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Cognition 274 (2026) 106559

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/cognit

Full Length Article

Structural representation of the body differs for glabrous and hairy skin surfaces

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ARTICLE INFO

Keywords:
Body structural representations
Hairy skin
Glabrous skin
Hand posture

ABSTRACT

Knowledge about body representation is drawn from different sensory modalities but relies strongly on tactile information. The body structural representation (BSR) is a topological map of the body in which the spatial configuration of different body parts is defined. Recent evidence has demonstrated that the BSR is not fixed but can be dynamically updated by external factors such as changes in body posture. However, the extent to which access to the structural representation of the hand differs for different skin regions (glabrous vs. hairy) remains unclear. To address this question, we conducted two experiments using an adapted version of the "in-between" test, where healthy individuals received tactile stimulations on the fingertips and estimated the number of unstimulated fingers between the two touched. In Experiment 1, the skin regions (glabrous vs. hairy) were varied across conditions. In Experiment 2, the stimulated skin region was manipulated while hand posture was held constant (palm down). Results showed a significant difference in finger numerosity estimation between the glabrous and hairy skin regions. Specifically, participants estimated greater numerosity with glabrous skin stimulation regardless of hand posture, but this effect was only evident when non-adjacent fingers were stimulated. This suggests that access to the BSR of the hand depends on the skin surface stimulated and varies as a function of the anatomical distance between different body parts.

1. Introduction

Knowledge about body representation is mediated by various hierarchical stages of analysis of tactile information, in which a low-level perceptual representation is gradually transformed into a high-level cognitive construct (Tamè & Longo, 2023). The higher level of abstraction of tactile processing is linked to the definition of the body structural representation (i.e., BSR), a topological map of the body in which the spatial configuration, location in space, and relative distance between body parts are defined (Corradi-Dell'Acqua, Tomasino, & Fink, 2009; Felician et al., 2004; Raimo et al., 2022; Schwoebel & Coslett, 2005). BSR was initially conceptualized as distinct from the body schema (this latter defined as a dynamic, unconscious, and automatic internal model of the body that is continuously updated as the body moves through space and changes posture, Serino & Haggard, 2010; Sattin et al., 2023), although recent findings have questioned this hard distinction (Tamè, Dransfield, Quettier, & Longo, 2017).

Knowledge of the structural description of different body parts is closely linked to the sensory coding that occurs within the somatosensory pathway and in the posterior parietal lobes (Longo, Azañón, & Haggard, 2010; Rusconi et al., 2014; Tamè, Azañón, & Longo, 2019). Neuropsychological evidence demonstrates that lesions in the left parietal lobe can result in several clinical conditions that disrupt access to body representation, including deficits in recognizing body parts upon verbal commands, such as autotopagnosia (Sirigu, Grafman, Bressler, & Sunderland, 1991), or the inability to precisely identify individual fingers, namely finger agnosia (Kinsbourne & Warrington, 1962). However, the ability to perform skilled actions remains intact in either condition (Buxbaum & Coslett, 2001), suggesting the existence of distinct representations of the body. Although the body is perceived as a highly stable structure during movement, the structural representation within the somatosensory areas is dynamically updated according to various sources of information.

A recent study by Tamè et al. (2017) demonstrated that the BSR is

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https://doi.org/10.1016/j.cognition.2026.106559
Received 12 August 2025; Received in revised form 14 April 2026; Accepted 15 April 2026

influenced by changes in finger posture. By adopting the in-between (IBT) task (Kinsbourne & Warrington, 1962), they showed that access to the BSR is affected by the posture of the finger in space. To correctly identify which fingers have been stimulated, it is necessary to know the spatial relation between body parts and their representation in the internal model of the body. Critically, a higher number of fingers in-between was estimated when non-adjacent fingers (e.g., index and ring fingers) were touched and positioned in a splayed posture than when they were close together or touching. In contrast, judgments were unaffected by postural conditions when adjacent fingers (e.g., index and middle fingers) were stimulated (Tamè et al., 2017). This finding suggests that the BSR is modulated by real-time physical distance between body parts. Moreover, a subsequent study replicated the same pattern with a similar paradigm, suggesting that tactile information is originally encoded relative to the anatomical reference frame, but the same information is also remapped according to the external space coordinates (Dolgilevica, Longo, & Tamè, 2020). These two reference systems dynamically interact and support the definition of multiple representations of the body in space.

Despite recent advances in understanding the factors that influence the BSR, it remains unclear whether a single structural representation for a certain body part is present or if, instead, multiple body representations are necessary. Such a question has critical implications especially when considering interventions in neurological conditions that can affect some aspects of body structure, such as, for instance, autotopoagnosia and/or finger agnosia (Rusconi et al., 2014; Schwoebel & Coslett, 2005; Sirigu et al., 1991). A possible way to test this hypothesis is to evaluate whether one or different body representations are present when tactile stimulation occurs on different types of skin regions.

Human skin can be classified into glabrous skin, as found on the palmar surfaces of the hands (Johansson & Vallbo, 1979), in the plantar surfaces of the feet (Strzalkowski, Peters, Inglis, & Bent, 2018), and on the lips, and hairy skin, which covers the remaining body surfaces (Longo & Sakka, 2025). In the hand structure, these two types of skin composition coexist; however, the innervation across the hand sides is not uniform. In particular, the median nerve innervates mostly the palmar surface of the hand and fingers, the radial nerve predominantly innervates the dorsum of the hand and the thumb, while the ulnar nerve supplies both the medial regions of the palm and dorsum (Corniani & Saal, 2020). This differential innervation is also accompanied by variation in afferent fiber composition and distribution across skin regions, determining the transmission of distinct cutaneous input to the brain.

Glabrous skin is primarily associated with fast-conducting myelinated Aβ afferent fibers (Corniani & Saal, 2020; Kandel, Schwartz, Jessell, Siegelbaum, & Hudspeth, 2013; Miller, Ralston 3rd, & Kasahara, 1958), which support the encoding of discriminative and sensorimotor aspects of touch. This rapid system enables rapid detection and discrimination of stimuli across the body surface and is also linked to the motor system for the manipulation of external objects (Craig & Lyle, 2001; Johansson & Vallbo, 1980; Mountcastle, 2005). Hairy skin is characterized by a combination of different afferent fibers (Corniani & Saal, 2020; McGlone, Wessberg, & Olausson, 2014), including myelinated Aβ fibers, and unmyelinated C-tactile fibers (Vallbo, Olausson, & Wessberg, 1999), which respond maximally to moving stimuli with moderate velocities and are associated with the pleasantness of touch (Löken, Wessberg, Morrison, McGlone, & Olausson, 2009). These two sub-modalities contribute to various aspects of somatosensory processing, although their role in the definition of the BSR remains unclear. Previous studies such as Longo & Haggard (2012), investigated the role of skin types in the definition of the hand representation. These authors suggested that this latter relies on a hybrid stage between the fragmentated representation of the two skin types and an integrated map that represents the hand as a unified object. Within this intermediate model, the degree of distortions of this internal configuration is not uniform between the two skin regions, as they are substantially reduced in the palmar surface compared to the dorsal hand surface (Longo & Haggard, 2012). This model is also coherent with the phenomenon of the anisotropies in tactile perception across the skin types, in which perceived distances between tactile stimuli are generally overestimated for the hand width in the hand dorsum, while evidence of the existence of this bias on the glabrous skin of the hand palm is less consistent (Longo, 2020; Longo & Golubova, 2017).

