Tactile Paper Prototyping with Blind Subjects

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Abstract. With tactile paper prototyping user interfaces can be evaluated with blind users in an early design stage. First, we describe two existing paper prototyping methods, visual and haptic paper prototyping, and indicate their limitations for blind users. Subsequently, we present our experiences while preparing, conducting and analysing tests performed using tactile paper prototyping. Based on our experiences, we provide recommendations for this new usability evaluation method.

Keywords: tactile paper prototyping, low-fidelity prototyping, usability evaluation method, visually impaired, tactile interaction, design methodologies, usability, user-centred design.

1 Introduction

Paper prototyping is a widely used method in user-centred design (see ISO 13407) to develop software that meets users' expectations and needs. Testing concepts with prototypes before implementation allows for inexpensive changes as paper mock-ups, e. g. hand-sketched drawings, can be adapted quickly according to users' comments.

Henry [1] describes common procedures for testing accessible software. Besides the conformance to accessibility standards, evaluation expertise and the experience of people with disabilities is needed to evaluate applications. Specified methods such as heuristic evaluation, walkthroughs and screening techniques can be conducted with design team members or users. Though, Henry does not describe any concrete methods for testing with subjects with disabilities in the early development stage.

Visually impaired access digital information using assistive technology such as screen readers and Braille displays. Within the project HyperBraille[1], a tactile two-dimensional display with the size of 120×60 pins, the BrailleDis 9000, is

[1] HyperBraille project website: http://www.hyperbraille.com/

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being developed which can be used to display multiple lines of text and graphical information [2]. Furthermore, interaction is possible through its touch-sensitive surface. In addition to the hardware, a software system for presenting content of conventional applications (e. g. Microsoft Office, Internet Explorer) is being developed which considers the special needs of blind users. The adaptation of detailed and coloured GUIs to a lower binary tactile resolution with adjusted interaction techniques required an elaborate conceptual design accompanied by ongoing formative evaluation[2].

The first usability test of our concept's tactile user interface was conducted in an early development stage. For this evaluation we applied tactile paper prototyping (see Section 3) in combination with audio confrontation [4]. The focus of this paper is not to give a summary of our evaluation, but to present our observations and recommendations for conducting tactile paper prototyping.

The paper is structured as follows. First, an overview of types of paper prototyping is given. After a brief description of the evaluation, our observations while preparing, conducting and evaluating our tests are discussed. In the following, recommendations for conducting tests using tactile paper prototyping with blind subjects are given. The paper closes with a conclusion and an outlook.

2 Paper Prototyping

In user-centred design, paper prototyping is a widely used low-fidelity usability inspection method to evaluate drafts in an early stage of product design. Prototypes similar to the final product are called *high-fidelity* while those less similar are called *low-fidelity* [5]. In this paper we focus on prototypes for user interfaces.

Subjects evaluate products or applications via mock-ups that provide low functionality and can consist of different materials. Alternatively, prototypes, usually computer applications, provide more functionality, but are normally created later in the development process when basic concepts have already been approved [6]. Paper prototyping does not only serve to evaluate existing concepts and to identify weaknesses, it also offers the possibility to the subjects to make suggestions for improvement. This technique is very inexpensive and effective as it allows for testing a product before implementation.

Mock-ups are prepared in advance by *mock-up designers* who are not necessarily identical to the product designers. Conducting paper prototyping normally requires four responsibilities: greeter, facilitator, computer and observer [7]. A greeter is responsible for welcoming subjects, the facilitator conducts the session. Usually developers play the role of computers, manipulating the interface pieces according to the subject's actions. Observers take notes and are responsible for recordings.

Depending on modes of perception, we can classify current paper prototyping methods in visual (2.1) and haptic (2.2) paper prototyping. According to this naming convention we call our new approach tactile (2.3) paper prototyping.

[2] For more information on formative evaluation see [3].

2.1 Visual Paper Prototyping

Among the three methods visual paper prototyping is the most widely used. Its mock-ups consist of drawn interfaces on one sheet of paper or of several movable and interchangeable individual interface elements which simulate interaction on a static background interface.

According to Snyder [8] most paper mock-ups do not need straight lines or typed text and consistent sizing of components. A complete and neat looking design rather encourages unwanted pedantic feedback, e. g. concerning alignment and sizing. Additionally, Snyder points out that paper prototyping encourages creativity as the handwritten mock-up looks unfinished.

The nature of visual paper prototyping assumes that subjects are sighted and can evaluate the designs with the help of visual information. Thus, this method excludes visually impaired and blind users.

2.2 Haptic Paper Prototyping

Haptic paper prototyping is a special form of haptic low-fidelity prototyping [9]. It serves to simulate and evaluate haptic interaction with a haptic application in an early development stage. A common material for mock-ups is cardboard.

