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ORIGINAL ARTICLE

An attentional approach to study mental representations of different parts of the hand

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Abstract The aim of this study is to investigate whether the fingers are represented separately from the palm. An exogenous spatial orientation paradigm was used where participants had to detect a tactile stimulus that could appear on the palm, the middle finger or the ring finger of the left hand. The tactile target was preceded by a non-predictive cue using different stimulus-onset asynchronies (SOA). We observed a Facilitation Effect in the palm and Inhibition of Return (IOR) for fingers using a short cue-target SOA, whereas the IOR was found in fingers and palm in long cue-target SOA. Also we observed a 'Cue above Target' effect (facilitation effect when the Cue had appeared distal to the target location in a vertical line) at the long SOA. Together, we suggest that the general pattern of results supports the proposed hypothesis about the different mental representation of fingers and palms, but with a considerable and hierarchical interrelation between them.

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Introduction

In recent years, the cognitive and neural processes underlying tactile localisation have received increasing attention. Interestingly, it matters whether tactile stimuli are applied to the fingers or to the rest of the hand. Studies of patients with finger agnosia provided evidence for a separate mental scheme for the fingers (Anema, Kessels, de Haan, Kappelle, Leijten, & van Zandvoort, 2008; Benton, 1959; Gerstmann, 1942; Mayer, Martory, Pegna, Landis, Delavelle, & Annoni, 1999; Kinsbourne & Warrington, 1962). Finger agnosia is a deficit in which individual fingers are not differentiated, suggesting a fused single percept. Importantly, this deficit can be found without difficulties in identifying other body parts (Haggard & Wolpert, 2005).

Other studies showed clear differences in the tactile identification when crossing the arms and hands versus crossing the fingers. For example, Spence, Lloyd, McGlone, Nicholls, and Driver (2000) and Spence, Pavani, and Driver (2000) performed a crossmodal attentional experiment when crossing the hands. They found that visual and tactile stimuli can interfere between them in uncrossed posture when they are presented in the right hemifield or on the right hand, respectively. The same interference is observed in crossed posture when tactile stimuli are presented to the left hand and visual stimuli to the right hemifield. This suggests that spatial distance is more important than anatomical distance (allocentric vs. somatotopic distance). Nevertheless, the studies of Aristotle Illusion (i.e., Benedetti, 1985) and Japanese Illusion (Van Riperm, 1935) demonstrated that recoding into external space does not occur when fingers are crossed.

A direct comparison between tactile stimuli to the fingers and to other parts of the body has rarely been studied (see, e.g., Tanosaki, Iguchi, Hoshi, & Hashimoto, 2003;

Tanosaki, Iguchi, Kimura, Takino, & Hashimoto, 2004) and there is only one study about the relationship between the fingers and the whole hand (Haggard, Kitadono, Press, & Taylor-Clarke, 2006). The latter study suggested separate processing mechanisms for stimuli presented to the hand as compared to stimuli presented to the fingers. Their participants were stimulated on the fingertips in different postures (right hand above left hand or both hands interwoven). Hand identification was impaired when the fingers were interwoven, nevertheless, this manipulation did not reduce finger identification. The authors concluded that fingers have a somatotopic representation, whereas the mental representations of the hands are influenced by external spatial localisation. Interestingly this study was unique in that it focused directly on differences in the mental representation of the fingers and hands. However, this task only focused on identification of the hands or fingers, resulting in a distinction between hand laterality and finger identification responses.

