind Users for a Perceptual Supplementation System

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ABSTRACT
With the spread of ICT and the Internet during the last two decades, more and more tools rely on graphical interfaces that make them scarcely accessible to the visually impaired. The ITOIP project aims at developing the use of a tactile perceptual supplementation system called Tactos. A partnership with a visually impaired persons (VIP) association allows us to conduct a participatory design approach intended to gather first community of users around our system. This article reports on the design approach we have implemented in order to develop usable and useful applications for VIP users. Through a rapid prototyping process we address the development of the use of our technology with blind users representatives. We present the interaction and use principles highlighted from the design of three Tactos applications: a tutorial, a street maps exploration system and a country level map application.

Author Keywords
Tactile, Perceptual Supplementation, Participatory Design, Rapid Prototyping

ACM Classification Keywords
H5.2 [Information interfaces and presentation]: User Interfaces. – User-centered design

General Terms
Design, Human Factors

INTRODUCTION
The spread of the Internet and of information and communication technologies (ICT) in our daily life has brought access to an unprecedented amount of content to the blind and visually impaired persons. However the general adoption of graphical interface as the primary mode of interaction remains a limiting factor for accessibility. Screen reader technology has considerably improved the accessibility of digital content, but lack the ability to clearly present complex shapes or page layout. Research in sensory substitution, or supplementation as we prefer terming it, have proven to be effective in enabling spatial and even visual perception through technical mediation [1, 12, 14]. These technologies have the potential to enable visually impaired users to deal with the widespread of graphical interfaces and the meaning related to spatial content hardly accessible through screen reading technologies. Several research projects show promising results on this approach, especially through the combination of audio and tactile modalities. For instance some of these works address traditional GUI application use [19], web browsing activity [23], or the accessibility of maps [3, 9].

The ITOIP project (Tactile Interaction for Information, Orientation and Presence) aims at developing the use of a tactile interface, called Tactos, developed within the framework of research on perceptual supplementation [12, 20, 24]. Tactos has been designed in order to enable users to perceive digital spaces through the active coupling of their actions and the sensory feedback delivered by the system. Inspired by research on sensory substitution, like the TVSS (Tactile Vision Substitution System) [1], Tactos enables users to access space with no need of sight through the integration of active manipulation of an input device and a feedback system.

In order to gather a first community of users around our system, we work in close collaboration with a visually impaired persons association (APICADEV) to design usable and useful content for Tactos. Our research is based on a 6 months field study, involving interviews and weekly design sessions with APICADEV members.

The contribution of this paper is twofold. First we report on the participatory approach we develop in order to design usable and useful applications intended for the Tactos perceptual supplementation system. Second, our design sessions with blind users help us to highlight and develop use and interaction principles with them for the development of future applications.

Section 2 reviews the participatory design approach we are taking on the ITOIP project. Section 3 presents the technical system we are working on, as well as the rapid prototyping framework which enable us to work with users representatives. Finally, section 4 focuses on the adaptation performed with users on three applications designed for

TEI 2013, Feb 10-13, 2013, Barcelona, Spain.

Tactos: the introductory tutorial, a street maps exploration system and an audio tactile country map. This work helped us to develop interaction and use principles with our users and to adapt our applications to their needs. Section 5 concludes and mentions future research.

METHOD: A PARTICIPATORY APPROACH TO THE DESIGN WITH BLIND USERS

Our approach is inspired by the lessons learned from the study of tailoring practices [8, 21, 22]. Tailoring refers to the practices of local adaptation of tools once implemented and deployed inside a group of users. The study of tailoring practices has its roots in the observation that design continue after implementation since end-users are used to customize their tools to fit their local needs. For instance, we can mention the sharing of email filtering rules or of customizable office software toolbar among members of an organization [13]. Another interesting dimension of tailoring practices lie in its cooperative dimension - users at ease with technology and customization can exchange their adaptations and tricks with less tech-enthusiast colleagues. They can also assist them in tailoring their work environment to fit their needs, and this way act as translator [13] between needs expressed by a colleague and the functions offered by the technical system.

