

# An Evaluation of Substrates for Tactile Displays: Scanning Speed and User Preferences

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**Abstract.** This study deals with the suitability of substrates for tactile maps and diagrams for visually impaired people. Visually impaired and sighted participants scanned symbol arrays by touch on 7 different substrates, including papers, plastics and aluminium. In general, papers were rougher than plastics and aluminium. Search time and participants' preferences were recorded. In general, rougher substrates were scanned faster than smoother substrates. Moreover, the majority of participants preferred rough substrates over smooth ones.

## 1 Introduction

Tactile maps and diagrams can be of great importance to visually impaired people, allowing them to study, work and live more independently. Tactile images are provided on a variety of substrates (the base material on which the raised image is presented), depending on the production method used [1], [2]. A new printing technology<sup>1</sup> [3] allowed us to print identical images onto a large range of substrates in order to determine what types of substrate are most suitable for the production of tactile displays. In this study, suitability is defined by scanning speed (which reflects the ease of extraction of information) and user preferences.

## 2 Method

**Participants.** Fourteen sighted (4 males and 10 females, aged 17 to 49, mean age 25.1) and 15 visually impaired people (10 males and 5 females, aged 17 to 50, mean age 29.8) participated.

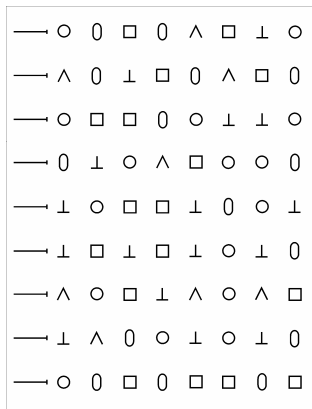
**Materials.** On the basis of crossing 7 types of substrate with 7 different arrays of symbols, 49 experimental displays were constructed. The 7 substrates were: rough

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<sup>11</sup> The APU custom printing machine uses a 500 nozzle, 180 dots per inch, piezo industrial, drop on demand printhead. Ultraviolet cured ink drops of 80 picolitres are built up in a multi-layer process.

plastic, smooth plastic, rough paper, smooth paper, microcapsule paper, Braille and aluminium. Printed onto the substrates (A4) were 9 rows of 8 symbols (8x8 mm). Line width and line height were 1.3 and 0.34 mm respectively. The arrays contained 5 highly discriminable shapes [4]. One of these shapes, an inverted V, was the target symbol. The first 8 rows contained 8 pseudo-randomly distributed targets, the ninth row contained 0, 1 or 2 targets. This last row was added in order to prevent counting of target symbols and was disregarded in the data collection. Figure 1 is an example of an array.

**Procedure.** The experiment consisted of a tactile search task and a preference rating task. Sighted participants and those with residual vision were blindfolded during both tasks. The search task was performed first. After a practise trial, 14 displays were presented randomly in 2 sets of 7, each set containing all substrates and all arrays. Participants scanned the displays as fast and as accurately as possible, proceeding from the top left corner to the bottom right corner. They gave a verbal response when encountering a target symbol. A digital video camera was used to record scanning time and errors. After the search task, participants gave a preference rating of each substrate on a 5 point scale. Finally, participants were asked what they had based this judgement on.



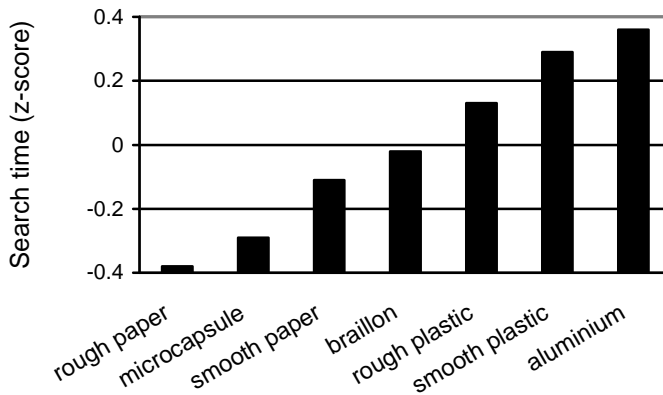
**Fig. 1.** Example of stimulus array

### 3 Results

Scanning time varied greatly over participants (mean = 77.6s, standard deviation = 33.5s), but varied less within participants (mean standard deviation = 10.2 s). Because of the large variability of time scores across participants, there were no significant differences between raw mean scores of substrates. In order to compare the mean score of participants on each substrate, z-scores were calculated, which indicate the number of standard deviations from the participant’s own mean for each time measurement. There were no differences in standardised scanning time and preferences between visually impaired and sighted people. Therefore, their data were collapsed. Very few errors were made in identification of the target symbol and there

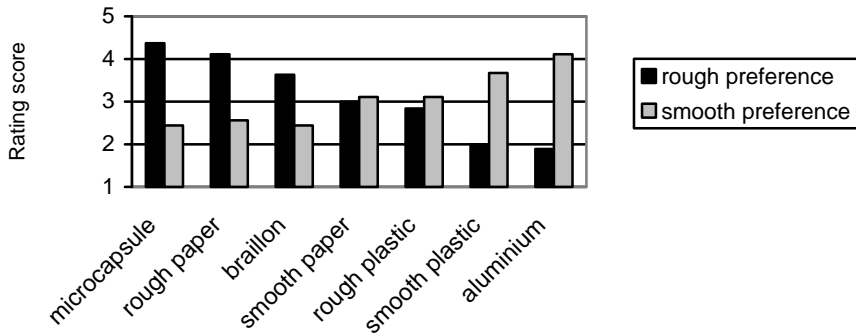
was little relationship between the number of errors and substrate type. Therefore, the error score was disregarded in further data analysis.

