Reading Braille and Tactile Ink-Print on a Planar Tactile Display

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Abstract. Reading characters by fingers depends on the tactile features of the medium in use. Braille displays were often found to be slower than Braille on paper. We study reading Braille on a novel planar tactile display by conducting three reading tests. A first study compares the reading speed on four different devices, namely paper, 40 cell Braille display and two varied conditions on the planar pin device. In a second study we isolate the factor of 'equidistance' which is due to the design of our planar tactile display. Our intention is to find out if equidistant Braille can be as fast as standard Braille. Because of the two-dimensionality, the pin device also can show graphics and tactile ink-print. The latter was evaluated with blind subjects in the third study.

Keywords: equidistant Braille, tactile ink-print, blind users, planar tactile display, reading speed.

1 Introduction

In times of graphical multimedia-based applications it becomes more and more difficult for blind people to get equivalent information as their sighted fellows. In the last years, multimodal solutions providing some access to graphical user interfaces for blind people became available. Existing approaches are based upon auditory output of voice or non-speech sound [10], haptic transformations through force feedback [11], or tactile output by Braille. In this paper the planar tactile display 'BrailleDis9000' (hereinafter referred to as 'pin device') described in [16] is used as input and output medium (see figure 1 a). This tactile device not only allows displaying Braille but also graphics through tactile pins in a matrix of 120 columns and 60 rows at a distance of 2.5 mm horizontally and vertically.

When developing a tactile approach for access to colored graphics or merging any kind of tactile graphics with Braille (see [15]), it becomes apparent that the following problem can arise if text is integrated into graphics. For a continuous presentation of tactile graphics it is necessary that every pin has the same spacing to its neighbors. Because of these equidistant pins, two Braille letters have to be

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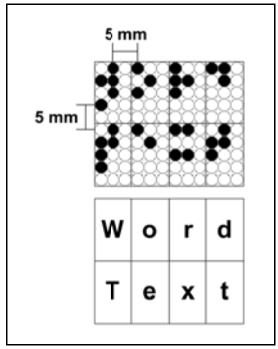
a)



b)

Fig. 1. Planar tactile display (a), 5 x 3 pin-matrix of equidistant Braille letters (b)

separated through a vertical and accordingly a horizontal line of lowered dots on the tactile display in order to be readable. Each letter is than assigned to a 5 x 3 matrix of pins as proposed in [14]. Thus, the spacing among two Braille characters is 5 mm (see figure 1 b), that is 1.5 mm larger than on a standard Braille display. In the following such a Braille font is referred to as *'equidistant Braille'*.

Allowing the user an equivalent reading on the pin device, the reading speed should not be adversely affected by equidistance, especially regarding the obvious slower reading speed of Braille readers in comparison to sighted people [3]. Numerous studies can be found addressing several aspects of reading Braille, like hand techniques [6,2], the comparison of reading rates in different tasks [4] or reading Braille in comparison to print readers [17], recognizability of Braille letters [13], and improvement of reading speed [3]. It was also tested how different spacing between Braille dots and between Braille letters influences the readability and therefore the reading speed [7]. But there are no predications for equidistant Braille on a planar pin device yet. For this reason, this paper shall discuss how the reading rate on a two-dimensional equidistant Braille display varies in comparison to a standard Braille device.

Besides displaying Braille, the BrailleDis9000 also allows the output of tactile ink-print fonts. Especially for former print readers and the elderly this could be an alternative reading solution, resembling the barb font (*Stachelschrift*) developed by Wilhelm Klein in 1807. Often these people have difficulties in learning Braille [1]. In a study by Chepaiti [1], seniors could read letters of a raised Roman Alphabet faster and more accurate than standard Braille. This success encouraged us to additionally inspect the use of tactile fonts on a planar tactile display.

In this paper we describe the effects imposed by the tactile medium on Braille reading speed, and discuss initial observations of exploring tactile ink-print.

2 Braille Reading Study

The central purpose of the first study was to compare the reading of equidistant Braille with standard spaced Braille. On the one hand, Braille is read on paper, which is planar, and on the other hand it is read on Braille cells showing only one line at once. In the experiment equidistant Braille should also be presented in a planar way, covering the whole output device and in a single-line modality. A single line standard Braille display may still be read differently if compared to a single line of Braille on a planar tactile display. We call this last mode the 'Braillex area'. It is the lowermost row of the BrailleDis9000 showing the same information as a standard 40 cell Braille device. Out of this, a total of four different reading conditions arise.