In contrast to visual paper prototyping, haptic paper prototyping can find limited use with visually impaired and blind subjects under the condition that pure haptic interaction is concerned and visual perception is unnecessary. For this reason this method is seldomly applicable with blind subjects when evaluating GUIs. One of the few examples is a media set (see Fig. 1) for teaching graphical user interfaces to blind students, developed by the project EBSGO [10].

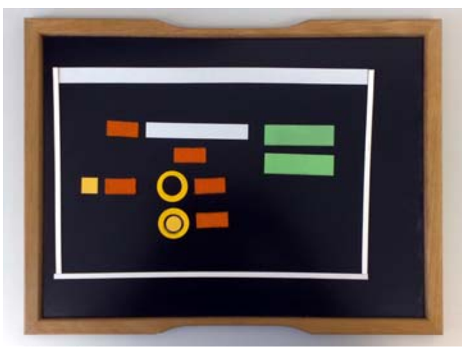

Fig. 1. GUI-Taktil of the EBSGO project showing a search dialog box

Moreover, Tanhua-Piironinen and Raisamo [11] used two types of haptic mock-ups consisting of cardboard models and plastic artefacts for tests with visually impaired children. They pointed out that a possible drawback of this method was the abstract model which does not allow for a full conception of the application as a whole.

2.3 Tactile Paper Prototyping

To be able to perform tests with blind subjects, we adapted visual paper prototyping according to our requirements. In principle, the concept (see Section 2.1) is also applicable to test user interfaces with blind subjects, but the special needs of this user group have to be considered.

Accordingly, our evaluation method allows for evaluating user interfaces respecting the subjects' needs. Indeed, speech output of screen readers can be presented neither by paper nor by tactile mock-ups. Thus, to create a realistic work environment, speech output needs to be presented by the conductors in the role of computers.

The integration of haptic prototyping techniques in our method is conceivable, as interface elements with a structured surface can be used to indicate certain details, e. g. focused elements, as a compensation for highlighting on visual mock-ups. In our special case, evaluating an interface for a device whose pins can only be set or not (on/off), additional haptic elements were not needed.

Fig. 2. Subjects exploring our tactile mock-ups

Test material for visual paper prototyping usually consists of individual interface elements which can be produced, arranged and changed quickly according to the simulated action or the suggestions of the subject. As more preparation is needed for tactile mock-ups when compared to the pen-and-paper approach, changes are unlikely while conducting the evaluation. Anyhow, it is possible to generate new mock-up elements with users during the evaluation e. g. using paper and heat-pen or Braille paper.

3 Evaluation

The evaluation is only briefly overviewed as the focus of this paper lies in the evaluation technique of tactile paper prototyping. A comprehensive description of the evaluation can be found in [4].

In our evaluation, we used paper prototyping in a vertical[3] and low-fidelity manner with a total of 11 blind subjects in groups of two to five. Low-fidelity

[3] Vertical prototyping tests the exact functionality of few elements of a GUI. In contrast, horizontal prototyping tests a broad spectrum of GUI elements with a low level of functionality.

prototyping was appropriate as it was the first test of the designed interface. We used vertical prototyping, as we only focused on some features such as layout and application concept, while neglecting navigation and interaction.

Our test comprised several scenarios with one or two pages each which represented the adapted GUIs for our two-dimensional tactile device. Embossed printings, matching the resolution of the target output device, served as test material. Within our project we relied on two self-developed programmes called HBGraphicsExchange and HBBrailleExchange [12] which allowed our blind and sighted designers to create mock-ups in the appropriate resolution and size, printable with any embosser. To allow for comfortable turning and to sustain the order, the sheets were assembled in binders (see Fig. 2). The hands of the subjects on the mock-ups were videotaped and the discussions were recorded.

4 Observations

In the following, we only report on observations concerning blind subjects. Of course, most general aspects for preparing, conducting and analysing a test with sighted subjects [3] apply as well. Additionally, general issues [1][13] regarding blind subjects have to be considered. Subjects might need escort and transportation to and from the facility and are likely to bring along a guide dog. Thus, setting up the test takes more time and during its conduction additional breaks might be needed. Furthermore, extra room for service animals or assistants is needed and obstacles should be cleared out of the way.

4.1 Preparing

For tactile paper prototyping thorough preparation is important. To be able to present several solutions, it is advisable to produce multiple mock-ups for each scenario in advance, as new ideas of subjects are difficult to cover during a test.

Embossers. Creating tactile paper mock-ups requires special hardware. In the following we only discuss Braille printers, called embossers, because their prints have similar physical properties as Braille displays and most planar tactile devices. In general, the material used should resemble the final product as much as possible to ensure realistic results.

