

Mirror touch and sense of self

Is that me in the mirror? Depersonalisation modulates tactile mirroring mechanisms

**Julia Adler¹, Nadine Schabinger¹, Matthias Michal¹, Manfred E. Beutel¹,
Helge Gillmeister²**

¹ Department of Psychosomatic Medicine and Psychotherapy, University Medical
Center Mainz, Germany

² Department of Psychology, University of Essex, Colchester, UK

Corresponding author:

Julia Adler

Department of Psychosomatic Medicine and Psychotherapy

University Medical Center Mainz, Germany

Untere Zahlbacher Str. 8

D-55131 Mainz

Telephone: +49 (0) 6131 - 17 - 6084

Fax: +49 (0) 6131 - 17 - 5563

E-Mail: Julia.Adler@uni-mainz.de

Highlights

- Sense of bodily self is strongly linked with mirroring mechanisms
- Mirroring for self- and other-related information differs at early and later stages
- Depersonalisation specifically alters mirroring for self-related events
- Mirroring thus depends on how connected one feels to one's bodily self

Abstract

Our sense of self is thought to develop through sensory-motor contingencies provided, not only by observing one's own body, but also by mirroring interactions with others. This suggests that there is a strong link between mirroring mechanisms and the bodily self. The present study tested whether this link is expressed at early, implicit stages of the mirroring process or at later, more cognitive stages. We also provide, to the best of our knowledge, the first demonstration of how inter-individual differences in our sense of bodily self may affect mirroring mechanisms. We used somatosensory event-related potentials (SEPs) to investigate the temporal dynamics of mirroring highly self-related information (viewed touch on one's own face) compared to other-related information (viewed touch on a stranger's face), in individuals with low and high levels of depersonalisation, a mental condition characterised by feeling detached or estranged from one's self and body. For the low-depersonalisation group, mirroring for self-related events (P45) preceded mirroring for other-related events (N80). At later stages (P200), mirroring was stronger for other-related than self-related events. This shows that early, implicit and later, more cognitive processes play different relative roles in mirroring self- and other-related bodily events. Critically, mirroring differed in the high-depersonalisation group, specifically for self-related events. An absence of early, implicit mirroring for self-related events over P45 suggests that the associated processes may be the neural correlates of the disembodiment experienced in depersonalisation. A lack of differential mirroring for self- and other-related events over P200 may reflect compensatory mechanisms that redress deficiencies in mirroring at earlier

stages, which may break down to give rise to symptoms of depersonalisation. Alternatively, or in addition, they may represent an attenuation of processes related to self-other distinction. Our study thus shows that mirroring, especially for events on one's own face, can be strongly affected by how connected the observer feels to their own bodily self.

Key words: tactile mirroring, self, somatosensory, ERPs, depersonalisation

Word count: 8,003

Introduction

That “the ego is first and foremost a bodily ego” was suggested over a hundred years ago (Freud, 1923, p.26), and is a notion that has been rediscovered and substantiated by neuroscientific research during the last decades (e.g. Blanke, Slater, & Serino, 2015; Lenggenhager, Mouthon, & Blanke, 2009).

Bodily self-consciousness, that is, the feeling of oneself as a bodily subject (e.g. Legrand, 2006), is described as the basic, pre-reflective representation of body-related information (e.g. Gallagher, 2000; Haggard, Taylor-Clarke, & Kennett, 2003; Jeannerod, 2007; Legrand, 2006). This pre-reflective sense of bodily self is based on sensory-motor coherence, and emerges in early childhood, strongly driven by interactions with others (e.g. Gallese & Sinigaglia, 2010; Legrand, 2006) in addition to one’s own bodily experiences (e.g. Rochat & Striano, 2000). Developmental psychologists surmised that experiences like seeing and feeling your own body move provide the multisensory-motor contingencies that are instrumental in giving rise to the bodily self (e.g. Rochat & Striano, 2000; Zmyj, Jank, Schutz-Bosbach, & Daum, 2011). In line with this, sensitivity to synchrony between seen and felt body-related stimuli (touch on the face) is present from birth (Filippetti, Johnson, Lloyd-Fox, Dragovic, & Farroni, 2013; Filippetti, Orioli, Johnson, & Farroni, 2015), and sensory-motor contingencies have been shown to modulate cortical processing at 5 months of age (Filippetti, Lloyd-Fox, Longo, Farroni, & Johnson, 2014).

The importance of, particularly imitative, interactions with others for the emergence of the self has been stressed more recently (e.g. Gallese & Sinigaglia, 2010; Legrand, 2006). Early imitative ("mirroring") experiences enable the motoric and emotional attunement between infants and their primary caregivers, and thus, allow infants to develop a basic sense of themselves as a self-structuring body (Gallese & Sinigaglia, 2010) that is the subject of experiences (the sense of "I am a body"; Stern, 1985). This self-structuring body is both capable of affecting others and of being affected by other bodies within a given motor repertoire ("power for action"), which is the basis of all social engagement and communication (Gallese & Sinigaglia, 2010). Further, mirroring interactions that are capable of establishing an affective reciprocity between an infant and their primary caregiver are thought to be the basis of the emergent ability to represent one's own self (and others) as a mental agent ("mentalising") (e.g. Fonagy, Gergely, & Target, 2007; see also Markova & Legerstee, 2006; Stern, 1995). In these ways, it is thought that our social being is based on mirroring - an intuitive bodily resonance with others (Merleau-Ponty, 1962; see Fuchs & Koch, 2014 for a recent illustration).

These processes would not be possible without a mechanism that allows sensory-motor resonance with other bodies. Such a mechanism exists in a core network of inferior frontal gyrus, premotor and parietal cortical areas ("mirror neuron system", MNS), which primes and encodes actions regardless of whether they are performed by oneself or observed on another person (e.g. di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Iacoboni, Woods, Brass, Bekkering,

Mazziotta, & Rizzolatti, 1999; Molenberghs, Cunnington, & Mattingley, 2012). Through the mapping of observed actions onto those in one's own motor repertoire, the MNS supports the internal simulation of others' sensory-motor experiences and is thus thought to enable an understanding of their intentions (e.g. Gallese & Goldman, 1998). While the involvement of the MNS in higher functions like intention understanding is debated (e.g. Cook, Bird, Catmur, Press, & Heyes, 2014; Dinstein, Thomas, Behrmann, & Heeger, 2008), studies over the past two decades have revealed mirror-like cortical activations not only for motor actions (see Avenanti, Candidi, & Urgesi, 2013 for a recent review), but also for emotions (see Bastiaansen, Thioux, & Keysers, 2009 for a recent review), and for sensations, like pain and touch (see Bufalari & Ionta, 2013 for a recent review). In line with this, a recent meta-analysis has suggested that human mirror functioning can engage a broader network of primary sensory and emotional processing areas in addition to the core MNS (Molenberghs et al., 2012).

As argued above, mirroring plays a crucial role in the development of the bodily self. That is, the basic functional features of the MNS are thought to give rise to different forms of self-consciousness (e.g. sense of agency and body ownership, for which *bodily* self-consciousness is both a prerequisite and core component; Gallese & Sinigaglia, 2010). Furthermore, a close relationship between mirroring mechanisms and our sense of bodily self can also be observed in adults. First, it has been argued that the inferior frontal and parietal areas which comprise the MNS overlap with those involved in self-related

processing, such as self-face observation (e.g. Uddin, Kaplan, Molnar-Szakacs, Zaidel, & Iacoboni, 2005; Uddin, Molnar-Szakacs, Zaidel, & Iacoboni, 2006; for reviews see Molnar-Szakacs & Uddin, 2013; Uddin, Iacoboni, Lange, & Keenan, 2007).

