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Multisensory Stimulation Modulates Perceptual and Post-perceptual Face Representations: Evidence from Event-Related Potentials.

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Abstract

Seeing a face being touched in spatial and temporal synchrony with the own face produces a bias in self-recognition, whereby the other face becomes more likely to be perceived as the self. The present study employed event-related potentials to explore whether this enfacement effect reflects initial face encoding, enhanced distinctiveness of the enfaced face, modified self-identity representations, or even later processing stages that are associated with the emotional processing of faces. Participants were stroked in synchrony or asynchrony with unfamiliar faces they observed on a monitor in front of them, in a situation approximating a mirror image. Subsequently, ERPs were recorded during the presentation of (i) a previously synchronously stimulated face, (ii) an asynchronously stimulated face, (iii) observers' own face, (iv) filler faces and (v) a to-be-detected target face, which required a response. Observers reported a consistent enfacement illusion after synchronous stimulation. Importantly, the synchronously stimulated face elicited more prominent N170 and P200 responses than the asynchronously stimulated face. By contrast, similar N250 and P300 responses were observed in these conditions. These results suggest that enfacement modulates early neural correlates of face encoding and facial prototypicality, rather than identity self-representations and associated emotional processes.

Keywords: Multisensory stimulation, enfacement, body ownership, own face recognition

Introduction

Faces are a distinctive feature of human appearance and important for the recognition of others. However, the face is also considered the signature of the *self* (McNeill, 1998). Self-recognition has been taken as evidence of self-awareness (Devue & Brédart, 2011) and of the existence of the self as someone different from others (Zahavi & Roepstorff, 2011). However, rather little is still known about the process of how internal visual representations of the own face are created and updated. The current study explored this question with event-related potentials (ERPs).

It has been traditionally assumed that visual representations of the own face are stable (see, e.g., Miyakoshi, Kanayama, Nomura, Iidaka, & Ohira, 2008; Porciello, Holmes, Liuzza, Crostella, Aglioti, & Bufalari, 2014). However, recent research suggests that this representation is flexible and constantly updated (see, e.g., Estudillo & Bindemann, 2017a; Maister, Tsiakkas, & Tsakiris, 2013; Sforza, Bufalari, Haggard, & Aglioti, 2010; Tajadura-Jiménez, Grehl, & Tsakiris, 2012; Tsakiris, 2008). As a consequence, it appears that the cognitive representation of the own face can be *contaminated* by other facial identities. To illustrate, when observers are stroked in synchrony with an unfamiliar face, they subsequently tend to perceive the other face as their own (Tajadura-Jiménez et al., 2012; Tsakiris, 2008). This bias in self-recognition is not obtained when both faces are stroked in asynchrony (i.e. when there is a delay between the strokes of the other and one's own face). The perceptual effect is accompanied by a phenomenological illusion that the other face *belongs* to the observer. This 'enfacement effect' (Sforza et al., 2010) has been replicated with morphed (Tsakiris, 2008), familiar (Sforza et al., 2010) and other-race faces (Bufalari, Lenggenhager, Porciello, Serra Holmes, & Aglioti, 2014; Estudillo & Bindemann, 2016; Fini, Cardini, Tajadura-Jiménez, Serino, & Tsakiris, 2013) and suggests that the representation of our own face is updated as consequence of multisensory input.

One question that arises refers to the cognitive locus of the enfacement effect. According to different models of face processing (e.g., Breen, Caine, & Coltheart, 2001; Bruce & Young, 1986; Valentine, 1991), this effect might reflect four different processes. Firstly, it might reflect the early perceptual processing that controls the structural encoding of a face (see Breen et al., 2001; Bruce & Young, 1986; Schweinberger & Burton, 2003). In support of this interpretation, an fMRI study has shown activation of the inferior occipital gyrus (IOG) while observers experienced the enfacement illusion (Apps, Tajadura-Jiménez, Sereno, Blanke, & Tsakiris, 2013). This brain structure has been linked to structural encoding of faces (Haxby, Hoffman, & Gobbini, 2000) and also includes the occipital face area (OFA), which is involved in the processing of individual facial features but not in the representation of identity (see Barton, 2008; Kanwisher & Barton, 2011).

Secondly, the enfacement effect might reflect an increased distinctiveness of the enfaced face compared to non-enfaced faces (see Valentine, 1991). Recent evidence also supports this argument. For example, after enfacing a face, observers accept more features of the enfaced face as the own face (see Tajadura-Jiménez et al., 2012), which could suggest that the enfacement illusion increases an enfaced face´s distinctiveness, thus reducing differences in distinctiveness between the own and the enfaced face.

Alternatively, the enfacement effect could also reflect a pre-semantic match of the visual stimulus to a stored identity representation (i.e., a “Face Recognition Unit”, FRU; see Breen et al., 2001; Bruce & Young, 1986; Schweinberger & Burton, 2003). Some evidence also supports this view. For example, psychometric approaches have shown that the main component of the enfacement illusion reflects the identification of another face as the own (Tajadura-Jiménez, Longo, Coleman, & Tsakiris, 2012b). In addition, the fact that the enfacement illusion affects performance in self-recognition tasks could also be considered as evidence of an identity locus in the process of updating the own face representation (e.g., e.g., Tajadura-Jiménez et al., 2012a; Tsakiris, 2008).

Lastly, the enfacement effect could be indicative of an affective evaluation of the face (i.e., arousal response) that mediates recognition (see Breen et al., 2001; Schweinberger & Burton, 2003). Some research also supports this hypothesis. For example, familiar faces produce changes of autonomic physiological responses, such as electrodermal activity (see, e.g., Damasio, Tranel & Damasio, 1990; Herzmann, Schweinberger, Sommer, & Jentzsch, 2004). These changes are considered to reflect the mediation of an arousal emotional response to that face (Damasio et al., 1990; Schweinberger & Burton, 2003). Interestingly, Tajadura-Jiménez and colleagues (Tajadura-Jiménez et al., 2012a) also showed that these physiological changes toward an enfaced face are higher during synchronous than asynchronous multi-sensory facial stimulation. In addition, it has been found that the level of positive perception of the enfaced face is positively related to the strength of the enfacement illusion (Bufalari et al, 2014; Paladino, Mazzurega, Pavani, & Schubert., 2010; Sforza et al., 2010).

The present study investigated directly which of these processes the enfacement illusion reflects by using ERPs. This technique has been used widely to explore the time course and test models of face processing (see, e.g., Eimer, 2011; Schweinberger, 2011), and has led to the identification of several face-related ERP components (for a review, see Schweinberger, 2011). Here, we focus on four components that reflect different stages of face processing. The N170 is a negative deflection over occipito-temporal sites approximately 170 ms after stimulus onset. It is enhanced in response to faces compared to non-face objects (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Eimer, 2000, 2011) and is considered to reflect early perceptual stages of face processing which precede identity recognition (Bruce & Young, 1986; Eimer, 2000, 2011). However, there is also evidence that this component is modulated by "self-information", as it is more negative for the own face, compared to familiar and unfamiliar faces (e.g., Caharel et al., 2002; Keyes, Brady, Reilly, & Foxe, 2010). Moreover, a recent study suggests that the N170 might reflect the perceptual locus of the enfacement effect, as its amplitude is enhanced for virtual avatar faces after these have mimicked observers' own head movements (Serino et al., 2015). However, these findings require further investigation as a familiarity advantage for the N170 is not consistently found (see, e.g., Sui, Zhu, & Han, 2006; Tanaka, Curran, Porterfield, & Collins, 2006).