In this paper, we report two experiments where we investigated whether different skin regions (glabrous vs. hairy) influence access to hand structural representations differently. We used an adapted version of the IBT task (Kinsbourne & Warrington, 1962; Tamè et al., 2017), in which healthy individuals received tactile stimulations on the fingertips and estimated the number of unstimulated fingers between the two touched on these different skin areas.

The task was selected to investigate higher-level processing of tactile signals. Specifically, participants were first required to identify which fingers were stimulated and then map them onto a structural representation of the hand to determine the number of fingers between the stimulated ones. We hypothesize that this complex analysis cannot be fully explained by the initial representation of the body in the primary somatosensory cortex, as it requires representing the structural relation between the touched and untouched fingers. This type of information is not encoded at this initial stage of analysis, but it is more likely derived from higher-level sensory processing in the parietal cortex, which supports the definition of BSR (Rusconi et al., 2014; Tamè et al., 2017).

2. Experiment 1

In Experiment 1, we investigate whether access to the BSR of the left hand differs across regions of the skin where tactile stimulation occurs (glabrous vs. hairy). We measure finger numerosity estimation and accuracy, participants' reaction times (RTs), and perceptual confidence to gain a subjective measure of their perceptual ability, as well as an index of their metacognitive efficiency (i.e., the capacity to monitor and be aware of one's thoughts and behaviours, reflected in subjective reports that should be consistent with the reality, Fleming, Dolan, & Frith, 2012; Palmer, David, & Fleming, 2014). If multiple BSRs are present, we expect different patterns of finger estimation according to the region of the skin stimulated (glabrous vs. hairy). Specifically, we expect a selective bias in finger numerosity estimation for the glabrous skin over the hairy skin, given its functional role in sensorimotor exploration of the external environment (Johansson & Vallbo, 1980; Johansson & Westling, 1984). Moreover, similar to previous studies (Dolgilevica et al., 2020; Tamè et al., 2017), a different pattern of finger estimation is also expected as a function of the combinations of fingers touched (i.e., adjacent vs. non-adjacent fingers). The identification of adjacent fingers is expected to be less differentiated between the skin types, as it relies on the use of anatomical coordinates in the primary somatosensory cortex, for which access to BSR is possibly not required (Tamè et al., 2017). Instead, the identification of non-adjacent fingers requires the knowledge of the structural relation between body parts, which is a signature of the BSR. If multiple BSRs are associated with the different regions of the skin, we expect a different pattern for the identification of non-adjacent fingers across the skin types, with more precise estimation in the glabrous skin compared to the hairy skin, as well as differences in accuracy. By contrast, if a single BSR is used to identify non-adjacent fingers, we should not see differences in both finger estimation and accuracy for the two skin regions. Although the differences in innervation patterns are relatively minor on the upper phalanges between these two skin regions, we may expect overall higher accuracy for the glabrous skin compared to the hairy skin region (Corniani & Saal, 2020; McGlone et al., 2014).

2.1. *Materials and methods*

2.1.1. *Participants*

An a priori power analysis was conducted using the software G*Power (version 3.1; Faul, Erdfelder, Lang, & Buchner, 2007) to determine the required sample size. The effect size used was estimated based on the partial eta squared ($\eta_p^2 = 0.09$) reported in a previous study (Tamè et al., 2017). With an estimated effect size $f = 0.31$, significance criterion $\alpha = 0.05$, and power $= 0.99$, the sample size required was twenty-five participants. We decided to recruit thirty participants (mean age ± SD = 21.6 ± 7.6 years; 20 females, 10 males) to replicate the previous published studies (Dolgilevica et al., 2020; Tamè et al., 2017). One participant was excluded from the analyses because their performance was at chance level. Therefore, the final sample was twenty-nine participants (mean age ± SD = 20.2 ± 2.3 years; 20 females, 9 males).

Participants reported normal or corrected to normal vision, audition, and sensorimotor abilities. All participants gave their informed consent before participation, and their privacy rights were observed. The study obtained ethical approval (Ethics ID: 202417278577289295) and was carried out according to the principles of the Declaration of Helsinki. Participants completed the Edinburgh Handedness Inventory questionnaire (Oldfield, 1971) to assess their handedness preference before starting the experimental sessions (M = 72, range = −77-100).

2.1.2. *Apparatus and stimuli*

Tactile stimulations were delivered on the fingers of the left hand at the level of the most distal phalanx, using five solenoid tappers (8 mm in diameter; Dancer Design, UK) driven by a 9 V square wave, with 50 Hz of frequency of stimulation.

A calibration phase was executed for all participants before the start of the testing session using a custom program written in MATLAB (version 2019b) and Psychtoolbox (Brainard, 1997) libraries. During this calibration phase, two tactile stimuli were delivered sequentially on pairs of fingers (starting with the thumb and index finger, index finger and middle fingers, middle finger and ring fingers, and ring finger and little fingers), and the intensity was adjusted until participants reported that each stimulus pair felt perceptually identical across all digits. The intensity of the stimulation was selected to be clearly suprathreshold and consistent between the two skin surfaces. The same procedure was repeated separately for both the glabrous and hairy skin regions.

During the testing session, tactile stimulators were placed centrally on the width and length of the fingertip using double-sided adhesive, either on the palm or on the dorsum of the fingers, according to the experimental condition. In each trial, the tactile stimulation lasted 50 ms. Stimulus presentation and response collection were controlled by a custom program written using MATLAB (version 2019b) and Psychtoolbox (Brainard, 1997) libraries.

2.1.3. *Design*

The design of the study was a within-subjects protocol. As illustrated in Fig. 1A, two different tactile stimulation conditions were administered, with hand posture adjusted accordingly (i.e., tactile stimulation on the hairy regions of the skin with the hand palm facing down, and tactile stimulation on the glabrous region of the skin with the hand palm facing up). There were four blocks, with 72 trials each, balanced between the pairs of fingers stimulated (i.e., zero, one, or two fingers in-

