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## Can we distinguish an “I” and “ME” during listening?—an event-related EEG study on the processing of first and second person personal and possessive pronouns

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### ABSTRACT

Theoretically, stimuli can be related to the self as subject (“I”) or object (“ME”) of experience. This event-related brain potential (ERP) study investigated whether listening to personal and possessive pronouns elicits different modes of self-processing regarding time-course and neural sources. Going beyond previous research, first (1PP) and second person (2PP) pronouns were included to determine the specificity of self-processing. Participants listened passively to German pronouns while the electroencephalogram was recorded. Modulation of ERPs revealed a processing advantage for the 2PP personal pronoun “du” (“you”) already in early time windows. Regarding possessive pronouns, N1 amplitudes indicated increased attention orientation to the 1PP pronoun “mein” (“my”), whereas during later time windows, processing of 1PP and 2PP possessive pronouns did not differ but differed from the third person pronoun “sein” (“his”). ERP source imaging suggests that primary sensory brain regions (auditory cortex), the insula and cortical midline structures are differentially involved into these two processing modes. The results support the idea of distinct self-processing modes (“I” and “ME”) and confirm their dynamic nature. Moreover, they demonstrate that on a neural level neither “I” or “ME” are invariantly tied to the first person, in line with the hypothesis that self-processing is relational and context-dependent.

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## Introduction

The self is multiple and dynamic. It encompasses several components such as the emotional self, the social self, or the bodily self (Gallagher, 2000; Northoff, 2013). Likewise, there is not

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a singular mode of processing self-related information. Instead, it has been suggested that information can be processed from the perspective of the “self as subject” or from the perspective of the “self as object” (James, 1890; Klein, 2014).

Theoretically, the distinction between different self-processing modes dates back to William James (1890), who proposed to distinguish between the “I” as subject and the “ME” as object of subjective experience. James’ distinction became part of many philosophical, neuropsychological, and linguistic theories about the self that guide research about the self in various scientific domains (for an overview see Gallagher, 2000). What all these conceptions have in common is the idea that they propose at least two dynamically organized selves: On the one hand, a “minimal self” that processes information as an “actor” and “immediate subject of experience” (“I”), and on the other hand, a “reflective” self, that evaluates information in reference to the self to determine its ownership (“ME”).

One major difference between these two aspects of the self concerns the depth of processing of information related to the self or self-processing. Processing information in relation to the self (“ME”) is thought to induce at least some kind of self-referential processing (Esslen et al., 2008; Gallagher, 2000). In contrast, processing information from the perspective of an “I” might trigger self-processing but neither self-referential processing nor a reflection about “who” is experiencing, sensing, or acting (Christoff, Cosmelli, Legrand, & Thompson, 2011; Gallagher, 2000; Legrand, 2007; Legrand & Ruby, 2009; Northoff, 2013, 2014). Stimuli addressing the self as the “I” should thus be processed preferentially or pre-reflectively; i.e., without reflection (Esslen, Metzler, Pascual-Marqui, & Jancke, 2008; Legrand, 2007). On the other hand, stimuli that address the subject as the “ME” and thus as the object of self-attribution might require more elaborate stimulus encoding allowing to refer the stimulus to the self and to discriminate self from non-self or self from other (e.g., Herbert, Herbert, Ethofer, & Pauli, 2011; Walla, Duregger, Greiner, Thurner, & Ehrenberger, 2008; for an overview: Christoff et al., 2011; Kaysers & Gazzola, 2007; Northoff, 2013, 2014).

Recently, neuroscientific research sought to determine whether the two processing modes related to the “I” and the “ME” are reflected in human language. Linguistically, many languages use first person personal pronouns (“I”) to refer to the self as the subject of experience and possessive pronouns (“my”, “mine”) to refer to the self as an object of experience (Bermudez, 1998). Compared to personal pronouns, possessive pronouns designate possession and ownership (“this is belonging to me, him/her.”), wherefore they are often also called reflexive or self-referential pronouns in order to underline this referential character. We propose that investigating how these two types of pronouns (personal vs. possessive) are processed in the brain could therefore give important insight into the two hypothesized self-processing modes (“I” vs. “ME”) and their functional dynamics.

A number of recent EEG studies already followed up on the distinction between “I” and “ME” using verbal stimulus material. Across studies pronouns were presented visually either within a sentence context (e.g., Esslen et al., 2008), as pronoun–noun phrases (e.g., Herbert, Herbert, et al., 2011; Herbert, Pauli, & Herbert, 2010; Herbert, Pauli, et al., 2011; Walla et al., 2008) or without any semantic context, for instance, in an oddball or silent reading task (e.g., Blume & Herbert, 2014; Shi, Zhou, Liu, Zhang, & Han, 2011b; Zhou et al., 2010). Despite differences that might be related to the experimental designs and tasks, the results of these studies converge on a number of observations:

Firstly, they show that the first person personal pronoun “I” (1PP) as compared to the third person personal pronouns (3PP) “he” or “she” is processed preferentially in very early time

windows already, e.g., at about 134 ms after stimulus onset and indicated by modulations of the P1 component (e.g., Blume & Herbert, 2014; Esslen et al., 2008). This supports the idea of very early or pre-reflective processing particularly for personal as compared to possessive pronouns addressing the self-as-subject and thus the immediate agent of perception and experience ("I") (Christoff et al., 2011; Legrand, 2007). Secondly, the literature provides converging evidence that this is also associated with activation in several brain regions including sensorimotor regions and the insula (e.g., Esslen et al., 2008). Interestingly, this is well in line with the suggestion that these brain regions are involved in very basic forms of self-representation (e.g., Damasio, 2012; Kaysers & Gazzola, 2007). A third important aspect is that, for possessive pronouns, a significant processing difference between self- and other-related pronouns has been observed only during later time windows, i.e., at processing stages, which have been related to memory updating and stimulus encoding as indexed by P3 or LPP modulation (Herbert, Herbert, et al., 2011; Herbert, Pauli, et al., 2010; Shi et al., 2011; Walla et al., 2008; Zhou et al., 2010). Moreover, in some of these studies, EEG source imaging revealed activity changes in these later time windows but not earlier time windows in cortical midline structures (CMS, medial prefrontal cortex and precuneus) (Herbert, Herbert, et al., 2011; Shi et al., 2011). Interestingly, these brain structures have previously been shown to be critically involved in self-referential processing and self-other discrimination (e.g., D'Argembeau, 2013; Herbert, Pauli, et al., 2011; for metaanalytic overviews e.g., Benoit et al., 2010; Northoff et al., 2006). This suggests that establishing reference to the self-as-object via the use of possessive pronouns is not automatically associated with self-referential processing but—as hypothesized—requires elaborate stimulus encoding at later processing stages, during which the stimuli are related to the self and discriminated from others.