Second, and more directly relevant for the present study, there is a functional link between mirroring and self-related processing. Behavioural studies have shown that mirroring is stronger the better the perceived match is between oneself and a viewed person (Cardini, Costantini, Galati, Romani, Làdavas, & Serino, 2011; Cardini, Tajadura-Jiménez, Serino, & Tsakiris, 2013; Serino, Pizzoferrato, & Làdavas, 2008; Serino, Giovagnoli, & Làdavas, 2009). Importantly, effects of mirroring are maximally enhanced when observing one's own face (Cardini et al., 2011, 2013; Serino et al., 2008; see also Keenan et al., 2001; Salomon et al., 2012), which is a typical approach to investigate the neuronal correlates of self-related processes (see Keenan, Wheeler, Gallup, & Pascual-Leone, 2000; Platek, Keenan, Gallup, & Mohamed, 2004; Salomon, van Elk, Aspell, & Blanke, 2012; Sugiura, Kawashima, Nakamura, Okada, Kato, Nakamura et al., 2000; Uddin et al., 2005; 2006). Uddin et al. (2005) surmised that, because we understand others by mapping them onto a representation of ourselves (making them "like me", Meltzoff & Brooks, 2001), one's own face activates fronto-parietal circuits more than another person's face because it results in a better match with existing representations.

In sum, while philosophical, developmental and neuroscientific studies have pointed to a strong link between mirroring mechanisms and the bodily self,

several questions remain hitherto unanswered. One is whether this link is expressed at early, implicit stages of the mirroring process or at later, more cognitive stages. Another is whether this link differs in observers with an altered sense of bodily self.

It is already known that synchronous visuo-tactile stimulation, which can be described as “mirror like experiences” because seen touches concur with felt touches (e.g. Tajadura-Jiménez, Lorusso, & Tsakiris, 2013), can alter cortical self-representations (e.g. Apps, Tajadura-Jiménez, Sereno, Blanke, & Tsakiris, 2013; Tsakiris, Hesse, Boy, Haggard, & Fink, 2007). This has been shown to increase identification with a stranger or avatar (e.g. Maister, Banissy, & Tsakiris, 2013; Serino, Sforza, Kanayama, van Elk, Kaliuzhna, Herbelin, & Blanke, 2015; Tsakiris, 2008; Tsakiris & Haggard, 2005), and to cause mirroring effects that are indistinguishable from those for one’s own face (Cardini et al., 2013).

In this study we ask whether individual differences in self-processing are associated with changes in mirroring. Stark alterations can be expected in depersonalisation, a psychological condition characterised by estrangement, detachment or disconnection from one’s own being while reality testing and sense of identity remain otherwise intact (e.g. Simeon, 2004). Depersonalisation can occur in healthy adults following severe stress, traumatic life events, or drug use (e.g. Charbonneau & O’Connor, 1999; Simeon, 2004; Trueman, 1984), or as a symptom of another mental disorder (e.g. panic disorder, post-traumatic stress disorder; e.g. Simeon, 2004). When depersonalisation symptoms are persistent and debilitating, however, they may indicate the presence of

depersonalisation-derealisation disorder. For mild (non-pathological) depersonalisation there is a high life-time prevalence of up to 80%, while the clinical disorder occurs in around 1% of the adult population (e.g. Hunter, Sierra, & David, 2004). The phenomenology of depersonalisation may entail abnormal sensory experiences, autoscopy or candid out-of-body experiences, and emotional blunting. However, one of the core components of depersonalisation is disembodiment - the disrupted relationship with one's own bodily self (e.g. feeling detached from body parts or the whole body; looking in the mirror and feeling estranged from one's image; not feeling in control of one's movements) (e.g. Sierra, Baker, Medford, & David, 2005; Sierra & Berrios, 2000; Sierra and David, 2011; Simeon, 2004), and it is thought that this disembodiment is due to faulty integration of self-perceptions with one's sense of self (Simeon, 2004).

The experimental literature on self-related processes in depersonalisation is relatively sparse, but one recent fMRI study has observed stronger frontal lobe activity in response to images of one's own face in contrast to strangers' faces (Ketay, Hamilton, Haas, & Simeon, 2014). Ketay et al. argued that these differences may reflect impairments in implicit self-processing, which exist alongside the preserved ability to explicitly recognise oneself, in patients with depersonalisation.

To investigate the stages of processing affected by the link between mirroring and self-related processing, and its alterations in depersonalisation, the present study used electroencephalography (EEG) in a tactile mirroring paradigm. The tactile mirroring paradigm is an effective method to delineate

mirroring processes (e.g. Banissy, Kadosh, Maus, Walsh, & Ward, 2009; Bufalari, Aprile, Avenanti, Di Russo, & Aglioti, 2007; Cardini et al., 2011; Deschrijver, Wiersema, & Brass, 2015; Serino et al., 2008, 2009; Gillmeister, 2014; Martínez-Jauand, Gonzalez-Roldan, Munoz, Sitges, Cifre, & Montoya, 2012). In most variants of this paradigm, observers receive tactile stimuli on their own, hidden body while viewing another person's body being touched or not touched at the same time. As mirroring entails an internal simulation of the observed event, a match between the representations of the felt and the seen stimulus should be present when viewing touch but not when viewing no touch. Thus, the differences in somatosensory processing between touch-viewed and no-touch-viewed conditions reflect tactile mirroring.

The precise time course of tactile mirroring, which may be elucidated with EEG, has so far only been described for viewing touch on the hands and independently of self-relatedness (Bufalari et al., 2007; Deschrijver et al., 2015; Martínez-Jauand et al., 2012). Mirroring for touch on the face, which is highly self-related, has only been investigated behaviourally and with fMRI, showing stronger effects of mirroring for self-related stimuli (observing touch on one's own face) compared to other-related stimuli (touch on another person's face) in behaviour, but the reverse pattern in fMRI (Cardini et al., 2011, 2013; Serino et al., 2008, 2009). As it is presently unknown whether the observed differences in tactile mirroring for self- and other-related stimuli operate at early or later stages of processing, this issue was addressed in the present study. Additionally we compared groups of adults with high and low levels of depersonalisation to

investigate the influence of their divergent subjective sense of bodily self on tactile mirroring mechanisms.

We expected two main findings. (1) Viewing one's own face should result in enhanced effects of tactile mirroring than viewing the face of another person because tactile mirroring is stronger the better the perceived match is between one's own and an observed body (Cardini et al., 2011, 2013; Serino et al., 2008, 2009), reflecting the link between mirroring mechanisms and self-related processing. This enhancement should be expressed as earlier or stronger tactile mirroring for self-related compared to other-related stimuli in observers with low levels of depersonalisation. (2) Observers with high levels of depersonalisation should show attenuated effects of tactile mirroring when viewing their own face. This is because depersonalisation is characterised by a feeling of detachment from one's bodily self, possibly due to impaired implicit self-processing (Ketay et al., 2014), which should be specifically associated with attenuated mirroring for self-related stimuli.

2 Materials and Methods

2.1 Participants

Initial screening for low and high levels of depersonalisation (see below) was done on healthy adults who responded to general or targeted (see below) advertisements sent via University of Essex mailing channels. Of these, 30 healthy adults participated in the EEG study, half of whom reported high and the

other half low levels of depersonalisation. All had normal or corrected-to-normal vision, and none reported currently suffering from any mental disorder. One high-scoring and two low-scoring participants were removed due to excessive noise in the EEG. Table 1 below describes the remaining sample.

The study was conducted in accordance with the 2008 Declaration of Helsinki and approved by the local ethics committee. Informed written consent to participation and use of their photographs was obtained from each participant prior to testing.

