Redesigning Input Controls of a Touch-Sensitive Pin-Matrix Device

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ABSTRACT

To support blind people in dealing with graphical user interfaces some two-dimensional Braille devices were developed. In order to ensure an efficient workflow not only the preparation of content, but also the handling of the device has to be well usable. In this paper, the redesign of a touch-sensitive pin-matrix device is discussed. At first, some mock-ups of additional input controls were designed and evaluated with six blind users. As the position of the keyboard has been found to be important for ergonomic aspects, a second user evaluation was conducted. Based on the results of these two studies, a proposal for redesigning the device as well as some basic design recommendations can be given. Furthermore, the new BrailleDis 7200 is described in detail.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*ergonomics, evaluation/methodology, haptic I/O, input devices & strategies, prototyping, user-centered design*

General Terms

Design, Experimentation, Human Factors

Keywords

Pin-matrix device, tactile display, Braille keyboard, blind users, mock-up test, ergonomic input

1. INTRODUCTION

In order to enable an efficient usage of graphical user interfaces for blind people, an ergonomic workstation has to be provided. Therefore, two-dimensional Braille displays were developed as they allow to explore graphical content and spatial relationships of interaction objects. Compared to single line Braille displays much more information can be provided simultaneously. To reduce mental and physical workload, not only the preparation of content, but also the handling of the device has to be well usable. For example, unnecessary hand movements between Braille output and

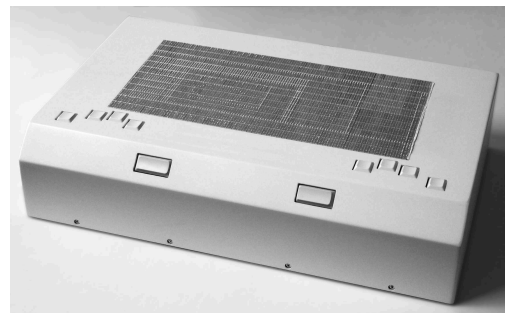*TacTT '14*, Nov 16 2014, Dresden, Germany.

Figure 1. BrailleDis 9000 with touch-sensitive pin-matrix area and Braille input keyboard on its front.

keyboard should be reduced. For this, the device should offer gestural input as well as some hardware keys allowing the user to trigger most important functionalities directly on the device.

The BrailleDis 9000, which is introduced by Völkel et al. [7], consists of a touch-sensitive pin-matrix made out of 7200 pins and a Braille input keyboard on its front side (see Figure 1). In addition, a special screen reader, called Hyper-Reader, was developed. With it, blind users are able to interact with graphical user interfaces shown on the BrailleDis. Based on further user studies with the pin-matrix device, e.g. [5] and [4], some requirements for the design of the device arose. For instance, while reading on the pin device users often triggered functions of the HyperReader by activating Braille input keys unintentionally. Furthermore, some users would like to have some more keys which can be freely configured. For adapting the interface of the BrailleDis hardware to these new requirements, a redesign of the device was necessary. In the following, the design of some input control mock-ups as well as their evaluation with blind users is presented. Based on the results, basic recommendations for an ergonomic tactile input device are given.