A subsequent component that has been related to face distinctiveness is the occipito-temporal P200 (e.g., Halit, de Haan, & Johnson, 2000; see also Estudillo, 2017; Schweinberger & Neumann, 2016). This component consists of a positive deflection that peaks between 200 and 250 ms and is larger for less distinctive (more typical) faces. For example, it has been found that other-race faces elicit a less positive P200 than own race faces (e.g., Stahl, Wiese, & Schweinberger, 2008). This finding may reflect that other-race faces are more distinctive than own-race faces in terms of their second-order spatial configuration (see Schweinberger & Neumann, 2016). Additionally, research has shown less positive P200 amplitudes for the own face compared to personally familiar faces and strangers' faces (Keyes et al., 2010). This reduced amplitude for own face seems to reflect the *uniqueness* of the own face compared to other faces (for behavioural results supporting this argument, see e.g., Tong & Nakayama, 1999).

The N250 component has been linked more specifically to the activation of identity representations (Kaufmann, Schweinberger, & Burton, 2009; Schweinberger, Pickering, Jentzsch, Burton, & Kaufmann, 2002; Schweinberger, 2011; Tanaka et al., 2006). This component consists of a negative deflection that peaks around 250 ms after the presentation of a known face at inferior-temporal electrodes. This deflection is larger for familiar compared to unfamiliar faces and has therefore been related to the activation of stored facial identity representations (see Schweinberger, 2011). In addition, research has shown that this component is more negative for the own face compared to unfamiliar faces (Pierce et al., 2011; Tanaka et al., 2006). Tanaka and colleagues (Tanaka et al., 2006) found, for example, that the N250 was enhanced for the own face compared to an unfamiliar target in the first half of an experiment. Following learning in the second half, however, the N250 was similar for both types of faces. The above findings suggest that the N250 reflects two different indexes of facial memory. One index corresponds to pre-existing familiar face representations, such as the own face. The other reflects newly acquired face representations, such as the target face. Furthermore, the increase of N250 amplitude during experimental familiarization is not restricted to the repetition of identical images, but generalises across different photographs of the same face, which indicates further that this component is related to person identification (Kaufmann et al., 2009).

Finally, the P300 component is a positive deflection at centro-parietal sites, which peaks 300 to 600 ms after stimulus onset. This component is modulated by the arousal or emotional saliency, as it is larger for stimuli with affective connotations (see, e.g., Carretié, Iglesias, Garcia, & Ballesteros, 1997). This component is also larger for the own face compared to unfamiliar faces (Ninomiya, Onitsuka, Chen, Sato, & Tashiro, 2007). Some prosopagnosic patients also show a preserved P300 response after the presentation of a familiar face (Bobes et al., 2004; Renault, Signoret, Debruille, Breton, & Bolgert, 1988), which indicates that this component may also reflect covert face recognition (Bobes et al., 2004; see also Meijer, Smulders, Merckelbach, & Wolf, 2007).

The fact that the own face has been shown to modulate ERP components in the early perceptual stages of face processing (N170), the post-perceptual stage of face distinctiveness (P200), the activation of facial identity (N250), and the emotional response to stimuli (P300) suggests that these components can be used to investigate the neural correlates and, by inference, the process/processes the enfacement illusion reflect. The present study explored this question directly with a task that has been used previously to track the learning of novel facial identities (see Pierce et al., 2011; Tanaka et al., 2006). In an initial stimulation stage, observers were exposed to blocks of synchronous or asynchronous stimulation. ERPs were then recorded during a subsequent detection task in which they were presented with pictures of their own face (OF), (previously) synchronously and asynchronously stimulated faces (SF and AF, respectively), two filler faces (FF), and a target face (TF), which was the only face that required an overt response. In the context of our experiment, this target detection task presents three advantages. (1) This task is highly sensitive to the recognition of faces that require a response (i.e., TF) and faces for which a response is not required (i.e., SF; see Partneky, Towler, & Eimer, 2015; Pierce et al., 2011; Tanaka et al., 2006). (2) In addition to the comparison of the asynchronously stimulated face (AS) and the own face (OF), the target detection task allows the comparison of the synchronously stimulated face (SF) with a recently learned face (i.e., TF). (3) Finally, this task also allows tracking of the course of self-face representation updating, via a comparison of whether this representation is updated after minimal exposure to synchronous multisensory stimulation (i.e., first half of the experiment) or after more extensive exposure (i.e., second half of the experiment; see Pierce et al., 2011; Tanaka et al., 2006).

We reasoned that if enfacement affects early perceptual encoding, then the N170 elicited by a synchronously stimulated face should be larger compared to that elicited by an asynchronous stimulated face, and similar to that the own face. If the enfacement effect increases the distinctiveness of the synchronously stimulated face, then this face should elicit less positive P200 compared to the asynchronously stimulated face. If, on the other hand, enfacement causes the updating of identity representations or emotional arousal responses to an enfaced face, then these effects should be observed at the N250 and the P300, respectively. Following Tanaka et al. (2006), separate analyses for the first and second halves of the current task should also allow to determine when these effects emerge over the course of the experiment. In line with previous research (e.g., see Tanaka et al., 2006; Pierce et al., 2011), we expected that response times to the target face should be shorter in the second half of the experiment than in the first half of the experiment.

Methods

Participants

This experiment was approved by the Ethics Committee, Department of Psychology, Friedrich Schiller University of Jena. Twenty-eight Caucasian students (10 females) from the Friedrich Schiller University of Jena, with a mean age of 23 years (*SD* = 2.8), participated in this study. All provided informed consent, reported normal or corrected-to-normal vision, and received course credits or a small payment for participation.

Stimuli

To generate the stimuli for the multisensory stimulation stage, videos footage of four Caucasian models (two males and two females) were recorded with a camcorder. For each observer, of the two same-sex model videos, with one each randomly assigned to the SF and AF conditions (and with both faces being of the same sex and similar age), respectively. In this footage, the models looked straight at the camera with a neutral expression while their left cheek was stroked with a cotton bud at two-second intervals for two minutes. An additional face photograph was taken of each model for the target detection task (see below). In the videos and the photographs, the models always wore a white EEG cap.

Face photographs of six additional identities with a white EEG cap were also taken (three males and three females) with a digital camera. In the experiment, these photographs were matched to the sex of each observer, with one of these serving as the target and the other two as filler faces. A posteriori analysis showed that all these faces were rated as similarly attractive[1].

Finally, a photograph of each observer wearing a white EEG cap was also taken prior the experiment for use in the own face condition. In total, observers therefore saw six face identities of the same sex and age: their own face (OF), a synchronously stimulated face (SF; i.e., observers received synchronous stimulation with this face), an asynchronously stimulated face (AF, i.e., observers received asynchronous stimulation with this face), a target face (TF; i.e., observers were asked to respond when this face was presented) and two filler faces (FF). The pictures measured approximately 350 (W)

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[1] There is evidence that the level of perceived attractiveness is associated with the size of the enfacement illusion (e.g., Sforza et al., 2010). To rule out possible attractiveness effects on our results, 10 independent observers (5 female) were asked to rate each face on a scale from 1 (very unattractive) to 5 (very attractive). For each sex, all faces were compared with each other. Results showed no differences in level of perceived attractiveness for female faces (all $ts \leq 1.86$, $ps \geq .09$) or male faces (all $ts \leq 1.10$, $ps \geq .29$)

x 470 (H) pixels (~ 7 x 9 degrees of visual angle) at a screen resolution of 72 ppi, and were presented on a black background. Examples are provided in Figure 1.