Before designing tactile mock-ups, essential facts of the embosser are needed. These comprise the embosser's resolution, equidistant or non-equidistant output, and the format and type of paper needed. Printable file formats of the chosen embosser affect the choice of the software for designing the mock-ups.

Software. Alternatively to the programmes for creating mock-ups used in our evaluation, Word documents can be interpreted by most printer drivers. While this works well for text, graphics are interpolated, resulting in tilted lines of varying thickness. Thus, it is best to create graphics matching the embosser's resolution. Graphics software can also be used, if its file formats are directly supported or if translation software is available.

Material. In contrast to sighted users who perceive representations as a whole and focus on details later on, blind users first explore details to construct a complete mental model. Thus, one representation of our test comprising multiple widgets on one sheet of paper caused difficulties in locating the described element. Therefore, it is advisable to display only one representation per sheet.

To avoid orientation difficulties due to sketchy representations it proved essential to map geometrical shapes as precise as possible, and to maintain the proportions and scale of the original output device, especially as Braille requires a fixed resolution. Thus, the special needs of the target group impede conformance to Snyders demand for handwritten visual mock-ups (see Section 2.1).

In our test, subjects were irritated by missing elements as some regions of our representation were not as detailed as the planned implementation. In such cases missing elements need to be indicated on the mock-ups or mentioned by the facilitator to avoid confusion. As it is more difficult to refer to and to discuss certain elements or positions on the mock-ups than with sighted subjects, a coordinate system can be helpful to improve the subjects' orientation, e. g. dividing the representation like a chess board and referring to the squares.

Proofreading. Before producing copies for the subjects, mock-ups should be proofread by Braille literates. This is necessary as spacing and spelling mistakes frequently occur when transcribing from print to Braille. In a non-visual context, spelling mistakes irritate even more than in visual mock-ups as the two-dimensional representation is unfamiliar to the users and an overall overview is missing. Additionally, the facilitator, not necessarily Braille literate, cannot control and correct mistakes as easily as in print.

Unless sighted designers are experts in Braille and working techniques of the blind, it is, of course, best to include blind mock-up designers in the preparation process. A couple of our mock-ups were dismissed by the subjects because the design strongly resembled visual concepts. These mock-ups had not been reviewed by our blind designers and had inevitably failed during the test.

Assembling. Supporting a smooth work flow, the order of the mock-ups used has to be consistent with the tasks. It proved useful to label the sheets with numbers or letters in Braille and print for the subjects and the facilitator.

When movable individual interface elements are used, they have to cling to the main representation (with help of magnets, sticker, felt etc.) to avoid shifting during exploration. As we conducted our tests with groups, individual interface elements would have been impracticable. Thus, changing screens were simulated by different prints, available by turning the page.

4.2 Conducting

After preparing the test material, five main aspects have to be taken into consideration. These comprise setup, recording and team structure. Furthermore, timing and explaining are crucial for tactile paper prototyping.

Setup. Our mock-ups were in landscape format; therefore the opened binders faced the subjects with their narrow side. In one location, the width of the table was not sufficient, thus the two facing binders touched each other and impeded the turning of pages. It is favourable to choose a table which is large enough to arrange all test materials comfortably and to allow the subjects to move their hands and arms freely to avoid collisions while exploring a paper mock-up.

Recording. As a repetition of tests with small user groups is difficult, it is advisable to prepare and record the sessions carefully. In advance, the positions of microphones and cameras need to be considered and tested depending on the seating arrangements and the area of interest to be recorded. We positioned a camera on the table to record the subjects' hands and the mock-ups.

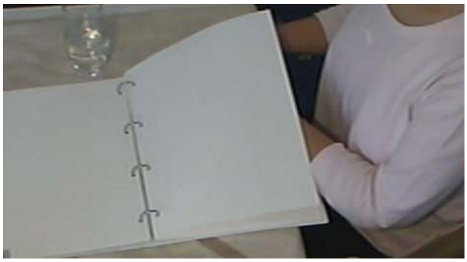

Fig. 3. Subject with hands under mock-ups

Unfortunately, with some subjects the recording was useless, as they explored the mock-ups with their hands underneath the previous sheet of paper, i. e. they did not turn the page (see Fig. 3). In such cases the facilitator must ask the subjects to turn the pages completely.

While the video shows, where the subjects' hands are positioned, it does not show satisfactorily if there was contact with the mock-up at all and which parts of the hand touched the mock-up, and how much pressure was applied.

Team. When using movable individual interface elements, the number of people needed for conducting tactile paper prototyping increases with the number of subjects. For a test with several subjects, the facilitator cannot demonstrate tactile representations to all group members simultaneously. Therefore, subjects must be provided with their own copy of a mock-up as it can only be explored by one person at a time. The subjects must be able to handle these copies on their own or, depending on complexity, one assistant (in the role of the computer) for one or two subjects is necessary.