2. EXTENDING THE BRAILLEDIS WITH ADDITIONAL INPUT CONTROLS

There are already numerous input controls that should allow graphical or haptic user interfaces to become more efficient and intuitive. Taking up these ideas, it can be possible to add some new input elements to the BrailleDis. By this means, important interaction commands could be triggered more fast and intuitive.
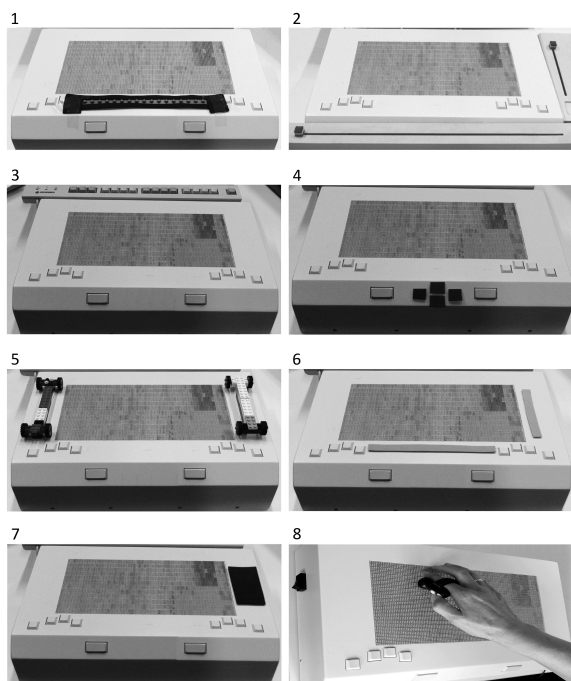
Figure 2. Input control mock-ups evaluated in first user study.

Experiences of blind computer users include some special input controls that are common for using with standard Braille devices. For example, Braillex devices from Papenmeier[1] inclose a joystick-like navigation bar (Easy Access Bar) allowing a fast and intuitive moving of the display. The VarioPro Braille device of Baum[2] can be extended with Tactile Acoustic Side Orientation (TASO) modules. These consist of vertical and horizontal sliders which can accelerate the navigation on the two-dimensional screen through audible signals.

Looking at a standard keyboard, function and cursor keys enrich the simple input of text. Besides, pointing devices, such as a mouse, are necessary for efficiently dealing with graphical user interfaces. In the world of sighted users there are also tools, such as mouse wheels and touch pads, which allow to simplify important scrolling interactions.

Existing two-dimensional tactile displays, such as GWP[3] and DotView graphics display[4], also use cursor keys or joysticks for realizing panning or zooming functions as these are important in the exploration of graphical user interfaces. The more often an input command is needed, the easier it should be triggered out.

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[1] F.H. Papenmeier GmbH & Co. KG - Braille devices, see http://www.papenmeier.de/en/reha-division/products/overview-braille-devices.html
[2] Baum Retec AG - VarioPro and TASO modules, see http://www.baum.de/cms/en/variopro/
[3] Maple GWP by Handy Tech GmbH, see http://handytech.de/produkte.php?produkt=58&lang=en
[4] DotView Series tacile graphic display devices by KGS, see http://www.kgs-america.com/gc.html

Therefore, the following mock-ups for extending BrailleDis 9000 should use the mentioned ideas:

1. navigation bar in front of the pin-matrix area

2. TASO modules in front and on the right of the device

3. function keys behind the device

4. cursor keys in the middle of the Braille input keyboard

5. mouse wheels on the right and left of the pin-matrix area

6. touch sliders[5] in front and on the right of the pin-matrix area

7. touch pad for gesture input on the right of the pin-matrix area

8. finger mouse[6]

In Figure 2 all input control mock-ups are shown. Some of these elements can be combined with others, too.

3. USER EVALUATION

To identify the most promising and helpful input controls and their positioning on the BrailleDis the designed mock-ups were evaluated by six blind people. In a first step the different interaction elements were rated separately. In a second step some new mock-ups, which combine the most suitable input controls, were evaluated based on different kinds of working tasks.

3.1 Evaluation of Different Input Controls

A study with six blind subjects (three female and three male with an average age of 34 years) was conducted to rate the applicability of the eight input control elements shown in Figure 2. All participants are Braille readers dealing with a computer several hours a day. All of them have some experiences with the pin-matrix device as they took part in former studies or were involved in the HyperReader development.

3.1.1 Method

The test was divided into an introduction, a Wizard of Oz and a questionnaire phase. At first the HyperReader's general functions were introduced. Then the mock-ups and their principles of operation were presented one after another. Thereby, the user had to fulfill a certain task with the current input control element while thinking aloud[7].

The task for mock-up 1 to 6 was to explore a dialog window within symbol view of the HyperReader [5], in which the spatial relationships of all GUI elements were obtained on the pin-matrix device, but all texts were presented in Braille.