2.1 Method

The study was conducted with 20 blind subjects. After a warm-up phase of 10 minutes on the BrailleDis9000, each subject had to read one of four texts on each of the four reading devices aloud. To avoid learning, order and tiring effects both the texts and the reading media were equally disposed on the four reading tasks. For each device 8-dot Eurobraille was used. At the end of a five minute session the last read phrase was noted. Out of this note, the number of words read was determined and the reading speed in words per minute could be calculated for each device.

2.2 Results

The resulting mean reading speed is shown in table 1. In figure 2 the variability of measured reading speed of all subjects is illustrated for each reading device. The high variation arises from the inhomogeneous group of subjects regarding their reading ability.

The ANOVA revealed a significant effect of the reading device on the reading speed (F=6.206, p = 0.001). Furthermore, two-sided t-tests show no significant difference on the reading rate between standard Braille display and pin device (t=2.035) as well as between pin device and Braillex area (t=1.932).

Table 1. Mean reading speed with standard deviation according to the used reading device

Reading device	Mean reading speed in words per minute (wpm)	Standard deviation
Printed Braille (Paper)	58.9	16.3
40 cell Braille device	50.0	12.8
Planar tactile display	45.2	14.0
Braillex area (40 cells)	41.2	10.9

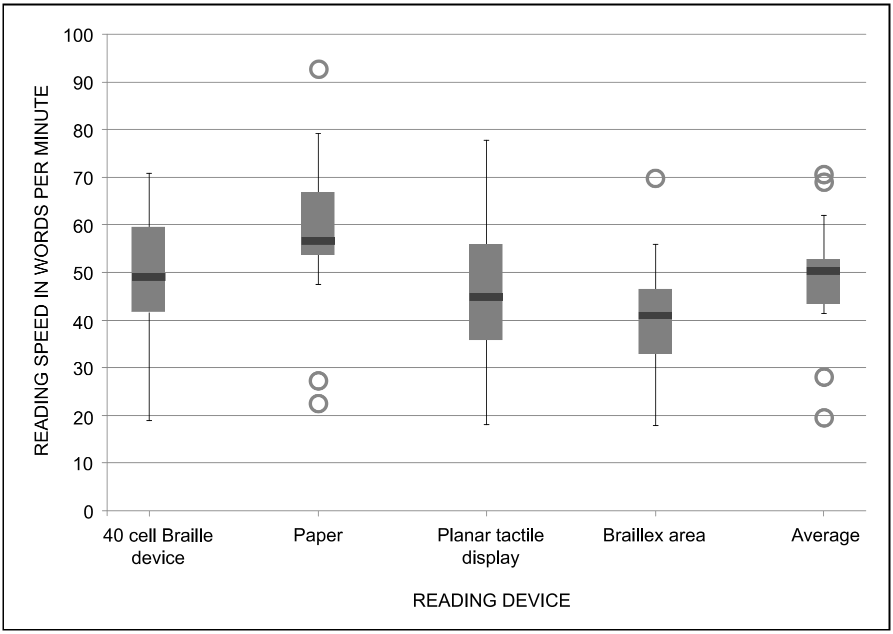


Fig. 2. Comparison of reading speed on different devices

2.3 Discussion

The test has shown that reading on the planar tactile display is not explicitly slower than reading on a standard Braille device. Especially the reading speed of the two slowest readers (identifiable as outliers in figure 2) shows marginal differences on all four reading devices. This suggests that beginners in reading Braille could profit from the major distance between two letters.

However, there were some confounding variables at testing the planar tactile display and the Braillex area, because some pins of the used prototype were damaged. Hence, reading was partially complicated. According to Millar's research, where some subjects spent a lot of time over degraded words, these wrong pins could lead to decreasing factual achievable reading speed by more than 10% [8]. To get more precise results of reading equidistant Braille, a follow-up study was necessary.

3 Follow-Up Study

Isolating the factor of 'equidistance' and, in particular, disabling the considerable confounding variable of incorrect raised pins has been possible by an additional pilot study with four new blind subjects. Hereby not only an initial comparison of different reading rates with standard and equidistant Braille is determined, but also first observations on possible learning effects can be made.