Table 1 here

2.2 Materials and Apparatus

Targeted advertisements to invite participants with potentially high levels of depersonalisation were sent through University of Essex participant mailing channels. The email text asked "Do you sometimes suddenly feel as if you were not real, or cut off from the world? Do your surroundings sometimes feel detached or unreal, as if there was a veil between you and the outside world?", followed by an invitation to complete a brief online survey if the answer to one or both questions was affirmative. Through the survey, initial screening for high depersonalisation was done using the 2-item form of the Cambridge

Depersonalisation Scale (CDS-2; Michal, Zwerenz, Tschan, Edinger, Lichy, Knebel et al., 2010), comprising the statements 'My surroundings feel detached or unreal, as if there was a veil between me and the outside world' and 'Out of the blue, I feel strange, as if I were not real or as if I were cut off from the world', scored on a 4-point Likert scale from 0 ('not at all') to 3 ('nearly every day'), relevant to the past two weeks. Preceding the CDS-2, an affirmative answer on one of four distractor questions ('Do you have nightmares more than 4 times/week?', 'Are you taking antidepressants or antipsychotics?', 'Do you see colours when you listen to music?', and 'Are you suffering from seizure disorder?') led to exclusion.

Participants with potentially low levels of depersonalisation were not specifically targeted, but a general email seeking participants was sent out through mailing channels, with the email text simply inviting interested persons to complete the same brief online survey.

Respondents from both recruitment rounds were invited if they scored either 3 or higher on the CDS-2, and 0 on the distractor questions (high-depersonalisation group), and if they scored 0 on the CDS, and 0 on the distractor questions (low-depersonalisation group), and matched the high-depersonalisation sample in terms of gender, age and ethnicity as closely as possible. All invited respondents completed the full CDS (29 items; Sierra & Berrios, 2000) to measure frequency and duration of depersonalisation symptoms within the last 6 months. The CDS contains statements describing abnormal sensory experiences and somatosensory distortions, inability to experience some emotions, heightened self-observation, autoscopia and out-of-

body experiences, abnormal body ownership and lack of agency (Sierra et al., 2005). The frequency of these experiences was measured on a 5-point Likert scale (never = 0, rarely = 1, often = 2, very often = 3, all the time = 4), and their duration on a 6-point scale (few seconds = 1, few minutes = 2, few hours = 3, about a day = 4, more than a day = 5, more than a week = 6). All scores were added to compute each person's global depersonalisation score (0 to 290).

Visual stimuli (faces) were presented life-size (17.1° horizontal x 22.6° vertical visual angle) against a white background on a computer screen. Neutral images showed a face and a pencil (see Figure 1). Touch images showed the pencil depressing the left or right cheek of the viewed face. No-touch images showed the pencil in a different position, next to the cheek, in a position chosen so that the perceived distance travelled by the pencil would be similar across touch and no-touch trials.

Figure 1 here

A tactile controller (Heijo Research Electronics, London, UK) and mechanical solenoid stimulators (M&E Solve, Rochester, Kent, UK) delivered suprathreshold taps by pushing a blunt plastic tip against the participant's skin whenever a current was passed through the solenoid. Taps were delivered to

participants' left or right cheeks during the presentation of each touch or no-touch image. White noise was played through in-ear headphones to mask solenoid sounds.

2.3 Procedure

During the initial session, participants completed the CDS, and photographs were taken of their faces being touched by a pencil. To save time, photographs were only taken for one of the cheeks being touched. In a separate session, EEG was recorded while participants completed seven blocks of 60 trials feeling touches on their face while viewing images of their own and a stranger's face being touched or not. The stranger was chosen to match each participant's gender, age and ethnic characteristics. In each block, 48 trials were experimental trials, and an additional 12 trials were randomly chosen from a set of experimental and catch trials. Figure 1 describes the design of experimental trials. In catch trials (to be silently counted by the participant), the touch image was shown twice, enveloping a 100-ms presentation of the neutral image (double touch). Only the second touch image was accompanied by a felt touch.

Participants were asked to view the images and silently count the number of double touches they saw. Performance feedback was provided after each block. The counting task ensured that participants viewed the images. Touch images were shown in half of all trials (touch), and no-touch images in the other half (no-touch). Half of all trials showed touch and no-touch images for the participant's own face (self-face), the other half showed them for the stranger's face (other-face). In half of all trials, the face was shown as photographed

(touch on one cheek), and for the other half it was shown mirror-reversed (touch on the other cheek). In half of all trials, the observer's cheek receiving a tactile stimulus was the same as that depicted on the screen (e.g. left cheek), and in the other half the viewed and felt tactile stimuli were on opposite cheeks (e.g. viewed touch on left cheek, felt touch on right cheek). This was done to control for effects of specular and anatomical congruency between viewed and felt touch¹. All trial types were randomly intermixed in each block.

2.4 EEG recording and ERP analysis

EEG was recorded from 64 actiCAP scalp electrodes (BrainProducts GmbH, Gilching, Germany), referenced off-line to the average of all electrodes. EEG was amplified, band-pass filtered at 0.01 – 100 Hz, digitised at 500 Hz, filtered off-line with a low-pass filter of 40 Hz, and epoched from 100 ms before to 400 ms after tactile stimulus onset. Trials with eye blinks or other artefacts (a voltage exceeding $\pm 100 \mu\text{V}$ at any electrode relative to the 100-ms pre-stimulus baseline) measured, or visually identified, in this interval were excluded from analysis.

¹ The authors would like to acknowledge that spatial congruency may play an important role in the mechanisms supporting mirror touch. Visual-tactile congruency affects early tactile processing (Deschrijver et al., 2015; Kuehn et al., 2014; Longo et al. 2012) even in newborns (Filippetti et al., 2015), but the specific effects of anatomical versus specular matching have received little investigation. Specular (rather than anatomical) congruency appears to drive the enhanced identification with another person's face following repeated synchronous visual-tactile stimulation on the cheek (e.g. Tsakiris, 2008; Tajadura-Jiménez & Tsakiris, 2014). However, the literature on mirror-touch synaesthesia (e.g. Banissy & Ward, 2013) and on bimodal visual-tactile neurons in monkey parietal cortex (e.g. Ishida et al. 2009) reports both specular and anatomical (as well as bilateral or central) matching between viewed and felt touch. The present study, which focuses on effects of (dis)embodiment on self- and other-related tactile mirroring, deliberately balanced specular and anatomical congruency for this reason. However, future studies should directly investigate how spatial congruency between viewed and felt touches specifically affect mirroring of self- and other-related tactile information.

ERPs to tactile stimuli were averaged for all combinations of observed touch (touch vs. no-touch) and observed face (self-face vs. other-face). Approximately 80 trials per participant contributed to each of these combinations. ERP mean amplitudes were computed within successive measurement windows covering somatosensory components P45 (25-50 ms), N80 (60-75 ms), P100 (80-100 ms) and N140 (110-130 ms), and fronto-central component P200 (150-240 ms). Contralateral C3/4, CP3/4, and CP5/6, which are situated over primary somatosensory cortex and inferior parietal lobule, were clustered for statistical analyses of all somatosensory components (P45, N80, P100, and N140). Over this cluster, all four somatosensory components were clearly present, even though voltages per se were not always maximal over these electrodes. However, as shown in the topographical maps below (Figure 2), the selected cluster covered peak voltages across most somatosensory components (see also Footnotes 3-4). For analyses of P200, which are typically done over frontal sites, bilateral FC1/2, FC3/4 and FC5/6, and central FCZ were clustered (see Figure 2).