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[5] For instance, SoftPot potentiometer sensors (see http://www.spectrasymbol.com/potentiometer/softpot) could be used to realize some touch sliders.
[6] Finger mouse could be used to start gesture input instead of thumb keys of Braille input device, which is utilized at present.
[7] The think aloud method means that the user verbalizes his reasoning and thoughts during a problem-solving task [3].

The exploration should be done from left to right and from top to bottom for getting a feeling of the input control's usage. In a second task the user should execute some zooming functions within the pixel based layout view of the Hyper-Reader [5]. This task should be done with mock-up 3, 5, 7 and 8. Depending on the user's input, the content shown on the pin-matrix display was modified by the test supervisor. That means, he presented some predefined output by button command (Wizard of Oz experiment, see [2]).

After each mock-up test some questions about the input control element were asked, for example about its intuitiveness or its positioning on the pin-matrix device. At the end, the user should rate all mock-ups on a scale from 1 (very bad) to 5 (very good) and he also could give some comments. Furthermore, some general questions about ergonomic aspects, for example, relating to the Braille input keyboard or the slant of the pin-matrix display, were asked.

3.1.2 Results

The rating of input control mock-ups given by the six blind participants was very heterogeneous for both tasks, panning and zooming (see Figure 3 and Figure 4). Only the navigation bar was accepted by every subject as it is very common for using as panning device on standard Braille displays. Therefore, it is the most intuitive input control for panning commands. In contrast, most of the participants want to have function keys, but they not seem to be very intuitive for panning or zooming. Cursor keys could be used for panning intuitively, but they are not sufficient as only possibility for panning.
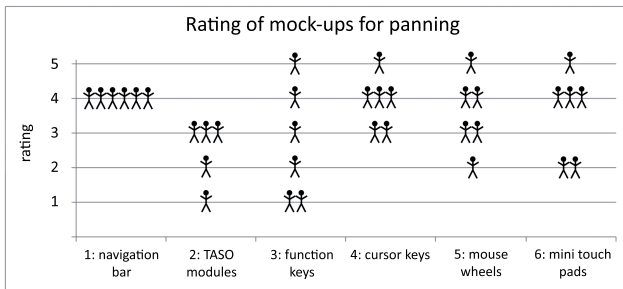

Figure 3. Participants' rating of input control mock-ups used for panning commands on a scale from 1 (very bad) to 5 (very good).
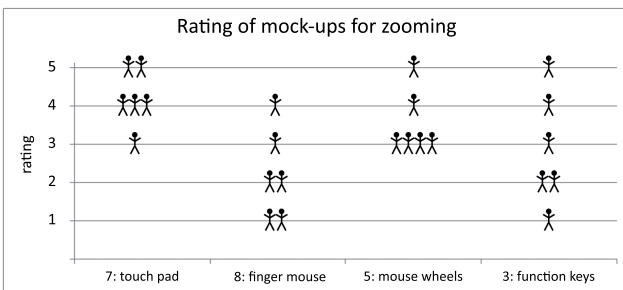

Figure 4. Participants' rating of input control mock-ups used for zooming commands on a scale from 1 (very bad) to 5 (very good).

Only three of the participants could orient themselves on the screen by using TASO modules as it seems to be unclear how much of the content was moved. Four of the subjects think that vertical mouse wheels are not intuitive for scroll operations, particularly for horizontal scrolling. For zooming functionalities most of the subjects would prefer gesture input on the touch pad. The finger mouse was not liked very much as it not only needs getting used to, but also annoys half of the users while reading the content. Regarding some ergonomic aspects of the mock-ups, five of the six subjects prefer to work on an inclined pin-matrix display as it would be more comfortable. Half of the participants like the keystroke of the Braille input keyboard and also the major spacing to the outer Braille keys. The other would like to have a consistent spacing and either a more smooth or a more rough keystroke.