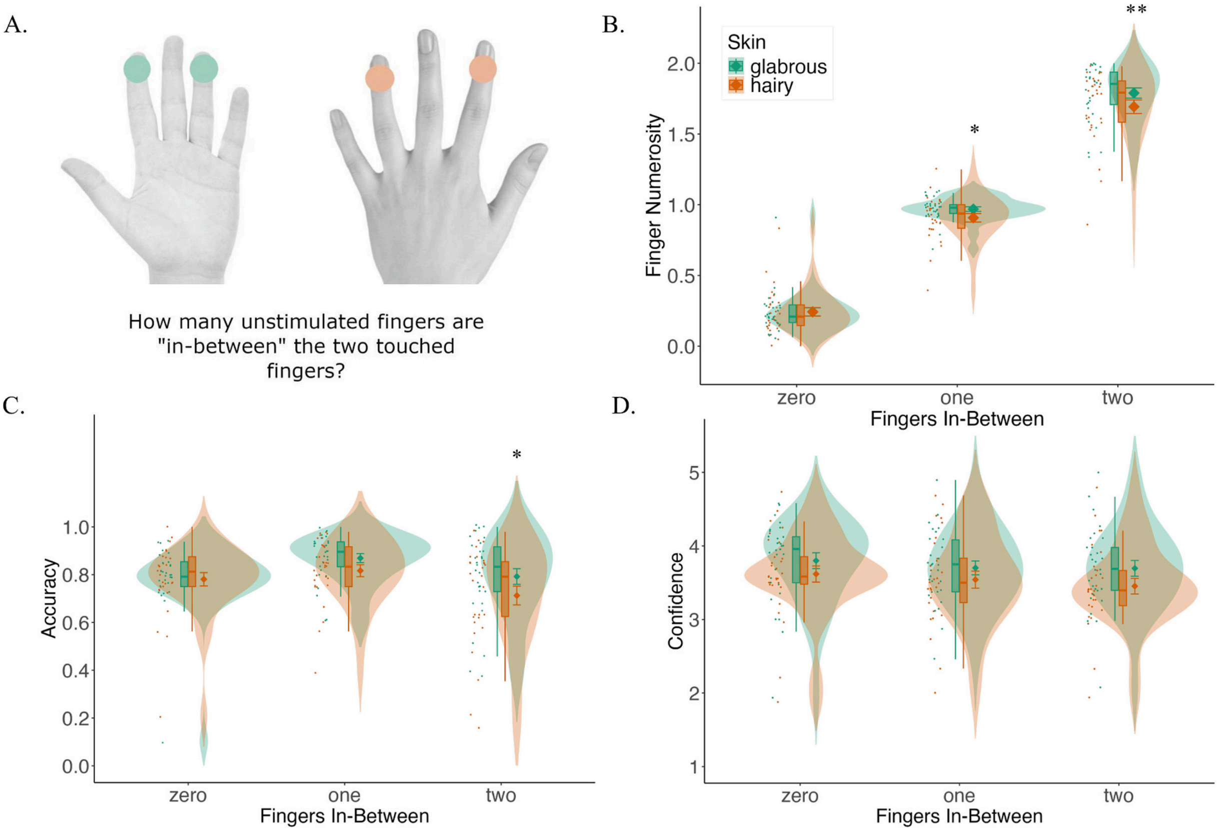

Fig. 1. The region of the skin stimulated (glabrous vs hairy) varied across blocks, as well as the relative posture of the hand in the space (palm up vs palm down). The solid-filled circle indicates the region of the skin in which the tactile stimulation was delivered (green = glabrous vs orange = hairy) (**A**). Finger numerosity estimation based on the actual number of fingers in-between (i.e., zero, one, two) for the glabrous and hairy skin condition (**B**). Accuracy for the different number of fingers in-between as a function of skin type (glabrous vs hairy) (**C**). Confidence response for the different number of fingers in-between as a function of the different regions of the skin stimulated (glabrous vs hairy) (**D**). Error bars indicate 95% Confidence Intervals of the within-participants variability (95%CI). * Denotes $P < .05$, ** Denotes $P < .01$. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

between), for a total of 288 trials. The order of block presentation was counterbalanced and presented in an ABBA sequence. The initial region of stimulated skin (glabrous vs. hairy) was counterbalanced across participants: half of the participants began with the hairy skin condition, whereas the other half began with the glabrous skin condition.

2.1.4. Procedure

Participants placed their left hand inside a box located in front of them to mask the vision of the fingers. The hand was positioned on a raised support so that the region proximal to the wrist rested on the surface while the fingers remained suspended. This arrangement prevented any contact between the fingertips and the support, avoiding the spread of vibrations beyond the intended area (e.g., nearby skin or body parts). Participants were asked to keep their gaze position constantly directed toward the wall in front of them. Throughout the experiment, white noise was presented over closed-ear headphones to prevent participants from hearing vibration noise from the tactile device. In each trial, two tactile stimulations were given simultaneously on a pair of fingers in different combinations so that there were zero (i.e., thumb-index, index-middle, middle-ring, ring-little), one (i.e., thumb-middle, index-ring, middle-little), or two (i.e., thumb-ring, index-little) fingers in-between the stimulated ones. Participants were asked to respond verbally by speaking into a microphone to report the number of fingers they perceived among the two stimulated and the level of confidence they had in their answers. Confidence responses were collected verbally using a scale from 1 to 5 (1 = not confident, 5 = entirely confident; Maurer & Pierce, 1998; Fairhurst, Travers, Hayward, & Deroy, 2018). The verbal responses of finger numerosity and level of confidence were recorded as audio files to allow for subsequent extraction and analysis of RTs. In parallel, the experimenter logged responses manually using a keyboard into the MATLAB program immediately upon verbalization. Participants were asked to give a verbal response as soon as they perceived the touches on their fingers. The temporal interval available for giving the response was 3000 ms. If the participant did not respond after 3000 ms, a new trial began. They were instructed to prioritize accuracy over speed, as the task was primarily designed to assess finger numerosity estimation, rather than response latency. RTs were recorded as a supplementary measure to remain consistent with the original design (Tamè et al., 2017). No feedback about the performance was provided. Participants were offered short breaks between each block. Raw data are publicly available on OSF (https://osf.io/phc4v/).

2.1.5. Data analysis

Participants' responses to finger estimation, accuracy, confidence rating, and RTs were averaged based on the skin type (i.e., glabrous vs. hairy) and the actual number of fingers in-between (i.e., zero, one, two). This enabled us to obtain an index of under- and over-estimation of finger numerosity, as well as the potential interaction between different finger combinations (i.e., adjacent vs. non-adjacent) and the region of the skin stimulated. The average responses were entered into four separate Analyses of Variance (ANOVAs) with Skin (glabrous vs. hairy) and Fingers In-between (zero, one, two) as within participants factors, for each of the four measurements.

RTs were extracted from the audio recording using a custom MATLAB script after excluding outlier trials, in which the response time fell outside the maximum temporal interval (>3000 ms). We added 404 ms to the mean of the RTs in each condition to correct for the temporal delay introduced by the MATLAB function used to record verbal responses (Tamè et al., 2017). Note that finger estimation and accuracy were our primary variables of interest, while RTs were considered a secondary measure as in previous studies (Dolgilevica et al., 2020; Tamè et al., 2017).

In addition to the primary analyses, we computed confidence rating measures as a function of participants' response accuracy to assess metacognitive efficiency (Fleming et al., 2012). Confidence ratings were extracted separately for correct and incorrect trials using a custom MATLAB script. Metacognitive efficiency was subsequently analysed in two separate ANOVAs as a function of correct vs. incorrect responses.

2.2. Results

Fig. 1B shows finger numerosity estimates for each condition. There was a main effect of Skin, $F(1,28) = 11.88$, $p = .002$, $\eta_p^2 = 0.30$, caused by a greater finger numerosity estimation for glabrous skin ($M \pm SE = 1 \pm 0.02$) compared to hairy skin ($M \pm SE = 0.95 \pm 0.03$). There was also a main effect of Fingers In-between, $F(2,56) = 800.35$, $p < .001$, $\eta_p^2 = 0.97$, showing that judged numerosity increased monotonically with actual numerosity of fingers in-between (as in Tamè et al., 2017). More interestingly, we observed a significant interaction between Skin * Fingers In-between $F(2,56) = 6.16$, $p = .004$, $\eta_p^2 = 0.18$, suggesting that finger numerosity estimates on glabrous vs. hairy skin differed based on the actual number of fingers in-between (adjacent vs. non-adjacent fingers). Post-hoc analysis showed no significant difference between glabrous ($M \pm SE = 0.24 \pm 0.03$) and hairy skin ($M \pm SE = 0.24 \pm 0.03$) for zero fingers in-between (i.e., adjacent fingers, $t(28) = -0.04$, $p = .968$, $d_z = -0.01$), but numerosity judgments were higher for glabrous compared to hairy skin when there was one (glabrous $M \pm SE = 0.97 \pm 0.02$; hairy $M \pm SE = 0.91 \pm 0.03$; $t(28) = 2.96$, $p = .012$, $d_z = 0.55$) or two fingers in-between (i.e., non-adjacent fingers, glabrous $M \pm SE = 1.79 \pm 0.04$; hairy $M \pm SE = 1.69 \pm 0.05$; $t(28) = 3.53$, $p = .004$, $d_z = 0.66$).

