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Different effects in tactile attention between the thumb and its metacarpus and the palm

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HIGHLIGHTS

- We investigate the mental representation of the thumb, its metacarpus and the palm.
- The thumb and its metacarpus share the same mental representation.
- The representation of the palm differs from that of the thumb and its metacarpus.
- Processing of tactile stimuli starts in the palm and progresses toward the fingers.

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ABSTRACT

The aim of this study is to establish whether the thumb is represented independently of the palm. An exogenous spatial cueing paradigm was used, where participants had to detect a tactile stimulus that could appear on the proximal and distal phalanges or metacarpus of the thumb (thenar area; Experiment 1) and the metacarpus of the thumb or hypothenar area of the palm (Experiment 2) of the left hand. Our results suggest the thumb and its metacarpus share the same mental representation, which is distinct from the representation of the palm.

1. Introduction

Strikingly little is known about the representational relation between the fingers and palm of the human hand since only a few studies have investigated this issue. Results from spatial tactile cueing paradigms [4] suggest the existence of distinct mental representations of the fingers (digits 3 and 4) and palm. Further evidence comes from the study of spontaneous somatosensory sensations [15,16], where the effects of attention were found to be of different nature in these two parts of the hand, with the factors influencing the frequency of these phenomena over the fingers different from those that changed their frequency over the palm. The research conducted by Haggard et al., [8] is also relevant here since the authors showed that the representation of fingers is somatotopic, whereas the mental representations of the hands are influenced by external spatial localisation. However, the target in this study was the whole hand, not the palm. This points towards the independence of mental representation between fingers and the palm. However, insofar as research focused only on digits 3–4, the results might not generalize to the thumb and, so, its relationship with the palm. There is indeed an ongoing debate on whether the thumb should be considered as sharing the same representation with other fingers or as distinct and independent [10,18]. There is empirical support for both these points of view. For example, studies on finger agnosia support the idea of different mental representations for different fingers [1,2,6,14,12]. Other studies, however, provided evidence supporting the idea that fingers share a common, overlapping representation [21,19].

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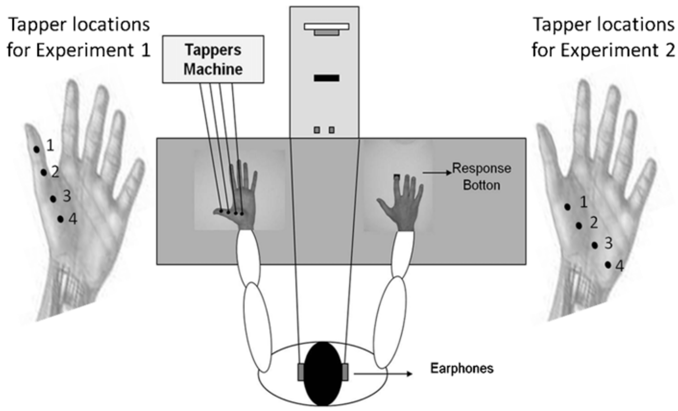

Fig. 1. Tapper locations and schematic drawing of the experimental set-up (Experiments 1 and 2).

Whether or not the thumb shares the same representation as other fingers also raises questions as to its relationship with the palm, since the latter seemingly has a different representation from the fingers. Whereas the metacarpus of all fingers constitutes the base of what is defined as the palm (i.e., a rather uniform and distinct anatomical zone), the metacarpus of the thumb has the additional feature of being more mobile and sometimes considered to be part of the thumb. However, to the best of our knowledge there has been very little research carried out in this area. Our aim in conducting this study was to examine the relationship between the thumb, its metacarpus and the rest of the palm, and to investigate whether or not they share the same mental representation. For this, we looked for similarities and differences in the speed with which tactile stimuli were detected in an attention task. We used a spatial cueing paradigm [4] where subjects had to detect a tactile target delivered at the location of a tactile cue or elsewhere, at varying time intervals from it. The stimuli were delivered through tappers placed on the thumb and the palm. In Experiment 1, the tappers were placed in the distal and proximal phalanx of the thumb, and the thumb metacarpus (thenar area). The logic was that if the thumb metacarpus were represented differently from the rest of the thumb, attention effects in these two areas would be different. In Experiment 2, the tappers were placed in the thumb metacarpus (thenar area) and hypothenar area. If the thumb metacarpus were represented differently from the rest of the palm, different attention effects would be observed between these two areas.