A two-way repeated measures ANOVA showed that the type of substrate had an overall effect on standardised search time ( $F(6, 162) = 8.03; p < 0.01$ ), as is shown in Figure 2. Pair-wise comparisons indicated which substrates differed significantly in search time ( $p < 0.05$ ). Aluminium and smooth plastic substrates were scanned more slowly than Braille, smooth paper, rough paper and microcapsule substrates. Participants required more time scanning rough plastic substrates than rough paper and microcapsule paper substrates. Search time for Braille substrates was longer than that for rough paper and microcapsule substrates.



**Fig. 2.** Mean standardised search time (z-scores) over substrates

Participants' preferences for substrates showed two distinct patterns, as also indicated by participants' comments about preferences. The majority (9 visually impaired and 10 sighted participants) preferred rough substrates over smooth substrates. A minority (5 visually impaired and 4 sighted participants) preferred smooth substrates over rough ones. A two-way repeated measures ANOVA, with preference groups as a factor, was conducted. There were no main effects for type of substrate ( $F(6, 165) = 1.06, p = 0.39$ ) and for preference group ( $F(1, 126) = 0.12; p = 0.73$ ). However, as figure 3 shows, there was a significant interaction between type of substrate and preference group ( $F(6, 156) = 16.26; p < 0.01$ ). This interaction lends support for the distinction between preference groups. Pair-wise comparisons showed which substrates differed significantly on their rating scores ( $p < 0.05$ ). The smooth preference group preferred aluminium substrates over rough paper, microcapsule paper and Braille substrates. The rough preference group preferred rough paper over rough and smooth plastic, smooth paper and aluminium. Microcapsule paper was preferred over all substrates except rough paper. Braille received higher rating scores than rough and smooth plastic and aluminium. Finally, rough plastic and smooth paper were preferred over aluminium and smooth plastic.



**Fig. 3.** Preferences ratings for substrates by preference group

A two-way repeated measures ANOVA, using preference groups as a factor, was conducted to investigate differences in exploration time for the two preference groups. There was a main effect of substrate type ( $F(6, 156) = 7.15$ ;  $p < 0.01$ ). However, there was no main effect of preference group on exploration time ( $F(1, 26) = 0.001$ ;  $p = 0.97$ ) and no interaction between preference group and type of substrate ( $F(6, 156) = 0.69$ ;  $p = 0.66$ ).

## 4 Discussion

In general, rough and/or paper substrates were explored faster than smooth and/or plastic and aluminium substrates. This might be related to surface characteristics such as roughness and absorbency. The plastic and aluminium substrates were smoother and less absorbent, possibly causing the fingers to stick to the substrate and slowing down exploration. The contrast between ink and substrate could be another explanation for the distinction between rough and smooth substrates, as the smooth ink might be more distinct on rougher substrates. However, preliminary informal investigations have suggested that this is not the case.

Not only did most participants explore paper substrates faster, they also preferred them over plastic and aluminium substrates. When asked for the reasons for their preferences, the majority of participants (18 out of 29) reported either that they liked paper and rough substrates because it was easier to move their fingers across these rougher substrates, or that they disliked the plastic and aluminium substrates because of their stickiness, which irritated their fingertips and made it more difficult to move across the display. Interestingly, a small number of participants (8 out of 29) preferred the plastic and aluminium substrates because of their smoothness, which reportedly made it easier to move their fingers across. Observations suggested that these participants had dry skin and/or used light touch, which might make it easier to run their fingers across a smooth surface than a rough one. However, the data on search time indicate that, regardless of preference, participants explored plastic and aluminium substrates more slowly than paper ones.

## 5 Conclusion

The results of this study suggest that paper substrates, in particular rough paper and microcapsule paper, are most suitable for the production of tactile displays. These results are based on exploration time and user preferences. However, other factors should be considered as well. Firstly, the selection of a substrate depends on the functions of display. For example, durable substrates such as plastic and aluminium are more suitable for use in public places (e.g. a map on the wall of a train station), whereas paper substrates, which are lightweight and can be folded up, can more easily be taken with the individual user. Production cost is another factor in the selection of substrates. Paper substrates are usually cheaper than plastics and aluminium. Another consideration is the use of tactile displays by visually impaired people with residual vision. The use of residual vision is often hindered by reflection. Matt substrates, which have less reflection, would be more suitable in this respect.

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