In the current study, we were interested in whether different parts of the hand (e.g. palm vs. fingers) may have distinct representations. We were particularly interested in whether attention paradigms could teach us something about continuities and discontinuities in the organisation of tactile palm and fingers representation. We used the cost and benefits paradigm (Posner & Cohen, 1984) to study the different representation systems involved in somatosensory stimulus detection and their location on the skin. In the version of this paradigm that measures exogenous attention with visual stimuli, participants must identify a target in the screen, which can appear at either side of the fixation point. Prior to this target, a signal (cue) is presented in the same place as the target (cued trials) or in the location opposite to it (uncued trials). Responses are usually faster when cue and target occur in the same place as compared to the opposite location. This is known as the Facilitation Effect (Posner & Cohen, 1984). After an interval (which varies depending of the task), the facilitation effect is reverted so that responses to uncued locations are faster than those to cued locations. This effect is well-known as Inhibition of Return (see Klein, 2000, for a review of this effect). The causes of this negative effect are not entirely clear but it has been suggested that it is due to a cost in stimuli capturing attention at a location where attention was captured before (Lupiáñez, Ruz, Funes, & Milliken, 2007). The cueing effect (facilitation and IOR) has been observed in auditory cue-target modality (e.g., Spence & Driver, 1998) and when cue and target are presented in different modalities (e.g., Spence, Nicholls, Gillespie, & Driver, 1998; Spence et al., 2000a, b). In fact, this has been taken as evidence that spatial attention in different modalities may be controlled by common neural system (Drive & Spence, 1994). Indeed, cueing effects have been found for the tactile modality as well (Cohen, Bolanowski, & Verrillo, 2005; Miles, Poliakoff, & Brown, 2008; Poliakoff, Spence, O'Boyle, McGlone, & Cody, 2002). Interestingly, tactile attention may operate in a different reference compared to visual attention. Röder, Spence, and Rösler (2002) assessed the effect of posture change on tactile inhibition-of-return (IOR) to investigate the frame of reference (somatotopic vs. allocentric) in which the IOR effect takes place. They placed tappers in the fingers and concluded that IOR in the tactile modality was modulated by somatotopic distance between cue and target rather than allocentric distance. This research showed how it is possible to study attentional effects (IOR) with tactile stimulation of the skin surface of the fingers.

Our aim was to test the attentional differences between fingers and palm to ascertain whether they do or do not share the same mental representation, independent of their nature (e.g. somatotopic and allocentric distance were the same). To do so, we used a detection task in which participants were required to detect a tactile target, which was preceded by a tactile cue. We placed different tappers on the fingers and the palm through which the cue and target were provided. The distribution of tappers on fingers and hand allowed us to make two different types of analyses. The intra-area analysis evaluated attentional effects in the finger and the palm separately, as cue and target were both on the same body part (though not necessarily on the same position). The inter-area analysis evaluated the same effects, i.e., facilitation and IOR, across the two adjacent areas (e.g. cue and target were on different parts of the hand), to assess whether different effects are observed between and within areas. If the fingers and palm share mental representations, we expected to find similar attentional effects within and across the two areas.

Experiment 1

Methods

Participants

Eighteen participants (seven women) took part in this study. Their mean age was 23 years, ranging from 19 to 28 years. All participants in this and the following experiment reported having normal or corrected to normal vision and normal tactile perception. They were naive as to the purpose of the experiment and all received a 6 euros gift voucher in return for their participation, for which they gave informed consent. The studies were performed in accordance with the ethical advisory committee of the Faculty of Social Sciences of the Utrecht University, the Netherlands.

Apparatus and stimuli

Tactile stimuli were presented with a Miniature Solenoid Tapper Controller (ME-Solve). Four tappers were placed on the volar side of the left hand; two on the middle finger and two on the palm, as shown in Fig. 1. A tactile stimulus was delivered by a small metallic rod (diameter 2 mm), propelled by a computer-controlled miniature solenoid with duration of 5 ms (MSTC3 M&E Solve, Rochester, UK: http://www.me-solve.co.uk). The skin indentation produced a stimulus that was well above detection threshold. Each of the four tappers was placed at a distance of 2.6 cm from its neighbours. The participant's face was oriented towards a loudspeaker placed at 40 cm in front of them. Participants responded by pressing a button with the index finger of the right hand which was placed on the right side of the table.

Procedure

We used a modification of the procedure reported by Röder et al. (2002). The participants wore a blindfold to focus their attention on the tactile sensation. The trials started with a central "fixation signal" from the central loudspeaker cone (auditory warning signal 70 dBA). Both tactile cue and target consisted of a tap (5 ms) delivered by an identical miniature solenoid (see above). The tactile cue was presented between 300 and 500 ms after the auditory warning signal, at one of the four stimulus locations. The tactile target occurred randomly either 100 or 1,000 ms after the onset of the cue. We ascertained that these cue and target stimuli were processed as two separate sensory events in a pilot test. Participants were informed that there was no relation between the position of the cue and that of the target and were instructed to ignore the cues. Participants responded to the targets by pressing the right button (with index finger of right hand), they had 1,000 ms from target onset to react. If the participants responded before the target appeared or they did not response 1,000 ms after the target onset an auditory error feedback was presented (1,600-Hz tone, 300 ms duration). Between the end of one trial and the onset of the next trial (fixation point) there was a variable interval of 1,000–2,000 ms. Cues and targets could be presented in each of the four positions of the tappers equiprobably and randomly.