2. Experiment 1

2.1. Methods

Eighteen students of Sport Sciences (eleven men, seven women) from Granada University, Spain, took part in this study. Their mean age was 21.4 ± 4.3 years. All participants reported normal or corrected-to-normal vision and normal tactile perception. They were unaware of the purpose of the Experiment, all received a €5 gift voucher in return for their participation, and all gave their signed informed consent. The study was carried out in accordance with the ethical guidelines of the Experimental Psychology Department of Granada University.

Tactile stimuli were presented with a Tapper Controller. Four tappers were placed on the volar side of the left hand: two on the thumb phalanges (one on the distal and one on the proximal) and two on the thumb metacarpus (thenar area; Fig. 1). A tactile stimulus was delivered by a small metallic rod (2 mm diameter) propelled by a computer which controlled a miniature solenoid with a duration of 5 ms. The skin indentation produced a stimulus well above the detection threshold. The 4 tappers were placed 2.6 cm apart. Participants were positioned so that they were facing a loudspeaker 40 cm in front of them and responded by pressing a button on the right hand side of the table with the index finger of their right hand. The experiment lasted approximately 40 minutes.

The participants were blindfolded so that they could focus their attention on the tactile sensation. Each trial started with a central "fixation signal" from the central loudspeaker cone (70 dB (A) auditory warning signal). Both tactile cue and target consisted of a 5 ms tap delivered by an identical miniature solenoid. The tactile cue was presented at an interval of between 300 and 500 ms after the auditory warning signal, at one of the four locations. The tactile target occurred randomly and equiprobably either 100 or 1000 ms after the onset of the cue. We ascertained that the cue and target stimuli were processed in a pilot test as two separate sensory events. Participants were told the position of the cue and that of the target were not related and were instructed to ignore the cues. Participants were given 1000 ms from target onset to respond to the targets by pressing the right button with the index finger of their right hand. If they responded before the target appeared or failed to respond within 1000 ms of target onset, an error feedback signal was emitted (1600-Hz tone, 300 ms duration). Between the end of one trial and onset of the next there was a variable interval of 1000–2000 ms. Cues and targets could be presented at each of the four tapper positions equiprobably and randomly.

A total of 32 conditions (2 SOAs; 100 and 1000 ms × 16 cue-target combinations) were presented 12 times each. To reduce the likelihood of participants' anticipating and responding prematurely, we added a subset of trials (96 catch trials) in which no target was presented. Trials were run in blocks, with participants completing 4 blocks of 120 trials, each divided into 4 sub-blocks. Before the experimental trials, participants took part in 36 practice trials, which were excluded from the analyses.

2.2. Data analyses

Response times faster than 150 ms (0.52%) or slower than 850 ms (0.72%) were excluded from the analyses. The mean correct RTs were submitted to an analysis of variance (ANOVA), with SOA (100 ms vs. 1000 ms), Target Area (thumb phalanges vs. thenar area) and Cueing (cue and target at Same Place vs. Different Place; coded as SP and DP, respectively) as within-subject factors. Post hoc comparisons were carried out with the Newman–Keuls test.

2.3. Results

No significant main effects of SOA ($F(1, 17) = 1.50$, $p > .23$, $\eta^2 = .29$) and Target Area ($F(1, 17) = 1.84$, $p > .19$, $\eta^2 = .03$) were obtained. The main effect of Cueing attained significance, $F(1, 17) = 22.8$, $p < .001$, $\eta^2 = .52$, with responses for DP being faster than for SP (321 and 333 ms, respectively). The SOA × Target Area interaction did not reach significance ($F(1, 17) = .03$, $p > .86$, $\eta^2 = .00$) and this was also the case for the Target Area × Cueing interaction ($F(1, 17) = .13$, $p > .72$, $\eta^2 = .00$). The SOA × Cueing interaction was significant, $F(1, 17) = 18.0$, $p < .001$, $\eta^2 = .15$. Post hoc comparisons showed that RT were faster in the DP than the SP condition both at short (329 ms vs. 335 ms, respectively; $p < .044$) and long (313 ms vs. 332 ms; $p < .001$) SOA. Furthermore, a reliable decrease in RT was found at the long SOA compared to the short SOA for DP ($p < .001$) but not for SP ($p > .24$). The SOA × Target Area × Cueing interaction did not reach significance ($F(1, 17) = .004$, $p > .95$, $\eta^2 = .00$).

3. Experiment 2

Experiment 1 provided no evidence on distinct representations for the thumb and its metacarpus. Their morphology and function