***Title page**

# A Touching Sight:

# EEG/ERP Correlates for the Vicarious Processing of Affectionate Touch

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## Abstract

Observers can simulate aspects of other people's tactile experiences. We asked whether they do so when faced with full-body social interactions, whether emerging representations go beyond basic sensorimotor mirroring, and whether they depend on processing goals and inclinations. In an EEG/ERP study, we presented line-drawn, dyadic interactions with and without affectionate touch. In an explicit and an implicit task, participants categorized images into touch vs no-touch and same vs opposite sex interactions, respectively. Modulations of central Rolandic rhythms implied that affectionate touch displays engaged sensorimotor mechanisms. Additionally, the late positive potential (LPP) being larger for images with as compared to without touch pointed to an involvement of higher order socio-affective mechanisms. Task and sex modulated touch perception. Sensorimotor responding, indexed by Rolandic rhythms, was fairly independent of the task but appeared less effortful in women than in men. Touch induced socio-affective responding, indexed by the LPP, declined from explicit to implicit processing in women and disappeared in men. In sum, this study provides first evidence that vicarious touch from full-body social interactions entails shared sensorimotor as well as socio-affective experiences. Yet, mental representations of touch at a socio-affective level are more likely when touch is goal relevant and observers are female. Together, these results outline the conditions under which touch in visual media may be usefully employed to socially engage observers.

Key words: mirror neurons, vicarious tactile processing, emotion, somatosensory perception, social touch, sex differences

## Introduction

Casual affectionate touch, such as a tap on the shoulder, creates a pleasurable sensation that is mood enhancing and that biases social interactions towards positive outcomes (for a review see Schirmer, Wijaya, & Liu, 2016). Interestingly, those who merely observe touch may also be affected. Research points to brain mechanisms that “mirror” other people's sensorimotor processes and that simulate associated physical experiences (e.g., Morrison, Lloyd, Pellegrino, & Roberts, 2004; Singer et al., 2004). Importantly, such mirroring has also been demonstrated for affectionate touch (Ebisch et al., 2008; e.g., Morrison, Björnsdotter, & Olausson, 2011; Schaefer, Heinze, & Rotte, 2012) suggesting that observers may share in the associated sensory pleasure. However, under which conditions vicarious tactile experiences emerge and whether they go beyond basic sensorimotor representations is currently unknown. Using the electroencephalogram (EEG), the current study tackled these issues.

The short touches individuals exchange in every-day social interactions shape feelings and behavior. In the context of field studies a so-called “Midas effect” has been identified (Crusco & Wetzel, 1984) whereby individuals report more positive affect and evaluate their interaction partners more favourably when they had been affectionately touched as compared to when they had not been touched (Fisher, Rytting, & Heslin, 1976). Moreover, the recipients of affectionate touch act more kindly in that they are more likely to be honest (Kleinke, 1977), to comply with a request (Guéguen & Fischer-Lokou, 2002), or to leave large tips (Crusco & Wetzel, 1984; for reviews see Gallace & Spence, 2010; Schirmer et al., 2016; Pawling, Trotter, McGlone, & Walker, 2017).

To understand why a simple somatosensory event can have such wide-reaching consequences it is useful to consider the somatosensory system and its projections to the brain. Like other mechanical stimulation of the skin, affectionate touch activates a variety of somatosensory receptors (for a review see McGlone, Wessberg, & Olausson, 2014). Different receptor types are differently tuned to physical attributes like temperature, velocity, or pressure. Thus, their collective input to the brain informs about stimulus properties. As an example take Aβ fibres, which are a receptor class that is present across the body's surface and that responds to light pressure changes. Microneurography recordings have shown that different Aβ fibres (e.g., Meissner's corpuscles, Raffini endings) are characterized by different receptive field sizes and response functions (e.g., slow vs fast adapting) but that as a class their activity increases linearly with the speed of pressure changes across the skin (Hagbarth & Vallbo, 1967; A. B. Vallbo & Johansson, 1984). Moreover, the upstream projection of Aβ input passes through relay stations in spinal cord and subcortical regions before reaching primary somatosensory cortex behind the central fissure (Abraira & Ginty, 2013; Mountcastle, 1957; Wilson & Kitchener, 1996).

Recent work has demonstrated that affectionate touch, apart from activating Aβ fibres, stimulates a special class of C fibres that seems specifically tuned to gentle physical contact between conspecifics. These fibres are referred to as C-tactile (CT) afferents and innervate the hairy skin of the body – that is all sites excepting a few glabrous regions such as the palms and soles. Their firing rates show tuning to the types of soft stroking that is typical of caress. Specifically, they are highest for velocities of 1 to 10 cm/s and drop off at slower and faster velocities. In line with a specific role for socio-affective communication, CT activity correlates linearly with psychophysical ratings of tactile pleasure (Löken, Wessberg, Morrison, McGlone, & Olausson, 2009; Olausson et al., 2002; Sehlstedt et al., 2016; A. B. Vallbo, Olausson, & Wessberg, 1999; for a review McGlone et al., 2014). CT input to the brain bypasses the cortical areas targeted by the Aβ pathway and instead projects to socio-affective circuits where it is integrated with other aspects of human mental functioning (for a review Schirmer & Adolphs, 2017). For example, CT stimulation has been shown to target insula (McGlone et al., 2012; Olausson et al., 2002; Voos, Pelphrey, & Kaiser, 2013; for a meta-analysis on pleasant touch more generally Morrison, 2016) and orbitofrontal cortex (Case et al., 2016; McGlone et al., 2012; Voos et al., 2013), which are relevant for emotion, as well as the superior temporal cortex (Ackerley et al., 2012; Bennett, Bolling, Anderson, Pelphrey, & Kaiser, 2014; Kaiser et al., 2015), which serves as a major hub in the processing of social stimuli like faces and voices (Schirmer, 2018).

Inspired by the discovery of “mirror neurons” (Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Rizzolatti & Fabbridestro, 2008), researchers asked whether individuals perceive touch vicariously, simply by observing another person's tactile experiences (for a review see Keysers, Kaas, & Gazzola, 2010). Initial support for this came from studies using functional magnetic resonance imaging (fMRI). Original work found that seeing someone else in pain activates the anterior cingulate (Morrison et al., 2004; Singer et al., 2004) – a major site for pain perception. Subsequently, studies focused on benign touch and found that viewing gentle pressure to the hand (Schaefer et al., 2012) or stroking of the arm (McCabe, Rolls, Bilderbeck, & McGlone, 2008) among other forms of stimulation (Ebisch et al., 2008; Keysers et al., 2004; Lamm, Silani, & Singer, 2015; Masson, Van De Plas, Daniels, & Op de Beeck, 2018; McCabe et al., 2008; Peled-Avron, Levy-Gigi, Richter-Levin, Korem, & Shamay-Tsoory, 2016; Schaefer et al., 2012) activates primary somatosensory cortex. Moreover, viewing stroking at a speed optimized for CT signalling recruits the posterior insula, which supports the somatosensory representation of such signals (Morrison et al., 2011).

Evidence for vicarious touch experiences raises a number of interesting questions. One such question is whether these experiences are limited to the somatosensory system or entail higher-order socio-affective responding. To date, only a few studies have approached this questions and their results are inconclusive. One example is work by Lamm and colleagues (2015) comparing the feeling and seeing of non-social pleasant and unpleasant touch. Overlap for pleasant touch in the orbito-frontal cortex and overlap for unpleasant touch in the anterior insula revealed that both felt and observed sensations recruit affective processing. However, whether such recruitment shows for social touch remains unclear. Another example is a study by Masson and colleagues (2018) reporting that compared to object-based touch, interpersonal touch elicits increased activity in a range of regions including those associated with pain (e.g., insula) and theory of mind (e.g., temporo-parietal junction). However, because they compared the physical contact between two people with that between two objects, Masson and colleagues isolated the presence of humans rather than the presence of touch.

