

Aims

Observing another person being touched has been reported to automatically elicit processing in the observer's somatosensory cortex (SCx) (Keysers, Kaas and Gazzola, 2010; Gallese and Ebisch, 2013). Support for this comes from fMRI studies that have shown that secondary SCx is activated when observing touch (Keysers et al, 2004), several others have even implicated activation of primary SCx (Kuehn et al., 2013, 2014, 2018, Schaefer et al., 2009, 2013). Such an increased activity in SCx when observing touch has been suggested to allow for internally simulating others' tactile perceptions and has been argued to play a key role in social interactions (Keysers and Gazzola, 2009, 2014). Likewise, theories of embodied cognition have proposed that ongoing cognition is grounded in modality specific simulations (Damasio, 1989, Barsalou, 1999). Importantly, previous studies have usually compared a touch with a no-touch condition confirming engagement of SCx in touch observation. However, touch perception is highly sensitive to surface texture which is encoded by neuronal populations in primary SCx (Lieber and Bensmaia, 2019). Understanding the extent to which SCx simulation of other's touch experiences also involves touch quality, like texture, would show whether it fully simulates the observed touch experience or situates it within the specific relevant modality. This question has not previously been addressed, and furthermore, a more recent study has even questioned whether previously reported SCx engagement rather reflects posterior parietal cortex activity (Chan and Baker; 2015). Thus, this study's aim was to investigate SCx engagement in touch observation and whether such engagement reflects stages of early perceptual touch processing or post-perceptual processes related to memorizing and appraising the observed touch.

To investigate the study's aim participants completed two experimental tasks while concurrent EEG was recorded. In the first experiment, participants saw touch on a hand or touch was prevented by a transparent screen placed in front of the hand (i.e. no-touch). In the second experiment, participants saw two different touch textures, soft foam and hard rubber, touch a hand. In addition to these other-directed touch trials, participants were instructed that the observed touch was self-directed and to 'feel' the seen touch. This condition allowed us to directly contrast mere observation of touch effects with touch observation effects involving self-engagement with the visual stimuli. Each touch sequence was followed by a go or no-go stimulus (e.g. Galang et al., 2017) to reveal any vicarious touch effects on post-perceptual, cognitive and motor processes.

Method

Participants

Fifty paid volunteers participated in a single 3-hour session. Three participants were excluded based on below overall 85% accuracy level in the go/no-go tasks. Four participants were excluded during visual inspection of the neurophysiological data due to not showing discernible somatosensory components (P45, N80, P100, N140) elicited by the task-irrelevant tactile stimulation. The remaining 43 participants' (18 males), aged between 18 and 55 years ($M = 29.19$, $SD = 10.60$) data was used for analysis. All participants had normal or corrected vision, two were ambidextrous and four were left-handed. All participants gave informed consent before participation. The study was approved by City, University of London, Psychology Research Ethics Committee. The study is also detailed on the Open Science Framework (<https://doi.org/10.17605/OSF.IO/GP4AU>)