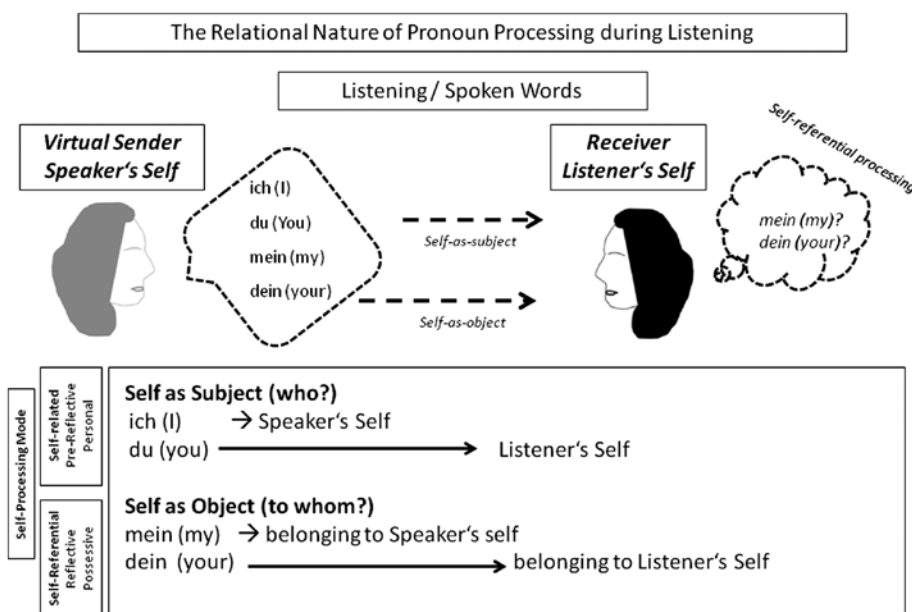
Altogether, these findings provide strong neurophysiological support for the assumption of two distinct self-processing modes: I and ME. At the same time, these two modes should be reflected by the processing of simple language stimuli such as personal and possessive pronouns.

Nevertheless, the observations described above also reveal important boundary conditions that obstruct the generalizability of the findings, especially with regard to the relational and social aspects of the self and of human language. So far, the literature suggests that self-reference is associated with pronouns of the first person. However, as outlined above, previous research focused only on visual stimulus presentation. Therefore, it is not clear whether the relationship between self and first person reference is invariant or varies across sensory modalities in a modality-specific way (e.g., visual vs. acoustic). Semantically, self-processing might indeed be activated especially by first person personal and possessive pronouns (e.g., "I" and "my"). This relationship between self and first person reference, however, changes during listening where listeners may rather automatically relate pronouns of the second person (2PP), and especially the personal pronoun "Du" ("You"), to the own self and pronouns of the first person (1PP) to the speaker's self (Ruby & Decety, 2001; Vogeley & Fink, 2003).

In addition, previous studies using pronouns almost exclusively compared first vs. person pronouns (either personal or possessive or both), without further distinguishing between significant and insignificant others or between first and second person perspective. At the same time, many neurophysiologic theories consider the self in a broader relational context and assume self-related processing to be intrinsically relational and composed in an

intersubjective way in relation between self and other (Northoff, 2011; Northoff, Heinzel, et al., 2006; Ruby & Decety, 2001). In line with these theoretical assumptions, recent meta-analytic research suggests that discrimination between self and other depends on the context as well as the relevance of the stimuli for the perceiver, i.e., whether the third person is a close other, a communication partner or irrelevant for the perceiver of the message (Heatherton et al., 2006; Qin & Northoff, 2011; Schilbach et al., 2013).

Crucially, however, whether such relevance effects could influence self-processing of pronouns related to the first ("I") and second person ("You") and whether effects differ for pronouns addressing the self-as-subject ("I"/"You") or object ("my"/"your") has not been investigated until now. In a very recent EEG study with visual stimulus presentation (Blume & Herbert, 2014), the 2PP pronouns "du" and "dein" ("you" and "your") were included in the analysis for exploratory purpose. ERP analyses revealed that second person pronouns were not processed differently from the first person (1PP) or third person (3PP) pronouns ("I" and "my" or "he" and "his"). This suggests that during visual stimulus presentation, the additional presentation of second person pronouns can produce conflicting information because they can be self-related or not, depending on the reader's perspective. However, we propose that these effects may be modality-dependent and that auditory stimulus presentation might change this. With auditory stimulus presentation, first person pronouns could produce conflicting information as during listening they also refer to the speaker's self. Hence, as illustrated in Figure 1, acoustic presentation of pronouns constitutes a particularly



**Figure 1.** Illustration of the relational nature of pronoun processing during listening. As described in the text and as illustrated by the black arrows and boxes below, during listening, the second person pronouns "du" ("you") and "dein" ("your") are related to the listener's self, whereas the first person pronouns "ich" ("I") and "mein" ("my") are related to the speaker's self. Semantically, however, first person pronouns are related to the self, which could produce conflict about ownership, especially for the possessive pronoun "my."

interesting testing case to determine the specificity of self-processing and its social and relational nature.

The present EEG–ERP study was designed to answer these questions. More specifically, we aimed at investigating event-related brain potential (ERP) modulation during listening to personal and possessive pronouns including self-related pronouns of the first and second person.

As already outlined above, ERP studies are especially suited to determine the time-course of self-referential processing even during mere stimulus exposure and in the absence of any explicit processing instruction. Moreover, previous ERP studies have already shown facilitated processing of self-related stimuli in the time window of early brain potentials such as the P1, N1, EPN, or P2 (e.g., Blume & Herbert, 2014; Shi et al., 2011) as well as in the time window of later ERP components such as the P3 or LPP (Blume & Herbert, 2014; Herbert, Herbert, et al., 2011; Shi et al., 2011). Amplitudes of the P1 have been found to be modulated by both, the physical properties of a stimulus and its salience, self-reference (Blume & Herbert, 2014) or emotional relevance (Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004; Delplanque, Lavoie, Hot, Silvert, & Sequeira, 2004). The P1 is, furthermore, sensitive to changes in physiological arousal, and similarly to N1 and P2, its amplitudes are modulated by changes in selective attention (Luck & Hillyard, 1994). However, during auditory processing, specifically the N1 and P2 can show an inverse relationship which is of special interest for this study using auditory stimuli. During listening, N1 and P2 are sensitive to changes in attention although reflecting different facets of sensory information processing (Crowley & Colrain, 2004 for a review). Modulation of the N1 indicates changes in external stimulus attention whereas P2 modulation could indicate the shift from external attention orientation towards internal sensory encoding of stimulus features. In line with these general assumptions about ERPs and previous results on their modulation by self-related stimuli, the following hypotheses were tested.

If self-processing is context- and modality-specific, we expect that during listening (unlike during reading), the second person personal pronoun “Du” (“You”) will be processed preferentially as compared to the first or third person personal pronouns. This might be reflected in very early ERP modulation, possibly already in the P1 time window. Crucially, during listening, the N1 and the P2 could indicate the direction of the effects (e.g., external attention orientation towards the speaker’s self vs. attention orientation away from external towards the listener’s self). Accordingly, if listeners spontaneously relate the second person personal pronoun “you” to the self, we expect smaller N1 yet larger P2 amplitudes during listening to the second person personal pronoun “you” as compared to when listening to first person (“I”) or third person personal (“he”) pronouns.