There were 32 conditions (2 SOAs; 100 and 1,000 ms × 16 cue-target combinations) presented 12 times. To reduce the likelihood of participants anticipating and responding prematurely, we added a subset of trials (hereafter called catch trials) in which no target was presented (96 catch trials). Trials were run in blocks, so that participants completed 4 blocks of 120 trials, each one divided in 4 subblocks. Before the experimental trials started, participants performed 36 practice trials, which were excluded from the analyses.

Data analyses

Trials with correct responses faster than 150 ms (1.07%) or slower than 850 ms (2.05%) were excluded from the RT analyses. Mean RT per experimental condition were computed on the remaining trials and were first analysed by means of a repeated measures analysis of variance (ANOVA), with SOA (100 vs. 1,000 ms), Cue location (Position 1, 2, 3, 4), and Target location (Position 1, 2, 3, 4). However, to simplify the analyses (there were 32 experimental conditions), these variables were recoded in a simpler design (12 experimental conditions) similar to that

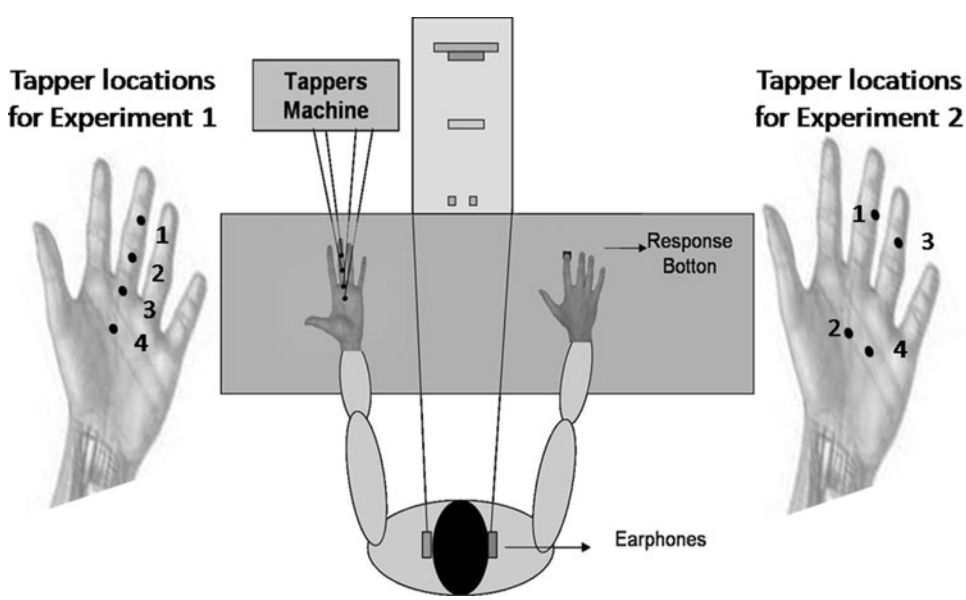


Fig. 1 Tapper locations and schematic drawing of experimental set-up in experiment 1 and 2

used previously to study visual hemifield modulation on visual cueing (e.g., Tassinari, Aglioti, Chelazzi, Peru, & Berlucchi, 1994). This new codification was as follows: SOA (100 vs. 1,000 ms) × Target Area (finger vs. palm) × Cueing (Opposite Area vs. Same Area vs. Same Place). Target area was the part of the hand that was stimulated by the second tactile stimuli (Target). Opposite area was coded when cue and target were presented in different anatomical parts of the hand (finger and palm). Same area was used when the cue and target were presented in the same studied area (finger or palm) but at different locations (e.g. different tappers). Same place means that the same tapper provided the cue and target stimuli.