The field of computer supported cooperative work (CSCW), which has developed the notion, puts a special emphasis on work context, but we find tailoring practices of special interest for the field of accessibility as we find numerous adaptation cases of existing technologies in the literature and inside our own field study with visually impaired persons. Some of the implemented devices that we saw in use were initially sold as ready for use, but have been further adapted by our users alone or with the assistance of a sighted caregiver. For instance, the APICADEV desktop computer keyboard has several keys that have been supplemented with tactile bumps in order to ease typing and the screen reader control. Through our approach we want to leverage such adaptation practices by submitting our applications prototypes to users and accompany them to adapt these applications.

In our view, use is a co definition process and cannot be decided by designers alone but has to be jointly elaborated with users. Thus, our approach is based on Participatory Design (PD) [10, 17] in order to develop end-users participation in our project at different stage. Few studies have focused on adapting participatory approach to the field of assistive technologies [4] and to the need of engaging visually impaired stakeholders participation [2, 15].

Our design approach has two purposes. First we seek to develop usable and useful applications with users through a rapid prototyping process. This process builds on the notion of tailoring and focuses on the practical usability of the designed functions and their usefulness. Discussions with users during design sessions are especially important for this last aspect since the concrete usefulness of the proposed functions is hard to grasp by designers alone. Second, we eventually seek to develop a user community. Thus we emphasize the need to consider community design as a part of our fieldwork and to prepare the deployment of our system in a real context.

Designing with Users Representatives

The APICADEV (Association PICarde des Aveugles et DEficients Visuels) is a non-profit organization located in the Picardie region of France at the north of Paris. The association provides support for blind and partially sighted people in all aspects of their lives. The organization provides information about visual impairment and helps members with the choice and ordering of adapted equipment. An audio book and document library service is open to members. Some of the library documents are recorded by the sighted member of the association like local bus and train schedules. APICADEV run several events each year in order to increase public awareness to the issue of visual impairment and organize trips and friendly meetings for its members.

Two APICADEV members, Laura and Elizabeth were especially involved in our research project (the names have been changed for anonymity purpose). They have taken part to the design sessions we ran twice a week during the 6 months period of our study. These two members have accepted to follow our weekly design session when we have negotiated the participation framework with APICADEV. End users participation is essential for our approach of iterating with prototypes to co develop usable and useful applications for the Tactos system. More users would have been difficult to engage at this first stage and our aim is to progressively extend the first users' group to gather a community around the practice of Tactos.

Laura has been blind since she was in teenage, while the other one, Elizabeth, progressively lost her sight. They are practicing regularly traveled routes, such as the route from their respective homes to the APICADEV headquarters. Laura is using a white cane whereas Elizabeth is accompanied by a trained guide dog. Both of them have access and use the Internet with a screen reader software. Laura have a good knowledge of the Braille writing system and she uses it on a daily basis. Elizabeth is much less familiar with the Braille since she recently lost her vision.

Design Setting

The room where our design sessions took place is a four persons open space with a big central table for prototype tests. The teams' developers and designers work in this room. Researchers in psychology involved in the project can also be present since they are used to drop by the team office. The firsts design sessions were dedicated to familiarization with Tactos interaction principles.

Each design session took on average 3 hours. It usually starts by the agenda of the afternoon as the lead designer presents the new application prototypes or their latest updates to the users. One or two applications are tried out during each session. The users with the help of the lead designer explore each application. Users are let to explore the prototype on their own at first. Then they are invited to report on their difficulties and experience with the application. During these discussions users mention their usability problems. Those discussions also enable users to express their opinion about the usefulness and the relevance of the proposed functions for their daily life.

The lead designer writes a synthetic note at the end of each session. These notes record a set of improvements to be implemented for the next design sessions as well as the ideas for new applications discussed with users and the team. This assisted adaptation process helps us from week to week to adjust applications' usability and functions. It also allows us to grasp their usefulness from users' point of view.

TECHNOLOGICAL CONTEXT

In this section we present in more details the Tactos technology. We use this perceptual supplementation system and its related software environment as a rapid prototyping framework in order to create interactive applications and adapt them with users representatives.