3.1.3 Discussion

Based on the results, the most suitable input controls can be chosen to extend the BrailleDis 9000. Most of these special controls allow for a more intuitive usage than it is possible with the Braille input keyboard. Like the function keys it is important and desired by the user, but its key role should be the input of text. For efficiently working on the pin-matrix device, the goal of the redesign should be to avoid the frequent handling with a standard keyboard. Therefore, the most important functionalities of graphical user interfaces, such as panning, zooming, text input and moving of focus or caret, should be available on the pin device. As mentioned above, the navigation bar is the most intuitive tool for realizing panning operations. Also cursor keys were rated very good, too. Therefore, they can complement the navigation bar by realizing some further moving operations, e.g. of the caret. Zooming can be implemented by gesture input. Instead of using a separate touch pad, this can be done much better directly on the pin-matrix as it is touch-sensitive, too, and it allows the user to keep a reference point. However, as the gesture recognition has to be started by holding down one of the Braille keys [6], a simple key pressing or scrolling on a mouse wheel could be more efficient in some situations where no reference point is necessary. Therefore, an additional mouse wheel can also be used on the pin device. Besides these new input controls, the new pin device should be reduced in its height and inclined in an angle between 10 and 15 degrees which allows for a more ergonomic working. Furthermore, the Braille input keys should be lowered to avoid accidental releases while reading on the pin-matrix. Combining all these requirements and ideas, the new BrailleDis could be designed as shown in Figure 5.

3.2 Evaluation of Input Control Placement

The first user study showed that the position of the keyboard is important for ergonomic aspects, too. Indeed, the new prototype is designed for working independently from a keyboard to some extent. In some situations a standard keyboard will be necessary nevertheless. For example, some users are not practiced in using a Braille keyboard or prefer to use a standard keyboard, especially when writing a lot of text. Therefore, a second study with five of the six blind participants was conducted. Aim of this evaluation was to find out how the keyboard should be placed in different situations of working.
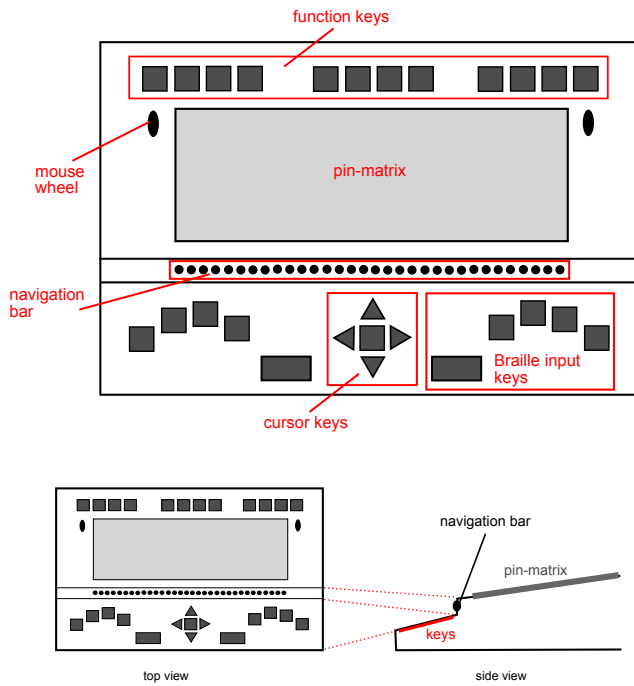
Figure 5. Prototype of new BrailleDis design in top and side view based on the first user study.

Figure 6. Four different mock-up scenarios consisting of pin device, Braille input and standard keyboard modules.