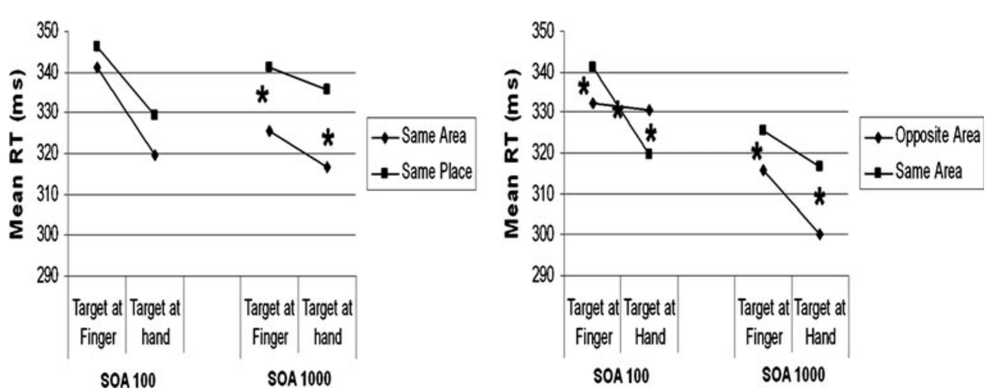
Results and discussion

The SOA × Target Area × Cueing repeated measures ANOVA showed a main effect of Target Area, $F(1, 17) = 26.52$, $p < .001$, with RT being 11 ms faster for the palm than the for finger locations. The main effect of Cueing was also significant, $F(2, 34) = 22.61$, $p < .001$, with responses to opposite area targets being 6 ms faster than those appearing at the same area, and 18 ms faster than those appearing at the same place. The interaction SOA × Cueing was also significant, $F(2, 34) = 12.01$, $p < .001$, but was modulated by Target Area, as shown by the SOA × Target Area × Cueing interaction, $F(2, 34) = 3.40$, $p = .045$. Interestingly, this interaction was not significant when we excluded the Opposite Area condition from the Cueing variable ($F < 1$). This indicates that the interaction seems to be driven by differences between areas rather than within areas (Thus, the exclusion of the Opposite Area condition entailed that Same Area and Same Place were not relevant for SOA × Area × Cueing interaction). To corroborate this finding, we performed two different ANOVAs, the Intra-area analysis [only including the Same Place and the Same Area cueing conditions; in other words cues and target are presented in the same part of the hand (finger or palm)] and the Inter-area analysis (only including the Same Area and the Opposite Area cueing conditions).

In the Intra-Area analysis (see left graph of Fig. 2), the main effect of Target Area was significant $F(1, 17) = 17.77$, $p < .001$, as well as the Cueing effect $F(1, 17) = 24.69$, $p < .001$ (Same Place trials were 12 ms slower than Same Area trials). Note that the Same Place and Same Area conditions correspond to the usual cued location (Same Place) and uncued location (Same Area) conditions that are used to measure facilitation (faster RT on cued than on uncued location trials) and IOR. Thus, we did not find facilitation at the short SOA (Faster RT in Same Place vs. Same Area); in fact non-significant IOR (Faster RT in Same Area vs. Same Place) was observed instead ($F < 1$) as facilitation is difficult to be observed in detection tasks (Spence & McGlone, 2001). As shown in Fig. 2, at the long SOA significant IOR effects were observed in both finger and hand ($p = .019$ and $p < .001$, respectively), with no difference between the two effects, $F < 1$. Thus, it can be concluded that the IOR effect is similarly observed in the finger and the palm.

In the Inter-Area analysis (see right graph of Fig. 2), however, the three-way interaction was significant, $F(1, 17) = 24.69$, $p < .001$. At the long SOA, the IOR effect (Faster responses in Opposite Area vs. Same Area) was again significant for both finger and palm (both $p < .05$), with no difference between the two effects ($F < 1$). However, as can be observed in Fig. 3, Opposite inter-area cueing effects were observed for finger and palm at the short SOA, $F(1, 17) = 13.24$, $p = .002$. In fact, a significant IOR was observed at the finger, $F(1, 17) = 4.83$, $p = .042$, whereas significant facilitation (faster responses in the Same Area condition vs. the Opposite Area) was observed instead at the palm, $F(1, 17) = 8.57$, $p = .009$. This might be taken as evidence that fingers and palms do not share the same reference frame or mental map. If they shared the same reference frame we should find the same pattern of cueing effects (facilitation or IOR in both areas). Note that the facilitation effect observed in the palm and the IOR effect observed in the finger can be altogether

Fig. 2 Intra-Area Cueing effect (Same Area vs. Same Place) as a function of SOA (*left*). Inter-Area Cueing effect (Opposite Area–Same Area) as a function of SOA (*right*). Experiment 1