Procedure

Participants were seated at a distance of 100 cm from the screen, which was maintained with a chin-rest. Stimuli were displayed using E-Prime^{TM} 2.0.8.22 (Psychology Software Tools, Inc., Sharpsburg, PA) on a 16'' monitor with a screen resolution of 768 (H) x 1024 (W) pixels. The experiment consisted of four blocks, comprising two blocks for the synchronous condition and two for the asynchronous condition. Synchronous and asynchronous blocks were alternated. This resulted in two block sequences (i.e., ASAS or SASA), which were counterbalanced across observers. Apart from the own face, which differed by definition across all participants, all female observers saw the same set of female faces across blocks, and all male observers saw the same set of male faces across blocks. However, within each participant sex, the allocation of faces to experimental conditions (apart from the own-face) was counterbalanced across participants.

Each block included two stimulation and two test phases. In each block, observers first saw a two-minute video of a model being stroked with a cotton bud on the cheek. At the same time, participants were touched with an identical cotton bud on the specular congruent location in synchrony (synchronous condition) or in asynchrony (with a delay of one second) with the model (asynchronous stimulation). Immediately after the video ended, the observers' subjective experience during the stimulation stage was assessed with a German translation of the statement "I felt I was looking at my own face" ("Ich hatte das Gefühl, dass das Video mein eigenes Gesicht zeigte"). This statement has been used repeatedly in previous work to measure the enfacement illusion (e.g., Apps et al., 2013; Tajadura-Jiménez et al., 2012b). Observers rated their level of agreement with this statement on a 7-point Likert scale, ranging from "strongly disagree" to "strongly agree".

After stimulation, participants were presented with the target face and a fictitious name ("Anna" for female targets and "Hans" for male targets) onscreen, which they were asked to memorize. During the recoding of EEG, they were then asked to monitor a sequence of faces and press the "SPACE" bar as fast as possible every time the target face was presented. Experimental trials started with a fixation cross for 500 ms, which was followed by a face for 1500 ms. Feedback was given if observers mistakenly responded to a non-target face (e.g., "This was not Anna!"), or when they failed to respond to the target face (e.g., "This was Anna!"). The feedback display was presented for 500 ms. No feedback was given for correct responses and correct omissions (i.e. no response to non-target faces) and a blank screen was presented for 500 ms instead.

Each of the six different face identities (OF, SF, AF, TF, and the two FF) was presented 30 times per block, resulting in a total of 180 trials. Observers took a break after 90 trials. After this break, the stimulation, rating and test phases were repeated once. Therefore, each block consisted of a total of two stimulation, rating and test phases, respectively.

The structure of the remaining blocks was identical to the first block but the type of stimulation (i.e., synchronous vs. asynchronous) was alternated (i.e., if observers received synchronous stimulation in the first and third blocks, asynchronous stimulation was administered in the second block and fourth block, and vice versa). The order of these conditions was counterbalanced across participants (i.e., SASA and ASAS).

EEG/ERP methods

EEG data were recorded with sintered Ag/AgCl electrodes mounted in an electrode cap (EasyCap™, Herrsching-Breitbrunn, Germany) using SynAmps amplifiers (NeuroScan Labs, Sterling, VA). Electrodes were arranged according to the extended 10/20 system at the scalp positions Fz, Cz, Pz, Iz, Fp1, Fp2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T7, T8, P7, P8, FT9, FT10, P9, P10, PO9, PO10, F9, F10, F9', F10', TP9 and TP10. Cz served as initial common reference and a forehead electrode (AFz) served as ground. Impedances were kept below 10 kΩ and were typically below 5 kΩ. The horizontal electrooculogram (EOG) was recorded from F9′ and F10′ at the outer canthi of both eyes. The vertical EOG was monitored bipolarly from electrodes above and below the right eye. Signals were assessed with AC (0.05–100 Hz, −6 dB attenuation, 12 dB/octave) and sampled at 500 Hz. Offline, ocular artefacts were automatically corrected using BESA ™ 5.1.8.10. Epochs were generated, lasting 1200 ms, including a 200 ms pre-stimulus baseline. Only trials with correct responses were analysed. Trials contaminated by non-ocular artefacts were rejected from further analysis using the BESA™ artefact rejection tool (amplitude threshold 100µV, gradient criterion 75µV). Trials were averaged separately for each channel and experimental condition. Averaged ERPs were low-pass filtered at 20 Hz (zero phase shift), and recalculated to average reference, excluding vertical and horizontal EOG channels. ERPs were quantified using mean amplitudes for the occipito-temporal N170 (155 - 175 ms) and P200 (199 - 219 ms), the inferior-temporal N250 (250 - 360 ms), and the P300 (370 - 570 ms), all relative to a 200 ms pre-stimulus baseline. Time-windows for these components were selected in accordance with distinct peaks identified in the grand mean waveforms. Effects were quantified at electrodes of interest, which were selected based on the maxima of a particular component in grand means and on previous research (Kaufmann et al., 2009; Schweinberger et al., 2002). Accordingly, N170 and P200 were assessed at P7, P8, P9, P10, PO9 and PO10, the N250 was captured at P7, P8, P9 and P10, and the P300 was measured at C3, C4, P3, P4 and Cz.

Results[2]

Self-report and Screening Criteria

Only participants who reported an enfacement illusion, by recording an overall higher enfacement score after synchronous than asynchronous stimulation, were included in the analysis (N = 18). Note that a similar approach has been applied previously in body ownership illusion studies involving hands (e.g., Kaneko et al., 2015; Schaefer, Konczak, Heinze, & Rotte, 2013) and faces (e.g., Apps et al., 2013). Observers reported a mean score of 3.08 (*SD* = 1.25) to the statement "I felt I was looking at my own face" after synchronous stimulation and a lower mean, of 1.72 (*SD* = 0.84), after asynchronous stimulation, $t(17) = 7.34$, $p < .001$. This indicates that participants perceived the other face as more similar to their own face in the synchronous compared to the asynchronous condition[3].

Behavioural Results

In the target detection task, accuracy was at ceiling level (> 99% correct across conditions). Reaction times (RTs) were analysed for hits only, as responses were only required to the target face. When necessary in this and all subsequently reported ANOVAS, epsilon corrections for heterogeneity of covariances were performed according to the Huynh-Feldt procedure. A 2 (stimulation: synchronous vs.

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[2] For access to data, see supplementary material.

[3] Note that when the same analysis was conducted on the entire sample, the same pattern of results was obtained (Mean Sync = 2.57, Mean Async = 1.78; $t(27) = 3.53$, $p < .001$). Importantly, these scores were comparable (e.g., Tajadura-Jiménez et al., 2012a; Tajadura-Jiménez et al., 2012b) or even higher (e.g., Sforza et al., 2012) than those reported in other enfacement studies.

asynchronous) x 2 (time: first half vs. second half of experiment) repeated-measures ANOVA was conducted. Observers were faster to respond to the target face in the asynchronous condition (*mean of medians* = 570 ms, *SD* = 14 ms) than in the synchronous condition (*mean of medians* = 586 ms, *SD* = 14 ms), $F(1,77) = 4.79$, $p = .043$, $\eta_p^2 = .22$[4]. Responses were also faster in the second half of the experiment (*mean of medians* = 562 ms, *SD* = 15 ms) than the first (*mean of medians* = 595 ms, *SD* = 14 ms), $F(1,17) = 15.53$, $p < .001$, $\eta_p^2 = .48$. The interaction between these factors was not significant, $F(1,17) = 2.09$, $p = .166$, $\eta_p^2 = .11$.

ERP Results

ERP amplitudes were analysed with repeated-measures ANOVAs of the factors stimulation (synchronous vs. asynchronous), time (first vs. second half of experiment) and face type (OF vs. SF vs. AF vs. TF vs. FF). Although two different filler faces were included in the task, ERP data for both faces were combined to obtain more stable results.