The Tactos technology

Tactos classic configuration (fig. 1) consists in two Braille cells, which constitutes the feedback system, and a two dimensional input device (e.g a pen tablet). The input device controls a small receptor field (like a mouse cursor) that allows users to explore the graphical content on the screen (e.g. simple shapes like squares, triangles). Along the user exploration, the system transforms the pixels under the receptor field into tactile stimulation on the Braille cells. Through this hack of the Braille cells (mainly used to display pieces of shapes instead of Braille characters), users get a tactile feedback analog to the small part of the shape over which the receptor field is located. In order to recognize a complete shape, the user has to actively move her receptor field.

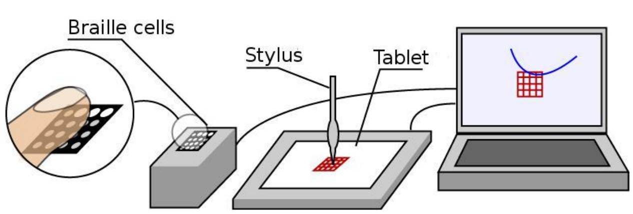

Figure 1. An illustration of the Tactos system principles.

The figure 2 shows the record of one user receptor field movement during her exploration of the letter "S" shape. This exploration allows users to discriminate straight from curved lines, as well as their orientation, and finally recognize a shape.

Figure. 2. The track of a user exploration of the letter shape "S".

Different configurations of the Tactos system exist (fig.3). The system is composed of one input device which gives control to users on the position of a receptor field. This receptor field reacts to the pixel color explored content and translate it into a sensory feedback according to the defined configuration. Due to the small scale of the stimulus, users are compelled to compensate the lack of local information by active exploration. Different kind of receptor fields can be defined to enrich or weaken the sensory feedback. The least feedback, called mode "mono", gives only one bit of information (i.e. The user is in or out a line). The richest feedback available, called "parallelism" mode, consist in associating several receptor fields to the sensory feedback device. For instance, we are used to associate each dot of a pair of Braille cells to one receptor field. The size of the receptor field can also be configured.

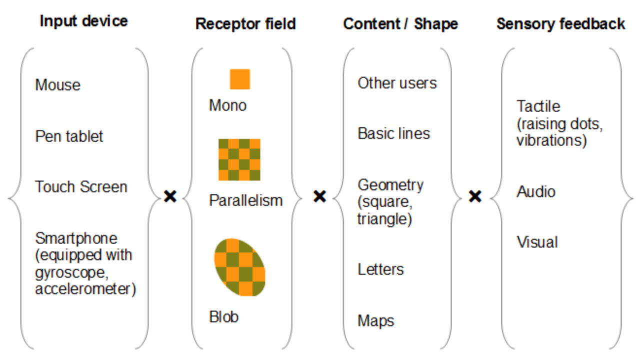

Figure 3. The space of the possible Tactos configurations.

The use of Tactos

Several years of research on the Tactos system have shown the ability of subjects to recognize basic and complex shapes with this device [7, 12]. The device has also been successfully used in the context of geometry teaching in an institution dedicated to the blind and visually impaired children [7, 18]. The Tactos system also allowed researchers in the domain of Psychology to develop new experimental paradigms to study perception and mediated communication [6, 24].

However, the device wasn't adopted by a lot of users after the pedagogical experiment. As only about 30 prototypes have been released, few end-users had the opportunity to bring the device at home in order to pursue their practice of tactile shapes exploration outside the educational establishment. Moreover, geometrical shapes exploration might be of few appeal to some users.

Our current project (ITOIP) continues the development of the Tactos technology and aims at overcoming some of the identified drawbacks for the development of its use. As illustrated in this article, we are working with users to design new contents to be explored with Tactos.

The software part of Tactos constitutes a multimodal platform which can deliver interactive content through:

- Sight: shapes and drawings can be displayed like in any other classical graphical user interface.
- Hear: sounds can be associated to area or shapes which respond to different users' actions (e.g. click, rollover). Besides, the speech synthesis of a screenreader can be controlled by Tactos to convey useful information and instruction to the users.
- Touch: on screen shapes can be felt with one or two finger tips through the Tactos technology. Tactile patterns, we called tacticons, or Braille characters can also be associated to an area of the screen.