The second specific aim was to investigate ERP patterns evoked by possessive pronouns and how they compare to those evoked by personal pronouns. If personal and possessive pronouns elicit distinct self-processing modes (I vs. ME) then different ERP modulation patterns should be observed for the two types of pronouns. Specifically and in accordance with previous studies (Herbert, Herbert, et al., 2011; Shi, Zhou, Han, & Liu, 2011; Walla et al., 2008), we expected that for possessive pronouns self-processing would start temporally later than for personal pronouns, probably in the time window of later brain potentials following the P2. Regarding later brain potentials such as the P3, these are only little affected by physical attributes of a stimulus and thought to be largely involved in post-sensory stimulus categorization and stimulus evaluation (Polich, 2007). Therefore, in this study, larger amplitudes of

late brain potentials such as the P3 to self-related possessive pronouns as compared to possessive pronouns of the third person would support the assumption that participants reflect more about self-related stimuli as compared to stimuli unrelated to the self and that this is specific to stimuli addressing the self as an object of experience. Again, we were particularly interested in differential processing of the 1PP and 2PP pronouns and specifically whether listeners would relate the 1PP possessive pronoun “mein” (“my”) to the speaker’s or to the own self and also whether—due to their self-relevance—the 1PP and 2PP possessive pronouns “mein” (“my”) and “dein” (“your”) would be processed differently at all.

The third specific aim was to explore the neural sources of these ERP changes. Activity changes in CMS have been discussed as critical markers of self-referential processing and self-other discrimination, whereas changes in sensorimotor cortex and the insula have been associated with more basic forms of self-representation (see above). We, therefore, hypothesized that preferential processing of personal pronouns during early ERP time windows would be associated with activity changes mainly in auditory cortex and neighboring regions (insula), whereas ERP changes associated with self-processing of possessive pronouns would specifically be related to changes in CMS.

## Methods

### Participants

Twenty-six native German speakers (5 male; mean age: 22.9 years) participated in the listening experiment. None of them reported problems with hearing, none of them had a history of prior neurological or psychiatric disorders or presented with an acute illness and none of them reported taking medication affecting brain activity. The study was conducted in accordance with the Declaration of Helsinki (World Medical Association). Participants received course credit or were reimbursed financially for their participation.

### Stimuli

Target stimuli consisted of the German first (1PP), second (2PP), and third person (3PP) pronouns “ich,” “du,” “er” (personal pronouns: “I,” “you,” “he”) and “mein,” “dein,” “sein” (possessive pronouns: “my,” “your,” “his”). Additionally, the non-personal pronoun “ein” (“a”) and the articles “es,” “der,” (“it,” “the”) were presented as filler items. Filler items contained no personal, self- or other-reference. All words were spoken by a female, native speaker, intonated in standard German with neutral prosody and comparable fundamental frequency F0 (pitch). The mean fundamental frequency (F0) and mean intensity (dB) of the pronoun stimuli were as follows: “ich” (78.2 dB, 222.2 Hz), “du” (82.3 dB, 223.6 Hz), “er” (81.2 dB, 220.4 Hz), “mein” (82.3 dB, 201.6 Hz), “dein” (80.8 dB, 209.5 Hz), “sein” (81.6 dB, 212.8 Hz).

### Procedure

Stimuli were presented in a serial acoustic presentation design without inter-stimulus intervals at a rate of 1 Hz. The experiment comprised two blocks. Within each block, each word (target stimuli and filler items) was presented 60 times in a pseudorandom sequence which controlled for transition probability between stimuli (see Herbert et al., 2008 for

methodological details). Participants were instructed to silently listen to the words via stereo headphones while fixating a visually presented cue on the computer screen to avoid involuntary eye-movements. Stimuli were controlled for loudness and the experiment was programmed and controlled by Presentation® software (Neurobehavioral Systems, Inc.).

The acoustic processing condition was part of a larger project which also included the series of visual presentations from Blume and Herbert (for an overview of the visual effects see Blume & Herbert, 2014). The acoustic presentation was always presented as the last and final condition after a short break of 5–10 min during which participants were allowed to rest.

### *Electrophysiological data collection and reduction*

Participants were seated on a comfortable chair at a distance of about 70 cm from the computer screen. Thirty-two active Ag/AgCl electrodes were placed on the scalp according to the international 10–20 system using an actiCAP® system (Brain Products GmbH). The electrooculogram (EOG) was recorded from two Ag/AgCl electrodes. Impedances were kept below 10 k $\Omega$ . Raw EEG signals were continuously recorded at a sampling rate of 500 Hz using a BrainVision BrainAmp® DC amplifier. Electrodes were connected to ground and referenced to AFz. Offline, EEG data were re-referenced to a linked mastoids reference, filtered at 100 Hz, and corrected for physiological and physical artefacts. Ocular artefacts were corrected according to the traditional algorithm of Gratton, Coles, and Donchin (1983). Additional physiological or physical artefacts were rejected using the semi-automated rejection algorithm of the BrainVision Analyzer2® software (BrainProducts GmbH). In total, 10% of all epochs were excluded from further analyses, leaving enough trials for averaging of ERPs. Artefact-free data were segmented from 100 ms before until 500 ms after stimulus onset using the 100-ms pre-stimulus time-window for baseline adjustment.