For the N170, P200 and N250 components, the factors hemisphere (left vs. right) and site (N170 and P200: P7/P8 vs. P9/P10 vs. PO9/PO10; N250: P7/P8 vs. P9/P10) were also included, whereas the factor electrode (C3 vs. C4 vs. P3 vs. P4 vs. CZ vs. PZ) was included for the P300. For brevity, main effects of face type and interactions with this factor are reported only when significant. To follow-up on main effect and interactions, planned comparisons involving the comparison between SF and the other faces were conducted. We performed planned comparisons, rather than multiple comparisons as, depending on the processes that the enfacement illusion affects, we

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[4] A deeper analysis of our data suggests that this effect seems to be driven by a participant who was particularly slow in the first synchronous block (775 ms) compared to the second synchronous block (641 ms) and both asynchronous blocks (first asynchronous block: 653 ms; second asynchronous block: 666 ms). When this participant was removed from the analysis, the main effect disappeared ($p = .080$).

predicted larger N170, N250 and P300 components or smaller P200 component for SF compared to AF and FF; and similar ERP responses for SF and OF and TF.

N170

The N170 for all conditions is illustrated in Figure 2. An ANOVA revealed a main effect of face type for the N170, $F(4,68) = 7.62$, $p < .001$, $\eta_p^2 = .30$. The main effect of face type was qualified by a two-way interaction with time, $F(4,68)$, = 3.72, $p = .009$, $\eta_p^2 = .18$. Visual inspection suggests that this interaction stems from larger N170 amplitudes for the SF and OF in the second half of the experiment (see Figure 3). This was confirmed by subsequent separate ANOVAs for the first and the second half of the experiment, which yielded main effects of face type for both times, $F(4,68) = 9.84$, $p < .001$, $\eta_p^2 = .36$ and $F(4,68) = 3.22$, $p = .015$, $\eta_p^2 = .15$, respectively. For the first half of the experiment, pair-wise comparison (LSD) revealed more negative amplitudes for SF compared to TF and FF, both $ps \leq .011$. In contrast, no differences were found between SF and OF or AF (see Figure 3 and Table 1). For the second half of the experiment, N170 amplitude for SF was more negative than for AF and FF, both $ps \leq .042$. Here, no differences were found between SF and OF or TF (see Table 1).

In sum, our results showed larger N170 amplitudes for the synchronously stimulated face compared to the asynchronously stimulated face in the second half of the experiment. Furthermore, N170 amplitudes were comparable for the synchronously stimulated face and the own-face.

P200

An ANOVA showed a main effect of face type, $F(4,68) = 17.20$, $p < .001$, $\eta_p^2 = .50$, which was further qualified by a two-way interaction with time, $F(4,68) = 3.38$, $p =$

.014, $\eta_p^2 = .16$. Visual inspection suggests that this interaction stems from less positive P200 amplitudes for the SF and OF in the second half of the experiment (see Figure 2 and 4). This was confirmed by subsequent separate ANOVAs for the first and the second half of the experiment, which yielded main effects of face type for both times, $F(4,68) = 14.87$, $p < .001$, $\eta_p^2 = .46$ and $F(4,68) = 16.09$, $p < .001$, $\eta_p^2 = .48$, respectively. For the first half of the experiment, pair-wise comparison (LSD) revealed a smaller P200 for SF compared to FF and a larger P200 compared to OF, both $ps \leq .015$. For the second half of the experiment, P200 was smaller for SF compared to AF and FF, both $ps \leq .032$. In addition, P200 amplitudes were larger for the own face than for SF, $p = .011$. A summary of all comparisons is shown in Table 2.

N250

For the N250, an ANOVA showed a main effect of face type, $F(4,68) = 20.92$, $p < .001$, $\eta_p^2 = .55$. Visual inspection suggests the most prominent differences between the OF and all other conditions (see Figure 2 and 5). The main effect of face type was further qualified by two-way interactions with hemisphere, $F(4,68) = 4.63$, $p = .002$, $\eta_p^2 = .21$, and time, $F(4,68) = 13.59$, $p < .001$, $\eta_p^2 = .44$. These interactions were tested further with separate ANOVAs with repeated measurements of face type for each hemisphere and time. The main effect of face type was significant at left, $F(4,68) = 12.27$, $p < .001$, $\eta_p^2 = .42$, and right hemispheric sites, $F(4,68) = 18.45$, $p < .001$, $\eta_p^2 = .52$, and both in the first, $F(4,68) = 15.53$, $p < .001$, $\eta_p^2 = .48$, and second half, $F(4,68) = 24.71$, $p < .001$, $\eta_p^2 = .59$. Visual inspections suggest larger N250 for the OF and TF, although in TF the larger amplitudes were more evident in the second half of the experiment. Planned pair-wise comparisons (LSD) focused on potential differences between SF and the other face types were conducted but, as can be seen in Table 3, none of these showed significant differences between the SF and the AF conditions.

In summary, there was no evidence for reliable differences in N250 between synchronously and asynchronously stimulated faces. In addition, N250 amplitudes largest for the own and the target face, although in the latter case this was only evident in the second half of the experiment (similar to Tanaka et al., 2006).

P300

An ANOVA with repeated measurements on electrode (C3, C4, P3, P4, Cz, Pz), time (first half vs. second half), stimulation (synchronously vs. asynchronously) and face type (SF vs. AF vs. TF vs. FF vs. OF) revealed a main effect of face type, $F(4,68) = 43.16$, $p < .001$, $\eta_p^2 = .72$, which was qualified by two-way interactions between face type and electrode, $F(20,340) = 15.69$, $p < .001$, $\eta_p^2 = .48$, and face type and time, $F(4,68) = 18.71$, $p < .001$, $\eta_p^2 = .52$. There was also a three-way interaction between face type, electrode and time, $F(20,340) = 1.73$, $p = .028$, $\eta_p^2 = .09$. Visual inspection suggests largest P300 amplitudes for own and target faces (see Figure 6 and 7).

The three-way interaction between face type, electrode and time was followed up by separate ANOVAs for each time point. These analyses revealed a main effect of face type for both the first and the second half of the experiment, both $Fs(4,68) \geq 36.93$, $ps < .001$, $\eta_p^2 \geq .69$. The main effect of face type was qualified by a two way interaction with electrodes in both halves of the experiment, $Fs(20,340) \geq 12.18$, $ps < .001$, $\eta_p^2 \geq .42$. The interaction of face type and electrode in both times was followed up by separate ANOVAs for each electrode and, in the case of significant main effects of face type, by pair-wise comparisons (LSD) between SF and the other conditions. These analyses revealed effects of face type for each electrode, all $Fs(4,68) \geq 17.84$, $ps < .001$,

$\eta s_p^2 \geq .51$. A summary of all comparisons is provided in Table 4. Overall, these data show that the own face and the target face consistently produced the largest P300 responses, whereas there was no evidence for differences in P300 between SF and AF conditions.

Discussion

We employed ERPs to investigate the processes that are affected by the enfacement illusion during face recognition. In line with other studies (see, e.g., Maister et al., 2013; Tajadura-Jiménez et al., 2012; Tsakiris, 2008), multisensory stimulation influenced observers' subjective experience of the enfacement illusion, such that they were more likely to report that the onscreen face felt like their own face after the synchronous condition (see footnote 1). This indicates that enfacement was successfully induced in those observers who were included in the ERP analysis. ERPs were then calculated for the target detection task. The N170 component, a marker of the early perceptual processing of faces (Eimer, 2000; Eimer, 2011), was enhanced for the synchronously stimulated face compared to the target face, but only in the first half of the experiment. In the second half of the experiment, the target face elicited a N170 comparable in amplitude to that of the synchronously stimulated face. It is possibly that extensive familiarity with the target face may have modulated the N170 ERP component (for familiarity effects on the N170, see, e.g., Jemel et al., 2005; Jemel, Schuller, & Goffaux, 2010; Jacques & Rossion, 2006; Caharel et al., 2009; Keyes et al., 2010, but see also Pierce et al., 2011; Sui et al., 2006; Tanaka et al., 2006 and below for further discussion). More interestingly, the N170 component was larger for the synchronously stimulated face compared to asynchronously stimulated faces. This effect was evident only in the second half of the experiment, which suggests that it emerges after multiple applications of multisensory stimulation. Finally, the N170 for synchronously stimulated faces did not differ from the N170 for observers' own face.