Another question resulting from previous work concerns the potential role of observer intention in modulating sensitivity to vicarious touch. For practical purposes, one may differentiate unintentional or implicit from intentional or explicit stimulus processing. Both types of processing have specific temporal trajectories and functional consequences. On the one hand, implicit processing is often faster and may powerfully interfere with explicit processing (Frith & Frith, 2008; Escoffier, Herrmann, & Schirmer, 2015). For example, an implicitly processed vocal tone will slow-down verbal emotion judgements if the vocal tone is emotionally incongruous as compared to congruous (e.g., a negative as compared to a positive voice saying “success”) (Min & Schirmer, 2011). On the other hand, explicit processing may be necessary for information representation in certain processing contexts and for certain types of information. For example, verbal emotions (excepting strong expressions like taboo words) may be readily represented when task-relevant but have little impact on listeners when task-irrelevant (Schirmer & Kotz, 2003). In the past, research on vicarious touch relied on images that zoomed in on touch and asked participants to view these images passively or to rate touch pleasantness. As such touch was always a fairly obvious, explicit manipulation that was in the focus of the participant’s attention. Hence, whether vicarious experiences persist when touch is an unattended detail in a complex visual scene is still unknown.

Another outstanding question is whether and how individuals differ in the susceptibility to vicarious touch experiences. In this regard, past research suggests that the observer's sex is potentially relevant. Much evidence has accumulated that women are more responsive than men to the socio-affective signals of other people (Bostanov & Kotchoubey, 2004; Löckenhoff et al., 2014; van den Brink et al., 2010). During explicit tasks, women are often more accurate than men in naming or categorizing emotional expressions (Hall, 1978; Hoffmann, Kessler, Eppel, Rukavina, & Traue, 2010; Sen, Isaacowitz, & Schirmer, 2017). However, this female advantage is relatively small and typically confined to subtle or otherwise difficult stimuli. During implicit tasks, sex differences are more robust. A greater female sensitivity to emotional expressions has been established with a range of paradigms (Alice M Proverbio, Adorni, Zani, & Trestianu, 2009; Alice M Proverbio, Zani, & Adorni, 2008; Alice M Proverbio & Galli, 2016) including behavioral interference tasks (Schirmer, Chen, Ching, Tan, & Hong, 2013; Schirmer, Seow, & Penney, 2013; Schirmer, Zysset, Kotz, & Yves von Cramon, 2004) as well as passive change detection assessed with online measures of brain activity (Fan, Hsu, & Cheng, 2013; Schirmer, Striano, & Friederici, 2005). Additionally and of particular relevance here, eye tracking of passive gazing at social interactions indicates that women are more likely than men to fixate on instances of touch suggesting that such touch is more readily noticed and perhaps more salient to them (Schirmer, Ng, & Ebstein, 2018).

Past efforts at examining vicarious affectionate touch are dominated by fMRI. Although fMRI offers good spatial resolution, its poor temporal resolution precludes insights into the time-course of somatosensory and socio-affective processes. Thus, insights from fMRI are usefully complemented by the EEG. Specifically, analysis of the EEG time-frequency domain can shed light on emerging somoatosensory processes. Of particular interest here are Rolandic rhythms, which are characterized by a mid-central scalp-topography with peaks in the alpha (8–15 Hz) and beta (16–30 Hz) bands. These rhythms are both up- (Brinkman, Stolk, Dijkerman, de Lange, & Toni, 2014; Nierhaus et al., 2015) and down-regulated (Ritter, Moosmann, & Villringer, 2009; Singh et al., 2014; Whitmarsh, Nieuwenhuis, Barendregt, & Jensen, 2011; Yang, Decety, Lee, Chen, & Cheng, 2009) by actual, imagined, and observed tactile as well as motor activity. As such they serve as a window onto the sensorimotor experience of vicarious touch. Further insights are offered by the event-related potential (ERP). Visual as well as auditory emotional stimuli enhance a late positive potential (LPP) when compared with neutral stimuli (Hajcak, Dunning, & Foti, 2009; Olofsson, Nordin, Sequeira, & Polich, 2008; Schupp et al., 2000). Additionally, there is evidence that affectionate touch elicits an LPP (Ackerley, Eriksson, & Wessberg, 2013) and that, relative to no-touch, it increases the LPP difference between emotional and neutral stimuli (Schirmer & Gunter, 2017b; Schirmer et al., 2011). Moreover, close-ups of human bodily contact evoke a greater LPP than close-ups of the same body-parts without contact (Peled- Avron & Shamay- Tsoory, 2017). Thus, the LPP promises insights into the socio-affective processing of observed touch.

In sum, there is evidence that observers mirror the sensorimotor aspects of affectionate touch. However, whether mirroring emerges from full-body social interactions, whether it entails socio-affective responding, and how it depends on the participant's task or sex are still open questions. We tackled these questions in an EEG study using a previously validated set of line-drawings showing social interactions with and without affectionate touch (Schirmer et al., 2015). The drawings were presented in two separate tasks. In an explicit task, participants indicated whether or not the two persons in each drawing touched, while in an implicit task they indicated whether the two persons were of the same (i.e., two women or two men) or opposite sex (i.e., woman and man). Previous research informed the following key predictions. First, we anticipated that touch displays would modulate both sensorimotor and socio-affective processes. Building on existing EEG evidence, the former were assessed via Rolandic rhythms over a mid-central region, whereas the latter were assessed via the LPP over a centro-parietal region. Second, we speculated that touch effects would be modulated by attention. Given the evidence reviewed above and the fact that touch in the images was fairly subtle, we expected touch effects to be smaller during implicit processing, when attention is directed away from touch, as compared with explicit processing, when touch is task-relevant. Of interest was whether the implicit task simply reduces or completely abolishes vicarious touch experiences. Finally, we predicted sex differences in the sensitivity to vicarious touch. Specifically, we hypothesized that, compared with men, women would show stronger correlates of sensorimotor and socio-affective touch mirroring when touch was task-irrelevant and that a similar sex difference may be absent or small when touch was task-relevant.

## Methods

### *Participants*

Forty-nine participants were invited to this study. One participant was excluded because his performance in the behavioural tasks fell below 3 standard deviations of the group mean. Twenty-four of the remaining participants were female with a mean age of 21.5 years (SD 1.23). The remaining participants were male with a mean age of 23.12 years (SD 1.95). All had normal or corrected to normal vision. Two women and three men were ambidextrous, one man was left handed and the remaining participants were right handed as determined with the Edinburgh handedness scale.

This study was approved by the Institutional Review Board of the National University of Singapore. Participants gave informed consent before starting the experiment.

### *Stimuli*

As stimulus material we used the Social-Touch Picture Set (Schirmer et al., 2015), which comprises 240 unique line drawings of dyadic interactions. Half the drawings entail touch between interaction partners, that can be deemed appropriate for platonic friends and acquaintances  (i.e., 10 different types of touch including shoulder hug, one hand on shoulder while target is standing, one hand on shoulder while target is sitting, two hands on shoulder while target is sitting, handshake, hug, one hand on upper arm while target is standing, upper arm touches upper arm while sitting, one hand on forearm while target is sitting, touching knees while sitting) and excluded romantic and sexually intimate forms of contact (e.g., kissing). The remaining drawings are no-touch controls. Specifically, each no-touch control matches one touch drawing in that it presents the same individuals with identical or very similar postures. However, the touch is replaced by a gesture or the positioning of a hand on a nearby object. Half of the touch drawings and their no-touch controls illustrate interactions between same-sex individuals (50% women, 50% men), whereas the remaining drawings illustrate opposite-sex interactions (25% woman touching man, 25% man touching woman, 50% woman and man touching each other). In the present study, the line drawings were presented in white on grey background (Figure 1).

### ***Procedure***

Participants were tested individually. After giving informed consent, they were prepared for the EEG recording. To this end, a 64-channel cap was placed on their scalp and individual electrodes were attached above and below the left eye, on the left and right outer canthi, and on the nose tip. After the EEG set-up, participants were seated in front of a computer monitor at a distance of 0.8 m.

The experiment comprised two tasks presented in two separate blocks. Task instructions were shown on-screen immediately at the beginning of each block. One task examined explicit touch processing and required participants to indicate whether they saw individuals touching. The other task examined implicit touch processing and required participant to indicate whether image characters had the same or opposite sex. A trial started with a 300 ms fixation cross that was followed by a 1 s presentation of a line drawing. Participants responded not during the image presentation but afterwards following a response prompt that served to avoid motor artifacts confounding EEG/ERP periods of interest (Luck, 2005). During the explicit task, images were replaced by the words “Touch” and “No Touch” shown on the left and right (or right and left) of the screen centre and prompting participants to push the left or right (or right or left) button indicating whether there was touch or no-touch, respectively. During the implicit task, the words “Same Sex” and “Opposite Sex” served as response prompts. After participants submitted their response by pressing one of two buttons on a response box, the screen turned completely grey for an inter-trial interval (ITI) of 0.5, 1, or 1.5 seconds. Each ITI occurred for one third of the trials in random order.