Instrument and Measures

A. Experiment 1: touch and no-touch

Stimuli of the first vicarious touch experiment consisted of sequences of images displayed to induced apparent motion perception while allowing to precisely mark the timing of an object touching the skin in the concurrent EEG recordings (see Figure 1). Those images were frames extracted from videos recorded specifically for this study. The videos showed a bare Caucasian, young adult, female, right hand centred in a black background, where an object (stick with rubber tip) would appear from the top left corner to touch the right index finger and go back. All stimuli were from an egocentric view, i.e., placed as if it were the viewer's own hand (Morrison et al., 2007). Before the start of the experiments, participants were shown the screen and the stick with the rubber and foam tips. They were prompted to feel the touch tips. The image sequence of experiment 1 always showed a stick with a rubber tip touching a hand (i.e. touch condition), and on half of the trials the hand was protected by a transparent screen (i.e. no-touch condition) with matched visual and kinetic properties of the touch condition but with the screen present (Fig. 1b). To probe somatosensory activity, we presented tactile probes (5 ms) through small solenoids attached to the top of the right and left index fingers. Tactile probes were randomly delivered on half of all trials and conditions, simultaneous with the onset of the touch image. Each touch sequence was followed by the presentation of a rectangle (6.5 x 5.5 cm) which was either orange or purple (go/no-go task). Participants were instructed to press with both thumbs the space bar if the colour indicated a go trial (80% of trials) and withhold the response to the colour that was associated with a no-go trial (20% of trials). The assignment of colour and response was counterbalanced across participants. At the end of the first experiment participants were asked to rate on a scale from 1 (= not at all) to 5 (= extremely) the similarity in physical appearance of their hand and the hand on the screen. Participants also completed the Interpersonal Reactivity Index (IRI) to collect self-report measures of empathy (Davis 1983) and the embodiment scale (ES) by Longo et al. (2008). For the latter the wording of questions was changed to fit the experiment, in particular references to 'rubber hand' were replaced with 'hand on screen'. These self-report measures were taken to explore the relationship between physical similarities between observed and own hand, embodiment and empathy with significant vicarious touch amplitude modulations of SCx activity.

B. Experiment 2: hard and soft touch during other- and self-directed touch

In the first half of the experiment the image sequence showed the same hand as in experiment 1 with the same stick moving to touch the hand and back (i.e. other-directed touch condition). On half of the trials the same rubber tip was shown as in experiment 1, on the other half of trials the stick was shown with a foam tip forming the hard and soft touch conditions, respectively. In this first part the hand shown was superimposed with a green circle indicating the touch location (Figure 1c). In the second half, only the green circle indicating the movement endpoint - and no hand - was shown (Figure 1d). Participants were instructed that the stick was moving to touch their hand and to feel the touch by the tip (i.e. self-directed touch condition). Like in experiment 1, tactile probes were randomly presented on half of all trials and conditions, and each touch sequence was followed by the same go/no-go task. At the end of this experiment participants were asked to rate on a scale from 1 (soft) to 8 (hard) the softness/hardness of the touch experience during the other-directed touch condition, and separately, the self-directed touch condition. Due to a technical issue the responses to all four ratings were only recorded for a subset of participants (n = 11).