Figure 2 here

For each component, a repeated-measures ANOVA was conducted on the within-subject factors observed touch (touch vs. no-touch) and observed face (self-face vs. other-face) and the between-subject factor group, in order to show interactions between observed touch, observed face, and group. Where significant three-way interactions between these factors were found, omnibus ANOVAs were followed up with group-specific ANOVAs for the two within-subject factors observed touch and observed face. Further follow-up ANOVAs for observed touch were done for each observed face condition where interactions between these two factors were found. Bayesian probabilities associated with the occurrence of the null ($H_0|D$) and experimental hypothesis ($H_1|D$) were calculated alongside standard statistics to allow for clearer inferences about the probabilities of both significant and nonsignificant effects in our data (see Masson, 2011; Wagenmakers, 2007). These probabilities range from 0 (no evidence) to 1 (very strong evidence).

3 Results

Somatosensory ERPs during touch and no-touch observation on one's own and another person's face are shown separately for observers with low levels of depersonalisation (Figure 3) and high levels of depersonalisation (Figure 4).

Figure 3 here

 Figure 4 here

For P45, there was an interaction between observed touch and group ($F(1,26)=4.77$, $p = 0.039$, $\eta^2=0.16$, $p(H_1|D)>.67$), as well as a three-way interaction between observed touch, observed face, and group ($F(1,26)=4.28$, $p = 0.049$, $\eta^2=0.15$, $p(H_1|D)>.61$). Follow-up ANOVAs for each group showed that, for observers with low levels of depersonalisation, there was a significant main effect of observed touch ($F(1,12)=5.53$, $p = 0.037$, $\eta^2=0.32$, $p(H_1|D)>.76$) as well as a significant interaction between observed touch and observed face ($F(1,12)=12.31$, $p = 0.004$, $\eta^2=0.51$, $p(H_1|D)>.96$). Further follow-up ANOVAs for each observed face condition showed that observed touch resulted in greater P45 amplitudes than no-touch only during self-face observation ($F(1,12)=10.23$, $p = 0.008$, $\eta^2=0.46$, $p(H_1|D)>.93$), but not during other-face observation ($F(1,12)<1$, $p = 0.979$, $\eta^2<0.01$, $p(H_0|D)>.78$; see Figure 3, upper panel, and Figure 5, left panel). Importantly, there was no interaction between observed touch and observed face for the high-depersonalisation group in this time range ($F(1,13)<1$, $p = 0.933$, $\eta^2<0.01$, $p(H_0|D)>.78$; see Figure 4, upper panel, and Figure 5, left panel). No other main effects or interactions were significant².

² Analysis of the P45 over a broader selection of electrodes (ie. including the more temporal-frontal C6 and FC6, where scalp topography also indicated strong positivities, see Figure 2) retained the

For N80, the interaction between observed touch and observed face was significant ($F(1,26)=7.32$, $p = 0.012$, $\eta^2=0.23$, $p(H_1|D)>.86$), but was unaffected by group ($F(1,26)=1.637$, $p = 0.213$, $\eta^2=0.06$, $p(H_0|D)>.68$). Follow-up ANOVAS for each observed face for all participants showed that observed touch resulted in greater N80 amplitudes than no-touch only during other-face observation ($F(1,26)=10.70$, $p = 0.003$, $\eta^2=0.29$, $p(H_1|D)>.95$), but not during self-face observation ($F(1,26)<1$, $p = 0.422$, $\eta^2<0.03$, $p(H_0|D)>.78$; see upper panels of Figures 2 and 3). No other main effects or interactions were significant.

For mid-latency components P100 and N140, no significant main effects or interactions were found³.

For frontal P200, observed touch resulted in greater positivities than observed no-touch (main effect of observed touch: $F(1,26)=89.05$, $p < .001$, $\eta^2=0.78$, $p(H_1|D)>.99$). There was also a three-way interaction between observed touch, observed face, and group ($F(1,26)=6.58$, $p = .017$, $\eta^2=0.21$, $p(H_1|D)>.81$). Follow-up ANOVAs for each group showed that, for observers with low levels of depersonalisation, there was a main effect of observed touch ($F(1,12)=56.71$, $p < .001$, $\eta^2=0.83$, $p(H_1|D)>.99$), and an interaction between observed touch and observed face ($F(1,12)=8.33$, $p = .014$, $\eta^2=0.41$, $p(H_1|D)>.89$). Further follow-up ANOVAs for each observed face condition

effect size for effects of observed touch during self-face observation in the low-depersonalisation group, but decreased the effect sizes of some group- and condition-based interactions. A similar pattern was observed for the N80. This shows that although the simple effects of tactile mirroring are robust, the reported early group- and condition-based differences are most stable over primary somatosensory and inferior parietal regions.

³ Analysis of the P100 over a broader selection of electrodes (ie. including central CPz, and ipsilateral and contralateral CP1/2, where scalp topography also indicated strong positivities, see Figure 2) also revealed no main effects or interactions. The same was true for P100 analysis exclusive to electrodes with maximal positivities at frontal sites (central Fz, and ipsilateral and contralateral F1/2; see Figure 2) - there were no main effects or interactions. N140 analyses over a broader selection of electrodes (ie. including the more temporal-frontal C6 and FC6) also revealed no main effects or interactions.

revealed that the P200 effect of observing touch compared to no-touch was stronger for other-face than self-face observation but present for both (self-face observation: $F(1,12)=18.34$, $p = .001$, $\eta^2=0.61$, $p(H_1|D)>.99$; other-face observation: $F(1,12)=92.48$, $p < .001$, $\eta^2=0.89$, $p(H_1|D)>.99$; see Figure 3, lower panels, and Figure 5, right panel). For those with high levels of depersonalisation, there was also a main effect of observed touch ($F(1,13)=35.03$, $p < .001$, $\eta^2=0.73$, $p(H_1|D)>.99$), but the absence of an interaction between observed touch and observed face showed that this was similar for self-face and other-face observation ($F(1,13)<1$, $p = .399$, $\eta^2=0.06$, $p(H_0|D)>.71$; see Figure 4, lower panels, and Figure 5, right panel). No other main effects or interactions were significant.⁴

 Figure 5 here

4 Discussion

The first aim of the present study was to delineate the neural time course of mirroring highly self-related information (touch on one's own face), compared to mirroring other-related information (touch on a stranger's face). Our second aim was to compare adults with low and high levels of depersonalisation to

⁴ No effect size changes were observed for P200 with a broader selection of electrodes (ie. including the more central C1/2 and Cz, where scalp topography also indicated strong positivities, see Figure 2), showing that the reported main effects and interactions are stable over frontal-central sites.

investigate the influence of their divergent sense of bodily self on tactile mirroring mechanisms in the context of self- and other-related stimuli. Tactile mirroring was measured as differences between somatosensory event-related potentials in response to tactile stimuli on the observer's face while viewing images of their own or a stranger's face being touched (touch condition) or not (no-touch condition) at the same time.

4.1 Tactile mirroring in observers with low levels of depersonalisation

We found that for the low-depersonalisation group, viewing touch compared to no touch resulted in greater amplitudes of early, more sensory SEP components (P45 and N80), which are thought to be generated in primary somatosensory cortex (SI) (e.g. Allison, McCarthy, Wood, Williamson, & Spencer, 1989; Allison, McCarthy, & Wood, 1992; Schubert, Ritter, Wüstenberg, Preuschhof, Curio, Sommer, & Villringer, 2008). When viewing their own face, these amplitude differences occurred at the P45, but when viewing another person's face, the N80 was found to be affected. That is, mirror touch for self-related events occurred earlier than mirror touch for other-related events. In addition, we found enhancement for touch over no-touch at the mid- to long-latency component P200, which is thought to be generated in areas beyond primary sensory cortices and influenced more strongly by cognitive processes (e.g. Freunberger, Klimesch, Doppelmayr, & Höller, 2007; Lefebvre, Marchand, Eskes, & Connolly, 2005; McDonough, Warren, & Don, 1992; Montoya & Sitges, 2006; Yamaguchi & Knight, 1991). Mirror touch over P200 was present for both

observed-face conditions, but stronger for other-face observation than for self-face observation.