Fig. 1C shows participants' accuracy for each condition. Analyses on accuracy revealed a main effect of Skin, $F(1,28) = 18.91$, $p < .001$, $\eta_p^2 = 0.40$, with overall higher accuracy for glabrous skin ($M \pm SE = 0.81 \pm 0.02$) compared to hairy skin ($M \pm SE = 0.77 \pm 0.02$). There was also a main effect of Fingers In-between, $F(2,56) = 3.73$, $p = .03$, $\eta_p^2 = 0.12$, and a significant interaction between Skin * Fingers In-between $F(2,56) = 4.58$, $p = .014$, $\eta_p^2 = 0.14$. Post-hoc analyses revealed no significant difference between glabrous ($M \pm SE = 0.78 \pm 0.03$) and hairy skin ($M \pm SE = 0.78 \pm 0.03$) for zero fingers in-between ($t(28) < 0.01$, $p = 1.00$, $d_z = 0.00$), or for one finger in-between (glabrous skin $M \pm SE = 0.87 \pm 0.02$, hairy skin $M \pm SE = 0.82 \pm 0.03$; $t(28) = 2.78$, $p = .103$, $d_z = 0.52$). In contrast, accuracy was significantly higher on glabrous ($M \pm SE = 0.79 \pm 0.03$) than hairy skin ($M \pm SE = 0.71 \pm 0.04$) for two fingers in-between ($t(28) = 3.81$, $p = .01$, $d_z = 0.71$).

Fig. 1D shows participants' confidence responses for the glabrous vs hairy skin conditions. There was a main effect of Skin, $F(1, 28) = 28.96$, $p < .001$, $\eta_p^2 = 0.51$, indicating that overall participants reported higher confidence ratings in finger numerosity estimates on glabrous skin ($M \pm SE = 3.73 \pm 0.09$) compared to hairy skin ($M \pm SE = 3.54 \pm 0.10$). No main effect of Fingers In-between was observed, $F(2, 56) = 2.28$, $p = .112$, $\eta_p^2 = 0.08$, or an interaction $F(2, 56) = 1.05$, $p = .357$, $\eta_p^2 = 0.04$.

Analyses of RTs revealed no main effect of Skin, $F(1, 28) = 2.97$, $p = .096$, $\eta_p^2 = 0.10$, or an interaction, $F(2, 56) = 1.97$, $p = .149$, $\eta_p^2 = 0.07$. There was a significant main effect of Fingers In-between, $F(2, 56) = 17.68$, $p < .001$, $\eta_p^2 = 0.39$, with RTs increasing monotonically with the actual number of fingers in-between.

Analysis on confidence rating as a function of participants' response accuracy revealed a main effect of Skin, $F(1,28) = 30{,}67$, $p < .001$, $\eta_p^2 = 0.52$, with overall higher confidence in the glabrous skin ($M \pm SE = 3.88 \pm 0.09$), compared to the hairy skin ($M \pm SE = 3.69 \pm 0.10$) for the correct trials. There was also a main effect of Fingers In-between, $F(2,56) = 6.84$, $p = .002$, $\eta_p^2 = 0.20$, suggesting that confidence responses in the correct trials decrease progressively with the increased number of fingers. Analysis on confidence rating as a function of participants' response accuracy for the incorrect trials revealed no main effect of Skin, $F(1,24) = 1.63$, $p = .214$, $\eta_p^2 = 0.06$, nor main effect of Fingers In-between, $F(2,48) = 0.53$, $p = .594$, $\eta_p^2 = 0.02$. These results suggest that participants showed preserved metacognitive efficiency.

2.3. Discussion

In Experiment 1, results showed that finger numerosity estimation changed as a function of the region of the skin stimulated, with a greater estimation of finger in-between as well as a higher accuracy for the glabrous compared to the hairy skin. However, this finger overestimation was only evident when non-adjacent fingers were stimulated. No difference in estimation was observed between the two skin regions when adjacent fingers were involved. This result suggests that the anatomical reference system is sufficient for the identification of adjacent body parts, regardless of the skin region, and without requiring access to the BSR. In contrast, the identification of non-adjacent fingers requires access to the full BSR of the hand, which may differ and be functionally segregated based on the specific skin region stimulated. These results provide additional support to the notion that multiple structural representations of the body are defined at the cortical level for the same body part (i.e., hand) and introduce the idea that the BSRs of the hand are also distinguished according to the type of skin stimulated (i.e., glabrous vs. hairy).

However, it is possible that the effect observed in this experiment partially derives from the postural modulation of the hand rather than from the different regions of the skin in which the tactile stimulation was delivered. Indeed, the region of the skin stimulated (glabrous vs. hairy) also corresponded to different postural conditions of the hand in space (palm up vs. palm down, respectively). To exclude this possibility and isolate the effect of skin region, we conducted a second experiment using an identical design but avoiding the postural modulation of the left hand by keeping it fixed in a facing-down position.

3. Experiment 2

Previous work has already highlighted that external spatial information, such as hand posture, can influence the BSR of the hand, particularly when non-adjacent fingers are stimulated (Dolgilevica et al., 2020; Tamè et al., 2017). Note, however, that in previous studies the spatial position of the individual fingers was specifically manipulated, though in Experiment 1 of the present work, we changed the posture of the entire hand. Nonetheless, to control for potential confounding spatial effects, in Experiment 2 we performed the IBT task on the two skin regions (glabrous vs. hairy), keeping the hand posture constant with the palm facing down (as in the original paradigm, see Tamè et al., 2017). If the effect observed in Experiment 1 does not depend on the posture of the hand, we should replicate the results in this second study.

3.1. Materials and methods

3.1.1. Participants

Thirty new participants (mean age ± SD = 21.1 ± 7.5 years; 24 females, 6 males) were recruited for the study. One participant was excluded from the analyses as their performance was at the chance level. Therefore, the analyses were performed on a sample of twenty-nine participants (mean age ± SD = 21.1 ± 7.7 years; 24 females, 5 males). All participants gave their informed consent before participation. Participants completed the Edinburgh Handedness Inventory questionnaire (Oldfield, 1971) to assess their handedness preference before starting the experimental sessions (M = 75, range = −90-100).