3.2.1 Method

In contrast to the first study, the BrailleDis hardware was not included in the test. Instead, some paper-based mock-ups of the pin-matrix display complemented with prototypes of navigation bar, mouse wheels and function keys were used. This pin device module was combined with a standard and a Braille input keyboard in four scenarios (see Figure 6):

1. Braille input keys in front of the pin-matrix as proposed in the design shown in Figure 5, keyboard is placed on a sliding carriage above the pin device

2. Braille input is integrated in the function keys, keyboard is placed in front of the pin device

3. Braille input keyboard is divided and placed next to the pin device (left and right), standard keyboard is placed behind the pin device

4. Braille input keys are in front of the pin-matrix like in scenario 1, standard keyboard is placed on the right of the pin device in the form of a corner seat scenario

The participants' task was to simulate three different situations of working:

a) skimming over a text and scrolling by keyboard input

b) writing text by keyboard input and checking it in detail area (lower line of BrailleDis output, see [5])

c) exploration of the pin-matrix content in different view types by interacting with Braille input keys and gesture input
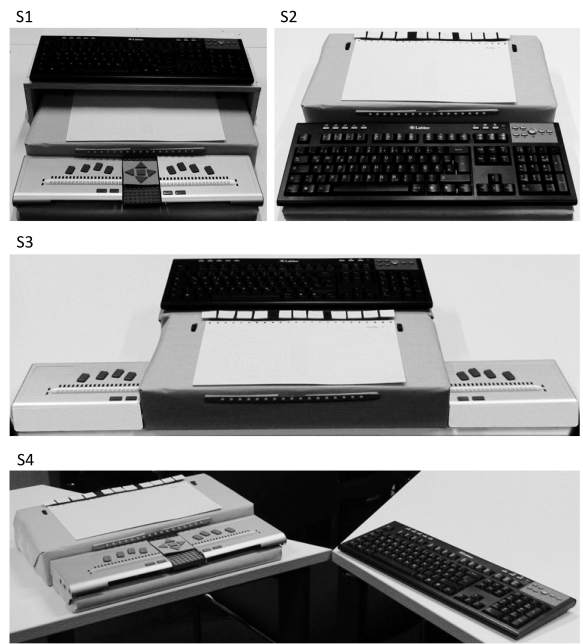
All of these three tasks were given to the user for each of the four different mock-up scenarios. For each task a time slot of 5 minutes was scheduled in which the subject should give his thoughts about the mock-up handling, e.g. ergonomics of arms and hands while reading and interacting. The output on the pin device paper prototype was simulated by changing some Braille print-outs with different content (comparable to Wizard of Oz experiment in the first study). After all, some questions about the different positions of keyboard and Braille input keys were asked (see Table 1).

Table 1. The participants' opinion about some possible usage of Braille and standard keyboard

	answer	
question	yes	no
Could you imagine to integrate a standard keyboard into the BrailleDis?	2	3
Do you need a Braille input keyboard?	1	4
Would you accept to use a divided Braille input keyboard?	3	2
Would you accept to assign the function keys with Braille input commands?	4	1

3.2.2 Results

In Figure 7 the results of user rating of some ergonomic aspects for placing the keyboard in different positions relating to the pin device are shown. The results for the Braille input keyboard are shown in Figure 8. Both keyboards got the highest rating in all ergonomic aspects when they are placed in front of the pin-matrix device. In contrast, placing a keyboard behind was rated the worst as it is far away from the user. On the other side, all participants criticized a long
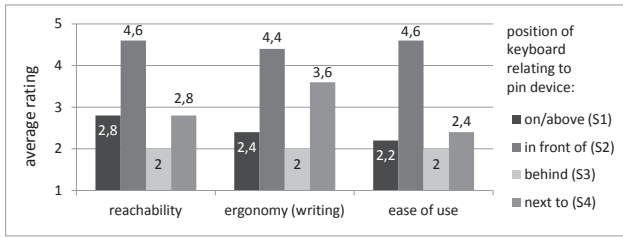
Figure 7. Average rating of some ergonomic aspects for placing the keyboard on different positions within the scenarios shown in Figure 6. The scale reached from 1 (very bad) to 5 (very good), n=5.
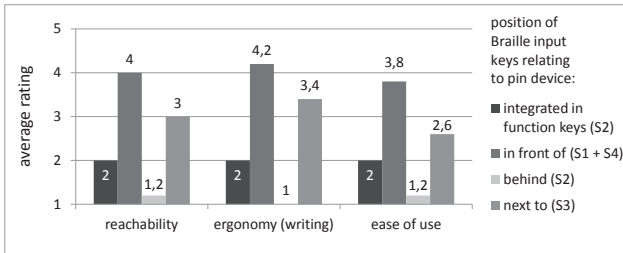