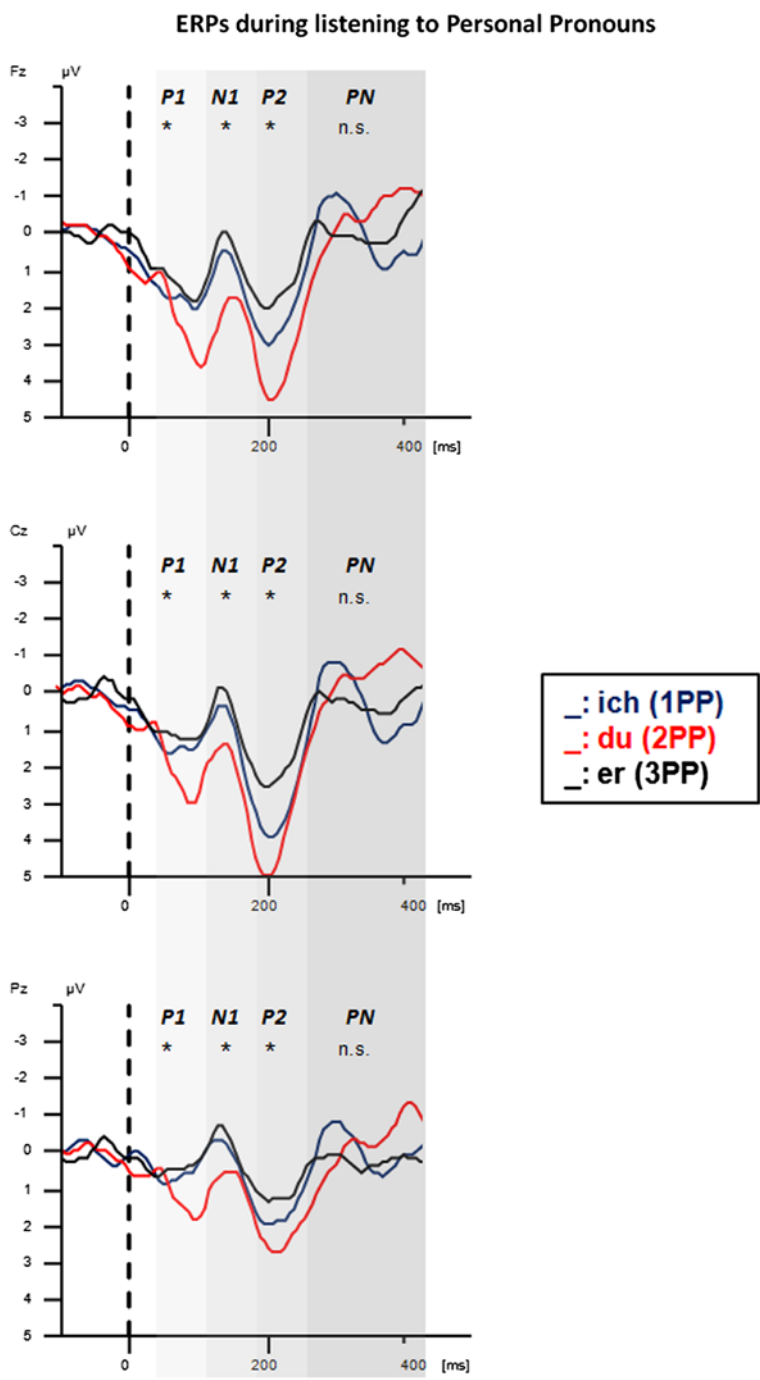
### *ERPs of interest*

Amplitudes of ERPs were analyzed in the time windows of the P1, N1, the P2 as well as in the time window following the P2, where particularly possessive pronouns elicited a processing negativity (PN) from about 250 ms until 400 ms post-stimulus onset (see Figures 2 and 3).

The peak amplitude of the P1, N1, and the P2 were determined for each participant and electrode with the automatic peak detection algorithm of the BrainVision Analyzer2® software (BrainProducts GmbH). This algorithm searched for the global maxima (either negative- or positive-going amplitude) in the ERP waveforms within predefined time windows. Peak amplitudes were then exported as the averaged activity in  $\mu$ V around the peak including  $\pm 10$  data points for the P1, N1, and the P2. The PN is a negative deflection in the ERP waveform in the time window following the P2 (see Figure 2). Therefore, its amplitudes were analyzed as the averaged mean activity (in  $\mu$ V) in the respective time window from 250 ms until 400 ms post-stimulus onset.

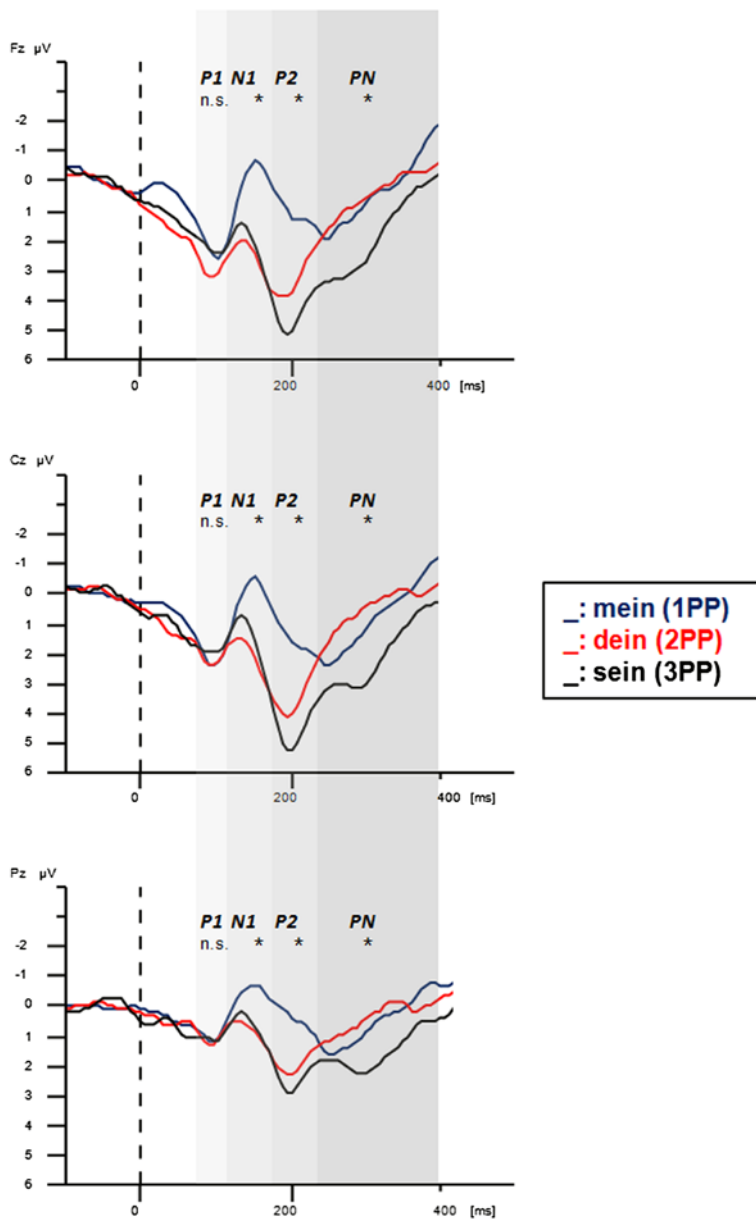
### *Low resolution brain electromagnetic tomography*

Standardized low resolution brain electromagnetic tomography (LORETA) was used to detect brain regions associated with changes in EEG activity during pronoun processing (Pascual-Marqui, Michel, & Lehmann, 1994). LORETA maps were created from the contrasts comparing personal or possessive pronouns of the first vs. second vs. third person. Source analysis was



**Figure 2.** Modulation of ERPs by first person (1PP), second person (2PP), and third person (3PP) personal pronouns during listing. Time windows with significant effects “du” (“you”) vs. “ich” (“I”) and “du” (“you”) vs. “er” (“he”) are marked with an asterisk. Non-significant effects are marked with “n.s.”. Effects are shown for frontal (Fz), central (Cz), and parietal (Pz) midline electrodes. Grey bars highlight the different ERP components: P1, N1, P2, and PN.

## ERPs during listening to Possessive Pronouns



**Figure 3.** Modulation of ERPs by first person (1PP), second person (2PP), and third person (3PP) possessive pronouns during listing. Time windows with significant effects (N1 and P2: “mein” (“my”) vs. “dein” (“your”) and “mein” (“my”) vs. “dein” (“your”); PN: “mein” (“my”) vs. “sein” (“his”) and “dein” (“your”) vs. “sein” (“his”)) are marked with an asterisk. Non-significant effects are marked with “n.s.”. Effects are shown for frontal (Fz), central (Cz), and parietal (Pz) midline electrodes. Grey bars highlight the different ERP components: P1, N1, P2, and PN.

applied only to the contrasts and time windows in which statistical analysis of ERPs revealed significant differences between the different stimulus types.