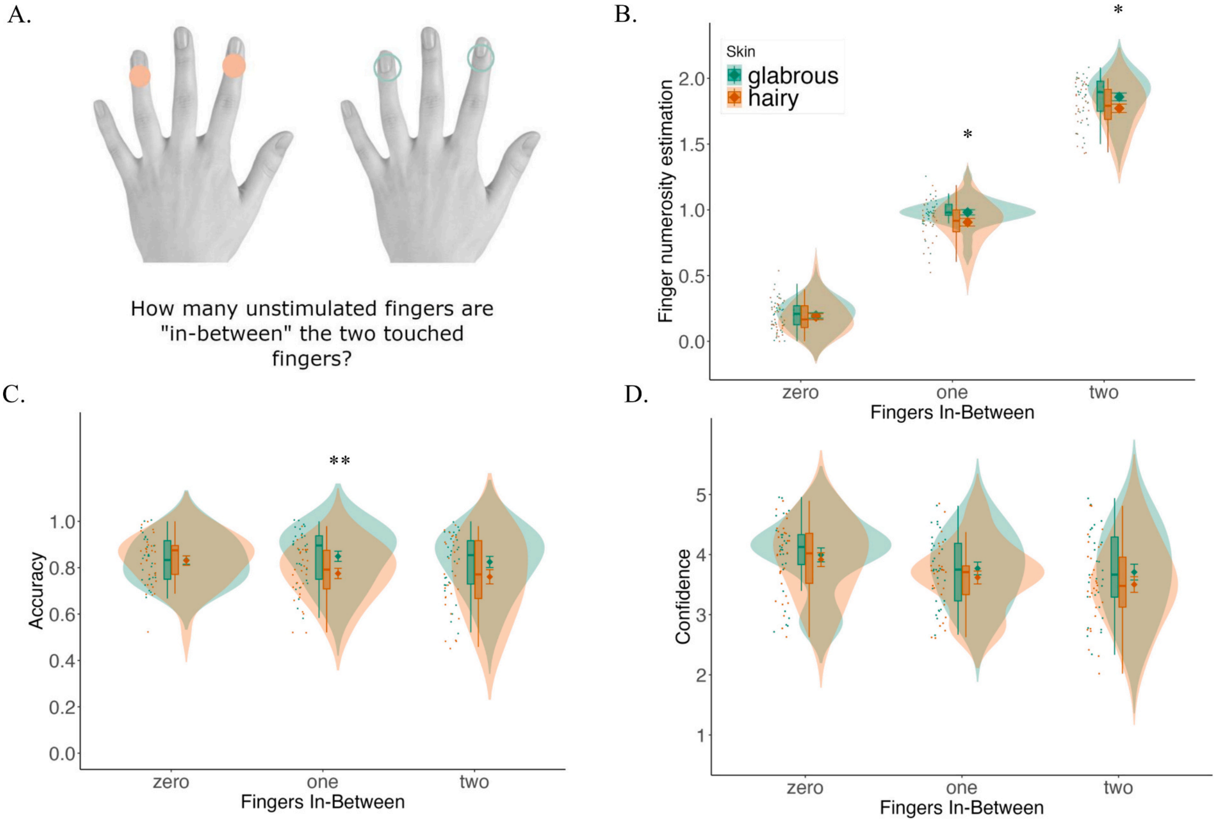

Fig. 2. The region of the skin stimulated (glabrous vs hairy) was varied across blocks while the posture of the hand was kept constant, with the palm facing down. The solid-filled circle indicates the hairy region of the skin in which tactile stimulation was delivered (orange = hairy). The empty circle indicates the glabrous region of the skin in which the tactile stimulation was delivered (green = glabrous) (**A**). Finger numerosity estimation based on the actual number of fingers in-between (i.e., zero, one, two) for the glabrous vs hairy skin condition (**B**). Accuracy for the different number of fingers in-between as a function of skin type (glabrous vs hairy) (**C**). Confidence response for the different number of fingers in-between as a function of the different regions of the skin stimulated (glabrous vs hairy) (**D**). Error bars indicate 95% Confidence Intervals of the within-participants variability (95%CI). * Denotes $P < .05$, ** Denotes $P < .01$ (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.1.2. *Design, procedure, and data analysis*

The design, procedure, and data analysis of Experiment 2 were identical to Experiment 1, with the only exception that the posture of the hand was kept constant with the palm facing down (as in Tamè et al., 2017). Fig. 2A illustrates the stimulation conditions for Experiment 2.

Participants' responses to finger numerosity estimation, accuracy, confidence rating, and RTs were calculated as in Experiment 1. We ran four separate ANOVAs with Skin and Fingers In-between as within participants factors, for each of the four measurements. As for Experiment 1, in addition to the main analysis, we computed confidence rating responses according to participants' accuracy to have a measure of their metacognitive efficiency (Fleming et al., 2012).

3.2. *Results*

Fig. 2B shows finger numerosity estimates for each condition. There was a main effect of Skin, $F(1, 28) = 8.03$, $p = .008$, $\eta_p^2 = 0.22$, showing a different finger estimation between the different skin regions, as for Experiment 1. Finger numerosity estimates were greater for glabrous skin (M ± SE = 1.01 ± 0.02) compared to hairy skin (M ± SE = 0.96 ± 0.02). A main effect of Fingers In-between was also found, $F(2, 56) = 1470.56$, $p < .001$, $\eta_p^2 = 0.98$, indicating that judged finger numerosity increased monotonically with actual numerosity of fingers in-between. More interestingly, we observed a significant interaction between Skin * Fingers In-between, $F(2, 56) = 3.75$, $p = .03$, $\eta_p^2 = 0.12$, indicating that finger numerosity estimation in the glabrous vs. hairy condition differed based on the number of fingers in-between. In particular, no significant difference between the glabrous (M ± SE = 0.20 ± 0.02) and hairy skin (M ± SE = 0.19 ± 0.02) was observed for zero fingers in-between, ($t(28) = 0.41$, $p = .685$, $d_z = 0.08$), whereas greater fingers estimations were present for glabrous compared to hairy skin when there was one finger in-between (glabrous M ± SE = 0.98 ± 0.02; hairy M ± SE = 0.91 ± 0.03; $t(28) = 2.49$, $p = .038$, $d_z = 0.46$) or two fingers in-between (glabrous M ± SE = 1.86 ± 0.03; hairy M ± SE = 1.77 ± 0.03; $t(28) = 3.06$, $p = .014$, $d_z = 0.57$). This pattern aligns with the results of Experiment 1, indicating that the effect observed in Experiment 1 cannot be attributable to postural factors.

As shown in Fig. 2C, analysis of accuracy revealed a main effect of Skin, $F(1,28) = 19.93$, $p < .001$, $\eta_p^2 = 0.42$, with overall higher accuracy for glabrous skin (M ± SE = 0.84 ± 0.01) compared to hairy skin (M ± SE = 0.79 ± 0.02). No main effect of Fingers In-between was observed, $F(2, 56) = 1.32$, $p = .274$, $\eta_p^2 = 0.05$, however the interaction between Skin * Fingers In-between was significant, $F(2, 56) = 3.42$, $p = .04$, $\eta_p^2 = 0.11$. Post-hoc analyses revealed no significant difference between glabrous skin (M ± SE = 0.83 ± 0.02) and hairy skin (M ± SE = 0.83 ± 0.02) for zero fingers in-between ($t(28) = 0.12$, $p = 1.00$, $d_z = -0.06$), and no significant difference between glabrous skin (M ± SE = 0.82 ± 0.02) and hairy skin (M ± SE = 0.76 ± 0.03) for two fingers in-between, $t(28) = 2.64$, $p = .172$, $d_z = 0.47$). However, accuracy was significantly higher for glabrous (M ± SE = 0.85 ± 0.02) than hairy skin (M ± SE = 0.78 ± 0.02) for one finger in-between ($t(28) = 4.34$, $p = .003$, $d_z = 0.85$).