Images were shown once in each block and twice across blocks. Thus, each block comprised 240 trials of which half were touch and the other half were no-touch trials. Images in each block were presented in pseudo-random order with the constraint that the two images from a given touch/no-touch pair occurred in separate block halves. After participants completed the first block, they could rest until they felt comfortable to commence the second block. Block order (i.e., the order of tasks) and button assignment to left and right hands were counterbalanced within the female and the male group.

### *Electrophysiological Recording and Analysis*

The EEG was recorded at 256 Hz with a Biosemi ActiveTwo system, which uses a common mode sense active electrode for initial referencing. Only an antialiasing filter was applied during data acquisition (i.e., sinc filter with a half-power cutoff at 1/5 the sampling rate). Recordings were done using a 64-channel cap with electrodes placed according to the 10-20 system. A set of four external electrodes attached above and below the left eye and at the outer canti of each eye was used to monitor eye movements.

The EEG was analyzed using MATLAB and EEGLAB (Delorme & Makeig, 2004). First, the recordings were re-referenced to the average of all electrodes and subjected to low- and high-pass filtering with a half-power cut-off at 30 and 0.1 Hz, respectively. The transition band was 7.5 Hz for the low pass filter (-6 dB/octave; 221 pts) and 0.1 Hz for the high pass filter (-6 dB/octave; 16501 pts). The continuous data were epoched using a 1000 ms pre-stimulus window and a 1000 ms post-stimulus window. The resulting epochs were visually scanned for non-typical artefacts caused by drifts or muscle movements. Epochs containing such artefacts were removed. After the application of a 1 Hz high-pass filter, the data were subjected to an independent component analysis (Onton, Westerfield, Townsend, & Makeig, 2006) and the component structure resulting from this analysis was applied to the original epoched data-set with the 0.1 to 30 Hz filter setting (Winkler, Debener, Müller, & Tangermann, 2015). Components reflecting typical artefacts (i.e., horizontal and vertical eye movements and eye blinks) were removed and the data back-projected from component space into EEG channel space and re-epoched. The resulting epochs were again scanned visually for residual artefacts and affected epochs as well as epochs followed by inaccurate behavioral responses dropped from further analysis. A minimum of 60 trials and an average of 106 (SD 10) trials per condition entered statistical analysis of both the ERPs and the time-frequency domain. Thus inaccurate responses and artefacts accounted for an average of 12% lost trials.

For the ERP analysis, epochs were baseline-corrected using a 200 ms pre-stimulus window and a 1000 ms post-stimulus window and averaged for each condition and participant. The LPP was quantified as the mean voltage in a window ranging from 400 to 1000 ms following stimulus onset as measured over C1, C2, Cz, Cp1, Cp2, Cpz, P1, P2, and Pz. This window and electrode group was selected based on previous work showing that the LPP emerges after 400 ms with maximum amplitudes over centro-parietal electrodes (Hajcak et al., 2009; Olofsson et al., 2008; Schupp et al., 2000).

For the time-frequency analysis, epochs were subjected to a wavelet transform covering frequencies between 5 and 28 Hz in steps of 1 Hz using the default EEGLAB wavelet. Wavelet length was set to 600 ms enabling the exploration of data between -663 to 667 ms around stimulus onset. Wavelet transforms entered a power analysis, power was averaged across trials for a given condition and participant, and baseline-corrected by dividing each data-point by the mean power obtained for a pre-stimulus baseline window ranging from -300 to -100 ms. For conversion to dB, matrices were transformed by taking the common logarithm (base 10) times 10.

For statistical analysis, power was first averaged across C3, C1, Cz, C2, and C4 in line with previous work (e.g., Forschack, Nierhaus, Müller, & Villringer, 2017; Nierhaus et al., 2015; Peled-Avron et al., 2016). Then, we examined condition contrasts of interest using an approach well established in the context of fMRI research. Specifically, for a given contrast, the data of its two conditions or difference scores (for more detail please see further below) were subjected to t-tests at each point in the time-frequency space and p-values were converted into Z-scores. The resulting time-frequency Z-score matrix was smoothed using a Gaussian filter (FWHM = 4 data points) and Random Field Theory (Adler & Hasofer, 1976; Worsley, Evans, Marrett, & Neelin, 1992), as described elsewhere (https://matthew-brett.github.io/teaching/random_fields.html), was applied to identify a Z-threshold that corrected for multiple comparisons. To further reduce the chance of spurious results, clusters with a size smaller than 1% of the time-frequency space were discarded.

The electrophysiological data were subjected to a series of hypothesis-driven contrasts. Specifically, four main contrasts were performed looking at general effects averaged across men and women and these contrasts were then further explored as a function of sex. They included 1) the task main effect (explicit vs implicit), 2) the touch main effect in the explicit task (touch vs no-touch), 3) the touch main effect in the implicit task (touch vs no-touch), and 4) the task by touch interaction explored using condition difference scores (explicit task [touch minus no-touch] vs implicit task [touch minus no-touch]). When exploring effects in men and women separately, we focused on regions in the time-frequency space for which the interaction between sex and either task or touch (e.g., women [touch minus no-touch] vs men [touch minus no-touch]) was significant thus limiting the chance of false-positive results.

## Results

*Time-Frequency Data.* As expected, inspection of the time-frequency plots revealed a power decrease in both the high alpha and the low beta band that varied as a function of task, touch, and sex (Figure 2; for plots illustrating effects from other scalp regions please refer to the Supplementary Materials). The statistical results for analyses done across male and female participants are presented in Table 1. Exploration of the overall task effect revealed that explicit touch processing suppressed power more than implicit touch processing in two time frequency clusters. An early cluster in the alpha band extended from 2 to 80 ms (C1.1 in Table 1 and Figure 2A) and a later cluster (C1.2 in Table 1 and Figure 2A) in the beta band extended from 139 to 667 ms. Additionally, between 401 and 515 ms, explicit relative to implicit touch processing increased power in the theta band typically quantified between 4 to 7 Hz (C1.3 in Table 1 and Figure 2A).

Power differences between touch and no-touch images were explored for each task separately. In the explicit task, touch images were associated with greater power than no-touch images in four clusters that spanned from 166 to 656 ms involving alpha and beta band (C2.1 – C2.4 in Table 1 and Figure 2A). Although similar effects were observed in the implicit task (C3.1 – C3.3 in Table 1 and Figure 2A), a task comparison showed that here the touch minus no-touch difference was smaller between 436 and 507 ms in the upper beta (C4.1 in Table 1 and Figure 2A) and larger between 534 and 667 ms in the upper alpha and lower beta band (C4.2 in Table 1 and Figure 2A).

Statistical comparisons between male and female participants are presented in Table 2. Sex differences in the task effect were pursued by comparing explicit minus implicit task difference scores between groups. This revealed that the power decrease for explicit vs implicit touch processing was smaller early in the alpha band (C5.1 in Table 2 and Figure 2B) and larger later in the beta band (C5.2 in Table 2 and Figure 2B) for men as compared with women. In other words, men's task difference score was less negative/more positive for the early alpha but more negative/less positive for the late beta effect when compared with women's task difference score.

Sex differences in the touch effect were pursued by contrasting female and male touch minus no-touch difference scores separately for the explicit and the implicit task. For the explicit task, this produced four significant clusters. The first cluster was located in the lower beta band (C6.1 in Table 2 and Figure 2B) and here the power increase for touch as compared with no-touch images was smaller in women than in men. In fact, women showed a significant drop in power for touch as compared with no-touch images as evident from a follow-up analysis (20-23 Hz, 25-88 ms, cluster size = 1%, mean Z = 4.277). The second, smaller cluster was also in the lower beta band (C6.2 in Table 2 and Figure 2B) and here the power increase for touch as compared with no-touch images was greater in women than in men. In fact, a follow-up test for each group indicated that this power increase was significant in women only (15-17 Hz, 174-401 ms, cluster size = 3%, mean Z = 5.068, p < .0001). The last two clusters spanned the upper beta band (C6.3 – C6.4 in Table 2 and Figure 2B) and, again, the touch minus no-touch difference was smaller in women than in men.

