
Blind Persons Get Improved Sense of Orientation and Mobility in Large Outdoor Spaces by Means of a Tactile Pin-Array Matrix

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Abstract

We show that a tactile feedback provided with a pin-array matrix (PAM) showing past allocentric positions is sufficient to improve the localization accuracy of visually impaired persons in the following attempts in large outdoor spaces. In particular, blind participants explored a map showing a scaled representation of a real outdoor space. The map further included a symbol indicating a virtual target position. Then, participants attempted to reach the target three times in the real space. While a control group only reviewed the same map on the PAM between trials, an experimental group received an updated map representing also the position they previously reached. The self-positioning error significantly decreased only in the experimental group. In conclusion, an updated tactile feedback is able to improve the accuracy of blind persons in locating a target also in a large outdoor space.

Author Keywords

Spatial representation; Tactile Maps; Visual impairment; Blindness; Pin array matrix; Tactile

BlindPAD: it is a refreshable multi-line tactile display composed of 192 pins (named *taxels*) on an 8 mm pitch. Each taxel is individually programmable to be in the 'up' or 'down' state in under 20 ms and the whole matrix is refreshable in under 2 s, thanks to the 12x16 array of electromagnetic actuators and to the electronic control board. The PAM was connected via wireless to a standard laptop and controlled by PadDraw, a software developed by Geomobile GmbH, Germany. The hardware was designed and built at EPFL, Switzerland. BlindPAD and PadDraw were developed within the scope of the FP7 EU BlindPAD project.

Feedback; Orientation & Mobility; Navigation; Tactile Graphics.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; K.4.2. Computer and Society: Social issues

Introduction

Navigating an unfamiliar environment is a complex task which is also based on the ability to form an effective spatial cognitive map [11, 12]. Blind persons have been shown to prefer route-like, egocentric, representations of spatial information which are often associated with lower navigation performances than survey-like, allocentric, representations [2]. The preference for route-like representations might be due to the fact that the blind acquire spatial information serially through touch, audition and motor information [8, 9]. Tactile maps are widely used in mobility training since they provide a global representation of an environment while including only essential information [4, 5, 13]. A recent study [3] took advantage of a pin array matrix (PAM), a novel technology which allows interactivity and real-time dynamic re-drawing of tactile maps through refreshable information [6, 7]. In that study, blind persons explored a map on the PAM showing a scaled representation of a room. The map included a symbol indicating a virtual target position. Then, the subjects entered the real room and attempted to reach the target three times. While a control group only reviewed the same, unchanged map between trials, an experimental group also received an updated map representing also the position they previously reached in the room. They found that only the experimental group improved significantly across trials in localization

accuracy and navigation time. In this study, we aimed at investigating whether the effectiveness of spatial maps presented on a PAM is evident also in large outdoor spaces. In particular, following [3], we tested whether an updated map containing also a feedback about the previously reached position gives a better localization performance in the following attempts than a simple re-exploration of a non-updated map. A second aim was to find out whether and how the self-location error magnitude correlates with the distance of the targets.

Materials and Methods

Participants

A group of blind and low vision participants was recruited by Istituto Chiossone Onlus of Genoa. Participants were divided in an experimental (EXP; n = 20; age range: 14-65 years; mean = 40; 16 blind; 9 females) and a control (CTR; n = 20; age range: 15-70 years; mean = 40; 13 blind; 7 females) group. The experiment was performed in three different outdoor locations: the cloister of the *Istituto dei Ciechi* in Milan, *Piazzetta dei Servi di Maria* in Bologna and *Piazza della Cernaia* in Genoa. Hence, the participants were divided in three subgroups, one for each location (Milan: n = 8; Bologna: n = 10; Genoa: n = 22). All participants were naïve to the experiment and none had a cognitive impairment that could influence the performance in the tasks. The participants gave informed consent in compliance with the Declaration of Helsinki and the protocol was approved by the local Ethics Committees.

Pin-Array Matrix

The experiments were performed using the PAM named BlindPAD (see also [2, 3, 14]). For a brief description here, see the sidebar.

Statistical analyses: The groups of the different locations were collapsed because of the small sample sizes. The independent variables were the Group (feedback/no feedback) as between-group factor and the Trial as within-group factor. The dependent variables was the error in meters as Euclidean distance (i.e. distance between the target and the final position of the participants) Finally, we correlated the self-positioning error with the distance of the targets. Since the Euclidean distances were not normally distributed (Shapiro-Wilk test), we employed non-parametric statistics (i.e. Friedman ANOVAs and Wilcoxon signed-rank tests). For the correlation, we used Spearman correlation coefficients.