Confidence responses for glabrous vs. hairy skin conditions are reported in Fig. 2D. There was a main effect of Skin $F(1,28) = 14.64$, $p < .001$, $\eta_p^2 = 0.34$, indicating that overall participants reported higher confidence ratings in finger numerosity estimation on glabrous skin (M ± SE = 3.82 ± 0.11) compared to hairy skin (M ± SE = 3.68 ± 0.11). A main effect of Fingers In-between was also observed, $F(2, 56) = 11.55$, $p < .001$, $\eta_p^2 = 0.29$, showing that confidence responses decreased progressively as the actual numerosity of fingers in-between increased. No significant interaction between Skin * Fingers In-between was found for confidence responses ($F(2,56) = 1.48$, $p = .236$, $\eta_p^2 = 0.05$.

RTs analyses were performed on a sub-sample of twenty-four participants (mean age ± SD = 21.3 ± 8.4 years; 20 females) due to the exclusion of six participants for a technical issue during the recording phase. Analyses on RTs revealed no main effect of Skin, $F(1,23) = 0.10$, $p = .759$, $\eta_p^2 = 0.004$. However, there was a main effect of Fingers In-between, $F(2,46) = 6.10$, $p = .004$, $\eta_p^2 = 0.21$, with RTs increasing monotonically with the number of fingers in-between, and a significant interaction between Skin * Fingers In-between, $F(2,46) = 4.65$, $p = .014$, $\eta_p^2 = 0.17$, though none of the post-hoc comparisons reached significance.

Analysis on confidence rating as a function of participants' response accuracy revealed a main effect of SKIN, $F(1,28) = 13.93$, $p < .001$, $\eta_p^2 = 0.33$, with overall higher confidence in the glabrous skin (M ± SE = 3.95 ± 0.11), compared to the hairy skin (M ± SE = 3.81 ± 0.10) for the correct trials. There was also a main effect of Fingers In-between, $F(2,56) = 13.61$, $p < .001$, $\eta_p^2 = 0.32$, suggesting that confidence responses in the correct trials decrease progressively with the increased number of fingers. Analysis on confidence rating as a function of participants' response accuracy for the incorrect trials revealed no main effect of SKIN, $F(1,22) = 0.13$, $p = .722$, $\eta_p^2 = 0.01$, nor main effect of Fingers In-between, $F(2,44) = 0.35$, $p = .704$, $\eta_p^2 = 0.02$. As for Experiment 1, these results suggest that participants showed preserved metacognitive efficiency.

3.3. *Discussion*

Consistent with Experiment 1, the region of stimulated skin modulated the BSR of the hand, with greater numerosity judgments on glabrous skin compared to hairy skin, and higher accuracy in the former. This effect was evident when pairs of non-adjacent fingers were stimulated, whereas no difference was present between the skin types when adjacent fingers were stimulated. Experiment 2 further ruled out the possibility that the observed effect in Experiment 1 was due to hand posture modulation, as the same results emerged when the hand posture was kept constant. The results of this second experiment corroborate the findings of Experiment 1 and support the notion that the BSR is not unique for a certain body part, as commonly thought, but instead varies as a function of the region of the skin stimulated. This suggests that the glabrous region of the skin may play a relevant role in accessing the hand's structural representation used to identify body parts.

4. General discussion

In the present work, we examined whether the skin type (glabrous vs hairy) can affect the access to the BSR of the hand and whether hand posture also contributes to this modulation. We adopted a well-established paradigm to assess finger agnosia (i.e., in-between task, Kinsbourne & Warrington, 1962), which requires knowledge about the spatial configuration between body parts. We hypothesized that if hand structural representation is influenced by the region of the skin stimulated, the judgments about finger numerosity should vary as a function of the skin site, as these two body parts have different tactile spatial acuity properties and differ in their intrinsic role in tactile discrimination and sensorimotor function (McGlone et al., 2014; Mountcastle, 2005). We observed greater finger numerosity estimation and accuracy in the glabrous skin conditions compared to the hairy ones in both experiments. It is important to note that this effect was significant only when non-adjacent fingers were stimulated, while no significant difference between skin regions in estimated fingers' numerosity was observed for adjacent fingers. Critically, this effect was present regardless of the hand position, ruling out any potential contribution of posture. The results of the present experiments also suggest that participants were more confident in their perceptual judgments on glabrous skin compared to hairy skin. They reported higher confidence when their estimations were objectively correct, and lower confidence when their estimations were incorrect. Therefore, these findings indicate that differences in numerosity estimation and accuracy across conditions were not driven by a reduced metacognitive efficiency, but rather, by the use of different body representations.

4.1. Adjacent finger identification is not affected by skin surface

The results of Experiment 1 and Experiment 2 for adjacent finger identification are in line with the original study of Tamè et al. (2017). According to their explanation, the identification of adjacent fingers relies on the primary somatosensory cortex, in which the anatomical coordinates are used to identify body parts, without requiring access to the higher-level structural representation. This initial somatotopic map of the body reflects the homuncular organization, in which the relative spatial configuration and distances between body parts are not yet defined. Indeed, the spatial relationships between adjacent body parts (e.g., neighbouring fingers) are assumed to remain constant, facilitating the maintenance of a stable representation of the body as we move through space or engage in actions (Tamè et al., 2017; Tamè et al., 2019). Several previous studies using different approaches, such as a tactile mislocalization task (Schweizer, Maier, Braun, & Birbaumer, 2000) and a tactile double simultaneous stimulation task (Tamè, Farnè, & Pavani, 2011), have shown convergent evidence to this theory, suggesting that the anatomical representation follows a homuncular organization, which is a signature of the primary somatosensory cortex involvement in the process. We assume that this initial representation can account for the results in our studies for the adjacent finger conditions. Within this initial stage of analysis, the different skin types do not affect the identification of the contiguous digits. Despite this, we cannot rule out the possibility that separated representations at the level of the primary somatosensory cortex are still present for the glabrous and hairy stimuli that our supra-threshold in-between task was not able to capture. Indeed, evidence from single-cell recording studies in monkeys demonstrated that the somatosensory cortex presents distinct and separated representations of hand and feet associated with the glabrous and hairy skin surfaces (Merzenich, Kaas, Sur, & Lin, 1978; Nelson, Sur, Felleman, & Kaas, 1980).

4.2. Non-adjacent finger identification is affected by the region of the skin surface

In contrast to the adjacent finger condition, tactile identification of non-adjacent fingers was affected by the specific regions of the skin stimulated, with a more accurate and precise estimation for the glabrous compared to hairy skin. This result suggests that the identification of non-adjacent body parts requires access to the full BSR, which extends beyond the homuncular representation in the somatosensory cortex to construct a volumetric representation of the body and of the single body parts (Longo et al., 2010; Manser-Smith, Tamè, & Longo, 2018). Within this high-level stage of analysis, we assume that multiple maps of the body are defined according to the different regions of the skin involved (glabrous vs. hairy). This distinction can account for the difference observed for non-adjacent finger identification in the task. When participants needed to identify digits within the map of the hand, performance in the glabrous skin was more accurate compared to the hairy skin. This suggests that the structural map associated with the former appears to be more accessible compared to the structural representation of the hairy skin. One possible factor that can explain this distinction relies on the functional role of the palmar surface of the hand. Specifically, the glabrous skin region is more likely to receive and be actively involved in tactile stimulation (Corniani & Saal, 2020), facilitating the execution of motor actions, such as grasping, haptic exploration, and object manipulation (Craig & Lyle, 2001; Johansson & Vallbo, 1980; Johansson & Westling, 1984; Mountcastle, 2005; Pons, Wall, Garraghty, Cusick, & Kaas, 1987). Moreover, considering the different tactile innervation densities across the skin type, we can assume that the type of sensory inputs derived from the glabrous skin determines a more reliable representation of the body in the higher stage of analysis, affecting the quality of the performance in the identification of digits in the task.