Analysis of the touch effect in the implicit task produced again four clusters. Here, all clusters indexed a greater power increase for touch relative to no-touch images in women as compared with men (C7.1 – C7.4 in Table 2 and Figure 2B). The clusters spanned across the beta band and epoch duration. Moreover, follow-up analysis by sex revealed one very extensive cluster in women (14-28 Hz, 18-667 ms, cluster size = 31%, mean Z = 7.348, p < .0001) but only four small clusters in men ([1] 24-26 Hz, 10-53 ms, cluster size = 1%, mean Z = 4.614, p < .0001; [2] 19-25 Hz, 131-252 ms, cluster size = 4%, mean Z = 5.677, p < .0001; [3] 20-21 Hz, 562-640 ms, cluster size = 1%, mean Z = 4.369, p < .0001; [4] 7-13 Hz, 577-667 ms, cluster size = 3%, mean Z = 5.417, p < .0001).

*Late Positive Potential.* The LPP is illustrated in Figure 3. Its mean amplitude was explored using the same series of hypothesis-driven contrasts as employed for the time-frequency analysis. We opted for this approach for two reasons. First, we wished to ensure that analysis steps and statistical models compared for the two electrophysiological measures. Specifically, analysing the LPP with a traditional omnibus ANOVA with Task, Touch, and Sex as factors would have addressed main effects as well as two and three-way interactions. However, that was not feasible for the time-frequency data as we could compare only two conditions or difference scores at a time. Second, the traditional omnibus ANOVA has been criticized for its increased probability of false-positive results due to multiple testing and planned t-tests have been suggested as a better alternative (Cramer et al., 2016). In our case, an omnibus ANOVA would have involved seven tests with only three being immediately relevant (Task, Task*Touch, Task*Touch*Sex).

As before, we first explored effects that showed irrespective of observer sex. Unlike for the time-frequency results, the effect of task was non-significant (p=.242). However, touch modulated the LPP amplitude during both explicit (t(47)=6.87, p < .0001) and implicit touch processing (t(47)=2.03, p = .04). In either case, the LPP was larger for touch as compared with no-touch images and this difference was more pronounced when touch was processed explicitly as compared with implicitly (t(47)=4.26, p < .0001).

Exploring the LPP by sex revealed a non-significant effect of task in both men and women (ps > .195). Moreover, in the explicit task, both men (t(23)=4.38, p = .0002) and women (t(23)=5.27, p < .0001) showed a larger LPP for touch as compared with no-touch images and this touch effect did not differ between groups (p = .489). However, in the implicit task, the LPP touch effect was significant in women (t(23)=2.93, p = .007) but not in men (p = .962). Accordingly, a t-test on the touch minus no-touch difference indicated that this difference was significantly larger in women than in men (t(45.74)=2.178, p = .035).

*Behavior.* In the present experimental tasks responses were prompted after the target as to avoid motor confounds in the EEG/ERP (Luck, 2005). Therefore, the value of the behavioral data in shedding light on vicarious touch perception is compromised. Nevertheless, accuracy was examined as to ascertain that individuals followed task instructions and to explore potential effects of task and touch.

The mean probability of accurate responding was high (0.938) and ranged from 0.845 to 0.987 across participants (Figure 4). A t-test comparing touch with dyad recognition indicated that the former was performed more accurately than the latter (t(47)=2.601, p=.0124). Looking at each task separately revealed that accuracy was lower for touch vs no-touch images in the explicit (t(47)=-11.28, p<.0001) as well as in the implicit task (t(47)=-6.38, p<.0001). However, touch vs no-touch differences were greater for the former as compared with the latter condition (t(47)=8.771, p<.0001).

Again, women and men were explored separately. The task effect was marginally significant in both groups (women, t(23)=1.88, p=.073; men, t(23)=1.74, p=.096) and the group difference was non-significant (p=.791). Likewise, both groups showed poorer performance for touch as compared with no-touch images in the explicit task (women, t(23)=-3.8, p<.001; men, t(23)=-3.81, p<.001) and the associated picture difference score was comparable between groups (p=.338). However, in the implicit task, the touch effect was significant in women (t(23)=-3.73, p=.001) and non-significant in men (p=.191) and this group difference approached significance (t(45.61)=-1.85, p=.07).

In addition to these planned analyses, we conducted an exploratory analysis in an effort to better characterize the touch effect in the explicit task. Specifically, we asked whether any of the touch images was more difficult to identify than the others. To this end, we averaged the participants' accuracy data for each image as a function of Touch Type (i.e., the 10 touch types mentioned above including hug, handshake etc.), Touch Version (there were three different versions taken from different angles with different people), and Dyad Sex (female/female, male/male, female/male, male/female). The mean accuracy computed across trials in the explicit/touch condition was 91.9% and the standard deviation was 13.6%. None of the images had an accuracy lower than three standard deviations away from the mean. However, accuracy varied substantially across images and visual inspection of this variation suggested that touch was more readily noticed when it involved the hands (e.g., handshake, hug) rather than other body-parts (e.g., two knees, two upper arms).

## Discussion

The present EEG/ERP data offer first evidence that the observation of touch in full-body social interactions has both sensorimotor and socio-affective effects and that these effects differ between an explicit and an implicit task and between the sexes. The following sections will describe this data in more detail with specific emphasis on the three questions formulated in the introduction.

### *Does affectionate touch in social scenes provoke sensorimotor and socio-affective mirroring?*

Although the present study does not allow clear dissociation of perceptual from higher-order mental processing, a case can be made that central Rolandic rhythms are more closely tied to sensorimotor representations (Ritter et al., 2009), whereas the LPP and theta activity (Güntekin & Başar, 2014) are more closely tied to socio-affective representations evoked by interactional stimuli (Hajcak et al., 2009; Olofsson et al., 2008; Schupp et al., 2000).

*Sensorimotor mirroring.* With this dissociation in mind, the present time-frequency results agree with previous studies that implicate Rolandic rhythms in the vicarious perception of discriminative (Forschack et al., 2017) and affectionate touch (Peled-Avron et al., 2016). In line with the notion that Rolandic rhythms are “idle” in that they desynchronize as a result of personal and vicarious sensorimotor processes (Ritter et al., 2009), alpha and beta power were reduced during explicit as compared with implicit touch processing. Whereas the alpha effect started early, at the beginning of the stimulus epoch, the beta effect began later at about 140 ms after stimulus onset. Thus, looking for touch in social interactions potentially activated sensorimotor areas and desynchronized their resting rhythms. Moreover, desychronization of the alpha and to a lesser degree of the beta band may have been relevant in preparing the participants' processing focus and in facilitating the detection of affectionate touch.

Notably, however, the actual representation of affectionate touch was not accompanied by a further reduction in Rolandic rhythms. To the contrary, touch compared with no-touch images were associated with higher alpha and beta-power. This finding is at odds with the notion that Rolandic rhythms are strictly “idle”. It also contradicts previous studies on vicarious pain (Whitmarsh et al., 2011; Yang et al., 2009) and vicarious affectionate touch (Peled-Avron et al., 2016). Specifically, a study on vicarious affectionate touch found a suppression of alpha power between 8 and 10 Hz when comparing the observation of touch between people with the observation of non-social touch between objects or social interactions without touch (Peled-Avron et al., 2016).

One explanation for these discrepant results concerns the nature of the touch displays. Earlier work reporting a suppression of Rolandic rhythms by painful and benign discriminative as well as affectionate displays used displays that strictly focused on touch and that removed touch from its wider context (Peled-Avron et al., 2016; Whitmarsh et al., 2011; Yang et al., 2009). By contrast, the line drawings used here presented full-body interactions in which touch was just one detail that, as evident from the behavioral data, was not always recognized.

Research suggests that the ease with which a stimulus can be perceived or processed differentially modulates associated time-frequency effects. For example, increased rather than decreased Rolandic rhythms emerged for motor imagery as the complexity of the imagined movement increased (Brinkman et al., 2014). Furthermore, unlike consciously perceived touch, touch presented below the threshold for awareness enhanced Rolandic rhythms (Nierhaus et al., 2015). Thus, a greater processing difficulty and/or a reduced touch awareness resulting from the present image set may explain why activity was greater for touch than no-touch images in the Rolandic frequency bands (Brinkman et al., 2014; Forschack et al., 2017; Nierhaus et al., 2015).