Thus, our system is primarily intended for the visually impaired persons but remains accessible to the sighted too. The content available through the system is presented though a building metaphor where users can visit different rooms linked to each other by doors. The visitor initiates her visit from the lobby. Each room proposes either an application with graphic shapes to be explored, or several doors that enable access to further content. It is also possible to enable multi-users exploration of contents.

A Rapid Prototyping Framework

Classical low-fi prototyping technique, like paper prototype of user interfaces, are hardly accessible to blind participant [2, 15]. The importance of audio feedback and description recommend the use of multimedia authoring environment.

The Tactos system enables us to build prototypes of future applications. Designers draw pictures and choose which colors are associated with tactile or audio feedback. A room can be composed with several pictures, tacticons, sound, or Braille objects which have screen coordinates attributes and click sensitive behavior. Interactivity can be added by the mean of LUA, a light embedded scripting language. This extends the prototyping possibilities to external resources like data stored on the Internet.

In the design space of Tactos configuration (fig. 3), the setting we have used during our prototypes evaluation session is presented on figure 4. The input device was the touch screen of a tablet.

Figure 4. The Tactos system configuration as for our design sessions.

This choice is supported by the observation that absolute positioning input devices (like pen tablet or touch screens) enhance users' shape recognition performance [5]. The tablet touch screen has been preferred on the consideration that the pen tablet introduces a supplementary mediation, the pen, which is not as familiar to blind persons than to sighted people. The "parallelism" mode has been preferred over the "mono" mode as the first one is judged more comfortable by Tactos system users. Thus, the user are controlling a receptor field analog to the resolution allowed by a pair of Braille cells (2 x 8 dots). The sensory feedbacks are related to the application content. Since most of the applications are concerned with bi-dimensional spatial content exploration, the feedbacks provided to the blind users for this purpose are tactile through a pair of Braille cells. Supplementary symbolic information, like explanation or event notification, are communicated through audio feedbacks. The spatial features of content is also displayed and accessible to sighted users.

HIGHLIGHTING INTERACTION AND USE PRINCIPLES FOR TACTOS APPLICATIONS

In order to illustrate our approach, we describe three applications and present their evolution through our prototyping process with users. These applications were chosen because of the interesting elements our work with users have pointed out on the use of a perceptual supplementation system for exploring interactive content. The first application is a tutorial aimed at enabling first users to learn Tactos principles and to recognize basic shapes. The second application is an audio tactile interface to widespread Geographical Information Systems (GIS) like Google Maps and the Open Street Map project. Tactos Map enables users to explore on demand street maps. It provides them with tactile feedback about the road shapes and audio information about the street names. The last application comes from the demand of one of the users involved for the creation of an application related to geography. We have created and adapted a room that presents a map of France with its main cities.

A Tutorial Application for Learning Tactos

Letting end-users discover Tactos and the content provided though it on their own, raised the need for creating learning material. Users can recognize basics shapes after few hours of training [18]. It is then essential to create simple and motivating content to encourage the users to spend time in learning Tactos basics. The two APICADEV members involved in our design session have discovered Tactos with the assistance of the lead designer and a researcher in Psychology who had taken part to past lab experiments with the system. They were guided to first recognize horizontal and vertical lines, then basics shapes (squares, triangles) and complex ones with curved lines. The different recognition strategies of users highlighted by former research on Tactos were explained to our users representatives.

These initial sessions with users emphasized the need to provide guidance to newcomers. They also underlined that the training mainly concerned with exploration of geometrical shapes may worry and discourage users. Users found letter shapes more interesting. These shapes appeared as more widely shared within our intended public. So we designed an interactive tutorial that begins by exercises on discriminating horizontal from vertical lines. Then it proposes to explore letters shapes (fig.5). The letter shapes are ordered by difficulty (number of lines, presence of oblique and curved lines). Users representatives find this tutorial more accessible and playful than geometrical shapes.