Previous SEP studies have found modulations of the P45 during the observation of touch versus no touch on the hand (Bufalari et al., 2007; Martinez-Jauand et al., 2012) or of touch on congruent versus incongruent fingers (Deschrijver et al., 2015). Our study is the first to show such modulations for touch on the face. It may be argued that P45 differences arise as a result of differential attention toward touch and no-touch stimuli. Indeed, attentional modulations of SEPs are known to occur in this time range (Desmedt & Tomberg, 1989; Garcia-Larrea, Bastuji, & Mauguier., 1991; Forster & Eimer, 2005; Schubert et al., 2008). Some of the previous findings of tactile mirroring over P45 (Bufalari et al., 2007; Martinez-Jauand et al., 2012) might be consistent with an attentional explanation. In these studies, viewed touch stimuli (a cotton swab approaching the hand) may have directed attention toward the hand, while no-touch stimuli (no cotton swab present) did not. Therefore, the P45 modulations in these studies may reflect greater engagement with the touch than the no-touch stimuli, instead of, or in addition to, reflecting effects of tactile mirroring. It is unlikely that an attentional explanation suffices to account for the present findings, however. This is because our design minimised attentional differences by presenting attention-directing cues (the pencil at the observed face; pencil movement during touch presentation) in both touch and no touch conditions (see also Gillmeister, 2014, for an argument against effects of more localised somatotopic cueing). It is similarly unlikely that our tactile mirroring effects may be explained in terms of “visual enhancement of touch” (VET) - the

functional tuning of somatosensory processes through mere vision of one's own body (e.g. Haggard, Taylor-Clarke, & Kennett, 2003). VET studies typically show improved tactile acuity (e.g. Harris, Arabzadeh, Moore, & Clifford, 2007; Kennett, Taylor-Clarke, & Haggard, 2001; Serino, Farnè, Rinaldesi, Haggard, & Làdavas, 2007) or spatial-selective attention (e.g. Làdavas, Farnè, Zeloni, & di Pellegrino, 2000; Sambo, Gillmeister, & Forster, 2009) when the relevant body part(s) are viewed, compared to when they are absent from view, or when an object or an unrelated (usually fake) body part is viewed. In our study, the face was viewed in both touch and no-touch conditions. Since this would have given rise to similar VET effects, differences between touch and no-touch conditions can thus not be accounted for by general visual enhancement of touch.

Instead, we posit that our SEP effects of touch observation are consistent with genuine tactile mirroring. In line with this, SI, from which P45 originates (e.g. Schubert et al., 2008), is considered to be part of a broader neural network responsible for mirroring (e.g. Keysers & Gazzola, 2009; Molenberghs et al., 2012; Molnar-Szakasc & Uddin, 2013; Pineda, 2005; Ruby & Decety, 2001), and has also been implicated in the recognition of others' facial emotions (e.g. Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000). Our findings further indicate that the P45 is more strongly associated with self-related than with other-related tactile mirroring. This is supported by the observation that SI is a critical component in the sense of body ownership (Aspell, Palluel, & Blanke, 2012; Otsuru, Hashizume, Nakamura, Endo, Inui, Kakigi, & Yuge, 2014) and in tactile mirroring mechanisms for egocentric (self-related) versus allocentric (other-related) hand postures (Schaefer, Heinze, & Rotte, 2012). Even though

Aspell, Otsuru and Schaefer and colleagues' studies investigated body ownership or mirror touch for the hands or the back, neither of which are as immediately indicative of one's self-identity as the face, studies like these purposefully invoke (mis)identification with the viewed body part by manipulating its location, orientation and / or felt experience of touch relative to the observer's own, hidden body part. Therefore, and perhaps precisely *because* the hands or the back are less obviously one's own, an identification with the viewed body part may be achieved at early stages of sensory processing even when the viewed body part is a stranger's (see Bufalari et al., 2007; Deschrijver et al., 2015; Martinez-Jauand et al., 2012; Schaefer et al., 2012; for related arguments see Bach, Feynton-Adams, & Tipper, 2014; Mahayana, Banissy, Chen, Walsh, Juan, & Muggleton, 2014).

Our findings for participants with low levels of depersonalisation are consistent with the hypothesis that mirroring differs in the context of self- and other-related bodily events. They are also consistent with findings from previous studies, which show differential neural activations for mirror touch during self-face and other-face observation (Cardini et al., 2011), as well as greater enhancement of tactile detection from viewing touch for better matches between one's own and an observed face, with maximal effects for own-face observation (Cardini et al., 2011, 2013; Serino et al., 2008, 2009). Our data extend this by demonstrating that the links between mirroring mechanisms and self-related processing, which underpin such findings, are expressed both at early, sensory stages of processing (P45-N80) and at later, more cognitive stages (P200). At

early, sensory stages, tactile mirroring effects for self-related stimuli (touch on one's own face; P45) precede those for other-related stimuli (touch on a stranger's face; N80). At later, more cognitive stages (P200), other-related stimuli give rise to larger effects of tactile mirroring than self-related stimuli. This pattern of results might suggest that early-stage, implicit processes play a larger role in the mirroring of self-related stimuli, while later, more cognitive processes are more important for mirroring other-related stimuli. This is likely to be because self-related stimuli have privileged access to the fronto-parietal networks that sustain mirroring mechanisms. In contrast, stimuli that do not directly match a representation of one's own bodily self (ie. events observed on another person's body) are less easily mapped onto existing representations during simulation (e.g. Uddin et al., 2005; see also Cardini et al., 2011, 2013).

Mirroring, especially for events on the face, may be subserved by several waves of visual and tactile cortical processing (e.g. Auksztulewicz, Spitzer, & Blankenburg, 2012; Bullier, 2001; Sugase, Yamane, Ueno, & Kawano, 1999). With respect to our findings, there may be a first-pass processing wave that gives rise to rapid differential mirroring of self- and other-related bodily events at time points consistent with P45 and N80 components, leading to earlier mirroring for self-face than other-face events. This may be followed, through re-entrant input via top-down feedback connections (e.g. David, Harrison, & Friston, 2005; Auksztulewicz et al., 2012), by a later wave of differential mirroring at time points consistent with P200, where a more complete transformation of the viewed person onto the observer's own body representations is achieved. This then may give rise to stronger effects of

mirroring for other-face than self-face events due to the more effortful mapping of a stranger's body onto existing representations (Uddin et al., 2005; Cardini et al., 2011, 2013). It then becomes possible to argue that, similar to our findings for P45/N80 and P200, the relatively larger behavioural effects of mirroring while viewing one's own face compared to a stranger's (Cardini et al., 2011; Serino et al., 2008) are more strongly driven by an initial wave of mirroring processes, while the stronger activations of premotor and somatosensory areas that have been reported when viewing touch on a stranger's face compared to one's own (Cardini et al., 2011) are more strongly driven by a later processing wave. While the precise unfolding of recurrent cortical mirroring processes awaits further investigation, it is conceivable that early and later stages of processing operate together to enable the simulation of self- and other-related stimuli by activating overlapping structures at distinctive time points and in distinctive ways.

