2025 IEEE World Haptics Conference (WHC)
Suwon Convention Center, Suwon, Korea
July 8 ~ 11, 2025

Exploration of pneumatic haptic display for Braille applications

Irene A. Kuling[1], Krishna D. Kommuri[1], Daniël E.M. Ris[2], Christian H.F. Janssen[2],
Daniël van der Valk[2], Astrid M.L. Kappers[1,2]

I. Introduction

Developing cost-effective reading systems for people with visual impairments or blindness is a significant challenge, as displays need to be responsive and reliable and must provide dynamic tactile feedback for applications such as Braille reading (the most prominent writing system used by and for blind people) [1]. A solution to produce more cost-effective displays is by making them smaller and with fewer items, e.g., in the form of a single cell static display [2]–[4], but this comes with an effectiveness cost; [5] compared static single-cell and sliding Braille displays and found that the lack of sliding on a single cell display leads to lower letter recognition. However, they also see a large potential for single cell displays due to their affordability [5].

Inspired by the single-cell concept of Braille readers, in this study, we explore pattern recognition on a pneumatic haptic display, and we compare two methods of switching between (Braille-inspired) patterns.

II. Methods

A. Participants

Twenty healthy participants (7 women, 13 men, aged 18-27 years) volunteered in the study. All participants were naive to the purpose of the experiment, and received a small financial compensation for their time (€12 for university students, €15 for others). Prior to the experiment, participants signed an informed consent form and received written instructions about the experimental task. Ethical approval for the experiment was provided by the ERB of dept. IE&IS of Eindhoven University of Technology (#ARCHIE ID 2134).

B. Set-up

In this study, we used a haptic display of nine small pneumatic actuators in a 3-by-3 grid; however, for the experiments described here, we only used the left 3x2 grid to mimic a braille pattern. The actuators are inspired by pneumatic unit cells and are a scaled-down version of those used in previous studies [6], [7]. The actuation of the PUCs was controlled using a custom Soft Robotic Control Unit (similar to [8]). This is a Raspberry Pi 4B based control box, which uses TCP/IP communication to communicate with a Matlab-based control system.

[1]Authors are in the Robotics section of the department of Mechanical Engineering at Eindhoven University of Technology, Eindhoven, NL. Corresponding author is Irene Kuling, e-mail: `i.a.kuling@tue.nl`

[2]Authors are with the HTI section in the IE&IS department at Eindhoven University of Technology, Eindhoven, NL.

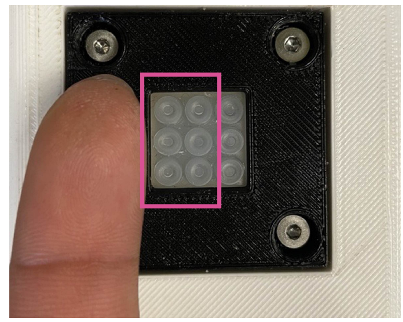

Fig. 1. Haptic display (finger for scale). The left two columns (pink box) were used for the experiments.

C. Experimental design

The experiment consisted of two parts. In the first part, 25 different patterns were presented on the haptic display. The number of dots raised was systematically varied (five patterns for 1-5 dots raised each; see Fig. 2). The set of 25 patterns was presented three times in randomized order to each participant.

In the second part of the experiment, 30 pairs of stimuli were presented. The pairs were selected to represent common two-letter combinations in the Dutch language and have a balanced combination of the number of dots active and the change between the letters in the pairs (Fig. 2). Each pair was presented with two transition methods, separate or immediate. In the separate transitions, the first pattern was presented for three seconds, then off for one second, followed by the second pattern for three seconds. In the immediate transitions, the display was not switched off in between, so the first pattern morphed into the second pattern.

D. Procedure

Participants were asked to place the index finger of their dominant hand on the haptic display to explore and identify tactile patterns. Each pattern was presented for three seconds followed by (a second pattern in part 2 and) a five-second response period in which participants indicated the pattern they felt on a 3-by-2 set of keys on the numpad of a regular keyboard. The first part of the experiment consisted of 75 trials after which the participants had a short break and continued with the second part (60 trials). Note that in the second part only the pattern of the second stimulus was asked. Both parts of the experiment started with ten practice trials. The experiment took about 60 minutes.

E. Data analysis

For each participant, the data were averaged for the different number of active dots (first part) and the number