### Statistical data analysis

ERP amplitudes were statistically analyzed with repeated measures analyses of variance (ANOVA). We first calculated an Omnibus-ANOVA to test for significant interaction effects between the factors *pronoun* and *reference*. These ANOVAs included the factors *pronoun* (personal vs. possessive), *reference* (first person (1PP) vs. second person (2PP) vs. third person (3PP)), and *electrode location* (frontal (F3, Fz, F4), central (C3, Cz, C4), posterior (P3, Pz, P4)) as well as *electrode site* (left (F3, C3, P3), midline (Fz, Cz, Pz), right (F4, C4, P4)) as within-subject factors.

The ANOVAs were then recalculated without the factor *pronoun* in order to determine the effects of stimulus-reference separately for personal and possessive pronouns. Degrees of freedom were Greenhouse–Geisser corrected where applicable to control for violation of sphericity. Significant main effects and interactions (all  $p < .05$ ) were tested with planned comparison tests.

## Results

### Time-course/ERPs

#### Omnibus-ANOVA

The Omnibus-ANOVA revealed significant main effects of the factor *reference* or *pronoun* in the P1, N1, P2 time windows as well as in the time window of the PN following the P2 (all  $p < .01$ ). In all respective time windows, main effects were modulated by significant interaction effects between the factors *pronoun* and *reference* (all  $p < .003$ ) or *pronoun*  $\times$  *reference*  $\times$  *electrode site* (P1:  $F(4, 100) = 3.6, p = .008$ ), indicating that 1PP, 2PP, and 3PP pronouns are processed differently depending on whether they were personal or possessive.

#### Personal pronouns

P1 amplitudes showed a main effect of *reference*,  $F(2, 50) = 12.68, p < .001, \eta^2 = .7$ , and additionally a main effect of *electrode location*,  $F(2, 50) = 65.98, p < .0001, \eta^2 = .7$ : P1 amplitudes were generally more pronounced at frontal and central than at parietal electrode sites. Planned comparison tests of the main effect of reference showed that P1 amplitudes were larger for the second person (2PP) personal pronouns, “du” (“you”) compared to the personal pronoun of the first (1PP) and third (3PP) person (2PP vs. 1PP:  $F(1, 25) = 12.9, p < .0005$ ; 2PP vs. 3PP:  $F(1, 25) = 22.51, p < .0001$ ). P1 amplitudes did not differ significantly between personal pronouns of the first (1PP) and third (3PP) person,  $F(1, 25) = .4, p = .5$ .

N1 amplitudes showed a main effect of *reference*,  $F(2, 50) = 6.06, p < .01, \eta^2 = .81$ , and of *electrode location*  $F(2, 50) = 7.48, p = .005, \eta^2 = .68$ : Like P1 amplitudes, N1 amplitudes were generally more pronounced at frontal and central than parietal electrode sites. Planned comparison tests of the main effect of reference revealed that N1 amplitudes were significantly reduced for the 2PP personal pronoun “du” (“you”) compared to the 1PP “ich” (“I”),  $F(1, 25) = 4.24, p = .04$ , and the 3PP personal pronoun “er” (“he”),  $F(1, 25) = 11.07, p < .01$ . However, N1 amplitudes did not differ significantly between the 1PP and the 3PP personal pronouns “ich” (“I”) and “er” (“he”),  $F(1, 25) = 2.7, p = .10$ .

P2 amplitudes showed a main effect of *reference*,  $F(2, 50) = 7.0, p = .003, \eta^2 = .9$ , *location*,  $F(2, 50) = 26.9, p < .0001, \eta^2 = .78$ , *electrode site*,  $F(2, 50) = 21.1, p < .0001, \eta^2 = .9$ , and a significant interaction effect of the factors *reference*  $\times$  *electrode site*,  $F(4, 100) = 3.41$ ,

$p = .03$ ,  $\eta p^2 = .56$ . P2 amplitudes were generally more pronounced at frontal and central than at parietal electrodes. In addition, P2 amplitudes were significantly enhanced for the 2PP personal pronoun “du” (“you”) as compared to both the 1PP personal pronoun “ich” (“I”),  $F(1, 25) = 7.95$ ,  $p < .0$ , and the 3PP personal pronoun “er” (“he”),  $F(1, 25) = 12.74$ ,  $p < .001$ , especially at midline electrodes.

Amplitudes of the PN in the time window following the P2 showed no significant main effects, (all  $p > .4$ ), but a trend towards a significant interaction effect of *reference*  $\times$  *electrode location*  $\times$  *electrode site*,  $F(4, 100) = 2.28$ ,  $p = .05$ . However, planned comparisons did not indicate any significant differences between personal pronouns of the 1PP, 2PP, or 3PP at left, right, or midline electrodes nor at frontal, central, or parietal electrode sites.

Differential processing of 1PP, 2PP, and 3PP personal pronouns in the P1, N1, and P2 time window is shown in Figure 2.

### Possessive pronouns

For possessive pronouns, P1 modulation showed no significant main effect of *reference*, but significant interaction effects of *reference*  $\times$  *electrode location*,  $F(4, 100) = 5.3$ ,  $p = .004$ ,  $\eta p^2 = .6$ , and *reference*  $\times$  *electrode site*,  $F(4, 100) = 3.4$ ,  $p = .02$ ,  $\eta p^2 = .7$ . Planned comparison tests, however, revealed no significant differences that would support differential processing of 1PP, 2PP, or 3PP pronouns at any of these electrode locations (frontal, central, parietal) or electrode sites (left, right, midline).

In the N1 time window, a highly significant main effect of *reference* was observed,  $F(2, 50) = 17.3$ ,  $p < .0001$ ,  $\eta p^2 = .9$ . There were also significant interaction effects of *reference*  $\times$  *electrode location*,  $F(4, 100) = 4.01$ ,  $p = .02$ ,  $\eta p^2 = .5$ , and of *reference*  $\times$  *electrode site*,  $F(4, 100) = 2.6$ ,  $p = .03$ ,  $\eta p^2 = .6$ . In addition, a main effect of *electrode location*,  $F(2, 50) = 9.8$ ,  $p = .002$ ,  $\eta p^2 = .6$ , was observed indicating that N1 amplitudes were more pronounced at frontal and central than at parietal electrode sites. Planned comparison tests of the factor *reference* showed that the 1PP possessive pronoun “mein” elicited significantly larger N1 amplitudes relative to the 2PP possessive pronouns “dein,”  $F(1, 25) = 26.8$ ,  $p < .0005$ , and also relative to the 3PP possessive pronoun “sein,”  $F(1, 25) = 15.68$ ,  $p < .001$ . Relative to the 1PP possessive pronoun “mein,” the 2PP possessive pronoun “dein” elicited only small N1 amplitudes, which also tended to be smaller in comparison with 3PP possessive pronouns,  $F(1, 25) = 3.04$ ,  $p = .09$ , especially when tested at midline electrodes,  $F(1, 25) = 5.2$ ,  $p = .03$ .