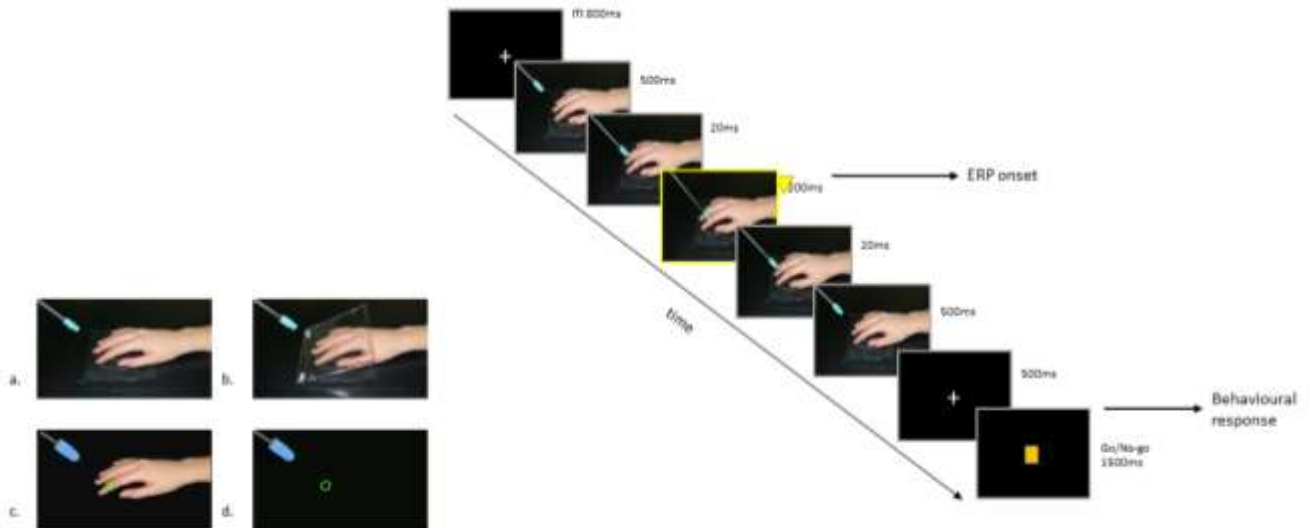


Figure 1. Touch sequences shown to participants. On the left the start image for four different experimental conditions are shown. Image a and b are the start images of the touch and the no-touch conditions of experiment 1. Image c is the start image of the soft, other-directed touch condition and image d shows the start image of the soft, self-directed touch condition shown in experiment 2. The timeline shows the sequence and duration of images presented. The yellow triangle and highlight around the image indicate the delivery of the tactile probe at the onset of the vicarious touch image which is also time zero for the ERP analyses. Following each touch sequence, a rectangle was shown and participants had to either respond by pressing the space bar on a keyboard or withhold the response which allowed calculation of response times from the onset of the rectangle and response accuracy.

C. Electrophysiological recordings

Participants were seated in an electromagnetically shielded, sound attenuated, dimly lit room, viewing a 60 Hz computer monitor at a distance of about 80 cm. EEG was recorded (BrainProducts Recorder software) from 64 Ag/AgCL active electrodes of which 60 were mounted equidistantly on an elastic cap (M10 montage; EasyCap GmbH, Herrsching, Germany) and standard EEG recording preparation procedures were used to ensure good signal quality (i.e. degreasing of skin and use of electrolyte). Electrodes were referenced to the right earlobe and re-referenced off-line to the average of the scalp mounted electrodes. The horizontal electrooculogram (HEOG) was recorded by placing two electrodes about 1 cm lateral to the external canthi of each eye, and the vertical EOG was recorded by placing one electrode about 2 cm under the left eye. Continuous EEG was recorded using a BrainAmp amplifier (BrainProducts; amplifier bandpass 0.01–100Hz) and a 500 Hz sampling rate. Off-line, EEG analysis was performed using Brain Vision Analyzer 2.2 software (Brain Products GmbH, Gilching, Germany). The data was digitally low-pass-filtered at 30 Hz (Butterworth zero phase filters). The EEG signal recorded during the touch observation experiments were epoched into segments lasting from 100 ms before to 500 ms after the onset of the image showing a stick touching the skin, the barrier or green circle which was also the onset of a tactile probe delivered to the index fingers on half of the trials. Segments were then baseline corrected to the first 100 ms. Eye movements were corrected (Gratton, Coles and Donchin, 1983) and trials with other artifacts (voltage exceeding ± 100 mV relative to baseline at any electrode except those on the outer rim of the cap) were excluded from the analysis.