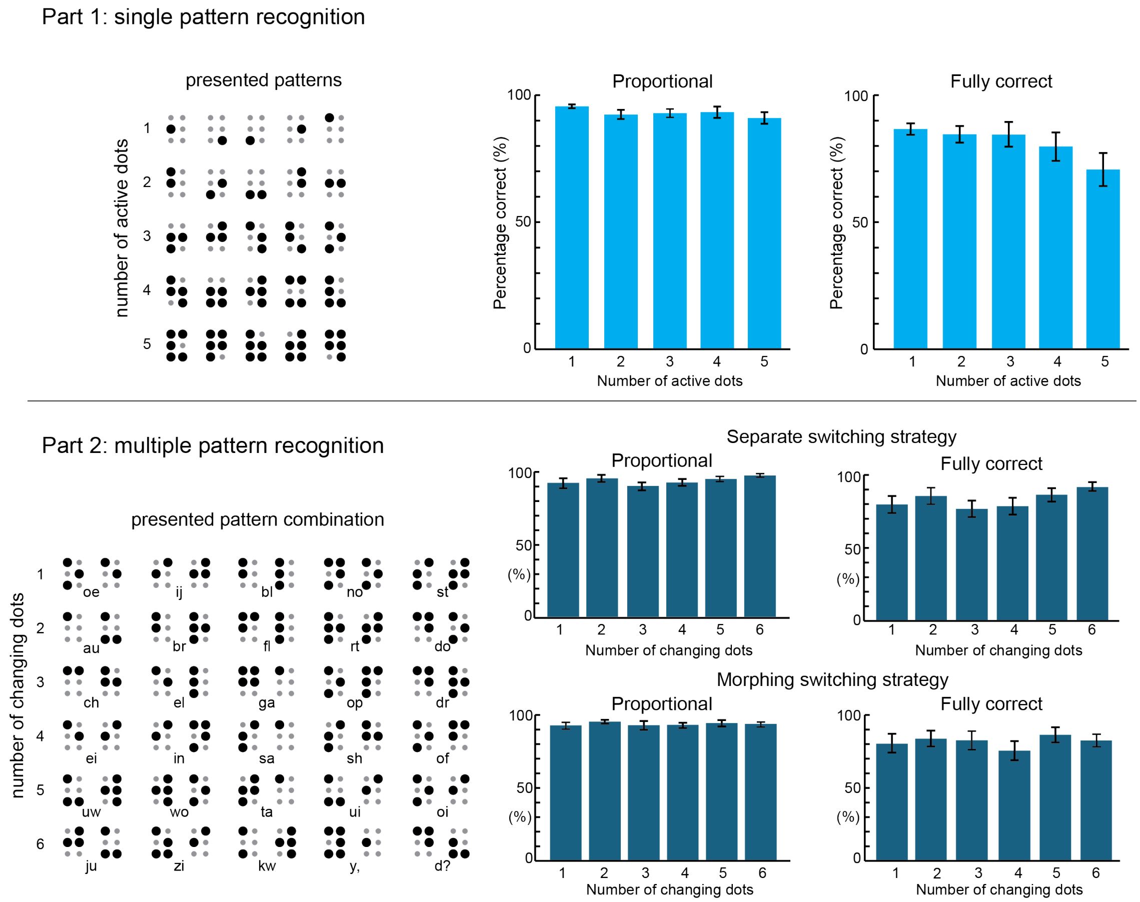

Fig. 2. Stimuli (left) and results (right) for the first (top) and second (bottom) part of the experiment. The results show a larger number of active dots leads to a lower percentage of fully correct responses (part 1). When presenting two stimuli in sequence there was no difference in recognition between switching and morphing strategies (part 2).

of changing dots (second part). For both parts, the data were analyzed proportional, i.e. the proportion of dots that were correctly identified, as well as binary, i.e. whether the full pattern is correct or not with repeated measures ANOVAs. Greenhouse-Geisser corrections were used when sphericity was violated, and Bonferroni corrections were applied for post hoc comparisons.

III. Results

In general, participants were able to identify the raised dots and the patterns quite well (see Fig. 2) . In the first part, the proportion-based accuracy was $> 91\%$ for all numbers of active dots and there was no significant difference between them ($F_{2.4,46.2} = 2.379, p = 0.094$). The one-way repeated measures ANOVA of fully correct answers shows a significant effect of the number of active dots ($F_{2.0,38.4} = 4.673, p = 0.015$) in which larger numbers of active dots have lower percentages of fully correctly identified patterns. Post hoc comparisons were not significant (all $p > 0.05$).
For part 2, the 2 (methods) x 6 (number of changing dots) repeated measures ANOVA on the proportional values showed no significant differences between methods or number of changing dots, and also no interaction effect. Similar results were found for the analysis on the fully correct data.

IV. Conclusion

In this study we successfully introduced a pneumatic haptic display for presenting patterns on the fingertip. The accuracy of the pattern recognition was high and Braille letter pairs were well recognized, both in a sequential and a morphing transition style. Although more work is needed to fine-tune and test the device, overall the pneumatic haptic display shows potential as a cost-effective Braille reader.

References

[1] Davert, "40 cells to empowerment: A comparison of five braille displays to fortify your success in 2023," 2023. [Online]. Available: https://rb.gy/d4jz3z

[2] Schmidt, Gustavo, and Ramírez, "Single braille cell," in *5th ISSNIP-IEEE BRC 2014*. IEEE, 2014, pp. 1–5.

[3] Ignat, Faragó, Hintea, Roman, and Vlad, "A Single-Character Refreshable Braille Display with FPGA Control BT," in *Int. Conf. Adv. Med. Health tr. Tech.*, Vlad and Roman, Eds., Cham, 2017, pp. 63–66.

[4] Bettelani, Averta, Catalano, Leporini, and Bianchi, "Design and validation of the readable device: a single-cell electromagnetic refreshable braille display," *IEEE ToH*, vol. 13 (1), pp. 239–245, 2020.

[5] Russomanno, O'Modhrain, Gillespie, and Rodger, "Refreshing refreshable braille displays," *IEEE ToH*, vol. 8 (3), pp. 287–297, 2015.

[6] van Beek, Bisschop, and Kuling, "Validation of a soft Pneumatic Unit Cell (PUC) in a VR experience: a comparison between vibrotactile and soft pneumatic haptic feedback," *IEEE ToH*, 2023.

[7] Kommuri, van Beek, and Kuling, "Fabrication and characterization of pneumatic unit cell actuators," in *Actuators*, vol. 13 (2). MDPI, 2024.

[8] Caasenbrood, van Beek, Chu, and Kuling, "A desktop-sized platform for real-time control applications of pneumatic soft robots," in *2022 IEEE RoboSoft*. IEEE, 2022, pp. 217–223.