4.3. Postural modulation affects BSR only when is relevant to the task

The results of our experiments suggest that postural modulation does not influence the identification of fingers within the structural representation of the hand for both types of skin surfaces. This finding complements the results of a previous study using the same IBT paradigm (Tamè et al., 2017), by showing that the postural components affect BSR only when the posture of the body parts is relevant for the task. In this respect, it has been demonstrated that somatosensory gating (i.e., the partial suppression of somatosensory processing during movement execution, Jiang, Chapman, & Lamarre, 1991; Chapman, 1994) is reduced when sensory information is relevant to the correct execution of voluntary movements (e.g., identifying an object by its features, haptic exploration of a surface, Wasaka, Kida, & Kakigi, 2017; Voss, Ingram, Wolpert, & Haggard, 2008). In Tamè et al.' (2017) version of the IBT task, the finger's spatial position was relevant for the identification of the fingers stimulated and for the correct execution of the task; thus, this spatial information was used to update the internal model of the body in space. By contrast, in the present study, the postural modulation was not related to the single digits but rather to the entire hand (i.e., palm up vs. palm down). This type of postural modulation was not relevant for the identification of fingers in the structural model of the body; therefore, such additional information was not incorporated to update the BSR.

5. Conclusion

The results of the present study introduce the idea that different regions of the skin have distinct roles in the structural representation of the hand. The glabrous skin plays a crucial role in defining the body's structural map, supporting the recognition of the single digits. However, this effect is specific only to the identification of non-adjacent fingers, for which access to the BSR is required. Within this higher level of analysis, the spatial relation between body parts is defined and used to update the somatotopic map in the primary somatosensory cortex. Within this high-order stage of tactile processing, multiple and segregated maps of the hands are defined according to the region of the skin involved (glabrous vs. hairy). In contrast, the anatomical reference system encoded in the primary somatosensory cortex is sufficient for the identification of adjacent body parts and is not influenced by the skin region stimulated.

CRediT authorship contribution statement

Carmen Lenatti: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Desirée Lopis:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization. **Sébastien Alexandre Krienen:** Methodology, Investigation, Data curation. **Heather J. Ferguson:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization. **Luigi Tamè:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare no competing financial interests.

Acknowledgements

This research was supported by a grant from the South East Doctoral Training Arc (SEDarc, ES/Y001656/1) to CL.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cognition.2026.106559.

Data availability

The preprint has been submitted to OSF. Raw data are publicly available (https://osf.io/phc4v/).

References

Brainard, D. H. (1997). The psychophysics toolbox. *Spatial Vision, 10*(4), 433–436. https://doi.org/10.1163/156856897X00357

Buxbaum, L. J., & Coslett, H. B. (2001). Specialised structural descriptions for human body parts: Evidence from autotopagnosia. *Cognitive Neuropsychology, 18*(4), 289–306. https://doi.org/10.1080/02643290126172

Chapman, C. E. (1994). Active versus passive touch: Factors influencing the transmission of somatosensory signals to primary somatosensory cortex. *Canadian Journal of Physiology and Pharmacology, 72*(5), 558–570. https://doi.org/10.1139/y94-080

Corniani, G., & Saal, H. P. (2020). Tactile innervation densities across the whole body. *Journal of Neurophysiology, 124*(4), 1229–1240. https://doi.org/10.1152/jn.00313.2020

Corradi-Dell'Acqua, C., Tomasino, B., & Fink, G. R. (2009). What is the position of an arm relative to the body? Neural correlates of body schema and body structural description. *The Journal of Neuroscience, 29*(13), 4162–4171. https://doi.org/10.1523/JNEUROSCI.4861-08.2009

Craig, J. C., & Lyle, K. B. (2001). A comparison of tactile spatial sensitivity on the palm and fingerpad. *Perception & Psychophysics, 63*(2), 337–347. https://doi.org/10.3758/bf03194474

Dolgilevica, K., Longo, M. R., & Tamè, L. (2020). Structural representations of fingers rely on both anatomical and spatial reference frames. *Journal of Experimental Psychology: Human Perception and Performance, 46*(2), 125–130. https://doi.org/10.1037/xhp0000715

Fairhurst, M. T., Travers, E., Hayward, V., & Deroy, O. (2018). Confidence is higher in touch than in vision in cases of perceptual ambiguity. *Scientific Reports, 8*(1), 15604. https://doi.org/10.1038/s41598-018-34052-z

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.3758/BF03193146

Felician, O., Romaiguère, P., Anton, J. L., Nazarian, B., Roth, M., Poncet, M., & Roll, J. P. (2004). The role of human left superior parietal lobule in body part localization. *Annals of Neurology, 55*(5), 749–751. https://doi.org/10.1002/ana.20109

Fleming, S. M., Dolan, R. J., & Frith, C. D. (2012). Metacognition: Computation, biology and function. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 367*(1594), 1280–1286. https://doi.org/10.1098/rstb.2012.0021

Jiang, W., Chapman, C. E., & Lamarre, Y. (1991). Modulation of the cutaneous responsiveness of neurones in the primary somatosensory cortex during conditioned arm movements in the monkey. *Experimental Brain Research, 84*(2), 342–354. https://doi.org/10.1007/BF00231455

Johansson, R. S., & Vallbo, A. B. (1979). Tactile sensibility in the human hand: Relative and absolute densities of four types of mechanoreceptive units in glabrous skin. *The Journal of Physiology, 286*, 283–300. https://doi.org/10.1113/jphysiol.1979.sp012619

Johansson, R. S., & Vallbo, A. B. (1980). Spatial properties of the population of mechanoreceptive units in the glabrous skin of the human hand. *Brain Research, 184*(2), 353–366. https://doi.org/10.1016/0006-8993(80)90804-5

Johansson, R. S., & Westling, G. (1984). Roles of glabrous skin receptors and sensorimotor memory in automatic control of precision grip when lifting rougher or more slippery objects. *Experimental Brain Research, 56*(3), 550–564. https://doi.org/10.1007/BF00237997

Kandel, E. R., Schwartz, J. H., Jessell, T. M., Siegelbaum, S. A., & Hudspeth, A. J. (2013). *Principles of neural science.* New York: McGraw-Hill.