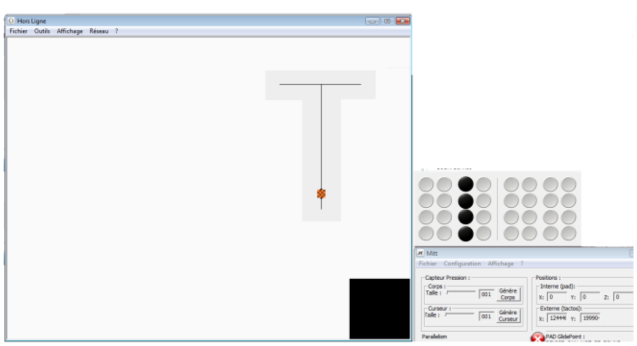

Figure 5. A screen excerpt from the tutorial room on letter recognition. Black pixels are associated with the tactile feedback and the gray area is associated with a sound.

Another problem raised by our design sessions on the prototype tutorial was the difficulty for users to find the shape in the Tactos space. Indeed, exploring the content on their own, often lost users in blank areas. Thus, finding the shape, especially for a new user, might be frustrating. We found that the thickness of the lines is beneficial for shape recognition but may also be a drawback when users try to catch it. Thus we decided to improve our prototype with a guidance system intended to make easier for users to find the shape and explore it. Three different guidance features were implemented and tried out with users:

1. tactile instructions: a tacticons indicates the direction (among eight animated symbols) to follow until the cursor is near the shape to explore.

2. sound mark (fig.5): an area associated with a sound feedback (the music note La) has been drawn around the shape to notify the user she is near the area of interest. When the user's cursor comes in the gray area a sound is played indicating the shape is near.

3. audio instruction: instructions are provided to the user about whether the shapes is leftward, rightward, near or far from her (upward or downward have been observed has misleading instructions since the touch screen used as input device is held on the table).

Users found easier to catch the shape when provided with verbal instructions. They preferred the third mode (3). While verbal instructions seem to efficiently support Tactos' use, our users have judged tactile instructions alone (1) confusing. While the tactile instructions are mixed up with the shape to explore, especially at the tips of the lines, verbal instructions have the advantage of not interfering with shape exploration. Only one user judged the second mode (2) efficient. She was the more experienced with Tactos and the indication of the proximity of the shape is sufficient for her to start exploration. However, the other, less experienced, user found it disturbing. She felt compelled to follow the sound feedback instead of exploring the tactile lines.

Tactos Map

Enabling access to city maps for the blind is a key concern in order to favor their displacement autonomy. This topic has motivated a lot of research [3, 9]. Already existing solutions include the use of raised paper enhanced with auditory information [16]. Today, access to numeric maps through GIS, like Google Maps, has considerably ease the development of such systems, leaving a part here the question of whether the planned path could warrant a safe trip for a visually impaired person.

Tactos map (fig. 6) is a city maps exploration application prototype which enable users to generate a tactile plan of the street shapes supplemented with auditory location information. This way, the user can follow the shape of streets and listen to their name by clicking on the touch screen. At the beginning the user request the map for a location by typing an address (for the moment with the assistance of a sighted person to manage switching from tablet to keyboard). Once the map has been generated, the users is free to go back to request another location or can use the button on the border of the map to displace it. We checked with users that they are able to recognize familiar streets and place with the application.

Figure 6. An example of an audio tactile street map generated by Tactos Map.

We report here on one use issue we had during the prototyping of this application. The size of the area available for a comfortable exploration on the displayed map with Tactos was often too limited to include a complete usual trip for Laura or Elisabeth, like going to the association office. This raised the problem of finding an accessible way to move through maps tiles in order to be able to follow a street when arrived at one border of the map. Our discussion with our users representatives about the drag and drop principle sighted users do seemed unclear for them. They were also anxious about being lost in the map or frustrated at the idea of searching for the last explored street at each update.

The implemented solution was suggested by Laura to add a tactile mark on the touch screen in order to pin out the center of the map. With a tactile bump or a small square of thin plastic sheet, the user can easily find this physical mark on the touch screen. We changed the configuration of the application to center the map on the last user's location at update. This way users can comfortably follow a street along the map tiles updates. When arrived at a border, the user just has to find the central tactile mark to go back to her last location. The central position is important since no surrounding area of the last location can be hidden by the map borders.