*Socio-affective mirroring.* Apart from elucidating sensorimotor processing, the present EEG results demonstrate socio-affective processing of affectionate touch displays. Specifically, a time-frequency effect emerged for the theta band, which has been repeatedly linked to emotion (Güntekin & Başar, 2014; Paré & Collins, 2000). Among other approaches, theta oscillations have been recorded from the rodent amygdala during fear (Paré & Collins, 2000) and from the human scalp in response to a range of affective stimuli such as faces, pictures, and music (Güntekin & Başar, 2014; Sammler, Grigutsch, Fritz, & Koelsch, 2007; Symons, El-Deredy, Schwartze, & Kotz, 2016). Moreover, both positive and negative stimuli were shown to produce greater theta power when compared with neutral ones (for a review see Güntekin & Başar, 2014). The current findings extend this work by showing that, compared with focusing on person identity, evaluating touch in social scenes increases theta power. Moreover, they suggest that observers share in some aspects of the socio-affective experience elicited by affectionate touch.

The present ERP results corroborate this possibility. As predicted, they entailed a modulation of the LPP, which, like theta power, is typically larger for emotional as compared with neutral events. Original work has implicated the LPP in affective picture processing (Olofsson et al., 2008). Subsequently, LPP modulations have been identified for voices (Pell et al., 2015; Schirmer & Gunter, 2017a), faces (Hartigan & Richards, 2017) and, most importantly, for touch. Specifically, gentle pressure to the forearm, which may also activate CT afferents (A. B. Vallbo et al., 1999), enhances the LPP difference between emotional and neutral pictures (Schirmer et al., 2011).

Additionally, brush stroking with CT velocity elicits an LPP with a very long latency as would be expected by the slow transmission of CT input (Ackerley et al., 2013). Last, observing touching body parts boosts the LPP relative to a no-touch control (Peled- Avron & Shamay- Tsoory, 2017).The present results extend these findings to the vicarious perception of affectionate touch in social scenes.

Although LPP amplitude reliably reflects affective value, it is also modulated by several other factors including stimulus frequency (Squires, Donchin, Herning, & McCarthy, 1977), difficulty (Goldstein, Spencer, & Donchin, 2002), and task-relevance (Squires et al., 1977). Therefore, it is thought to denote a more general increase in motivated attention (Schupp et al., 2000) that arises from bottom-up as well as top-down processes associated with affective stimulus (e.g., intrinsic pleasure) and task-characteristics (e.g., incentive; Hajcak et al., 2009), respectively. Adopting this general framework in the context of the present findings, we conclude that affectionate touch displays are processed at a socio-affective level thereby attracting attentional resources.

### ***Do explicit and implicit vicarious touch processing differ?***

Apart from exploring the neural signatures of vicarious affectionate touch, this study addressed the role of processing intention by comparing vicarious touch effects elicited during an explicit and an implicit task.

Interestingly, processing intention played a fairly minor role in the sensorimotor responses reflected by Rolandic rhythms. Here, a task effect emerged for only two small clusters, one in the upper beta band between 440 and 510 ms (cluster size = 1%) and one in the upper alpha and lower beta band starting at 530 ms and lasting until the end of the analysis epoch (cluster size = 3%). Whereas the earlier cluster reflected a larger touch effect during explicit as compared with implicit processing, the opposite was true for the latter cluster. Possibly, these task differences were due to small functional differences in the way vicarious touch modulates sensorimotor activity when touch is processed automatically as compared to when it is processed intentionally.

Importantly, socio-affective responses measured with the LPP were characterized by a robust interaction between touch and task. As predicted, the touch effect during explicit processing was significantly larger than the touch effect during implicit processing indicating that different processing intentions translate into different post-perceptual responses to affectionate touch displays. When touch is task-relevant, its affective value more readily enhances motivated attention than when touch is task-irrelevant (Hajcak et al., 2009; Schupp et al., 2000). Possibly, a tactile processing intention facilitates the translation of early sensorimotor and basic affective responses into a higher-order emotional meaning that is held in awareness (Barrett, 2017). Moreover, such facilitation may be especially pronounced in full-body social scenes where touch is but one of many interactional signals. Nevertheless, when processing intention directs attention away from touch, its affective value may still be accessed (Frith & Frith, 2008). Additionally, it may potentially interfere with and bias task performance as demonstrated by the present touch effect on the behavioral accuracy of dyad sex categorization.

Taken together, it seems that both sensorimotor and socio-affective representations of third-party tactile interactions persist during implicit processing conditions. However, whereas a lack of intention has minimal effects on the former, it substantially subdues the latter. We, therefore, speculate that sensorimotor mirroring occurs more automatically than socio-affective mirroring possibly because socio-affective mirroring is more complex and more strongly engages top-down processes that integrate a tactile incidence with contextual information (e.g., who is touching, where are they touching). Nevertheless, the fact that socio-affective mirroring persists suggests that observers can share in the high-order consequences of affectionate touch even when their attention is engaged elsewhere.

### *Are there sex differences in the processing of affectionate touch displays?*

As expected, this study revealed sex differences both in the Rolandic rhythms indicative of sensorimotor processing and in the LPP indicative of socio-affective processing.

Looking at Rolandic rhythms, the task main effect captured in the overall difference between explicit and implicit processing irrespective of image type was larger in women than in men. Specifically, the early suppression of alpha power at image onset was more pronounced (sex effect cluster size = 8%) indicating that women more readily prepared for the sensorimotor demands associated with recognizing touch. Moreover, a smaller later effect in the beta band (sex effect cluster size = 2%) suggested that men emphasized task-directed processing with delay.

Additionally, the sexes diverged in the Rolandic touch effects. Again, these effects are interpreted based on the idea that Rolandic rhythms are not strictly “idle” but show more differentiated activity for mental representations of bodily states when these states are difficult to represent (Brinkman et al., 2014) and when they are processed without awareness (Forschack et al., 2017; Nierhaus et al., 2015). Accordingly, explicit task results indicate that the sexes differ both quantitatively and qualitatively in their early response to vicarious touch. Three clusters in which the touch effect was smaller or more negative in women than in men (summed sex effect cluster size = 12%) suggest that explicit touch perception was less effortful for the former relative to the latter group. This agrees with the fact that women more readily prepared for explicit touch perception as indexed by the down-regulation of alpha rhythms as a function of task. Additionally, it agrees with earlier reports that, compared with men, women show stronger Rolandic suppression to vicarious pain (Yang et al., 2009) and more readily gaze at touch in social interactions (Schirmer et al., 2018). A smaller cluster in the lower beta band (cluster size = 2%) points to qualitative differences in that effortful processing focused on a lower frequency range in women than men. In the implicit task, the touch minus no-touch difference was more positive in women than in men (summed sex effect cluster size 18%) and this sex effect spanned the entire beta band and epoch duration pointing to a consistent modulation of sensorimotor representations. Moreover, it suggests that women are more sensitive than men to affectionate touch displays in situations where processing intentions are directed away from nonverbal behavior.

LPP and behavioral data support this possibility. While touch enhanced LPP amplitude irrespective of sex during explicit processing, a similar effect showed in women but not men during implicit processing. Additionally, women but not men showed a behavioral performance decrement during touch as compared with no-touch trials when touch was task irrelevant. Although a statistical comparison of this group effect was only marginally significant, the general pattern agrees with that observed for the LPP. Moreover, together both measures indicate that women were more likely than men to implicitly distinguish between touch and no-touch images and to emphasise higher-order representations of touch.

The present study explored sex differences in the touch effect separately for explicit and implicit processing. As such no task comparisons can be made and no conclusions drawn as to whether women are more likely to differ from men under implicit as compared with explicit task conditions. Nevertheless, the current results corroborate and extend sex differences reported in the literature. As was shown for other nonverbal signals (Ahrens, Awwad Shiekh Hasan, Giordano, & Belin, 2014; Alice M Proverbio & Galli, 2016; Alice M Proverbio et al., 2008; Schirmer & Gunter, 2017a), women were more sensitive than men to displays of interpersonal touch. Specifically, they seemed to activate associated sensorimotor representations more readily both when touch was task-relevant and when it was task-irrelevant. Additionally, when touch was task-irrelevant, they showed more pronounced post-perceptual responding in that the affective meaning associated with touch seemed to facilitate touch-motivated attention and increased the likelihood that information about touch biased ongoing task-directed behavior.

At present, we can only speculate as to what caused this female benefit. Apparent is that touch is but one of several modalities showing sex effects. Moreover, the fact that these effects are typically most robust under passive, implicit or otherwise challenging processing conditions (e.g., Sen et al., 2017), suggests that they concern the automaticity of social processing and perhaps the supremacy of bottom-up mechanisms in the social brain. There exist different theories as to why women may be socially more perceptive than men. One set of theories hold that evolutionary pressures associated with child care and the division of labor have created sex-specific social needs and strategies (Alice Mado Proverbio, 2017; Taylor, 2006; Trofimova, 2015). For example, Taylor argues that women depend more than men on social support for stress regulation and calls this a tend-and-befriend response (Taylor, 2006). By contrast, she argues that men, when faced with stress, more readily engage in a fight-or-flight response. Possibly then, sex differences in the need for affiliation have shaped sex-specific mechanisms that help boost the creation and maintenance of female bonds.