4.2 Mirroring self-related bodily events differs in observers with high levels of depersonalisation

In observers with symptoms of altered self-perception, that is, high levels of depersonalisation, different patterns of effects were found. In line with our hypotheses, these differences arose specifically for self-face observation (P45, P200), while other-face observation patterns were similar to observers with low levels of depersonalisation (N80). During self-face observation, there was no evidence for the early (P45) effects of tactile mirroring that were seen in observers with low levels of depersonalisation. In addition, tactile mirroring over P200 did not differ during self- compared to other-face observation. This

contrasted with low-depersonalisation observers, for whom tactile mirroring over P200 was stronger during other-face than during self-face-observation.

The absence of mirroring effects for self-related stimuli at the P45 may indicate that the altered sense of bodily self in depersonalised individuals may relate to changes at early, implicit levels of processing. Ketay et al. (2014) have previously suggested that depersonalisation is associated with implicit neuronal abnormalities, and the attenuation of P45 effects of mirroring for self-related information found in the present study may be a linked correlate. As outlined above, the P45 and its neural generator, SI, are attractive candidates for the processes stage at which deficits related to one's sense of bodily self would be expressed. This is because both P45 and SI have previously been linked with sense of body ownership (Aspell et al., 2012; Otsuru et al., 2014; see also Dieguez, Mercier, Newby, & Blanke, 2009) and with tactile mirroring sensitive to self-relatedness (Schaefer et al., 2012; Bach et al., 2014). Further support for the suggestion that the altered sense of bodily self is associated with impairments over P45 stages of processing may be derived from a recent study, which observed greater body ownership illusions in observers with high levels of depersonalisation than in those with low levels (Kanayama, Sato, & Ohira, 2009; see also Sierra, Lopera, Lambert, Phillips, & David, 2002).

The effects of seeing one's own or a stranger's face on tactile cortical processing are likely to occur as a result of visual input into SI via multisensory neurons in parietal cortex (e.g. Ishida, Nakajima, Inase, & Murata, 2010).

Measurable effects of mirroring for tactile events on the observer's own face may

be absent over P45 because deficits in implicit self-related processing prevent the resulting visual enhancement of tactile processing from taking place in the context of self-related information. An alternative, or additional, explanation for the absence of P45 mirroring effects may be that seeing their own body causes depersonalised individuals to actively inhibit the processing of bodily stimulation via this pathway. This may cause feelings of disembodiment, and is akin to the suggestion that fronto-limbic inhibitory mechanisms acting on emotional processes cause the emotional numbing experienced in depersonalisation (Sierra & David, 2011).

Our findings for the P200 wave could be interpreted in two, not necessarily mutually exclusive, ways. For one, it has been shown that processing in the time range of the P200 is affected by conflicts in the integration of body-related information (Aspell et al., 2012; Longo, Musil & Haggard, 2012). Conflicts may be assumed during mirroring of other-related information, that is, when observing touch on a stranger's face while feeling touch on one's own face. Dealing with this conflict, for example by remapping the viewed information onto one's own body to make it more "like me" (e.g. Meltzoff & Brooks, 2001; Uddin et al., 2005), would presumably require some computational effort. As argued above, this may lead to larger mirroring effects over P200 during other-face observation than during self-face observation. For observers with depersonalisation symptoms, similar efforts may be expended during self-face observation as a reflection of the conflict between the explicit knowledge of the self as the subject of bodily sensations, and the experienced detachment from

those sensations (e.g. Simeon, 2004). This may have led to similar effects of tactile mirroring during self- and other-face observation in our high-depersonalisation group.

Therefore, the P200 might not only be the earliest expression of the explicitly experienced conflicts in depersonalisation regarding the sense of bodily self, but it might also reflect operations that contribute to the processes of self-other distinction, which are typically found at comparatively later stages of processing (P300; e.g. Knyazev, 2013; Longo et al., 2012; see also discussion in Deschrijver et al., 2015). The posited interactions between self- and other-related processing at tactile P200 and P300 stages should be investigated further. In this regard, Knyazev (2013) has recently remarked that even though the majority of studies investigating self-referential processing (e.g. seeing one's own face, hearing one's own name, self-relevant possessive pronouns) have found effects at stages associated with visual and auditory P300, visual ERP enhancements for seeing one's own compared to another person's face can potentially also come about at slightly earlier stages (at around 170 and 250 ms; e.g. Geng, Zhang, Li, Tao, & Xu, 2012; Keyes, Brady, Reilly, & Foxe, 2010; Serino et al., 2015), that is, at time points overlapping with tactile P200.

That said, it is possible that the feeling of estrangement from one's self experienced in depersonalisation is associated with an attenuation of processes related to self-other distinction, such as those measured in P200 time ranges, in addition to its links with processes at earlier, implicit stages (P45). In depersonalisation, weak self-relatedness may cause one to represent one's bodily self somewhat more like a stranger. The previously discussed increase in

body ownership illusions found for individuals with high levels of depersonalisation (Katayama et al., 2009), and also in eating disorders (Eshkevari, Rieger, Longo, Haggard, & Treasure, 2011; Mussap & Salton, 2006), may link with this reduced relatedness to, and thus greater malleability of, one's bodily self, which characterises both of these groups. For depersonalised individuals, this may reduce the effectiveness of the processes related to self-other distinction (e.g. those measured over P200 in our study), without changing the explicit ability to identify oneself.

Alternatively, it is possible that our P200 effects indicate a compensatory mechanism, which enhances the mirroring of self-related events at later stages when mirroring at early, implicit stages (P45) is impaired. This would again suggest that mirroring processes at early and later stages are not independent but can operate together. As the P200 is sensitive to cognitive processes such as guessing, working memory, and attention to motivationally relevant stimuli (e.g. Lefebvre et al., 2005; McDonough, Warren, & Don, 1992; Montoya & Sitges, 2006), it is conceivable that observers with high levels of depersonalisation may use cognitive strategies to attempt to compensate for deficiencies in implicit mirroring of self-related stimuli. Visual and auditory ERP studies of dysthymic and schizophrenic patients have suggested that deficits at early stages of processing may be compensated at later stages (Kayser, Bruder, Tenke, Stuart, Amador, & Gorman, 2001; Wood, Potts, Hall, Ulanday, & Netsiri, 2006; Yee, Deldin, & Miller, 1992). For example, Kayser et al. (2001) reported reduced auditory N1 and N2 amplitudes, together with a preserved P300, in

schizophrenic patients relative to control participants in auditory oddball tasks. As P300 is typically reduced in schizophrenic patients (e.g. Mathalon, Ford, & Pfefferbaum, 2000), Kayser et al. proposed that the preserved P300 in their study may reflect increased cognitive effort to compensate for deficient allocation of attentional resources at earlier stages. With regard to our study, it may be argued that tactile mirroring at later, more cognitive processing stages is typically smaller for self-related stimuli than for other-related stimuli due to the relative ease with which one's own viewed bodily events may be mapped onto existing representations, reflected over P200 by our participants with low levels of depersonalisation. Then, participants with depersonalisation symptoms may have exhibited relatively stronger P200 mirroring effects for self-related stimuli because they compensated for their absence over P45 at this, later processing stage. There is little comprehensive knowledge of the covariation or co-operation across processing stages in the somatosensory system to substantiate this interpretation at present. However, Bolton & Staines (2011) have recently suggested that ineffective attentional suppression at early (P100) stages may be compensated by attentional mechanisms operating at longer latencies (200-350 ms). It may thus be possible that in non-clinical observers who experience symptoms of depersonalisation, compensatory mirroring processes for self-related events at P200 latencies make up for reduced mirroring processes at P45 latencies.