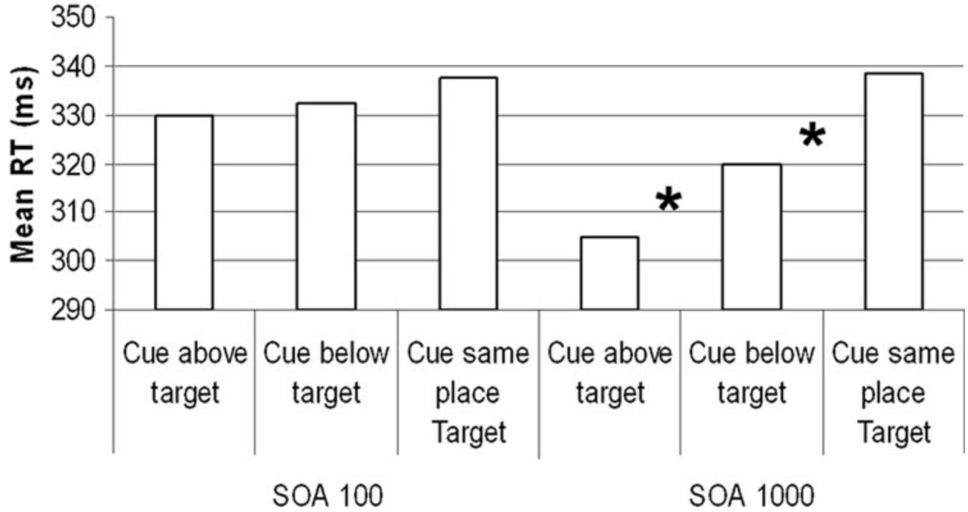


Fig. 3 Cue above Target effect in experiment 1

reinterpreted as additive effects of cue and target location, so that RT is faster when either the cue or the target are presented at the palm, as compared to when they are presented at the finger. In other words, the general facilitation of presenting the cue in the palm overrides the facilitation effect that should be measured at the finger. In any case this is evidence that finger and palm have different mental representations.

We subsequently performed a ANOVA to assess whether RT depended on the specific locations of cues and targets; SOA (100, 1,000 ms), Cue location (1, 2, 3, 4), and Target location (1, 2, 3, 4) and discovered another interesting effect in long SOA that co-exists with the IOR effect; the Cue above Target effect. RT seems to be faster when the cue appeared above the target in a vertical line where the tip of the finger is the higher point (i.e., at a more distal position). To specifically test this effect we recoded the variables in the following design: SOA (100, 1,000) × Cueing (Cue above the Target, Cue below the Target and Cue at the same place as the target) (see Fig. 3). No effects were observed at the Short SOA. At the long SOA, however, RT was 19 ms slower at the Cue at same place as the Target condition as compared to the Cue below the Target condition, $F(1,17) = 17.59$, $p < .001$, and 15 ms slower at the Cue below Target condition than at the Cue above Target condition, $F(1,17) = 16.80$, $p < .001$. Thus, there is a general facilitation towards the inside position of the hand, more concretely, when the cue and the target appear in a sequence oriented to centre of the hand direction. This effect could be explained as facilitation induced towards the centre of the hand or more generally as facilitation induced from distal to proximal locations in the body. A related hierarchical relationship between fingers and hands has been reported previously. Haggard et al. (2006) postulated a process of assigning fingers to hand according to a hierarchical and modular system in mental representation (Haggard & Wolpert, 2005).

Experiment 2

In experiment 1 we observed a different pattern of attentional effect in finger and palm. In intra areas analysis we only found a reliable IOR effects in long SOA for finger and palm. In inter areas analysis the same results were found for long SOA, but at a short SOA, IOR was observed at the finger and a Facilitation Effect at the palm. Interestingly, at the long SOA the observed IOR effect (similar in finger and palm) coexisted with what we have called a cue-above effect, i.e., faster RT with cues being presented at a more distal location than the target. The novelty of these data led us to run a new experiment to test their reliability and to assess whether this could also be observed when different fingers were involved because there is evidence that suggests that fingers are represented separately (i.e. Hari, Hämäläinen, Hämäläinen, Kekoni, Sams, & Tiihonen, 1990). Therefore, we conducted a new experiment in which we changed the tappers location of the experiment 1 (See Fig. 1) to extend our results to other fingers and to a different arrangement of the tappers. With this purpose we placed one tapper on the middle and one on the ring finger. If we obtain the same results as in the previous experiment, we could conclude that fingers share the same mental representation (or more precisely middle and ring fingers) and we could generalise the pattern of results of experiment 1 to other fingers. Subsequently, we also needed to place two tappers in the palm to compare areas. These tappers were placed vertically below the tappers of fingers at a distance of 5.2 cm (see Fig. 1). This allocation allowed us to measure the cue above effect in equal conditions for the two fingers with respect to the palm.

Methods

Participants

Eighteen participants (ten women) took part in this study. Their mean age was 25 years, ranging from 18 to 28 years.