The P200 component, thought to reflect face typicality/distinctiveness (for a review, see Schweinberger & Neumann, 2016), was smaller for the own face compared to other faces. This may indicate that the own face is perceptually distinctive and more salient compared to other faces (e.g., Tong & Nakayama, 1999). Importantly, in the second half of the experiment only, the synchronously stimulated face also elicited a smaller P200 compared to the asynchronously stimulated face. This suggests that as the synchronously stimulated face becomes integrated in the own self-face representation after more extensive learning, perceived distinctiveness of this face increases in parallel.

In contrast to these early effects, the N250, a marker of the activation of facial identity (for a review, see Schweinberger, 2011) did not differ significantly between synchronously and asynchronously stimulated faces and filler faces. At the same time, the N250 was particularly prominent for the own face across the experiment; in the second part of the experiment only, a similarly prominent N250 was also elicited by the target face. This finding is in line with reports indicating that the N250 reflects the activation of pre-experimentally familiar face activation, such as the own face, and that it is sensitive to newly acquired facial representations (see Kaufmann et al., 2009; Pierce et al., 2011; Tanaka et al., 2006). This suggests that observers created and consolidated a representation of the target face during the course of the experiment.

Finally, the P300 component, which seems to mediate the emotional response to familiar faces (Bobes et al., 2004; Ninomiya et al., 1998), also demonstrated a general enhanced response to the own face. Again, however, the amplitude of this component became more similar for the target and the own faces in the second half of the experiment. In addition, synchronously stimulated faces evoked a larger P300 than filler faces, but no reliable differences were found between synchronously and asynchronously stimulated faces.

Overall, these results suggest that enfacement affects the early perceptual ERP markers of face processing (N170) and face distinctiveness (P200), but not subsequent recognition stages (N250), or later affective evaluations of the face (P300). These data support recent research on the updating of self-face representations, which has shown that mirror exposure to a virtual avatar subsequently elicits an enhanced N170 to the avatar’s face that is of comparable amplitude to that for the observers’ own faces (Serino et al., 2015). In addition, our results also reflect the importance of the P200 as a marker of face distinctiveness and indicate that as the synchronously stimulated face becomes integrated in the self-face representation, this face also becomes more distinctive compared to other faces.

In the present study, the enfacement modulation in the N170 and P200 was evident only in the second half of the experiment. The absence of an enfacement effect in the first part of the experiment might be explained by two related and non-exclusive reasons. It is possible that acquisition of a face as the own face during enfacement reflects a *gradual* process (Tajadura-Jiménez et al., 2012), the time course of which might be similar to that observed in unfamiliar face learning (Pierce et al., 2011; Tanaka et al., 2006). Studies of face matching indicate that this assimilating process would be even more difficult for the face processing system when different facial instances of the synchronously stimulated face are used in the stimulation stage and the test stage (see, e.g., Bruce, 1982; Estudillo & Bindemann, 2014; for a review, see Burton, 2013), as was the case in the present study.

Additionally, it is possible that the effects of synchronous stimulation are short-lived and dependent on *constant* stimulation, and may therefore start to decay when the

SF is presented in absence of stimulation (see Ehrsson et al., 2010; Estudillo & Bindemann, 2017b), as was the case during the current target detection task. Under these circumstances, reactivating the changes in the own face representation as a consequence of multisensory stimulation might require more extensive stimulation with the SF. In the context of our experiment, no stimulation was administered to the SF during an asynchronous block, and any changes in the representation of observers' own faces therefore might have decayed during this block, thus reducing the overall effect of synchronous stimulation. At the end of the second half of the experiment, observers had already received extensive stimulation with the SF, so attenuation of observers' own face representation by asynchronous stimulation would be reduced, which could explain why the effects of multisensory stimulation are more evident in the second half of the experiment. Although this explanation is tentative, it seems to be supported by clinical reports which suggest that the sense of body ownership over denied limbs can be reinstated by extensive multisensory stimulation (see, e.g., D'Imperio, Tomelleri, Moretto, Moro, 2017).

Our results also converge with previous findings showing larger N170 and more negative P200 for the own face compared to other familiar and unfamiliar faces (e.g., Caharel et al., 2002; Keyes et al., 2010). Although the N170 has is often found to be insensitive to face familiarity (e.g., Eimer, 2000, 2011), several studies reported familiarity effects in the N170 component (see, e.g., Jemel et al., 2005; Jemel, Schuller, & Goffaux, 2010; Jacques & Rossion, 2006; Kovacs et al., 2006; Caharel et al., 2009; Keyes et al., 2010). In our study, face familiarity effects on the N170 were evident for three different faces: the own face, the synchronously stimulated face and the target face. These effects, which were more evident in the second half of the experiment, converge with those previous studies showing familiarity effects on the N170 component. However, we are cautious about this interpretation, as some authors have also suggested that familiarity effects on the N170 could be artefacts reflecting factors such as the number of face identities and the cognitive task employed (see Pierce et al., 2011).

The P200 has been reported to be reduced for familiar faces (e.g., Itz, Schweinberger, Schulz, & Kaufmann, 2014). Although this finding could be a by-product of increased perceived distinctiveness for familiar compared to unfamiliar faces (Faerber, Kaufmann, Leder, Martin, & Schweinberger, 2016), it is consistent with the learning effects observed in the P200 for the TF. Interestingly, in contrast to the SF, this learning effect was consequence of overt learning of the target face. It is remarkable that although no response was required to the synchronously stimulated face, P200 amplitudes reflect that this face was learnt to the level of the target face. This suggests that the effect of learning the SF was a consequence of synchronous stimulation.

Despite these novel findings on the neuronal correlates of the enfacement illusion, possible limitations of this study include that we did not quantify (1) perceptual similarity of the observers' faces and the faces seen during the induction of the enfacement illusion, (2) the exact temporal precision of synchronous and asynchronous stroking (although it should be noted that our procedure of manual stroking is quite common in bodily illusion studies), or (3) the perceived distinctiveness of faces after the experiment. Although more precise control of those factors in future studies might further enhance and refine the present findings, the successful induction of the enfacement illusion suggests that the present conditions ensured both sufficient overall visual form similarity, and a sufficiently large temporal integration window to compensate for possible small deviations from visual-tactile synchrony during the induction of the illusion (for the relative importance of such cues for illusions of self-representations, see Pritchard, Zopf, Polito, Kaplan, & Williams, 2016; Shimada, Fukada, & Hiraki, 2009).

In summary, in the current study observers experienced a phenomenological enfacement illusion that modulated early ERP components reflecting the perceptual processing of faces (N170) and perceived face distinctiveness (P200). By contrast, there was no evidence that the enfacement illusion modulated later representations of facial identity (N250), or emotional responses (P300). This indicates that enfacement mainly alters early perceptual face processing.

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FIGURE 1. Example photographs of male (left) and female (right) faces.