Figure 8. Average rating of some ergonomic aspects for placing the Braille input keys on different positions within the scenarios shown in Figure 6. The scale reached from 1 (very bad) to 5 (very good), n=5.

distance to the pin-matrix area as it appeared in scenario 2 (see S2 in Figure 6), too.

Even before the study it was clear that compromises must be made. Therefore, some further questions about possible usages of the Braille and the standard keyboard were asked. In Table 1 the opinion of the five participants relating to these questions is shown.

3.2.3 Discussion

Expectedly, positioning the input device in front of the pin-matrix device is liked the most by the participants, regardless of whether the standard or the Braille input keyboard is used. For writing text this would allow to have the keyboard and the detail area (for checking the written words) next to each other. This shortens the distance which is necessary for movements of the hand and, therefore, can increase the efficiency. Nevertheless, if both keyboards would be placed in front of the BrailleDis, the pin-matrix output would be far away from the user. Especially for exploration tasks this is not very comfortable. On the other side, most of the participants could do without an extra Braille input keyboard, but would accept to assign the function keys with text input commands.

Based on these results, a new prototype design was created (see Figure 9). For shortening the distance between the user and the pin-matrix area with all input keys behind it, the Braille input keyboard on its front side was omitted. Only an ergonomic tray for putting the heel of hand on it was added enabling a more comfortable usage. If the user needs
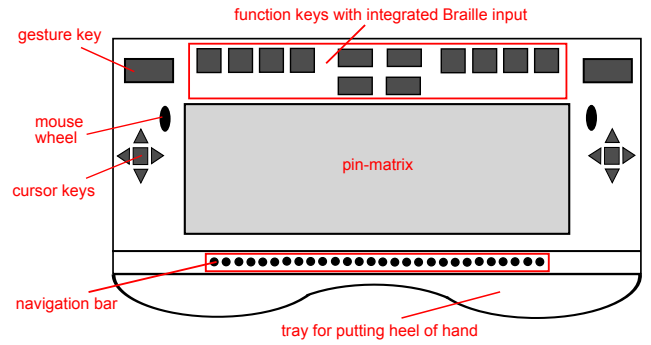

Figure 9. Prototype of new BrailleDis design in top view adapted to the results of the second user study.

a keyboard, e.g. for writing long text, he can put it in front of the pin device or in any other position. Otherwise, in exploration tasks the use of hardware keys placed on the pin device, namely the navigation bar, mouse wheels as well as function, cursor and gesture keys, is sufficient. This allows to individualize the work station much more as the old design could do.

4. THE NEW BRAILLEDIS 7200

The design proposed in this paper was included into the process of constructing a new version of BrailleDis (called BrailleDis 7200, see Figure 10). Thereby, all basic ideas were realized.

4.1 Description

Instead of the suggested mouse wheels two toggle switches were embedded. Besides the new input controls, the height of the device could be reduced from about 95 to 60 mm. Apart from that, the new BrailleDis has a dimension of 410 x 255 mm and a weight of about 5.5 kg. To minimize the risk of injury, all edges of the body are rounded. On the left and right bottom side there is a notch facilitating the carrying of the device. Additionally, there are two keyboard feet allowing to increase the tilt of the display by about six degrees.
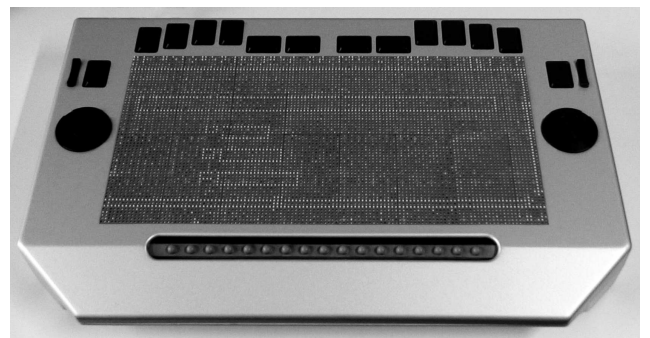