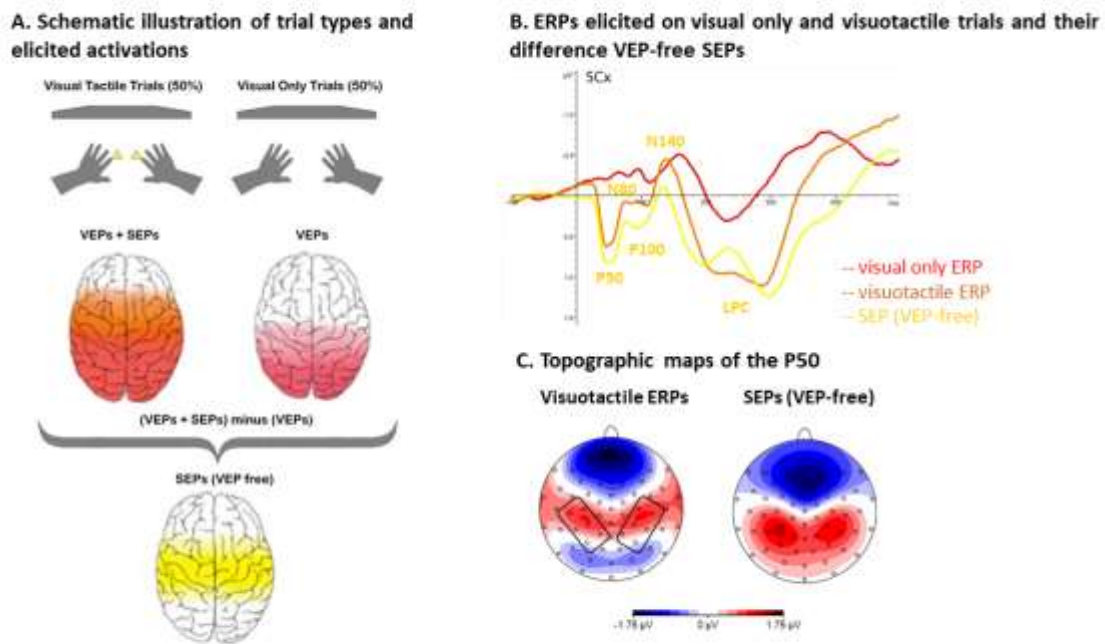


Figure 2. ERP analysis approach. Panel A illustrates the subtraction method used whereby ERPs elicited on visual only trials are subtracted from trials on which somatosensory activity is probed (visuotactile) to generate VEP-free SEPs. Panel B shows ERPs elicited on visual only (red) and visuotactile (brown) trials, and their difference resulting in VEP-free SEP (yellow). Timepoint zero is the onset of the tactile probe and equivalent in time on visual only trials. The waveforms are grand averaged ERPs pooled over electrodes over right and left somatosensory cortex and across all visual only and visuotactile trials across both experiments and all touch observation conditions. Panel C shows topographic maps for the P50 of visuotactile ERPs and VEP-free SEPs including two boxes encompassing the electrodes included in the analyses.

Procedure

Participants completed first 10 practise trials to familiarize them with the experimental task and tactile probes. Then they proceeded with experiment 1 which was followed by the similarity rating task followed by the ES and IRI questionnaires. They then completed experiment 2. Each of the trials of the experiments started with the presentation of a fixation cross for 800 ms. This was followed by an image of a hand in the centre of the screen and a stick in the left top corner (or only a stick and a circle for the self-directed touch condition) for 510 ms followed for 30ms by an image with the stick halfway towards the index finger and then 200 ms of an image with the stick touching the index finger or the circle or the no-touch. On half of the trials the start of the touch image was accompanied by a task-irrelevant tactile probe randomly delivered by small solenoids to top of the right and left index finger for 5 ms. The touch image was followed by the image with the stick in the intermediate position for 20 ms and the image with the stick in the starting position for 500 ms. This image sequence (see Figure 1) was followed a fixation cross for 500 ms and then either an orange or purple rectangle for up to 1500 ms if no response occurred. Participants responded with their thumbs by pressing the space bar on go trials (80%) while keeping the hands static on top of the keyboard. In total, there were 960 trials: 384 go trials and 96 no-go trials in each of the experiments.

Throughout the experiments white noise (~65dB) was presented from a speaker in front of participants to mask any noise from the tactile stimulators, and participants were monitored via a camera positioned above the monitor.