Timing. Before dealing with a new mock-up, the facilitator has to make sure through announcing the mock-up's label that each subject has the correct material in front of him. Furthermore, the facilitator has to consider different reading speeds and exploration styles (one- or two-handed) of the subjects. Without allowing for sufficient exploration time, subjects might be overwhelmed by the amount of information, try to keep up at the expense of exploring details, ask unnecessary questions or be more likely to abort the test.

Presenting mock-ups in binders can be problematic, when subjects are too curious. Some of our subjects were distracted by successive scenarios because they turned pages. An alternative could be to hand out individual sheets of paper. When doing so, the computer has to ensure that all mock-ups lie in the correct orientation in front of the subjects to avoid confusion. Therefore piles of mock-ups should not be circled around but rather be placed in front of each subject individually. Though, this procedure can be disruptive and time consuming. The facilitator should thus, when using binders, indicate during and in the beginning of the test when it is appropriate to explore which mock-up or when e. g. listening is desired.

Explaining. As blind subjects seldom have experience and knowledge about GUIs, it is essential to explain the design, content and purpose of the general design concept and the current mock-up from their perspective. This task can become a challenge, because difficulties in understanding might occur, even if the facilitator and his assistants are familiar with blind work techniques. It is advisable to take help from blind experts in advance and prepare explanations with them beforehand.

Additional illustration is also needed for specific tasks in applications that blind users are not familiar with, in order to allow them to comment on the implementation proposal. In our test, prior explanation of the mock-ups proved helpful because not all subjects possessed sufficient background knowledge.

4.3 Analysing

Shortly after the test, the results and impressions should be documented and analysed to avoid forgetting important details. The evaluation can comprise reading and completing the minutes, transcribing the audio to collect comments and evaluating the video. When video recordings are used, it is advisable to have ink printing superposed with embossing on one sheet. One could first print and then emboss or use a special printer which can do both simultaneously. In our test the sole embossed printings were hard to perceive on the recording when analysing the video, so that the elements explored in scenes could only be guessed by the positions of the subjects' hands.

After extracting impressions and comments of the subjects, it should be decided whether it is a problem of concept, material, explanation or a personal preference. When testing multiple mock-ups, e. g. for different scenarios, it is advisable to compare the comments concerning the different mock-ups to extract aspects which can be applied to the entire concept or design.

5 Recommendations

The main goal of an evaluation is to identify existing problems and to find potential for improvements. To achieve this aim, the evaluation must be prepared, conducted and analysed carefully and adequately. In the following, we present recommendations for tactile paper prototyping which have been condensed from our observations (see Section 4):

– Consider general issues when hosting blind users.
– Provide adequate facilities according to the special needs.
– Check for special hardware and software required.
– Design mock-ups not for sighted but for blind users.
– Even better, have blind people design the mock-ups.
– Proofread the mock-ups before conducting the test.
– Check the recording before and during the test, as repetition is expensive.
– Provide a sufficient number of assistants.
– Make sure that mock-ups are provided synchronously to each subject.
– Allow for sufficient time to explore the mock-ups.
– Explain from the blind users' perspective.

Different usability evaluation methods have different aspects which should be considered. Nevertheless, many of these recommendations do not only apply to tactile paper prototyping but are also applicable for other evaluation techniques involving blind subjects.

6 Conclusion and Outlook

Tactile paper prototyping is a new approach to design haptic user interfaces. It allows to bridge between the visual and haptic modality while ensuring multimodality when using assistive technology to gain access to graphical user interfaces. Tactile paper prototyping applies to user centred design.

We developed 16 tactile paper mock-ups to design a user interface which includes Braille and tactile graphics using a planar tactile display. Due to limitations of resolution and size of such a tactile display re-design of visual concepts is required. Like paper mock-ups, tactile mock-ups allow for verification of design concepts before implementation and involvement of end users. Therefore, we found it essential that blind people contribute to mock-up production and that mock-ups are evaluated by prospective blind users.

To aim at validation of our approach a follow-up study using a wizard-of-oz approach has been conducted. It involved three separate users who confirmed the suitability of a selection of haptic designs on the actual planar tactile device [14]. The mock-ups that were rejected during the tactile prototyping had deliberately not been included in this evaluation.

Future work will have to extend our approach to the design of audio-haptic interfaces possibly supporting also Braille-illiterate users. The suitability of tactile paper prototyping must be tested for other application areas such as maps, games, or collaborative software. The analysis of hand contact will have to be considered in more detail in order to understand failures and mismatches in the design more easily.

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