Procedure

The procedure and set-up were the same as in experiment 1, apart from the following changes. The tappers were located at different locations (see Fig. 1). Now the "finger area" consists of two separate fingers, that is, the middle and ring finger, and we changed the tapper number 2 in experiment 1 to another position in the palm (e.g. vertically below the tappers on the fingers) to ascertain the consistency of the pattern of results observed in experiment 1. In addition, a more intense auditory fixation signal was used due to a change in earphones (i.e., the intensity of the fixation sound was 90 dBA as compared to 70 dB in the first experiment).

Results and discussion

Trials with correct responses faster than 150 ms (1.98%) or slower than 850 ms (2.13%) were excluded from the RT analyses. Mean RT per experimental condition were computed on the remaining trials and were submitted to a SOA × Target Area × Cueing repeated measures ANOVA. The analysis showed an effect of SOA, $F(1, 17) = 45.99$, $p < .001$, with RT being now 30 ms faster at the Short than at the Long SOA. The reason for this was probably the use of different earphones which inadvertently could produced an increase of 20 dBA in the intensity of the fixation point. This increase might have led to higher alertness (Carlsen, Dakin, Chua, & Franks, 2007). However, because alertness is a general process, it is expected that its influence will be the same over all attentional components, and the global enhancement in performance would only be observed during short SOAs (Posner & Boies, 1971; Posner & Wilkinson, 1969). This was, indeed, the case since the same pattern of results was observed in both experiments 1 and 2 (i.e., Target Area × Cueing), apart from a supplementary acceleration of RT for short SOAs in Experiment 2. As in experiment 1, the main effect of Target Area was also significant, $F(1, 17) = 17.29$, $p < .001$, RT being 8 ms faster for the palm as compared to the finger locations. The Cueing effect was again significant, $F(2, 34) = 19.35$, $p < .001$, with responses to opposite area targets being 7 ms faster than those appearing at the Same Area $F(1, 17) = 1.67$, $p = .004$, and 13 ms faster than those appearing at the same place $F(1, 17) = 27.88$, $p < .001$. The interaction SOA × Cueing was also significant, $F(2, 34) = 14.98$, $p < .001$, but was modulated by Target Area, as shown by the SOA × Area × Cueing interaction, $F(2, 34) = 7.57$, $p = .002$. To further study this interaction two additional ANOVAS were performed similar to experiment 1, one to study Intra-area effects (only including the Same Place and the Same Area cueing conditions), the other to study Inter-area effects (only including the Same Area and the Opposite Area cueing conditions).

In the Intra-Area analysis the three-way interactions was not significant [$F(1, 17) = 1.26$, $p = .277$] as we can observe in left graph of Fig. 4, the main effect of Area was significant, $F(1, 17) = 11.14$, $p = .004$ as it was the main effect of Intra-Area cueing, $F(1, 17) = 12.83$, $p = .002$ (Same Area trials were 6 ms faster than same place trials). We did not find facilitation or IOR at the short SOA; like in experiment 1). However, at the long SOA significant IOR effects were observed in both finger and palm ($p = .005$ and $p = .035$, respectively), with no difference between the two effects, $F < 1$. Thus, it can be concluded that the IOR effect is similarly observed between the two fingers and in the palm. It is important to realise that we observed the same pattern of Intra-Area results in both experiments, even though the tappers' position was very different. Thus, the differences seem to be again between areas rather than within areas. These results reinforce the hypothesis that the two fingers are represented in a similar mental representation. Similar results are reported in the literature. Haggard et al. (2006) found interference of tactile stimulation to homologous fingers, suggesting that the mental representation of all fingers share the same neural circuit.

In the Inter-Area analysis (right graph of Fig. 4), the three-way interaction was significant again, $F(1, 17) = 15.97$, $p < .001$. At the long SOA, the IOR effect was again significant for both finger and palm ($p = .005$, $p < .001$, respectively) with no difference between the two effects ($p = .286$). However, as can be observed in Fig. 4, Opposite Inter-area cueing effects were observed for finger and palm at the short SOA, $F(1, 17) = 11.65$, $p = .003$. Significant facilitation was observed for targets on the palm $F(1, 17) = 5.09$, $p = .037$, whereas IOR was observed for targets on the fingers, $F(1, 17) = 1.93$, $p = .041$. This result confirms the finding of experiment 1 regarding different patterns of attentional effect in fingers and palm.

