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Allocation of attention to self-name and self-face: An ERP study

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ABSTRACT

Self-related information, due to its high social/adaptive value, seems to have a preferential access to our attentional resources (cf. the cocktail party effect). However, it remains uncertain whether this attention preference is the same for different kinds of self-related cues. In this ERP study we showed that self-name and self-face when compared with other names and faces, produced very similar patterns of behavioral and neural responses, i.e., shorter reaction times (RTs) and enhanced P300. The processing of the two self-related cues did not differ between each other, neither in RTs nor in P300 responses. In fact, the amplitudes of P300 to self-name and self-face were correlated. These results suggest that the adaptive value of different kinds of self-related cues tends to be equal and they engage attention resources to a similar extent.

1. Introduction

Attention allocation seems to be shaped in a large part by individual concerns, values and expectancies (Deutsch and Deutsch, 1963). Stimuli carrying a high social/adaptive value for a specific person (e.g., his or her own name) seem to automatically attract this person's attention, i.e., the so-called cocktail party phenomenon (Cherry, 1953; Moray, 1959; Wolford and Morrison, 1980; Wood and Cowan, 1995). Electrophysiological studies on the neural processing of self-related cues generally support this hypothesis. These stimuli showed enhanced P300 amplitude – the positive waveform occurring around 300 ms after the stimulus onset – which has been commonly attributed to attention allocation processes (see Polich, 2007, for review). For example, the amplitude was greater for the subjects' own name than for other names (Berlad and Pratt, 1995; Müller and Kutas, 1996; Folmer and Yingling, 1997; Gray et al., 2004), especially if spoken by a familiar voice (Holeckova et al., 2006). Perrin et al. (1999) found differential P300 responses to self-name even during sleep. Fischer et al. (2008), in turn, discovered such effects in comatose patients. As far as the neural processing of self-face is concerned, the P300 was also found to be higher for this stimulus than for famous and unknown faces (Scott et al., 2005). An analogous pattern of results was reported by Sui et al. (2006). Moreover, the enhanced P300 to self-face was absent in prosopagnostic patients (Eimer, 2000) and reduced in patients with autism (Webb et al., 2006).

However, none of these studies investigated more than one type of self-related cue at the same time, using the same experimental procedure, the same stimulus modality and with the same group of subjects. As a result, it remains uncertain whether different kinds of self-related cues engage human attentional resources to a similar or different extent.

Variations in the access to these resources would suggest that the cues differ in terms of adaptive/informative value. It might be assumed, for example, that in principle self-name carries more social relevance than self-face as in order to address a person, we call his or her name, not show them the image of their face. Consequently, human reaction to self-name should be more automatic and should engage more attentional resources. Still, faces inform us not only about a person's identity, but also about their age, sex, mood, direction of gaze, etc. The ability to extract this kind of information within a fraction of a second might have played a crucial role in the survival of our primate ancestors. Along these lines, the face-specificity hypothesis (Kanwisher and Yovel, 2006) suggests that humans have developed specialized cognitive and neural mechanisms dedicated specifically to the processing of faces. As an 'evolutionary privileged' stimulus, self-face might be likely to trigger stronger attention engagement than self-name.

Similar responses to self-name and self-face, in turn, would support the theory of late selection of attention which states that resource allocation is based on semantic characteristics of the stimuli (Deutsch and Deutsch, 1963). Once the recognition is completed, it is the denotation of a particular name or face, i.e., whose name or face it is, but not the physical characteristics of these stimuli, e.g., brightness, loudness, size, shape, etc., that determines the involvement of attention. As self-name and self-face denote the same person, they would engage attentional responses to a similar extent.

Considering the above, the aim of this study was to investigate similarities and/or differences in behavioral (reaction times, RTs)

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and neural (event-related potentials, ERPs) responses to both self-name and self-face vs. other famous and unknown names and faces (all stimuli were presented visually). Additionally, what is novel about this study, instead of the first names only, we used the full names of persons (still called names for the ease of reference). There are many life situations in which this stimulus, instead of just the first name, is used to attract our attention, e.g., a call for passengers at the airport, checking attendance at school, calling someone to have a public speech, etc. These situations might be less frequent but more formal, i.e., important for people, therefore, worth investigating.