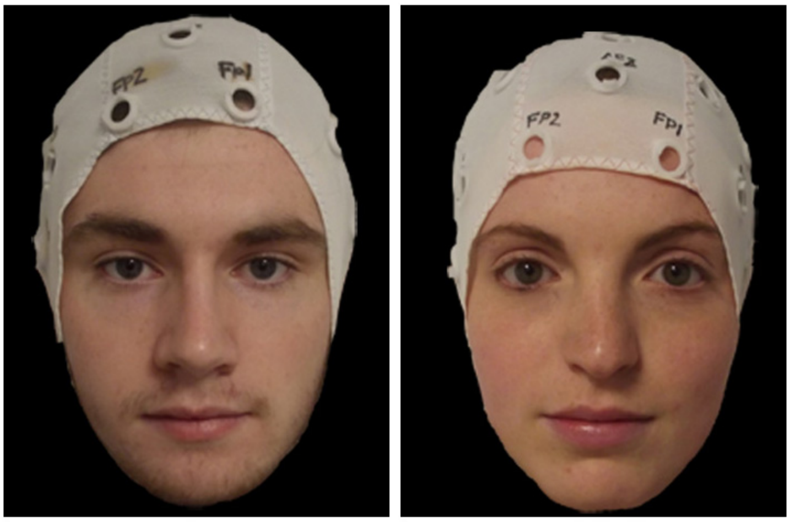

FIGURE 2. Grand-average ERPs for sites P9/P10 and PO9/PO10 and for the first half and the second half of the experiment illustrating the N170, P200 and N250. SF = Synchronous face; AF = Asynchronous face; TF = Target face; FF = Filler face; OF = Own face.

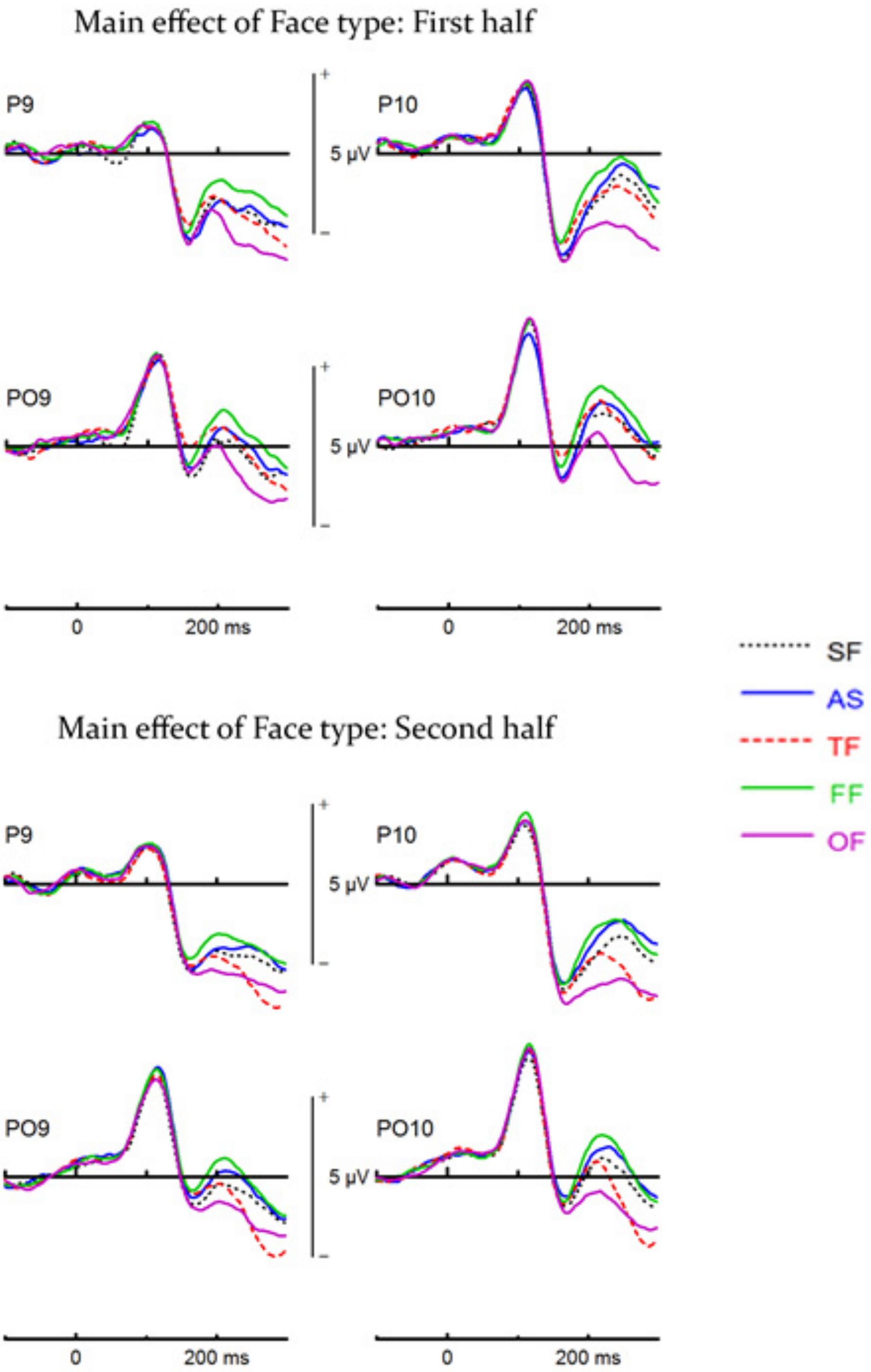

FIGURE 3. N170 mean amplitudes for each face type. Error bars represent the standard error of the mean. SF = Synchronous face; AF = Asynchronous face; TF = Target face; FF = Filler face; OF = Own face.

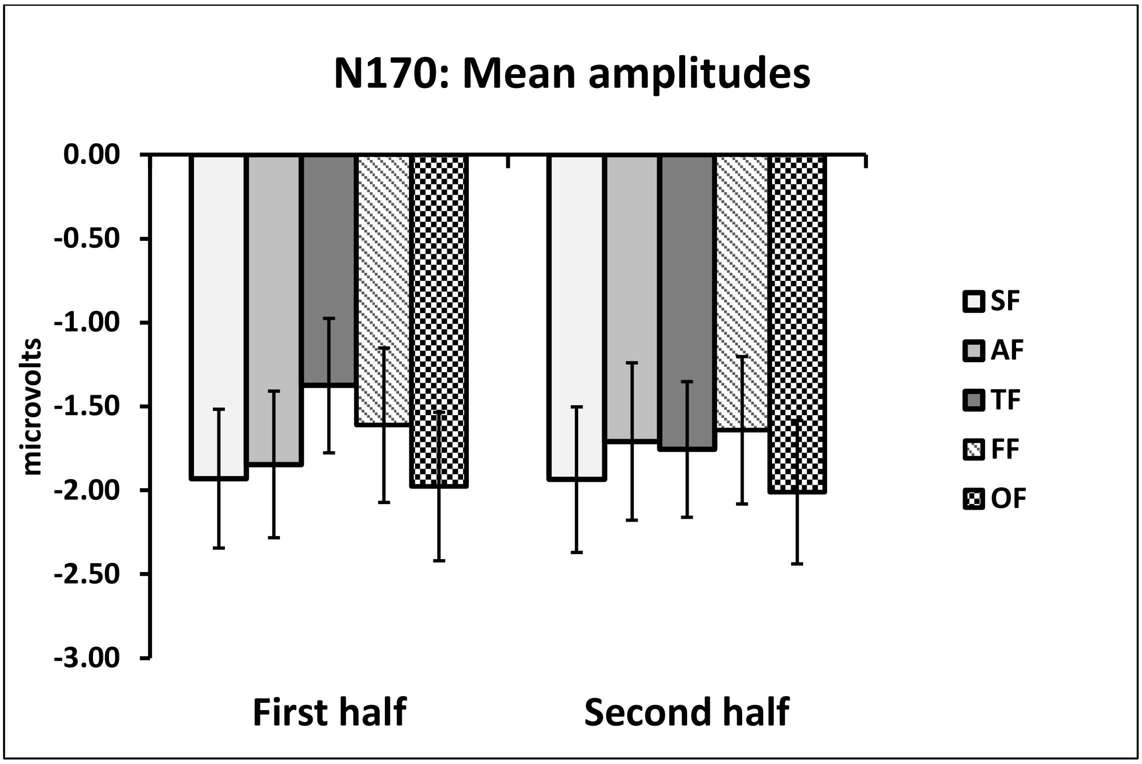

TABLE 1. Pair-wise comparisons between SF and the other conditions for the N170 component. SF = Synchronous face; AF = Asynchronous face; TF = Target face; FF = Filler face; OF = Own face.