Results and Discussion

We used ERP methodology and an innovative experimental and analysis approach to address to what extent observers feel touch that they see. Somatosensory ERPs allowed us to tease apart vicarious touch effects on early perceptual (i.e. P50, N80, P100, N140 components) from post-perceptual processes (i.e. LPC and behavioural responses). Moreover, we investigated whether the engagement of early sensory SCx activations during vicarious touch reflects different touch qualities as expected with a full simulation of others' touch experiences. In two separate experiments participants observed touch sequences with the first contrasting touch with no-touch and the second contrasting two touch textures (i.e. soft foam and hard rubber) while touch was either other- or self-directed. Despite a large participant sample (n=43), neither the touch/no-touch or soft/hard touch contrast showed significant modulations of early and mid-latency components (as supported by further explorative Bayesian analyses). However, we found effects on behavioural responses in the subsequent go/no-go task, in line with the notion of post-perceptual effects of vicarious touch on higher order somatosensory and motor cortex. In contrast, comparing amplitudes elicited on self- compared to other-directed touch trials showed strong modulation of early and mid-latency components, in line with the activations of primary and secondary SCx. Importantly, like in the other-directed touch condition also in the self-directed touch condition no difference between touch textures on early and mid-latency SCx components was present. Taken together, our findings show that when vicarious touch observation is purely observational (i.e. other-directed touch) no early sensory SCx modulations are found, showing that SCx activation is not automatic in vicarious touch. Only when participants were instructed that the observed touch is self-directed and to feel the touch early SCx modulations were observed. However, also in this condition no modulations of early SCx activity by touch texture was present, indicating that the early sensory aspect of the observed touch experience is not be fully simulated.

Previous ERP studies of vicarious touch (Adler and Gillmeister, 2019; Adler et al., 2016, Bufalari et al., 2007, Rigato et al., 2019) have delivered tactile stimuli concurrent to visually observed touch or no-touch. Such a paradigm is akin to crossmodal congruency paradigms which have shown that tactile discrimination and somatosensory ERPs are affected by task irrelevant visuospatial distractors that mismatch the tactile location (e.g. Igarashi, Kitagawa and Ichihara, 2004; Pavani, Spence and Driver, 2000; Sambo and Forster, 2008). Moreover, none of the prior vicarious touch ERP studies have accounted for any visual evoked activity by the observed movement which may have distorted the somatosensory probed activity. Our experimental paradigm diminished spatial congruency effects and allowed us to isolate SCx activity from visual carry-over effects (see Galvez-Pol, et al., 2020, 2021). In contrast to previous studies (Adler & Gillmeister 2019; Adler et al., 2016; Bufalari et al., 2007; Rigato et al., 2019), we did not find any significant vicarious touch effects (touch versus no-touch) in experiment 1, neither on visuotactile trials or once any visual carry-over effects were subtracted out. We also did not find any touch texture effects in experiment 2. However, we did find amplitude differences between self- and other-directed touch on early and mid-latency components in experiment 2. These effects were stronger over the left hemisphere on visuotactile trials for the P50 and N140 components. However, this lateralization may reflect mainly visual carry over effects as it was diminished in the analysis of VEP-free SEPs.

We only found evidence for behavioural modulations of responses to a go/no-go stimulus presented after each vicarious touch sequences suggesting differential representations of touch and no-touch, and touch textures in higher cognitive and motor processes.

Our finding of an absence of any touch observation modulations on early SCx components is in line with recent fMRI studies suggesting posterior parietal rather than SCx is involved in touch observation (Chan and Baker, 2015; Sharma, Fiave and Nelissen, 2018). In these studies participants were instructed to perform a task at fixation while task-irrelevant touch observation videos were presented. One explanation for the absence of SCx touch observation effects in these studies may be that participants' attention was diverted away from observing the touch. In our study, participants were instructed to merely observe touch (Experiment 1 and first half of Experiment 2) without engaging simultaneously in another task. Yet, we also did not find early SCx modulations. Importantly, only when participants were instructed that the touch is self-directed and to feel the touch, rather than merely observe, strong modulations of early and mid-latency SCx components (i.e. P50, N80, P100, N140) were present. Likewise, previous fMRI studies that have reported SCx involvement have instructed participants to attend to the vicarious touch to either judge its frequency (Ebisch et al., 2008; Schaefer et al., 2009, 2012, 2013) or quality (Blakemore et al., 2005; Kuehn et al., 2014 a,b, 2018). Together these findings suggest that SCx engagement in vicarious touch is driven by attention to the observed tactile sensations as required by task instructions. Similarly, theories of grounded and embodied cognition (Damasio, 1989, Barsalou, 1999) have suggested that SCx engagement reflects modality specific simulations as part of ongoing cognitive processes related to the instructed task. In contrast, theories of embodied simulation (Gallese and Ebisch, 2013) have argued for an automatic engagement of SCx when observing touch. Our findings together with previous research show that SCx is purposely engaged, only when attention is directed to the somatosensory modality suggesting that top-down, cognitive control rather than automatic, stimulus-driven processes drive modulations of SCx activity in vicarious touch.