Figure 10. BrailleDis 7200 with touch-sensitive pin-matrix area and additional input controls (navigation bar in the front; cursor key pads, toggle switches and gesture keys on left and right side; Braille input and function keys behind).

Like the previous version of BrailleDis it also has a 150 x 300 mm sized tactile area built up of 720 Braille modules, each consisting of 2 x 5 pins (on the whole 120 x 60 pins). However, the amount of touch sensors was doubled from one per module to a total of 1440 sensors [1]. The modules are covered with some replaceable gray caps. This allows for more color contrast against the white pins. In the same way, the black input keys on a silver-gray background can support some remaining vision abilities of the users. BrailleDis 7200 allows for a refreshment of touch and pins each 50 ms, the keys can be readout each 10 ms. It is connected via USB and needs a separate power adapter.

In total, there are 14 standard push-buttons, two toggle switches, two cursor key pads consisting of five buttons and one navigation bar. The cursor key pads are made of one piece (comparable to a swash plate) allowing to press them in the middle or on one of the four directions. The navigation bar enables eight input levels, two in every direction. To avoid an unintentional activation it is embedded into the device and inclined a little bit. Under the wrist rest, which narrows to the front, there is some space for placing a keyboard about 2 cm closer to the pin device.

4.2 First Evaluation

Based on the new input controls, a more intuitive concept for using the HyperReader was developed. For example, scrolling operations can be triggered with the navigation bar, zooming functions with the toggle switches and the cursor keys on the pin device can emulate that of the standard keyboard. To allow for a first evaluation of the new BrailleDis 7200, some questions about the device were given to twelve visually impaired users after they had taken part in a user study dealing with the HyperReader on this device. Seven of the participants already had some experiences with the previous version, namely BrailleDis 9000.

Some important results of the interviews are presented in the following. For seven users the height of the device is adequate, while five of the participants think it is still too high. The form of the device is liked by ten users, only two people think it is too chunky. Eleven participants think that none of the input controls is needless. The input by navigation bar, cursor key pad and toogle switches is rated as easy. Only the handling of the function keys appears a bit more complicated as these are farthest from the user. In summary, the BrailleDis 7200 was liked by the users and could allow for a more intuitive handling of the HyperReader functionalities.

5. CONCLUSION

Depending on the current working task there are very different requirements a two-dimensional Braille device has to fulfill. For example, in reading tasks the pin-matrix area showing the content has to be close to the user. Thereby, important functions for zooming and panning should be available directly on the device for avoiding hand movements over a long distance. In contrast, writing tasks require a comfortable access to the keyboard, either a Braille input or a standard keyboard. Besides, the distance between keyboard and Braille content area for proofreading should be minimized, too. Keeping this in mind, allowing the adaptability of a workstation is very important.

In addition, some further recommendations for an ergonomic tactile input/output device can be given:

1. Keys that can be easily triggered should not be placed directly in front of the reading area to avoid an unintentional activation.

2. Unneeded hand movements over a long distance should be avoided.

3. Additional input controls placed on the device can increase the user's efficiency. Therefore, they should be mapped to a specific function as intuitively as possible.

4. A comfortable arm positioning should be ensured. For instance, in front of the reading area some kind of tray for putting the heel of hand should be available.

These recommendations arose out of two user evaluations in the process of extending the BrailleDis 9000 with additional input controls. Depending on the tasks and context of using a special two-dimensional pin-matrix device some other or supplemental requirements can be necessary.

6. ACKNOWLEDGMENTS

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