Kinsbourne & Warrington. (1962). A study of finger agnosia. *Brain, 85*, 47–66. https://doi.org/10.1093/brain/85.1.47

Löken, L. S., Wessberg, J., Morrison, I., McGlone, F., & Olausson, H. (2009). Coding of pleasant touch by unmyelinated afferents in humans. *Nature Neuroscience, 12*(5), 547–548. https://doi.org/10.1038/nn.2312

Longo, M. R. (2020). Tactile distance anisotropy on the palm: A meta-analysis. *Attention, Perception & Psychophysics, 82*(4), 2137–2146. https://doi.org/10.3758/s13414-019-01951-w

Longo, M. R., Azañón, E., & Haggard, P. (2010). More than skin deep: Body representation beyond primary somatosensory cortex. *Neuropsychologia, 48*(3), 655–668. https://doi.org/10.1016/j.neuropsychologia.2009.08.022

Longo, M. R., & Golubova, O. (2017). Mapping the internal geometry of tactile space. *Journal of Experimental Psychology. Human Perception and Performance, 43*(10), 1815–1827. https://doi.org/10.1037/xhp0000434

Longo, M. R., & Haggard, P. (2012). A 2.5-D representation of the human hand. *Journal of Experimental Psychology. Human Perception and Performance, 38*(1), 9–13. https://doi.org/10.1037/a0025428

Longo, M. R., & Sakka, C. (2025). Precise tactile localisation of hair stimulation in humans. *Cortex, 194*, 1–11. https://doi.org/10.1016/j.cortex.2025.11.002

Manser-Smith, K., Tamè, L., & Longo, M. R. (2018). Tactile confusions of the fingers and toes. *Journal of Experimental Psychology: Human Perception and Performance, 44*(11), 1727–1738. https://doi.org/10.1037/xhp0000566

Maurer, T. J., & Pierce, H. R. (1998). A comparison of likert scale and traditional measures of self-efficacy. *Journal of Applied Psychology, 83*(2), 324–329. https://doi.org/10.1037/0021-9010.83.2.324

McGlone, F., Wessberg, J., & Olausson, H. (2014). Discriminative and affective touch: Sensing and feeling. *Neuron, 82*(4), 737–755. https://doi.org/10.1016/j.neuron.2014.05.001

Merzenich, M. M., Kaas, J. H., Sur, M., & Lin, C. S. (1978). Double representation of the body surface within cytoarchitectonic areas 3b and 1 in "SI" in the owl monkey (*Aotus trivirgatus*). *The Journal of Comparative Neurology, 181*(1), 41–73. https://doi.org/10.1002/cne.902580208

Miller, M. R., Ralston, H. J., III, & Kasahara, M. (1958). The pattern of cutaneous innervation of the human hand. *The American Journal of Anatomy, 102*(2), 183–217. https://doi.org/10.1002/aja.1001020203

Mountcastle, V. B. (2005). *The sensory hand.* Cambridge: Harvard University Press. https://doi.org/10.4159/9780674275447

Nelson, R. J., Sur, M., Felleman, D. J., & Kaas, J. H. (1980). Representations of the body surface in postcentral parietal cortex of *Macaca fascicularis*. *The Journal of Comparative Neurology, 192*(4), 611–643. https://doi.org/10.1002/cne.901920402

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 9*(1), 97–113. https://doi.org/10.1016/0028-3932(71)90067-4

Palmer, E. C., David, A. S., & Fleming, S. M. (2014). Effects of age on metacognitive efficiency. *Consciousness and Cognition, 28*, 151–160. https://doi.org/10.1016/j.concog.2014.06.007

Pons, T. P., Wall, J. T., Garraghty, P. E., Cusick, C. G., & Kaas, J. H. (1987). Consistent features of the representation of the hand in area 3b of macaque monkeys. *Somatosensory Research, 4*, 309–331. https://doi.org/10.3109/07367228709144612

Raimo, S., Boccia, M., DI Vita, A., Iona, T., Cropano, M., Ammendolia, A., … Palermo, L. (2022). Body representation alterations in patients with unilateral brain damage. *Journal of the International Neuropsychological Society, 28*(2), 130–142. https://doi.org/10.1017/S1355617721000151

Rusconi, E., Tamè, L., Furlan, M., Haggard, P., Demarchi, G., Adriani, M., Ferrari, P., Braun, C., & Schwarzbach, J. (2014). Neural correlates of finger gnosis. *The Journal of Neuroscience, 34*(27), 9012–9023. https://doi.org/10.1523/JNEUROSCI.3119-13.2014

Sattin, D., Parma, C., Lunetta, C., Zulueta, A., Lanzone, J., Giani, L., … Parati, E. A. (2023). An overview of the body schema and body image: Theoretical models, methodological settings and pitfalls for rehabilitation of persons with neurological disorders. *Brain Sciences, 13*(10), 1410. https://doi.org/10.3390/brainsci13101410

Schweizer, M., Maier, C., Braun, N., & Birbaumer, R. (2000). Distribution of mislocalizations of tactile stimuli on the fingers of the human hand. *Somatosensory & Motor Research, 17*(4), 309–316. https://doi.org/10.1080/08990220020002006

Schwoebel, J., & Coslett, H. B. (2005). Evidence for multiple, distinct representations of the human body. *Journal of Cognitive Neuroscience, 17*(4), 543–553. https://doi.org/10.1162/0898929053467587

Serino, A., & Haggard, P. (2010). Touch and the body. *Neuroscience and Biobehavioral Reviews, 34*(2), 224–236. https://doi.org/10.1016/j.neubiorev.2009.04.004

Sirigu, A., Grafman, J., Bressler, K., & Sunderland, T. (1991). Multiple representations contribute to body knowledge processing: Evidence from a case of autotopagnosia. *Brain, 114*(1), 629–642. https://doi.org/10.1093/brain/114.1.629

Strzalkowski, N. D. J., Peters, R. M., Inglis, J. T., & Bent, L. R. (2018). Cutaneous afferent innervation of the human foot sole: What can we learn from single-unit recordings? *Journal of Neurophysiology, 120*(3), 1233–1246. https://doi.org/10.1152/jn.00848.2017

Tamè, L., Azañón, E., & Longo, M. R. (2019). A conceptual model of tactile processing across body features of size, shape, side, and spatial location. *Frontiers in Psychology, 10*, 291. https://doi.org/10.3389/fpsyg.2019.00291

Tamè, L., Dransfield, E., Quettier, T., & Longo, M. R. (2017). Finger posture modulates structural body representations. *Scientific Reports, 7*, Article 43019. https://doi.org/10.1038/srep43019

Tamè, L., Farnè, A., & Pavani, F. (2011). Spatial coding of touch at the fingers: Insights from double simultaneous stimulation within and between hands. *Neuroscience Letters, 487*(1), 78–82. https://doi.org/10.1016/j.neulet.2010.09.078

Tamè, L., & Longo, M. R. (2023). Emerging principles in functional representations of touch. *Nature Reviews Psychology, 2*(8), 459–471. https://doi.org/10.1038/s44159-023-00197-6

Vallbo, Å. B., Olausson, H., & Wessberg, J. (1999). Unmyelinated afferents constitute a second system coding tactile stimuli of the human hairy skin. *Journal of Neurophysiology, 81*(6), 2753–2763. https://doi.org/10.1152/jn.1999.81.6.2753

Voss, M., Ingram, J. N., Wolpert, D. M., & Haggard, P. (2008). Mere expectation to move causes attenuation of sensory signals. *PLoS One, 3*(8), Article e2866. https://doi.org/10.1371/journal.pone.0002866

Wasaka, T., Kida, T., & Kakigi, R. (2017). Facilitation of information processing in the primary somatosensory area in the ball rotation task. *Scientific Reports, 7*(1). https://doi.org/10.1038/s41598-017-15775-x. Article 15507.