N1 amplitudes elicited by the 1PP pronoun “mein” continued into the P2 time window and therefore elicited only small P2 amplitudes. Additionally, the latency of the P2 was also significantly longer for the first person pronoun “mein” (“my”) relative to the second and third person possessive pronouns “dein” (“your”) and “sein” (“his”), 1PP > 2PP:  $F(1, 25) = 21.68$ ,  $p < .001$ ; 1PP > 3PP:  $F(1, 25) = 21.01$ ,  $p < .0001$ . P2 amplitudes showed a significant main effect of *reference*,  $F(2, 50) = 14.7$ ,  $p < .0001$ ,  $\eta p^2 = .9$ , *location*,  $F(2, 50) = 46.6$ ,  $p < .0001$ ,  $\eta p^2 = .7$ , and significant interactions of *location*  $\times$  *site*,  $F(4, 100) = 8.0$ ,  $p = .001$ ,  $\eta p^2 = .7$ , and *reference*  $\times$  *location*,  $F(4, 100) = 6.2$ ,  $p < .01$ ,  $\eta p^2 = .57$ . The first person possessive pronoun “mein” (“my”) elicited significantly smaller P2 amplitudes than the 2PP possessive pronoun “dein” (“your”), 1PP < 2PP:  $F(1, 25) = 5.41$ ,  $p = .02$ , and the 3PP possessive pronoun “sein” (“his”), 1PP < 3PP:  $F(1, 25) = 23.7$ ,  $p = .001$ . These effects were significant at frontal and central electrodes.

Amplitudes of the PN showed a main effect of *reference*,  $F(2, 50) = 10.4$ ,  $p < .0005$ ,  $\eta p^2 = .93$ . Amplitudes of the PN were significantly more pronounced during listening to first person

**Table 1.** Results from source imaging (Loreta) for the different contrasts. Results are displayed separately for personal and possessive pronouns. Numbers in parentheses describe MNI coordinates (x, y, z) in mm for peak voxels. BA: Brodmann areas.

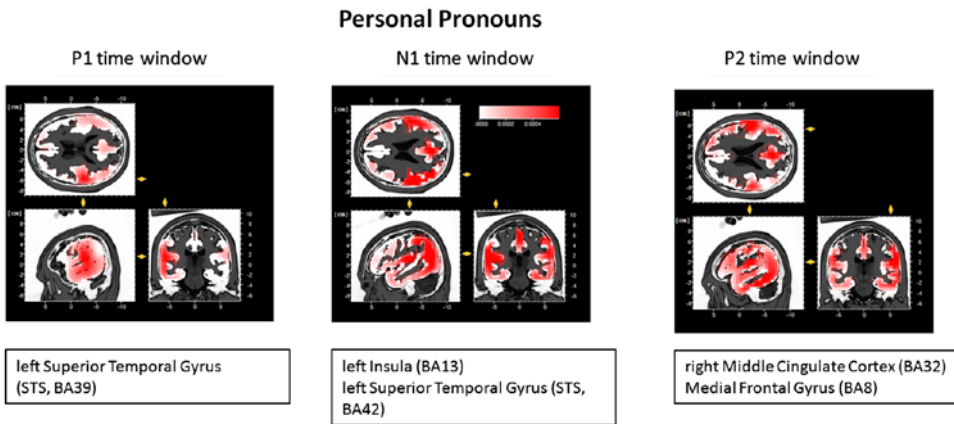
| Time window                | Contrast    | x, y, z (MNI) | Brain region (BA)                        |
|----------------------------|-------------|---------------|--|
| <i>Personal pronouns</i>   |             |               |  |
| P1                         | 2PP vs. 1PP | −40 −60 30    | Left Superior Temporal Gyrus (STS, BA39) |
|                            | 2PP vs. 3PP | 40 −25 10     | Left Temporal Lobe (BA41)                |
|                            |             | −45 −20 10    | Left Superior Temporal Gyrus (STS)       |
| N1                         | 2PP vs. 1PP | −55 −30 15    | Left Superior Temporal Gyrus (BA42)      |
|                            |             | −45 −20 15    | Left Insula (BA13)                       |
|                            | 2PP vs. 3PP | −55 −30 5     | Left Superior Temporal Gyrus (BA22)      |
| P2                         |             | −35 −20 15    | Left Insula (BA13)                       |
|                            | 2PP vs. 1PP | 5 35 45       | Right Middle Cingulate Cortex (BA32)     |
|                            |             | −15 5 40      | Medial Frontal Gyrus (BA8)               |
|                            | 2PP vs. 3PP | 50 −20 5      | Right Superior Temporal Gyrus (BA41)     |
|                            |             | 50 −15 5      | Right Superior Temporal Gyrus (BA22)     |
|                            |             | 40 −85 20     | Right Middle Temporal Gyrus (BA19)       |
| <i>Possessive pronouns</i> |             |               |  |
| N1                         | 1PP vs. 2PP | 4 52 8        | Anterior Cingulate Cortex (BA32)         |
|                            |             | 2 50 9        | Medial Frontal Gyrus (BA10)              |
|                            | 1PP vs. 3PP | 4 10 57       | Superior Frontal Gyrus (BA6)             |
| P2                         | 1PP vs. 2PP | 46 −37 48     | Inferior Parietal Lobe, Precuneus (BA40) |
|                            | 1PP vs. 3PP | −46 −32 50    | Inferior Parietal Lobe (BA40)            |
| PN                         | 2PP vs. 3PP | 2 10 57       | Superior Frontal Gyrus (BA6)             |
|                            | 1PP vs. 3PP |               | Middle Frontal Gyrus (BA6)               |
|                            |             | 0 14 56       | Superior Frontal Gyrus (BA8)             |
|                            |             | 0 5 98        | Medial Frontal Gyrus (BA10)              |
|                            |             |               |  |

(1PP) and second person (2PP) pronouns relative to pronouns of the third (3PP) person, 1PP > 3PP:  $F(1, 25) = 16.05, p = .004$ ; 2PP > 3PP:  $F(1, 25) = 19.4, p = .0001$ , and did not differ significantly between 1PP and 2PP pronouns ( $F(1, 25) = .9, p = .9$ ).