	SF vs. AF	**SF vs. TF**	**SF vs. FF**	**SF vs. OF**
First half	$p = .449$	$p < .001$	$p = .011$	$p = .743$
Second half	$p = .042$	$p = .174$	$p = .020$	$p = .476$
Overall	$p = .058$	$p = .490$	$p < .001$	$p = .540$

FIGURE 4. P200 mean amplitudes for each face type. Error bars represent the standard error of the mean. SF = Synchronous face; AF = Asynchronous face; TF = Target face; FF = Filler face; OF = Own face.

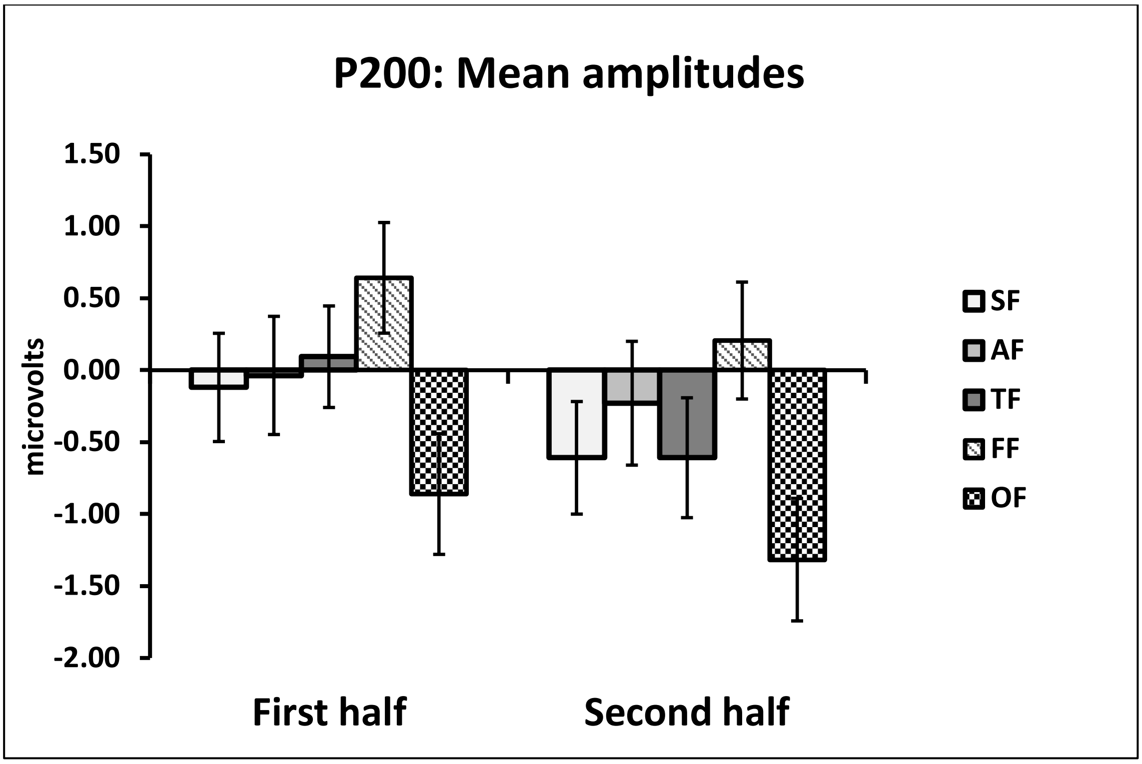

TABLE 2. Pair-wise comparisons between SF and the other conditions for the P200 component. SF = Synchronous face; AF = Asynchronous face; TF = Target face; FF = Filler face; OF = Own face.

	SF vs. AF	**SF vs. TF**	**SF vs. FF**	**SF vs. OF**
First half	$p = .645$	$p = .158$	$p < .001$	$p = .015$
Second half	$p = .032$	$p = .997$	$p < .001$	$p = .011$
Overall	$p = .164$	$p = .490$	$p < .001$	$p = .009$

FIGURE 5. N250 mean amplitudes for each face type. Error bars represent the standard error of the mean. SF = Synchronous face; AF = Asynchronous face; TF = Target face; FF = Filler face; OF = Own face.

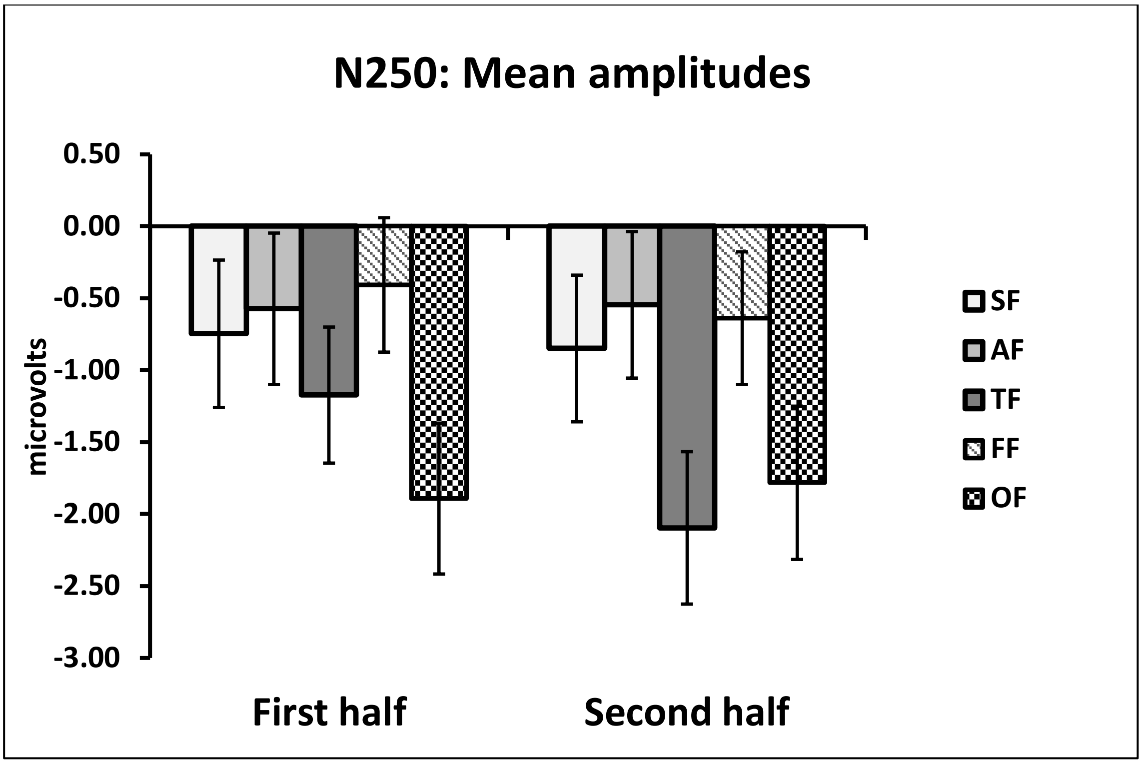

TABLE 3. Results of pair-wise comparisons between SF and the other conditions for the N250 component. SF = Synchronous face; AF = Asynchronous face; TF = Target face; FF = Filler face; OF = Own face.