Stimuli

The three outdoor locations differed for shapes and dimensions. Three maps of each location were prepared on the BlindPAD (see Figure 1 for one example for each location). The maps depicted the essential features of the outdoor spaces (i.e. walls, apertures) complying with the dimensions of the real spaces (*Milan*: 16.7x16.7m; *Bologna*: 36.5x28m; *Genoa*: 14.5x12m). As in [3], the maps also included a cue (i.e. a single taxel raised up) which indicated a virtual target position that participants had to reach. The three maps of each location only differed in the position of the target. A synthesized audio description of the space which provided also cardinal directions and the scale of the map was concurrently presented with the map.

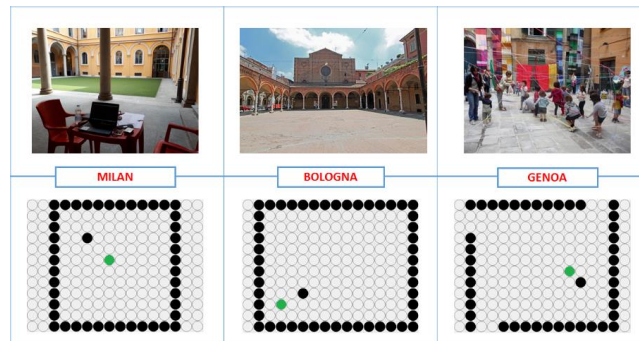


Figure 1: Upper panels: the three locations where the experiments were performed. Lower panels: example of maps used in that locations. The black taxel inside the spaces represents the virtual target location; the green taxel represents the tactile feedback provided to the EXP group.

Procedure

Participants with residual sight were blindfolded to avoid visual inspection of the material. The experiment comprised two phases: 1) tactile map exploration; 2) physical navigation and review. In 1), the participants haptically explored a map shown on BlindPAD. In 2), the participants navigated the outdoor space starting from a pre-defined corner. The participants were instructed to reach the hypothesized target position and to raise an hand. The experimenter measured the Euclidean distance between the correct target location and the actual participants location using a Laser Distance Meter. As in [3], the subjects had three attempts (trials) to reach the target. The experimental group received a feedback on BlindPAD (one blinking taxel) about the previously hypothesized target location together with the actual target location. The feedback on BlindPAD was given at the end of each trial. On the contrary, the control group only re-explored the same map before each navigation, i.e. the map showing only the target position without feedback. In this way, we could disambiguate between the effect of feedback and the effect of learning.

Results

Self-Positioning Errors in Navigation

Only the experimental group improved across trial. The self-positioning error significantly decreased in trial 3 compared to trial 1 ($p_{FDR-corrected} = .005$; Figure 2).

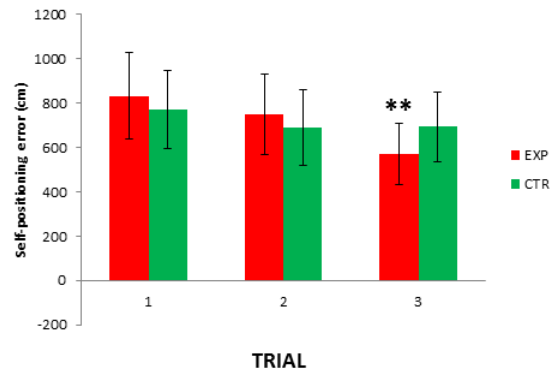


Figure 2: Absolute value of the Euclidean distance (in cm) from the target during the three trials. Asterisks indicate a significantly smaller self-positioning error in trial 3 compared to trial 1 in the EXP group. **, $p < .01$.

Correlation

The distance of the target strongly positively correlated with the self-positioning error ($R = 0.71$, $p < .001$).

Discussion

In this work, we showed that providing tactile feedback about self-position on a map displayed with a refreshable tactile display improves the orientation abilities of visually impaired persons better than

reviewing the non-updated map also in large outdoor spaces. The self-location error indeed decreased only in the group that was exposed to the tactile feedback and not in the group that could only explore again the original map. This finding reinforces the idea that a tactile feedback about the self-location error can act as a novel reference point of the map from which the visually impaired can make further spatial inferences, allowing him/her to improve his/her performance in the following attempts. We also found that the magnitude of the self-location error strongly positively correlated with the distance of the target. The average self-position error we observed was 7.11 m for an average target distance of 15.32 m. In a similar indoor study, it has been reported an average self-position error of 1 m for a mean target distance of 3.4 m [3]. In other words, the ratio error/distance is 0.46 in our study and 0.29 in [3]. This difference might be due either to some non-linearity in the error as a function of the distance of the target [e.g. 1] or to the facilitation in performing the task in a more controlled and less noisy indoor environment. In conclusion, an updated tactile feedback could represent an effective tool for navigation, both in rehabilitation and real-life situations, improving the spatial abilities of blind persons and favoring their autonomy.

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