Compensatory mechanisms are an attractive way to interpret our P200 effects also because they may explain why depersonalisation occurs along a

continuum. One might speculate that mirroring mechanisms in the context of self-related information may be deficient at early, implicit levels of processing for many observers, including those who are at risk of developing depersonalisation, eating disorders, schizophrenia or other conditions characterised by weakened relatedness to the bodily self. For most, compensatory mechanisms like the one proposed above may ensure that these deficiencies do not reach phenomenological awareness. With severe stress, trauma, or drug use, however, the ability to compensate may break down, and result in the experience of depersonalisation symptoms (e.g. Simeon, 2004). Chronic depersonalisation may be the result of more fundamental impairments in the implicit mirroring of self-related information, and / or an impaired ability to recruit compensatory mechanisms at higher levels of processing. While these suggestions are highly speculative, it is clear that a better understanding of the processes involved in the experience of feeling disconnected from one's bodily self could help to develop targeted interventions for chronic depersonalisation, which is considered to be a debilitating illness that is difficult to treat with traditional therapeutic methods.

Future research should attempt to resolve the relative contributions of self-other related processing and compensatory operations to the reported P200 differences in mirroring self- and other-related events. It is possible that weak self-relatedness causes observers with depersonalisation symptoms to represent viewed touch on their own body somewhat like touch on a stranger's body, while compensatory mechanisms operate at the same processing stage to ensure that

inadequacies in earlier mirroring for self-related bodily events are redressed before they reach phenomenological awareness.

4.3 Conclusions

The present study has shown how tactile mirroring for highly self-related information (touch on one's own face) unfolds over time, and how it differs from mirroring for other-related information (touch on a stranger's face). Tactile mirroring consists of both early, implicit and late, cognitive processes, with implicit processes playing a larger role in mirroring self-related events, while later cognitive processes are more important in mirroring other-related events. We suggest that early and later stages of mirroring operate together to enable the simulation of self- and other-related bodily events in the same fronto-parietal networks at distinctive times and in distinctive ways.

Our study is also, to the best of our knowledge, the first demonstration of how inter-individual differences in the subjective sense of bodily self may relate to mirroring processes. We have shown for the first time that depersonalisation is associated with altered mirroring for highly self-related information, and that these differences occur at both early and later stages of processing. Further research should address the question whether the differences related to depersonalisation are specific to mirroring mechanisms, or affect the processing of self-related information in general (see Ketay et al., 2014), as well as whether they are associated with abnormal activity in the fronto-parietal networks associated with mirroring self-related bodily events (e.g. Cardini et al., 2011; Uddin et al., 2005, 2006, 2007).

We speculate that the abnormalities related to depersonalisation may be based on a lack of mirroring interactions in early childhood. Several recent papers culminated in the idea that mirroring experiences in early life - the process of moving and being moved by others, both physically and affectively - give rise to our sense of bodily self (e.g. Gallese & Sinigaglia, 2010; Legrand, 2006). This bodily self forms the core of other forms of self-consciousness, from body ownership to the sense of agency and the ability to mentalise (e.g. Fonagy et al., 2007; Gallese & Sinigaglia, 2010; Markova & Legerstee, 2006; Stern, 1995). It may be expected that in cases where the primary caregiver mirrors the child inadequately, i.e. adjusts insufficiently to the child's emotions, the child is unable to develop an authentic self (e.g. Winnicott, 1960; see also Fonagy, Gergely & Jurist, 2004), because she cannot construct bodily self-consciousness in the first instance, and the higher-level, cognitive representations of the self in the second. Depersonalisation could be a potential consequence of such developmental experiences. In line with this speculation, studies show that depersonalisation is specifically associated with *emotional* neglect and maltreatment in childhood (Simeon, Guralnik, Schmeidler, Sirof, & Knutelska, 2001; Michal, Beutel, Jordan, Zimmermann, Wolters, & Heidenreich, 2007). Understanding the processes that give rise to the estranged sense of bodily self in depersonalisation offers a chance to amend them in the therapeutic context.

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Figure captions

Figure 1. Schematics of the trial design showing two example trials (other no-touch and self touch) and their component event durations. During each trial the pencil appeared to move upward either next to the face (no-touch conditions) or against the face (touch conditions), and each trials also presented a tactile stimulus to the observer's own cheek ('200-ms tactile stimulus'). ITI = inter-trial interval. Consent for the use of these images was obtained from participants.

Figure 2. Voltage maps for time windows of somatosensory (maps 1-4) and frontal (map 5) components, with electrodes of interest highlighted (see text). For P100 (map 3), positivities were maximal over frontal-polar sites, while the somatosensory component P100 itself was found at central-parietal sites including those of interest. Maps do not show some frontal and lateral electrodes where no clear ERPs were visible.

Figure 3. SEPs in response to tactile stimuli for participants with low levels of depersonalisation observing touch (thick line) or no-touch (thin line) on their own face (left panel) or another person's face (right panel). SEPs are shown for components P45 and N80 at a cluster of central-parietal electrodes located over somatosensory cortex (average of contralateral C3/4, CP3/4 and CP5/6) (upper panels), and for component P200 at a frontal electrode cluster (average of bilateral FC1/2, FC3/4, FC5/6, and FCZ) (lower panels).

Figure 4. SEPs in response to tactile stimuli for participants with high levels of depersonalisation observing touch (thick line) or no-touch (thin line) on their own face (left panel) or another person's face (right panel). SEPs are shown for components P45 and N80 at a cluster of central-parietal electrodes located over somatosensory cortex (average of contralateral C3/4, CP3/4 and CP5/6) (upper panels), and for component P200 at a frontal electrode cluster (average of bilateral FC1/2, FC3/4, FC5/6, and FCZ) (lower panels).

Figure 5. Illustrates differences in tactile mirroring ("observed touch effects") for self-face (dark grey bars) and other-face (light grey bars) observation between participants with low levels ("Low-DP group") and high levels of depersonalisation ("High-DP group") over P45 (left panel) and P200 (right panel) components of the SEP wave. Observed touch effects are SEP differences between observing touch and no-touch, such that positive values indicate a greater positivity for observed touch than for observed no-touch. Asterisks indicate significant interaction effects (see text).