Previous studies of vicarious touch have usually compared a movement sequence where a hand or body part was touched by an object to a sequence where no touch occurred. Differences in SCx activations in these observation conditions have been interpreted as sensory simulation including the 'extraction and mapping of the sensory qualities' (Bufalari et al., 2009; Keysers et al., 2010). However, to understand whether such engagement of SCx in touch observation fully simulates the observed touch experience it is necessary to show that touch qualities, like texture, are reproduced as part of such a simulation. Touch is optimally designed to distinguish between textures with several different types of receptors in the skin contributing to texture perception and this information is processed in primary and secondary SCx (Ballesteros et al., 2009; Chung et al., 2013; Genna et al., 2018; Lieber and Bensmaia, 2019; Lederman und Klatzky, 2009). We found no reliable effects of tactile texture on early SCx components, even under conditions when participants were instructed to feel the touch texture. This latter point is supported by the fact that there was no interaction between the factors touch direction and touch texture in experiment 2. While we did not find evidence for texture effects during vicarious touch, studies investigating tactile imagery have shown differential activation patterns in primary and secondary SCx for different tactile texture (Nierhaus et al., 2023; see also Yakovlev et al., 2023). However, in tactile imagery studies participants are repeatedly presented with the tactile stimuli they subsequently imagine. In our study participants experienced all the experimental objects once before the start of the experiments and were encouraged to touch these. Data of a subset of participants showed that they rated foam tip touch as softer than rubber tip touch. Likewise, participants showed texture dependent modulations of behavioural responses to the go/no-go stimulus following the vicarious touch sequences. Such post-perceptual texture

effects suggest that seeing tactile texture activates concepts stored in higher order cortex about these textures (see also Smith et al., 2023). Importantly, our data does not support a full perceptual simulation of the texture experience itself in sensory cortex as proposed by embodied simulation theories. Our findings are in line with theories of embodied and grounded cognition that have suggested that while modality specific information is situated in modality specific representations (Barsalou, 2010), such activations of neural representations may not be complete (Barsalou et al., 2003, 2005), and thus, not fully match the neural representation of the sensory experience.

Conclusions and Recommendations

Our findings suggest that higher cognitive processes related to the current cognitive task engage primary and secondary SCx in vicarious touch. Such purposeful engagement of SCx may aid our understanding of other’s experiences. Yet, it comprises a partial simulation of other’s perceptual, tactile experiences in SCx, as it lacks the perceptual quality of the observed touch which is nevertheless manifested in post-perceptual processing. Thus, SCx activations during vicarious touch reflect purposely situated activity rather than automatic sensory simulations.

Our findings

Table highlighting the differences between expected and achieved output indicators

Expected and achieved output indicators (number of actions)

| Output indicators | Expected (according to application) | Achieved |
|---------------------------------------|--|-----------------|
| PhD thesis | | |
| Master’s thesis | | |
| Organization of seminar or conference | | |
| Book | | |
| Book chapter | | |
| Conference presentation | | |
| Conference paper | 1 | 3 |

| | | |
|-------------------------------------|---|---|
| Journal article | 1 | 1 |
| Other (specify) Data publication | | 1 |

Notes:

List of publications

Forster, B., & Abad-Hernando, S. (2024). In your skin? Somatosensory cortex is purposely recruited to situate but not simulate vicarious touch. *NeuroImage*, 289, 120561.

<https://doi.org/10.1016/j.neuroimage.2024.120561>

Forster, Bettina; Abad Hernando, Sonia (2024). In your skin: psychophysiology of touch observation - EEG data set. City, University of London. Dataset. <https://doi.org/10.25383/city.24961599.v1>