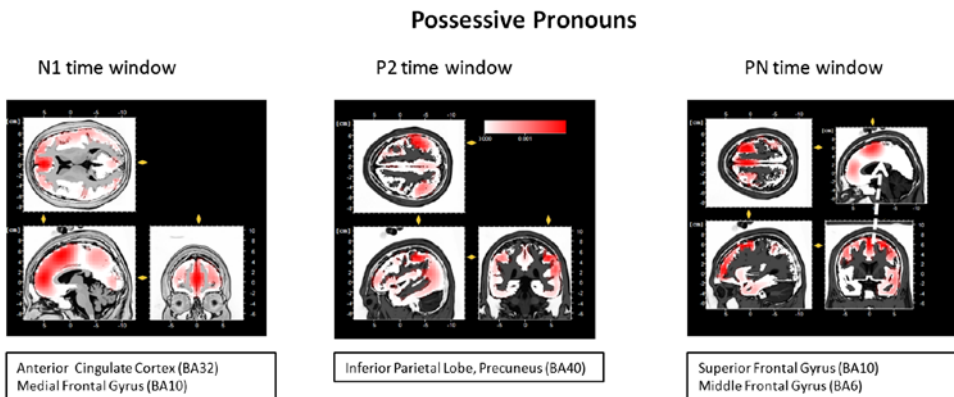
Differential processing of possessive pronouns in the N1, P2, and PN time windows is shown in Figure 3.

**Low resolution brain electromagnetic tomography**

Results obtained from LORETA are summarized in Table 1 and visualized in Figures 4a and 4b. For the contrasts comparing the second person (2PP) personal pronoun “du” (“you”) against the first (1PP) or third (3PP) person personal pronoun “ich” (“I”) or “er” (“he”), changes in electrocortical activity were mainly localized in the left and the right superior temporal gyrus (STS), the left and right middle temporal lobe as well the left insula (BA13) in the time window of the P1, N1, and P2. In the P1 and N1 time window effects were lateralized to the left; in the P2 time window to the right temporal hemisphere. For the contrasts comparing possessive pronouns of the first (1PP) against the second (2PP) or third (3PP) person, activity changes were associated with activation of CMS. In the N1 time window, peak voxels were located in the superior medial frontal cortex and the anterior cingulate cortex (ACC) and the parietal cortex (including the precuneus) in the P2 time window. In the time window of the PN following the P2, possessive pronouns of the first (1PP) and the second person (2PP) were contrasted against those of the third person (3PP) which revealed additional peak activation in the middle and superior frontal gyrus (BA6 and BA8).



**Figure 4a.** Results from source localization ( $\mu\text{V}/\text{mm}^2$ ) contrasting ERP effects for personal pronouns in the time window of the P1, N1, and P2, where significant differences were observed between 2PP and 1PP as well as between 2PP and 3PP personal pronouns. The three different plots show the results for the contrasts comparing 2PP and 1PP personal pronouns in the P1, N1, and P2 time window. For further comparisons, see Table 1.



**Figure 4b.** Results from source localization ( $\mu\text{V}/\text{mm}^2$ ) contrasting ERP effects of possessive pronouns in the N1, P2, and PN time windows. The left two plots show the results for the contrast comparing 1PP vs. 2PP possessive pronouns in the N1 and P2 time window. The plot on the right shows the results observed in the PN time window, where 2PP as well as 1PP possessive pronouns differed significantly from 3PP possessive pronouns. For further comparisons, see Table 1.

## Discussion

The present EEG–ERP study investigated the relationship between self-reference and stimulus-reference during processing of personal and possessive pronouns. In contrast to previous research, stimuli were presented acoustically and pronouns of the first as well as the second person were included to determine the spatio-temporal dynamics of self-processing and its specificity across sensory modalities.

### *Self-relatedness and personal pronouns*

The second person pronoun “du” (“you”) was processed preferentially across different ERPs supporting the hypothesis that self-processing is indeed relational (Northoff, 2013) and not specific for stimuli of the first person. As predicted, a processing advantage for the 2PP personal pronoun “du” was observed in the P1 time window already suggesting a very early stimulus-driven stimulus selection mechanism specifically for personal pronouns addressing the self-as-subject of experience (“I”) (e.g., Blume & Herbert, 2014; Esslen et al., 2008).

Crucially, listening to the 2PP personal pronoun “du” (“you”) elicited an ERP modulation pattern that provides support that during listening, especially the 2PP “du” (“you”) prompted self-related processing. Listening to the personal pronoun “du” (“you”) elicited significantly larger P1 amplitudes than listening to the first (1PP) or the third (3PP) personal pronouns “ich” (“I”) and “er” (“he”). However, as expected, it elicited significantly smaller N1 amplitudes and then significantly larger P2 amplitudes than the first person (1PP) or the third (3PP) person personal pronoun. Thus, as hypothesized, hearing the pronoun “du” (“you”) seemed to instantaneously arouse (P1) and draw attention towards the own self (i.e., the listener’s self) and away from the environment towards internal sensory processing thereby eliciting smaller N1 but larger P2 effects. In particular, the P2 is assumed to be an early brain potential that reflects stimulus-driven categorization processes that match sensory input with stored internal representations or concepts in memory (Schupp, Lutzenberger, Rau, & Birbaumer, 1994; Tremblay et al., 2001). This study suggests that these processes are triggered spontaneously during listening because participants were not asked to attend to a specific stimulus type.

The processing advantage of the 2PP personal pronoun “du” (“you”) is in clear contrast to what has been reported during visual presentation of pronouns, where particularly first person (1PP) pronouns (personal and/or possessive ones) were chosen as self-related stimuli and found to be processed in a facilitated manner as compared to third person stimuli (e.g., Blume & Herbert, 2014; Esslen et al., 2008; Shi et al., 2011; Zhou et al., 2010). As outlined above, the present ERP analysis confirms the suggestion that listeners unlike readers spontaneously relate the 2PP personal pronoun “du” (“you”) to the own self and the 1PP personal pronoun to the speaker’s self (Ruby & Decety, 2009). This initial switch in self-reference from 1PP to 2PP during listening is in line with the hypothesis that processing of self-related stimuli is relational, context- and modality-specific (Northoff, 2013; Qin & Northoff, 2011), at least when self-related stimuli are considered that are less personally unique than, for instance, the subject’s own name.

Notably, these early ERP effects are unlikely to be biased by differences in physical stimulus properties. Despite some variation, pronouns differed only slightly in acoustic stimulus parameters such as fundamental frequency (F0) and intensity. Moreover, if, for instance, differences in word length had influenced the reported ERP effects for personal pronouns, one would have expected facilitated processing of the 2PP and 3PP personal pronoun “du” (“you”) and “er” (“he”) as these pronouns are on average shorter than the 1PP personal pronoun “ich” (“I”). Furthermore, preferential processing compared to both 1PP and 3PP pronouns continued into the N1 and in the P2 time window. Thus, for personal pronouns, a clear differentiation between 2PP vs. 1PP and 3PP pronouns emerged immediately after stimulus onset.