### *Open Questions and Directions for Future Research*

Although this study provides novel insights, it also raises questions for future research. One such question concerns the different types of touch and potential differences in the way they are processed. For example, the casual affectionate touch that was studied here may involve a range of body parts, may be initiated by only one or both parties of an interaction, and may occur within different settings as relates to biological identity markers (e.g., sex), cultural background (e.g., ethnicity), and the place of the interaction (e.g., public vs private). One may venture that some if not all of these aspects shape the extent and quality of vicarious touch experiences. More typical touches may be observed with greater comfort (Schirmer et al., 2015). Additionally, intentional touches may be perceived more readily than unintentional ones. In line with this, an exploratory analysis of the present behavioral results revealed much variance in touch recognition accuracy from the Social Touch Picture Set and hinted at processing benefits for touch performed with the hand, which may be perceived as more intentional than touch involving other body parts (e.g., upper arm, knee). It would be interesting to pursue these variables to and examine their role for the sensorimotor and socio-affective mirroring observed here.

A second question concerns the ecological validity of the present results. For convenience and ease of standardization, we have used only static cartoon snapshots of social interactions. However, in real life, interactions have much more detail and evolve in time. Moreover, their temporal trajectory is relevant when it comes to first-hand tactile sensations. As mentioned in the introduction, mid-range velocities excite a special class of skin receptors called CT afferents that are thought to play a central role in coding the socio-affective value of touch (Löken et al., 2009; McGlone et al., 2014). It has been shown that their central projection target, the posterior insula, is more active in individuals observing stroking at CT optimal as compared with sub-optimal speed (Morrison et al., 2011). Thus, one may venture that a similar effect holds for upstream socio-affective processes as those examined here. To address this possibility it would be useful, albeit challenging, to move from the presentation of static to dynamic social interactions in future studies.

## *Conclusions*

Past research found that observers mirror the sensorimotor aspects of affectionate touch (e.g., Morrison et al., 2011; Peled-Avron et al., 2016). The present study extends this literature in several ways. First, it provides original evidence that mirroring occurs for affectionate touch embedded in full-body social scenes and entails shared sensorimotor as well as socio-affective experiences. Second, this study offers a first demonstration for a role of processing goals. It shows that a task-based focus on touch has little impact on sensorimotor mechanisms but significantly facilitates socio-affective mechanisms. Thus, early perceptual representations seem to emerge more automatically than later conceptual ones, which may be more relevant for the conscious pleasure derived from touch and its impact on social processing. Additionally, an individual's inclinations are relevant. Compared with men, women showed enhanced sensorimotor and socio-affective responding. Moreover, socio-affective responding in particular was more resistant to attention being directed away from touch in women than in men. Taken together, the current findings underscore the intricacy of vicarious affectionate touch and point to affectionate touch displays as a means for soliciting observer involvement in social interactions.

## Acknowledgements

The authors express their gratitude to Nicolas Escoffier and Trevor Penney for comments on an earlier version of this manuscript. This research was funded by Singapore MOE grant FY2015-FRC3-007 awarded to Annett Schirmer.

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Figure legends:

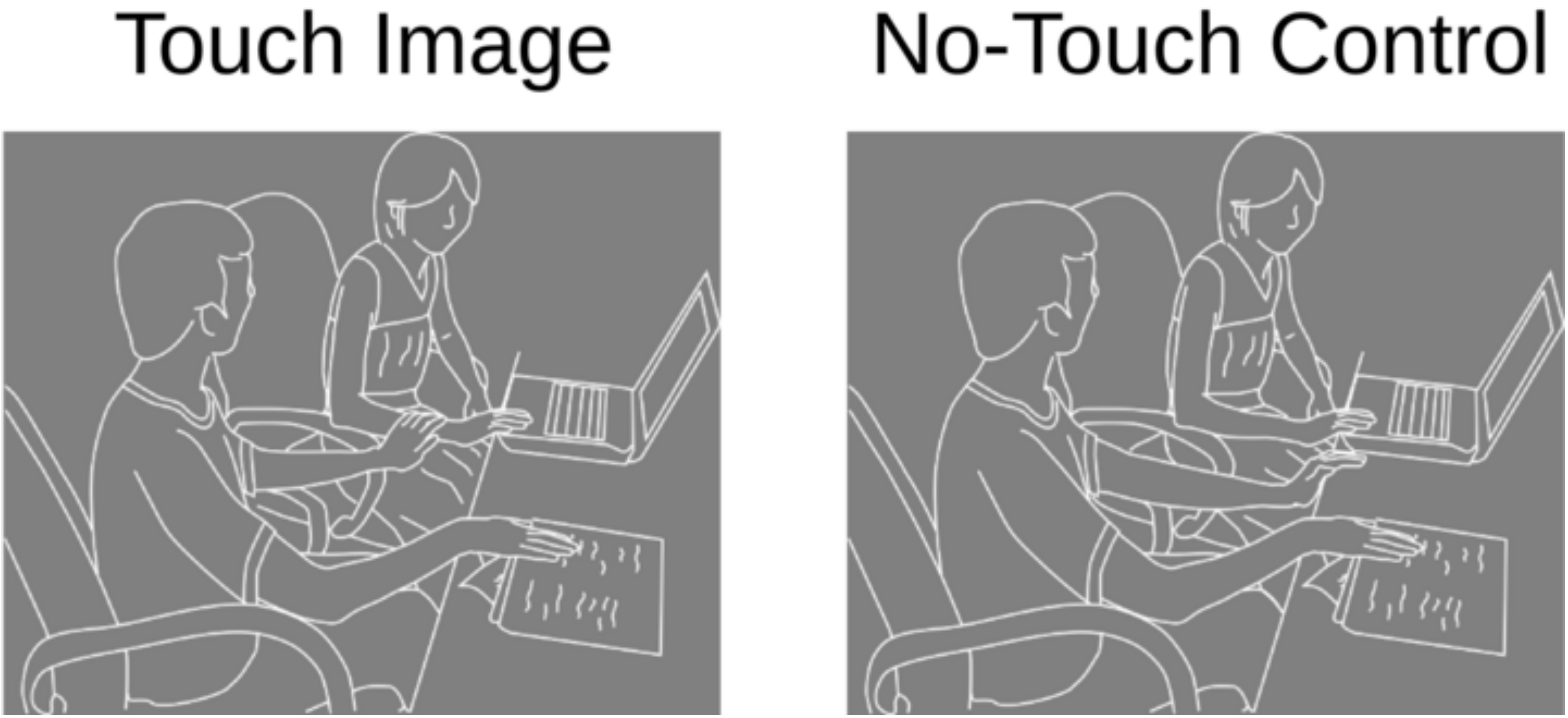
Figure 1. Sample images from the Social Touch Picture Set.

Figure 2. Time-frequency results averaged across C3, C1, Cz, C2, and C4 (as done for statistical analysis). (A) Effects identified across participants; (B) sex differences in the time-frequency response. Non-significant data points are shaded by a transparent white filter and significant clusters exceeding our cluster size threshold are outlined in black. Please note that the non-shaded areas in Panel B illustrate the significant interaction of sex with task or touch – not the task/touch effects for each sex. Cluster numbers (C1.1 etc.) refer to those used in Tables 1 and 2.

Figure 3. ERP results. Scalp-maps illustrate the topography of the mean LPP amplitude difference in the analysis window. No-touch traces were subtracted from touch traces. ERP traces time-locked to stimulus onset are presented for a representative centro-parietal electrode. Touch traces are shown in dashed and no-touch traces in solid lines. The mean voltages within the LPP window are plotted in the bar-graph. Error bars reflect the within subjects standard error.

Figure 4. Behavioral results. The probability of correct responses is presented for touch and no-touch images as a function of participant sex. Error bars reflect the within subjects standard error, asterisks denote significant simple effects.