Country Level Map Exploration

Content related to Geography has been requested by one of our user. This type of content appears to be interesting for APICADEV members. Prototypes of this room always receive a lot of attention at the occasion of our demonstrations. The implemented map (fig. 7) enables users to follow countries borders and to know in one click over which country or sea they are.

Figure 7. On the left, the evolution of points of interest audio tactile marks (orange triggers audio feedback, black triggers tactile feedback). On the right, a room with the France map queried from Google Maps.

Tactos hardly allows users to identify countries' shapes as a whole. Users are more interested in the spatial relations between countries and those between countries and sea areas. This initial prototype led users' representatives to request additional information on the map like main cities, administrative areas, mountains and rivers. Thus we implemented a new version of the application with landmarks for cities.

Two design sessions were thus dedicated to the design of a landmark pointing the presence of a city. The mark has to be easily recognized as well as sufficiently easy to catch for letting users click and listen to the city name. The first designed landmark (1) provided only audio feedback (the music note "La") in order to prevent mixing up tactile marks with countries shapes, especially for border cities. However, this solution has proven to be unusable. When users hear the sound, they often keep moving the cursor and are no more on the landmark to trigger the voice synthesis. To prevent this frustrating situation, we added a little tactile square on the middle of the landmark (2). This way users trigger the sound that notifies the presence of a city. They then have to catch the tactile square to center the cursor over the landmark. Evaluation with users representatives shows better results than with the solely audio landmark. However, as catching the tactile square is difficult over the tactile frontiers of countries, we inverted the landmarks feedback (3). Since users tend to stop when they hear the sound feedback, this solution creates a small shift that places them over the landmark when they halt. This solution is felt as the most suitable for our users. They find easier to catch the landmark over frontiers and they can still center on it in blank areas.

DISCUSSIONS AND FUTURE WORK

This paper dealt with the design of usable and relevant applications for a perceptual supplementation system intended to visually impaired users. We focused on the design approach that we are developing within the framework of the ITOIP project. A rapid prototyping framework has been built from the Tactos technology. We have illustrated our approach and its results through three cases of applications' rapid prototyping with users representatives. These design sessions have helped us to highlight and solve use issues for future Tactos applications. To sum up we have addressed the guidance system intended to novice users in tutorial material, the navigation on city maps by the use of a touch screen, and the design of audio tactile landmarks to be used in maps content.

This design work with users is also an opportunity to initiate a community of practice [11] around our system. The two APICADEV members who are the most involved in the design process regularly share information with other members about their participation within the ITOIP project. Thus they inform us of the expectations and applications ideas of other APICADEV members. This way they act as ambassadors and build links between the research project and its future users. Their experience with the system, as well as their ability to share their practice of Tactos with new users, will be a valuable asset for the release of the first version of our system. We expect that having some experienced users will greatly facilitate the introduction of the system.

The ITOIP project is an ongoing and ambitious project. A lot of work remains to complete the different applications before we make the system available to the APICADEV members. This first deployment will be the occasion of further refinements to adapt the system to the needs of users with the help of the visually impaired persons involved in the design process. As mentioned with the need of assistance from a sighted person for typing the address request in Tactos Map, one core component to be designed for the Tactos system is to provide users with an accessible text input solution. This system is essential to enable an autonomous use and will open the possibility to send messages to other users. Introducing a communication channel inside the system is an important aspect to support the community driven development process we aims to engage. Besides, we are currently working on adapting Tactos to smartphones equipped with touch screens. This raises several new issues as to the system use in mobility contexts we are currently working on.

Our project insists also on the general benefits of engaging participation with end-users, especially with the blind persons involved in our project. This aspect is essential to think about the ways a technology can be relevant for assisting them in their daily life. As shown in our example, the blind persons we are working with teach us a lot about the way they perceive their environment and technologies. Blind persons experience has also to be viewed as a great potential to orient the design and the understanding of tangible interaction.

ACKNOWLEDGMENTS

This research is part of the ITOIP project funded by the Regional Council of Picardie.

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