### *Self-reference and possessive pronouns*

For possessive pronouns, a different ERP pattern emerged in line with the hypothesis that self-processing differs for stimuli addressing the self as the object of experience (i.e., ME). No processing advantage of either the first or second person was observed in the P1 time window suggesting that for possessive pronouns self-reference is not established in very early in very early time windows. As predicted, differential processing started temporally later than for personal pronouns, however earlier than expected, i.e., during the N1 time window. Listening to the first person (1PP) pronoun “mein” (“my”) elicited a well-pronounced N1 amplitude compared to the second (2PP) and also the third person (3PP) pronouns (i.e., “dein” and “sein”). Moreover, listening to the first person (1PP) pronoun “mein” (“my”) did not affect stimulus processing in the P2 time window: Instead, N1 amplitudes continued into the P2 time window indicating sustained external attention to the 1PP possessive pronoun “mein.” Semantically, the first person possessive pronoun “mein” (“my”) refers to the own self indicating ownership (“this is belonging to me”). However, as illustrated in Figure 1, during listening, the first person possessive pronoun “mein” could also refer to the speaker thereby producing conflicting information about ownership. We suggest that this mismatch between the listener’s semantic expectancies and the communicative context could have led to sustained attention to the 1PP possessive pronoun “mein.” Indeed, prolonged negativities in the N1–P2 time window during acoustic stimulus presentation have been well described in the ERP literature (for a recent overview, see Patel & Azzam, 2005). They are thought to reflect continuous updating of information from an internal memory trace and the reorientation of attention that is triggered by a mismatch between external information and internally stored memory representations. Whether this early processing effect is already associated with self-referential processing or self-other discrimination is uncertain and up to future research.

In addition, processing of possessive pronouns was characterized by a PN starting after the N1 effect at about 250 ms post-stimulus onset. As hypothesized, personal pronouns were no longer processed preferentially in this time window providing further evidence for the hypothesis that pronouns addressing the self-as-subject (“I”) or object (“ME”) differ regarding the depth of self-processing. The amplitudes of the PN were significantly more negative for 1PP and 2PP possessive pronouns than for 3PP possessive pronouns. However, they did not differ for the possessive pronouns of the first (1PP) and second person (2PP). This suggests that self-processing is not only relational, but as suggested by recent research also modulated by the self-relevance of the stimuli for the perceiver (Northoff, 2011; Schmitz & Johnson, 2007; Tacikowski, Cygan, & Nowicka, 2014). The present findings suggest that such relevance effects can extend to stimuli of the first and second person, particularly those addressing the self as an object of experience (“my”/“your”). Interestingly, differential processing of possessive pronouns was reflected by a PN and did not elicit a P3 component. However, the P3 is elicited almost exclusively in oddball tasks in which stimuli differ in presentation frequency (low-probability targets vs. high-probability non-targets). In the present design, stimuli were presented in a serial stream and each stimulus had the same presentation frequency. Whether the modulation of the PN by possessive pronouns in the later time window indicates more elaborate stimulus evaluation akin to the P3, possibly reflecting self-reflection is not known, although results from source imaging would partly support this assumption.

## Brain structures involved in self-processing

Facilitated processing of the 2PP personal pronoun “du” (“you”) in the P1–N1–P2 time windows was associated with increased activity in the superior temporal sulcus (STS) bilaterally, and the left insular cortex (BA13). The STS and the adjacent insular cortex have been suggested to play a prominent role in auditory processing, sensory integration, and in social cognition (Bamiou et al., 2003). Regarding the STS, voice-selective areas in the auditory cortex have been shown to be activated specifically by personally relevant stimuli, with the left STS rather processing temporal aspects and the right STS spectral aspects of auditory stimuli (Zatorre & Belin, 2001). The left STS also includes the Wernicke area (BA22) which is involved in the decoding of speech and language comprehension (Zatorre & Belin, 2001).

Activity changes in the STS and neighboring regions (insula) support previous studies showing that sensory processing regions including the insula are especially activated during processing of self-related personal pronouns (e.g., Esslen et al., 2008). More speculatively, though, activation of the insula could also imply that listening to the personal pronoun “you” prompted self-awareness. Moreover, functional imaging studies suggest that the insular cortex participates in auditory processing by allocating auditory attention to the stimuli of interest. Besides this, the insular cortex is well known for its role in somatosensory and somatovisceral integration, wherefore insular activity is often interpreted as a neural correlate of conscious stimulus processing (Craig, 2009).

Nevertheless, preferential processing of personal pronouns may still have occurred without self-reflection or self-referential processing. In line with previous findings (e.g., Herbert, Herbert, et al., 2011; Herbert, Pauli, et al., 2011; Shi et al., 2011), in this study, this seems to be restricted to possessive pronouns. Activity in the CMS could only be found during listening to possessive pronouns. Especially the comparison between the possessive pronoun “mein” (“my”) and “dein” (“your”) in the N1–P2 time windows revealed activity changes in the CMS including ventro- and dorsomedial prefrontal cortex as well as parietal cortical regions (precuneus). CMS activation was also found in the PN time window in addition to changes in the inferior frontal cortex.

Medial prefrontal parts of the CMS have been shown to be essentially involved in self-referential processing (Northoff et al., 2006). In addition, it has been shown that different parts of the medial prefrontal CMS are differently related to the self. While the ventromedial prefrontal cortex is more strongly activated during introspection (e.g., when participants attribute personality traits to themselves), the dorsomedial prefrontal cortex is more strongly activated during reflections on other people’s mental state (for an overview see Han & Northoff, 2008; Northoff et al., 2006). The current observation from source imaging clearly warrants further approval from functional imaging. On the other hand, it is well in line with the ERP modulation pattern described above and confirms the role of CMS in self-other discrimination of possessive pronouns of the first and second person (“my” and “your”) and temporally later then in first and second person vs. third person processing.

## Summary and conclusion

Language and the self are closely related. Nevertheless, this study demonstrates that the self is not fixed to specific words with first person reference. Instead, when listening to personal pronouns, the second person “du” (“you”) was preferentially processed in very early time

windows already. This early processing bias is well in line with the notion that when the self is addressed as the subject of experience, self-reference can be established pre-reflectively without self-reflection (e.g. Esslen et al., 2008). In contrast, for possessive pronouns, cortical processing patterns varied considerably across the time-course indicating that for the self-as-object, self-reference needs to be actively construed during processing. Moreover, the 1PP and 2PP possessive pronouns “mein” (“my”) and “dein” (“your”) were not processed differently during later time windows. Given the relevance of the first and the second person perspective for the perceiver during listening, this possibly indicates a transition from “Me” to “We.” Source localization suggests that these processes are associated with activation in the brain’s self-referential processing network (including CMS), whereas primary sensory brain regions (auditory cortex and insula) are primarily involved in preferential processing of personal pronouns. Although LORETA suffers from its limited spatial resolution, the present observations encourage contemporary theoretical models of the self and support them neurophysiologically.

### Future outlook and limitations

Although future studies are necessary to validate the present findings, it appears that very simple language paradigms such as the present one can provide insight into the self, its neuro-functional organization, and the intrinsically relational nature of self-processing. Given that in this study, all words were spoken in “neutral prosody” by the same speaker and therefore no ERP differences with regard to this dimension were expected to appear for the 1PP, 2PP, and 3PP personal or possessive pronouns, it would be very interesting to investigate in future studies what happens in the brain if pronouns are spoken with different intensity or timbre or if the gender of the speaker varies (female vs. male speaker). One could even include non-human voices as speakers as this could shed further light onto the relational and social character of the self and the question of domain-specific specialization in auditory perception of sounds of human origin (Belin, Fecteau, & Bedard, 2004).

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