Figure 1



Touch Image

No-Touch Control

Figure 2

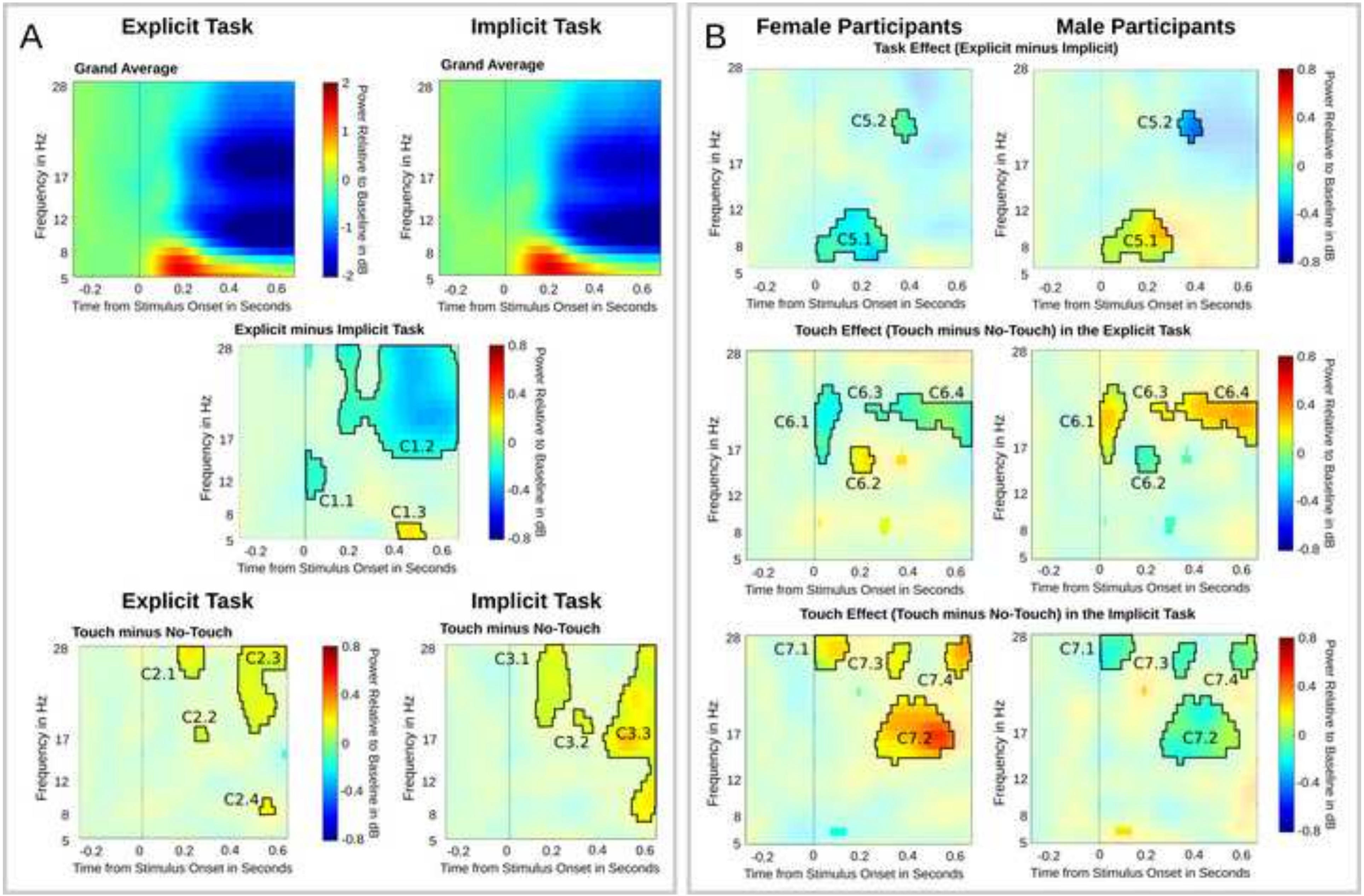

A
Explicit Task
Implicit Task
Grand Average
Grand Average
Frequency in Hz
28
17
12
8
5
-0.2
0
0.2
0.4
0.6
Time from Stimulus Onset in Seconds
2
1
0
-1
-2
Power Relative to Baseline in dB
Explicit minus Implicit Task
C1.1
C1.2
C1.3
0.8
0.4
0
-0.4
-0.8
Explicit Task
Implicit Task
Touch minus No-Touch
Touch minus No-Touch
C2.1
C2.2
C2.3
C2.4
C3.1
C3.2
C3.3
B
Female Participants
Male Participants
Task Effect (Explicit minus Implicit)
C5.1
C5.2
Touch Effect (Touch minus No-Touch) in the Explicit Task
C6.1
C6.2
C6.3
C6.4
Touch Effect (Touch minus No-Touch) in the Implicit Task
C7.1
C7.2
C7.3
C7.4

Figure 3

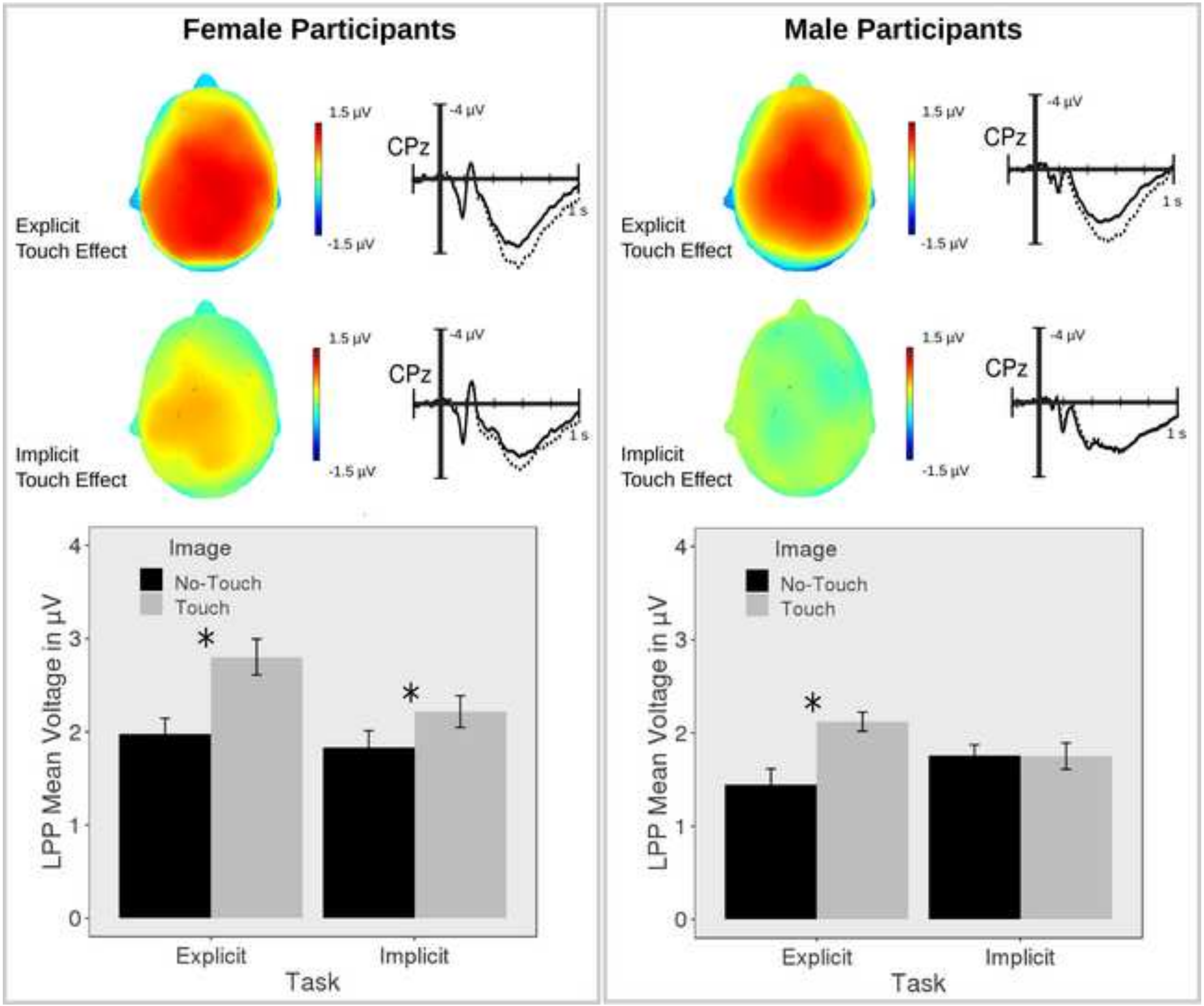
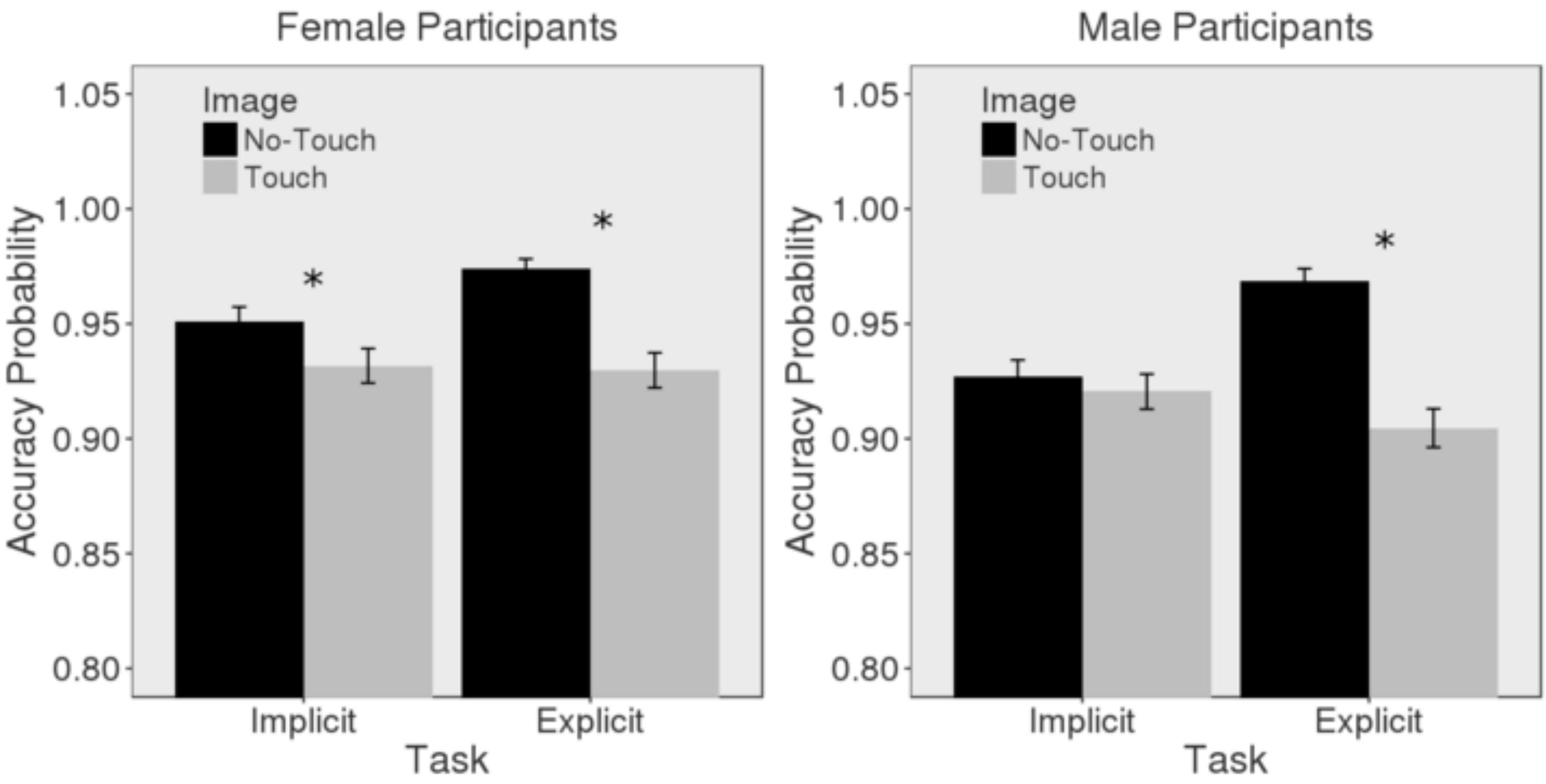

