Proceedings of EuroHaptics 2004, Munich Germany, June 5-7, 2004.

Measuring Point Localization Errors in Spatiotemporal Tactile Stimulus Patterns

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Abstract. In saltation, a tactile illusion, the subjective localization of a first stimulus is altered by a second one at a different site depending on its delay. The stimulus onset interval (SOA) and the amount of displacement are negatively correlated. In this study tactile point localization errors in the course of a saltation experiment were measured with 3D trackers (Polhemus Isotrak II and Fastrak). In experiment 1 we applied saltation patterns to the forearm. Beside the expected saltation effect our data show a constant distortion of the perceived body map. Spatial perception of stimuli was affected by their distance to the elbow. In experiment 2 we chose the abdomen as stimulus site, assuming that it is to a lesser extent influenced by anatomical landmarks. As in experiment 1, SOA affected the displacement of the successive stimuli. Contrary to experiment 1, no constant distortion of the perceived stimulated area occurred.

1 Introduction

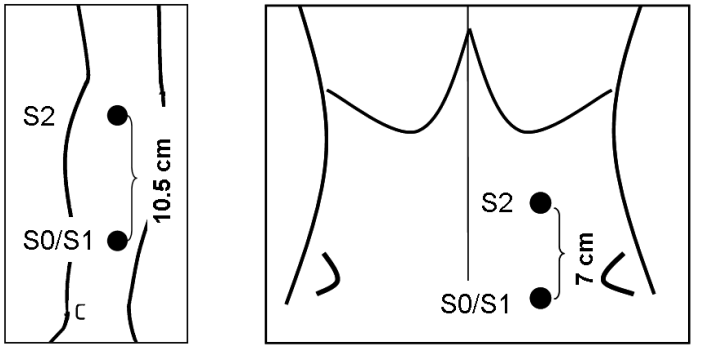
In sensory saltation [2], a tactile stimulus, followed by a second one closely in time, is perceptually displaced depending on the stimulus onset interval (SOA). The SOA and the amount of displacement are negatively correlated. This phenomenon has been investigated at different stimulus sites [3]. In the present study we focus for the first time on measuring the perceived displacement of the whole stimulus pattern on the body map. This gives us information about how spatiotemporal patterns are integrated in this map. The spatial perception of stimuli is affected by their distance to anatomical landmarks such as joints [1, 4]. Therefore we assumed that presenting saltation patterns on the forearm near the elbow should result in a constant distortion towards the elbow, whereas on the abdomen no such distortion should occur because of presumably less anatomical landmarks. Point localization errors were measured with 3D trackers (Polhemus Isotrak II and Fastrak).

2 Experiments

2.1 Method of Experiment 1

33 healthy subjects were examined. The pneumatically driven tactors were applied on the subjects' left forearm. The first tactor was placed 8 cm apart from

the wrist in proximal direction and the second tactor 10.5 cm apart from the first one towards the elbow (see Fig. 1a). The saltation patterns consisted of three stimuli (S0, S1, S2). Each single stimulus was a rectangular pressure pulse of 20 ms duration. S0 served as a warning stimulus. After a constant SOA of 1020 ms, S1 was presented at the same site. S1 was followed by S2 in a spatial distance d[phys] of 10.5 cm. The SOA between S1 and S2 varied in the range of 0–1020 ms.



a Arrangement of tactors in experiment 1.

b Arrangement of tactors in Experiment 2.

Fig. 1. Arrangements of tactors. a) In experiment 1 the two tactors were placed on the left forearm. b) In experiment 2 the two tactors were applied in vertical arrangement on the left side of the subjects' abdomen

2.2 Method of Experiment 2

29 healthy subjects were examined. The tactors were applied in a vertical arrangement to the left side of the subjects' abdomen (see Fig. 1b). One tactor was placed near the spina iliaca anterior superior, the other one in a distance of 7 cm near the costal arch. The saltation patterns consisted of three vibrating stimuli (S0, S1, S2) of 40 ms duration. S0 served as a warning stimulus. After a constant SOA of 700 ms, S1 was presented at the same site followed by S2 in a spatial distance d[phys] of 7 cm. The SOA between S1 and S2 varied in the range of 57–500 ms.