3.1 Method

We choose two subjects with no experience in reading equidistant Braille and two subjects who participated in the project and therefore worked with the planar tactile display for more than half a year. Comparability of the reading material was ensured by printing the text in 8-dot Eurobraille on raised paper in both cases - one in normal space, one as equidistant Braille. After a short warm-up phase, the subject had to read aloud alternating two pages of normal and two pages of equidistant Braille. In all of the four reading phases the needed time was measured and the reading rate was calculated.

3.2 Results

In table 2 the mean reading speed is summarized for every subject. This results in an average reading speed of 84 wpm (normal Braille) and 74.7 wpm (equidistant Braille) for inexperienced subjects, and of 70.1 wpm (normal) and 71.9 wpm (equidistant) for experienced subjects. Thus, it appears that equidistant Braille is not significantly slower than standard Braille.

Table 2. Mean reading speed for standard and equidistant Braille

	Mean reading speed in wpm	
Subject	**Standard Braille**	**Equidistant Braille**
1 - not experienced	126.1	109.4
2 - not experienced	41.9	40.0
3 - experienced	68.9	70.6
4 - experienced	71.3	73.3
Average of all subjects	77.0	73.3

3.3 Discussion

It is even seen that the experienced readers are minimal faster in reading equidistant Braille. So we can assume that people can get used to equidistant Braille. Furthermore, this result also confirms our assumption that poorer readers (like subject 2) could benefit from higher letter spacing. In contrast, subject 1 is a very fast reader but requires significantly more time to read the equidistant Braille in relation to standard Braille. Probably this could be explained from the fact that fast readers are very proficient in recognizing Braille letters and therefore need slightly more time because of the longer distance to cover on equidistant Braille.

4 Study with Tactile Ink-Print Fonts

In addition to Braille output, blind users also have the possibility of touching tactile ink-print on the planar tactile display using our screen explorer software.

Fig. 3. Layout view with tactile ink-print

Thus, conventional letters can be displayed on the pin device (see figure 3) and therefore can be perceived tactilely by blind or visually impaired people.

Tactile output on the display can be based on screenshots consisting of pixel data, so the blind user can also make content accessible which is not available using a standard Screenreader yet. For example, text embedded in some graphics can be detected by zooming functions allowing manual resizing of the letters. Furthermore, font changes in standard electronic documents are frequent and are often not detected by blind people [4]. The so called layout view (see [12]) preserves the layout of a document, and users can find, for instance, mistakes in alignment or formatting.

4.1 Method

Identifying the usefulness and the practicality of this tactile view for blind users was the objective of another study with 12 subjects. Half of the subjects had good or medium knowledge of ink-print font in a tactile manner, the other half had minor or no knowledge. The task was to explore a text document, which shows the structure of an invoice. Therefore, the subjects had to work on the planar tactile display showing the content in layout view. The interaction was realized through the buttons of the BrailleDis9000. After navigating and exploring the presented invoice, four of the subjects were presented the same document but with multiple mistakes in formatting and layout. Their additional task was to find these inconsistencies.

4.2 Results

It turned out that the layout view can be a good supplement for blind people, especially for users which cannot read Braille but are able to recognize tactile fonts. Depending on the letter itself and its formatting but also on the tactile ability and the ink-print knowledge of the blind person, a tactile letter can be identified well from a size of nine pins, which is about 22 mm. Furthermore, the two-dimensional presentation allowed the subjects to perceive spatial relationships within the document. Although 75% of the subjects had some problems in orientation, most of the users rated the layout view positively. Formatting mistakes could be identified easily, but exploring large documents was very time-consuming. In addition, a certain amount of orientation and spatial perception of the user is required to ensure a reasonable usage of the layout view and an efficient way to read tactile fonts.

5 Conclusion

The three conducted studies have shown that users have to get used to equidistant Braille, but they can reach a reading speed comparable to standard Braille devices. Particularly beginners can benefit from faster distinction due to extra spacing between the single letters of the equidistant Braille (see also [9]). Moreover, displaying tactile ink-print can offer completely new possibilities. Primarily persons who became blind at a later age, typically with no Braille skills, can now use tactile information additionally instead of only relying on auditory output.

Based on these findings further research is possible. For example, in the reading tests there was no ascertainment of mistakes while reading on equidistant Braille, although this is an essential criterion for success of a reading device. In detecting layout errors in the layout view a direct comparison of planar tactile displays and standard Braille displays, in respect of how fast and well mistakes can be identified, might be conducted.

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