Female Participants
Explicit Touch Effect
1.5 µV
-1.5 µV
CPz
-4 µV
1 s
Implicit Touch Effect
1.5 µV
-1.5 µV
CPz
-4 µV
1 s
Image
No-Touch
Touch
LPP Mean Voltage in µV
0
1
2
3
4
*
*
Explicit
Implicit
Task
Male Participants
Explicit Touch Effect
1.5 µV
-1.5 µV
CPz
-4 µV
1 s
Implicit Touch Effect
1.5 µV
-1.5 µV
CPz
-4 µV
1 s
Image
No-Touch
Touch
LPP Mean Voltage in µV
0
1
2
3
4
*
Explicit
Implicit
Task

**Figure 4**


Female Participants
Male Participants
Image
No-Touch
Touch
Accuracy Probability
1.05
1.00
0.95
0.90
0.85
0.80
*
Implicit
Explicit
Task

**Table**

*Table 1. Time Frequency Results Averaged Across Men and Women*

| Cluster | Frequency | Time | Cluster Size in Percent | Peak Z-Score | Median Z-Score |
|---|---|---|---|---|---|
| Task Effect (Touch Task - Dyad Task) | | | | | |
| C1.1 | 10-15 | 2-80 | 2 | 7.66**** | 5.19**** |
| C1.2 | 15-28 | 139-667 | 35 | 19.21**** | 10.47**** |
| C1.3 | 5-6 | 401-515 | 1 | 5.76**** | 5.16**** |
| Touch Effect during the Explicit Task (Touch - No-Touch) | | | | | |
| C2.1 | 25-28 | 166-280 | 3 | 7.68**** | 5.78**** |
| C2.2 | 17-18 | 245-299 | 1 | 4.38**** | 4.23**** |
| C2.3 | 18-28 | 448-656 | 10 | 6.77**** | 5.17**** |
| C2.4 | 8-9 | 542-605 | 1 | 4.82**** | 4.28**** |
| Touch Effect during the Implicit Task (Touch - No-Touch) | | | | | |
| C3.1 | 19-28 | 123-272 | 7 | 8.02**** | 5.07**** |
| C3.2 | 18-20 | 299-378 | 1 | 4.53**** | 4.11**** |
| C3.3 | 7-28 | 429-667 | 17 | 10.39**** | 6.35**** |
| Task Differences in the Touch Effect<br>(Explicit Task [Touch Effect] - Implicit Task [Touch Effect]) | | | | | |
| C4.1 | 25-28 | 436-507 | 1 | 5.27**** | 4.73**** |
| C4.2 | 13-18 | 534-667 | 3 | 7.42**** | 5.16**** |

* p < .05; ** p < .01; *** p < .001; **** p < .0001

***Table 2. Time Frequency Results By Sex***

| Cluster | Frequency | Time | Cluster Size in Percent | Peak Z-Score | Median Z-Score |
|---|---|---|---|---|---|
| Sex Differences in the Task Effect<br>(Women [Task Effect] - Men [Task Effect]) | | | | | |
| C5.1 | 6-11 | 10-299 | 8 | 6.27**** | 4.75**** |
| C5.2 | 20-23 | 331-429 | 2 | 6.94**** | 5.17**** |
| Sex Differences in the Touch Effect during the Explicit Task<br>(Women [Touch Effect] - Men [Touch Effect]) | | | | | |
| C6.1 | 16-24 | 2-104 | 4 | 8.58**** | 5.68**** |
| C6.2 | 15-17 | 159-245 | 2 | 6.31**** | 4.86**** |
| C6.3 | 21-22 | 217-307 | 1 | 4.24**** | 4.06**** |
| C6.4 | 18-23 | 323-667 | 7 | 9.96**** | 5.51**** |
| Sex Differences in the Touch Effect during the Implicit Task<br>(Women [Touch Effect] - Men [Touch Effect]) | | | | | |
| C7.1 | 25-28 | 2-139 | 3 | 8.43**** | 5.91**** |
| C7.2 | 14-21 | 264-585 | 11 | 13.15**** | 7.64**** |
| C7.3 | 24-27 | 315-401 | 2 | 6.03**** | 4.79**** |
| C7.4 | 24-28 | 562-667 | 2 | 7.52**** | 5.91**** |

* $p < .05$; ** $p < .01$; *** $p < .001$; **** $p < .0001$

# Highlights

Seeing touch in complex social interactions enhances Rolandic rhythms in the EEG.
It also enhances the late positive potential in the ERP.
Both effects likely reflect sensorimotor and socio-affective responses, respectively.
Explicit relative to implicit touch processing enhances primarily the ERP effect.
Women have larger effects than men during implicit touch processing.