Following the same logic of analysis as in experiment 1, the SOA (100, 1,000) × Cueing (Cue above Target, Cue below Target, Cue same place Target) ANOVA again revealed a Cue above Target effect at the long SOA. RT was 22 ms slower for targets at the same place as compared to the Cue below Target condition, $F(1, 17) = 32.67$,

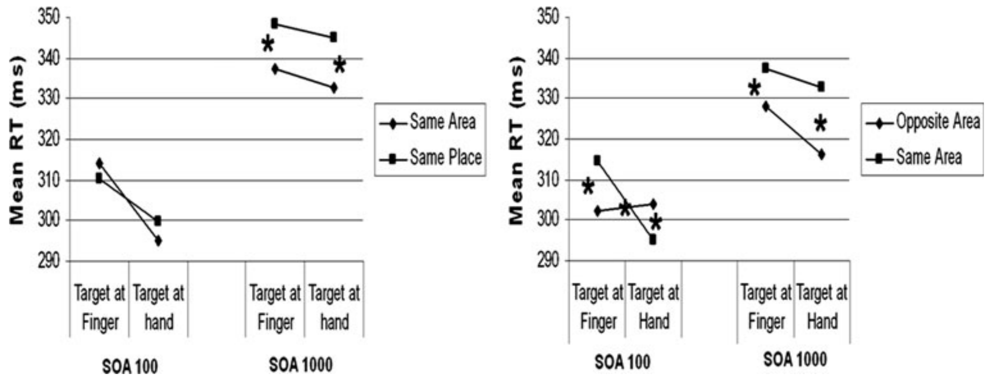


Fig. 4 Intra-Area Cueing effect (Same Area vs. Same Place) as a function of SOA (*left*). Inter-Area Cueing effect (Opposite Area–Same Area) as a function of SOA (*right*). Experiment 2

$p < .001$, and 8 ms slower at the Cue below Target condition compared to the Cue above Target condition, $F(1, 17) = 7.22$, $p = .016$. To sum up, the same general pattern of results were observed as in experiment 1, in spite of using two fingers, and a different distribution of the tappers.

General discussion

The aim of our research was to study differences in mental representation between the fingers and the palm. We manipulated spatial attention within and between tactile stimuli on the fingers and the palm to investigate this. More specifically, we used a spatial cueing paradigm where we studied the Facilitation and IOR effects to learn about continuities and discontinuities in the organisation of tactile representations between fingers and the palm independent of whether they occur in an allocentric or somatotopic mental representation.

For this purpose, we designed two experiments with a tactile detection task where tappers were placed in fingers and palm to ascertain similarities and differences in the observed attentional effects between the studied areas. Having two tappers on the finger/s and two on an equidistant position on the palm, made it possible to perform an intra-area analysis in which the facilitation and IOR effects observed in the finger and the palm can be compared directly. We obtained two findings in both experiments that provided evidence about different mental representation in fingers and palm. First, at the short SOA in inter areas analysis, Facilitation was found in the hand (i.e., responses were faster when cue and target were presented in the hand, than when the cue was presented in the finger and the target in the hand) and IOR in fingers (i.e., responses were faster when the cue was presented in the hand and the target was presented in the finger, than when both were presented in the finger). This difference in exogenous attentional effects supports the hypothesis that fingers and palm have different mental representations. If they shared the same reference frame we should find the same pattern of cueing effects. Secondly, in the same way that IOR is reliably observed between visual hemifields (supporting a role of different hemifields representations, in the two cerebral hemispheres) (Weger, Al-Aidroos, & Pratt, 2008) IOR is observed between finger and hand in our two experiments (long SOA), thus supporting the idea that they are represented as different areas. Our results confirm previous findings about a separate mental representation of fingers compared to other parts of the body, in line with studies of finger agnosia (Anema et al., 2008, Benton, 1959; Gerstmann, 1942; Mayer et al., 1999; Kinsbourne & Warrington, 1962) and the study of Haggard et al. (2006) with healthy participants. However, there are some important differences as well. While the Haggard et al. (2006) study compared identification of whole hand (left vs. right) with that of the individual fingers for crossed and uncrossed postures, or interleaved fingers, in the current study we contrasted tactile attention to different areas of a single hand (e.g. palm vs. fingers), irrespective of posture [see also Zampini, Harris, & Spence, 2005]. Nevertheless, it may be possible that the study of Haggard et al. (2006) and our study were focused on similar differences in representation, if we consider the fingers as specific part of the hand, and the palm as a more general part of the whole hand.