	SF vs. AF	**SF vs. TF**	**SF vs. FF**	**SF vs. OF**
Left hemisphere	$p = .882$	$p = .001$	$p = .052$	$p = .011$
Right hemisphere	$p = .176$	$p = .020$	$p = .273$	$p < .001$
First half	$p = .485$	$p = .087$	$p = .083$	$p < .001$
Second half	$p = .212$	$p < .001$	$p = .176$	$p < .001$
Overall	$p = .320$	$p = .002$	$p = .097$	$p < .001$

FIGURE 6. Grand-average ERPs for electrodes C3, P3, CZ, PZ, C4 and P4 illustrating the P300 across both times. SF = Synchronous face; AF = Asynchronous face; TF = Target face; FF = Filler face; OF = Own face.

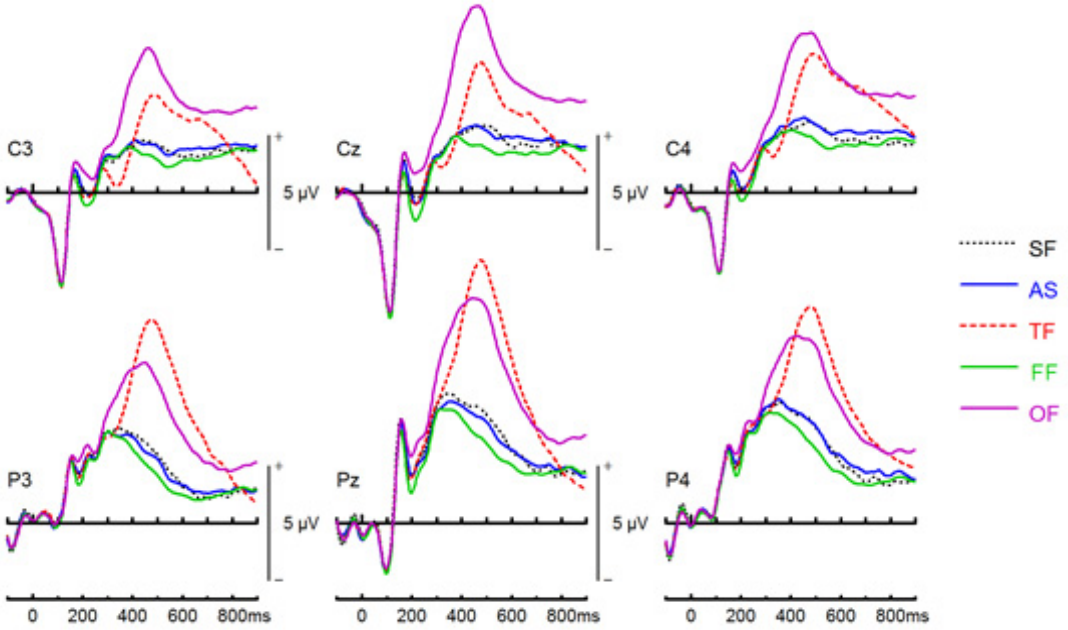

FIGURE 7. P300 mean amplitudes for each face type in the first and the second half of the experiment. Error bars represent the standard error of the mean. SF = Synchronous face; AF = Asynchronous face; TF = Target face; FF = Filler face; OF = Own face.

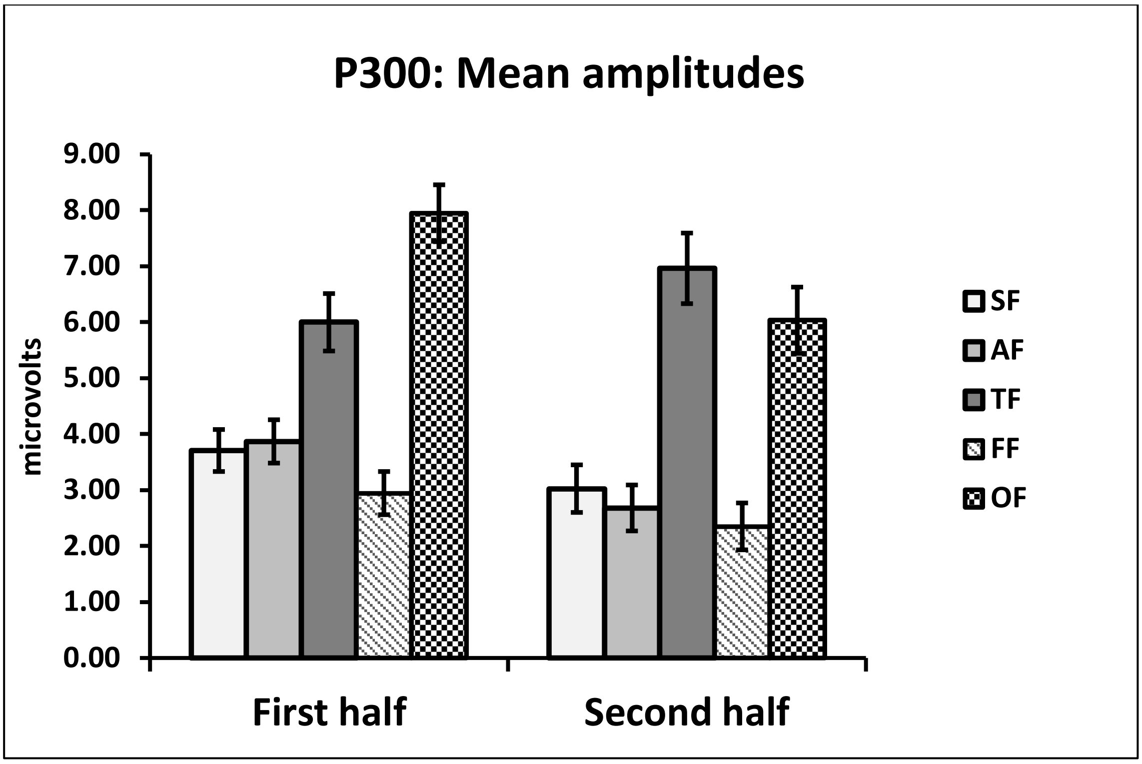

TABLE 4. Results of pair-wise comparisons between SF and the other conditions for the P300 component. SF = Synchronous face; AF = Asynchronous face; TF = Target face; FF = Filler face; OF = Own face.

		SF vs. AF	**SF vs. TF**	**SF vs. FF**	**SF vs. OF**
First Half	C3	*p = .984*	*p = .201*	*p = .022*	*p < .001*
	C4	*p = .817*	*p = .023*	*p = .015*	*p < .001*
	P3	*p = .842*	*p < .001*	*p = .005*	*p < .001*
	P4	*p = .974*	*p < .001*	*p = .002*	*p < .001*
	CZ	*p = .554*	*p = .048*	*p = .018*	*p < .001*
	PZ	*p = .561*	*p < .001*	*p = .004*	*p < .001*
Second Half	C3	*p = .122*	*p < .001*	*p = .003*	*p < .001*
	C4	*p = .431*	*p < .001*	*p = .099*	*p < .001*
	P3	*p = .081*	*p < .001*	*p = .001*	*p = .002*
	P4	*p = .337*	*p < .001*	*p = .004*	*p < .001*
	CZ	*p = .283*	*p < .001*	*p = .005*	*P = .001*
	PZ	*p = .166*	*p < .001*	*p = .021*	*p < .001*
Overall		*p = .333*	*p < .001*	*p = .002*	*p < .001*