Figure 1

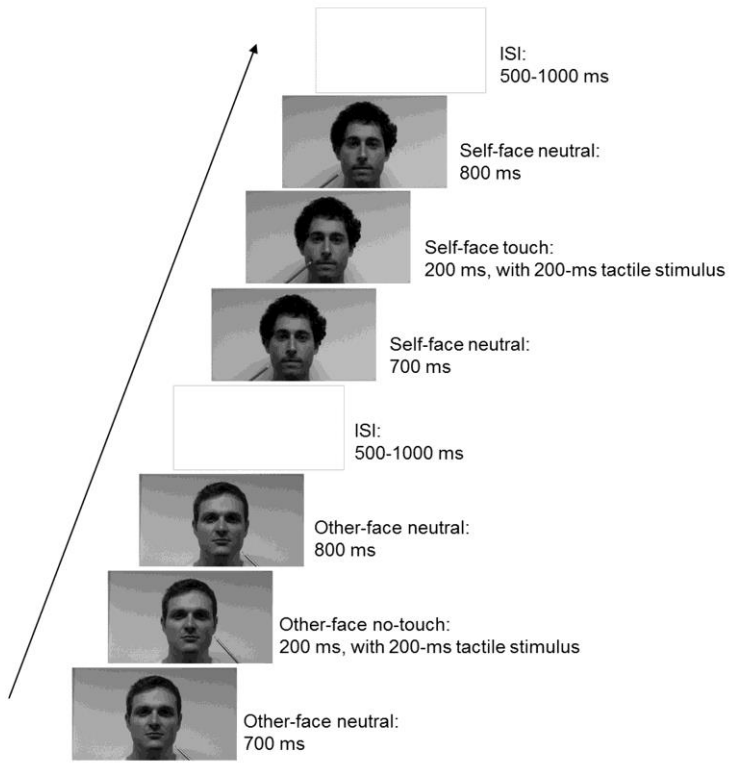


Figure 2

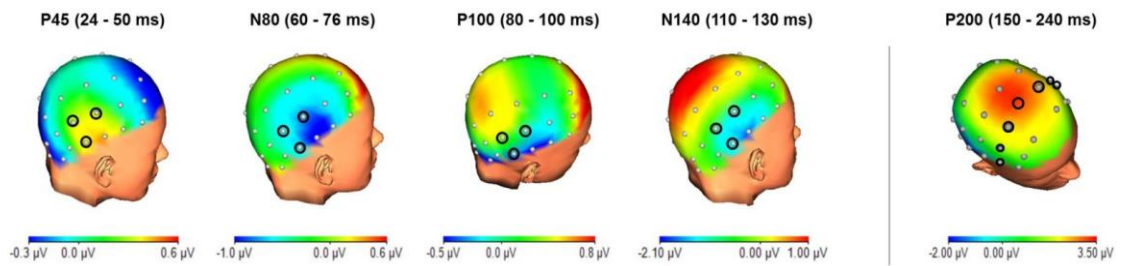


Figure 3

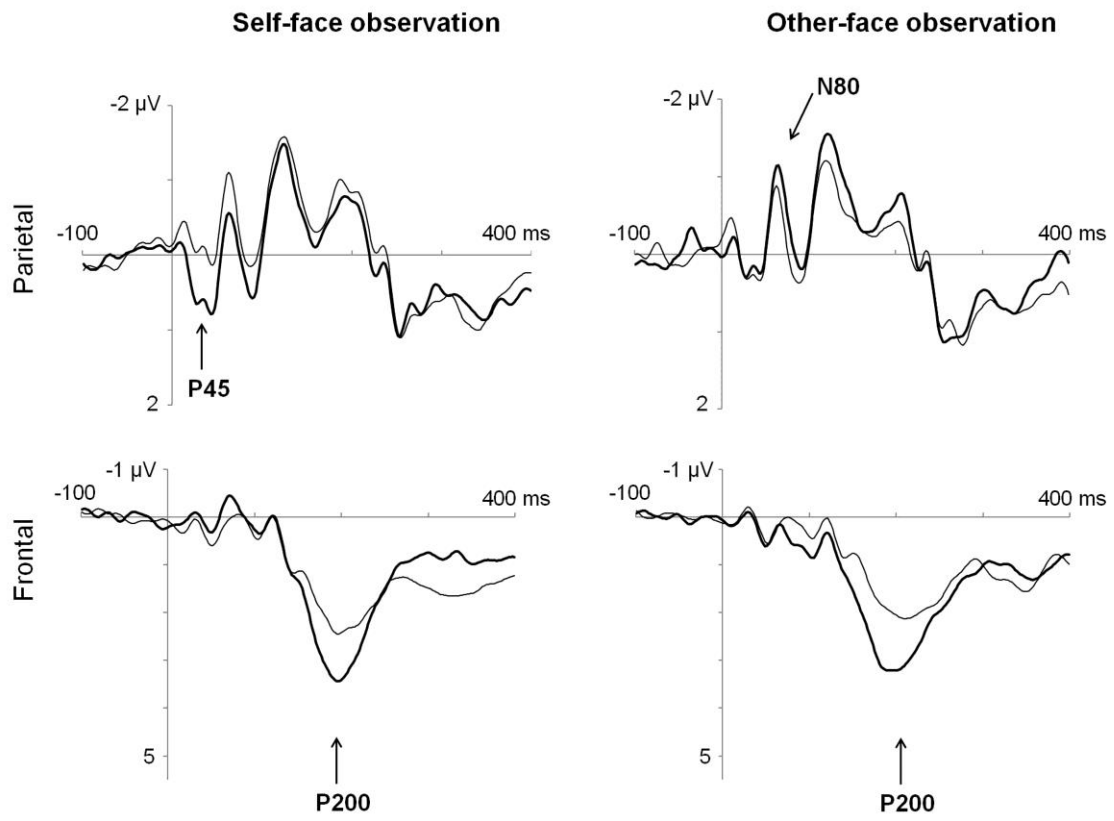


Figure 4

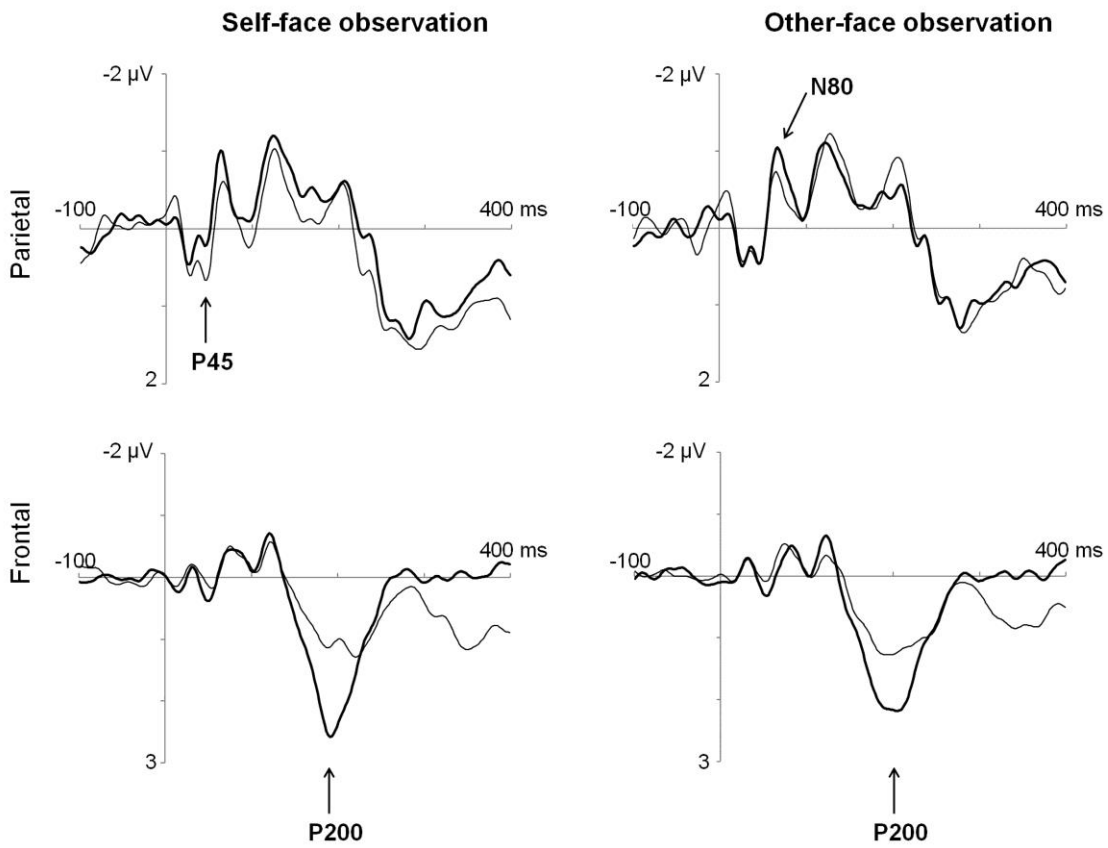


Figure 5