2.3 Results and Discussion

In both experiments a saltation effect could be elicited (see Fig. 2). The amount of displacement of S1 towards S2 increased with smaller SOAs (linear mixed model: exp. 1: $F = 412.05$; $p < 0.0001$; exp. 2: $F = 288.77$; $p < 0.0001$). Because of

different physical distances (d[phys]) between the tactors in the two experiments, in Fig. 2 the displacement of S1 is displayed in relation to the subjective distance (d[subj]) between the perceived positions of S0 and S2 ($S1_{rel}[\%] = \frac{S1}{d[subj]} \times 100$) to make the data comparable. This transformation makes sense, because in subjects' perception S1 varied between the perceived positions of S0 and S2.

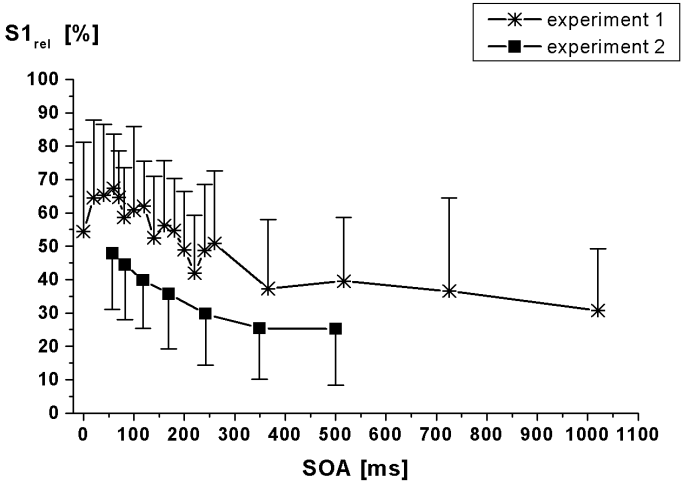


Fig. 2. Saltation effect. Depicted in the diagram is the amount of displacement of S1 in relation to the distance (d[subj]) between the perceived positions of S0 and S2 ($S1_{rel}[\%] = \frac{S1}{d[subj]} \times 100$). Because of different physical distances (d[phys]) between the tactors in the two experiments, the transformation of S1 to $S1_{rel}$ was chosen to make the data comparable. Furthermore, this transformation makes sense, as the two anchor stimuli S0 and S2 determine the distance S1 could vary in between.

Furthermore, in experiment 1 there is a constant effect of displacement of the perceived position of the warning stimulus S0 (see Fig. 3). Independent of the stimulation time course, S0 is displaced towards the elbow, resulting in a reduction of the perceived stimulated compared to the physical area ($d[subj] = 6\,cm < d[phys] = 10.5\,cm$). In experiment 2 no constant distortion could be observed ($d[subj] = 6.5\,cm \leftrightarrow d[phys] = 7\,cm$).

3 Conclusions

As expected the perceived stimulus positions of spatiotemporal patterns on the forearm are influenced by anatomical landmarks [1, 4], resulting in a constant distortion of the perceived body map on the forearm in dependence of the proximity to the elbow. This effect could not be detected on the abdomen. These

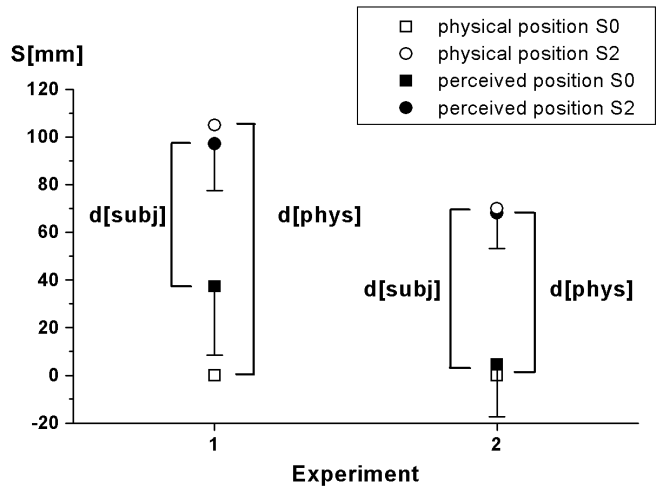


Fig. 3. Constant effect of displacement. Depicted in the diagram is the amount of displacement of the warning stimulus S0 and stimulus S2. As is clearly demonstrated, in experiment 1 on the forearm S0 is displaced towards S2 and to a much lesser extent S2 towards S0. In experiment 2 on the abdomen no such constant effects of displacement could be observed.

differences are unlikely due to the different methods in the two experiments [1]. Therefore, we conclude that the abdomen differs from other stimulus areas such as the forearm, because there is no constant distortion of the body map, indicating that there are less anatomical landmarks on this body area.

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