Another similarity with Haggard et al. (2006) study may be that it provides evidence for the hierarchical nature of the representations of palm and fingers. At the long SOA, the observed IOR effect co-existed with what we have called the Cue above Target effect. In both experiments when the cue is presented at a more distal location than the target, responses are faster than in the opposite condition, where the target is presented more distally. This effect can be explained in terms of facilitation induced by the succession of events towards the centre of the hand or more generally as facilitation induced from distal to proximal locations in the body. The general facilitation observed in the hand at short SOA (IOR in fingers and Facilitation in palm in the short SOA) and the Cue above Target effect at the long SOA seems to be consistent with the idea that the hand is important in a hierarchically organised mental representation. This hierarchy is reflected in our study in the attentional facilitation towards the hand. Indeed, we did not find this modular feature between fingers. This mental hierarchy has been described previously in the literature, Haggard and Wolpert (2005) suggested that the body scheme is modular and hierarchical. Thus, fingers are parts of the hand; the hands are parts of the arms, etc. Possibly when the finger is stimulated a process of assigning the touched finger to the hand is started [see Haggard et al., 2006 to know more details about this mechanism], and a second stimulus applied close to the middle area of the palm or in this direction, can facilitate this assignation and thus, the detection of the second stimulus. In any case our research has provided a direct evidence about the mental hierarchy between two adjacent anatomical structures. Future research will be necessary for the study of the cue above effect to provide answers to its nature because with our methodology we cannot distinguish between this effect as a facilitatory effect towards the centre of the hand and a rather more general facilitation effect induced from distal to proximal locations in the body and thus a general mechanism between limbs.

In contrast to a distinction between palm and fingers, our results support the idea that different fingers share a similar mental representation. We observed the same pattern of intra-area results in both experiments (there is IOR in for cue and target both on fingers or on the hand), but with an entirely different tapper arrangement. In experiment 1 the two tappers were placed on one finger. In experiment 2 there was one tapper on the middle finger and another on the ring finger (and two tappers in the hand aligned with the tappers of the fingers). These results suggest a common attentional mechanism for tactile stimuli on the different fingers, but it is necessary to be cautious about this finding because this may be related to partially overlapping finger representations (Schweizer, Maier, Braun, & Birbaumer, 2000; Overvliet, Anema, Brenner, Dijkerman, & Smeets, 2011). This may suggest that when the cue and target are presented at fingers that are not adjacent to the effects may be different. Alternatively, separate finger representations (Gelnar, Krauss, Szeverenyi, & Apkarian, 1998; Hamada, Nozawa, Kado, & Suzuki, 2000; Jarvelainen & Schurmann, 2002; Schweizer, Voit, & Frahm, 2008) co-exist with a general attentional distribution that affects to middle and ring fingers, and is different for the palm. Future research should explore these options, particularly because our research only compared two fingers of the hand. It may be very interesting to particularly study the thumb with our methodology because its particular anatomical, physiological and functional features may be different to the other fingers (Olatsdottir, Zatsiorsky, & Latash, 2004) and thus, the study of attentional effects could provide evidence about what role this "special" finger plays with respect to the rest of the hand.

Finally, an interesting data of tactile attention is reported in both experiment in our research that there is facilitation when the cue and target appear in the palm, but not when they appear in the finger/s. Spence and McGlone (2001) suggested that it is difficult to observe tactile facilitation, because the tactile modality may be insensitive to the spatial distribution of attention, and thus to the early facilitatory effect of exogenous orienting. However, we found the effect in the palm location, which might be due to the palm more sensitive to the spatial distribution of attention than the fingers. Miles et al. (2008) suggested that the facilitation found in the previous literature (Spence & McGlone, 2001; Santangelo & Spence, 2007; Chambers, Payne, & Mattingley, 2007) may have been the consequence of the cue providing participants a spatial framework within which to interpret the subsequent target. However, no facilitation was observed for the fingers in our experiment, suggesting that a spatial framework per se cannot explain the facilitatory effects observed for the palm cueing.

Two corollary conclusions of our study: Firstly, fingers and palm have different mental representations but with a considerable and hierarchical interrelation between them. We consider these findings can be really useful for future research of mental representation and/or tactile attention, because it highlights the importance of taking into account different mental representations in the whole hand. Secondly, we have provided a new tool to compare different tactile representations where the participants are not required to move or change the position of the limbs, which may allow the study of these representations independent of allo- or somatotopic reference frames.

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