2. Methods

2.1. Participants

Thirty right-handed volunteers (15 male and 15 female) between 22 and 38 years of age (mean = 27.4; SD = 3.7) participated in this study. None of them had ever changed their first or last name. Handedness was confirmed with the Edinburgh Inventory (Oldfield, 1971). The participants were either Ph.D. students or employees of the Nencki Institute of Experimental Biology, Warsaw, Poland. They were free from any neurological dysfunctions and had normal or corrected-to-normal vision. None of the subjects had any previous experience with the task. Due to technical problems in data acquisition three of the subjects were excluded from the study. As a result, the total of 27 subjects were included in the analyses (13 male and 14 female).

The experimental protocol was approved by the Bioethics Committee of Warsaw Medical University and informed consents were obtained from all the subjects prior to the study. The subjects were paid PLN 100 (about $30) for their participation.

2.2. Stimuli

All the stimuli (names and faces) were presented visually. They were displayed in central vision on a 19-in. NEC MultiSync LCD 1990Fx monitor. For stimulus presentation and measurement of the subjects' responses we used Presentation® software (Neurobehavioral Systems, Albany, CA, USA).

The set of names consisted of 240 compounds of first and last names, written in white block capitals (Arial, 30 pt) against a black background. The size of the stimuli ranged from $2^\circ \times 2^\circ$ to $2^\circ \times 6^\circ$. They belonged to three categories: (1) the subject's own name (60 presentations), (2) names of famous people from various fields, e.g., politics, entertainment, sports (60 presentations), and (3) unknown names (120 presentations). Although there were three categories of names, the subjects performed a two-choice recognition task: familiar vs. unfamiliar, with self-name being treated as a familiar name. The number of the presentations was adjusted to make each type of response equally probable (i.e., 120 familiar and 120 unfamiliar names). In addition, the number of female and male names used for each participant was equal. The mean length of the famous names was 13 letters (SD = 2.8), of unknown ones—13 letters (SD = 2.5) and of the subjects' own names—14 letters (SD = 2.9).

The set of face stimuli also consisted of 240 images. They were grey-scaled pictures of faces (extracted from the original background so that only the face, ears and hair were visible) displayed against a black background. The size of the stimuli ranged from $4^\circ \times 4^\circ$ to $4^\circ \times 5^\circ$. Analogously, the stimuli belonged to three categories: (1) the subject's own face (60 presentations), (2) faces of famous people from various fields, e.g., politics, entertainment, sports (60 presentations), and (3) unknown faces (120 presentations). The photos of subjects' were taken three weeks before the study (participants have not seen these pictures before the experiment), whereas photos of other famous and unknown persons were downloaded from the Internet. Also in this part of the study, the number of female and male faces was equal. Possible differences in the luminance of pictures were addressed by matching the color (gray-scale) statistics of all images to the same image (arbitrarily chosen from the stimuli set).

In both parts of the experiment, we used names and faces of the same people (e.g., Albert Einstein's name and the image of his face). The order in which two parts were carried out was counterbalanced: half of the subjects were assigned the name-recognition task first while the other half were asked to begin with the face-recognition part. The pause between the two parts was 10 min. To prevent habituation, the order in which the stimuli were presented within one part was pseudo-randomized, so that no more than three names or faces of the same category were presented consecutively.

2.3. Experimental procedure

The participants were seated in an acoustically and electrically shielded dark room at a distance of 60 cm from the computer monitor. As mentioned earlier, they were asked to indicate whether they knew the identity of the person whose name/face was presented to them or not. They were to respond as quickly and accurately as possible by pressing one of two buttons on a Cedrus response pad (RB-830, San Pedro, USA). The participants used only the index and the third finger of the right hand to press the keys.

After reading instructions displayed on the computer screen, the participants started the experiment by pressing a button. After the presentation of a fixation point (a white '×' against a black background) a target item (a first and last name or an image of a face) was displayed for 300 ms. To prevent habituation, different inter-stimuli intervals (ISI) were used: 2100, 2200 or 2300 ms. One part of the experiment lasted about 9 min without pauses.

2.4. EEG recordings

EEG was continuously recorded from 62 scalp sites, plus two electrodes placed on the mastoids using a 136-channel amplifier (QuickAmp, Brain Products, Enschede, the Netherlands) and BrainVisionRecorder® software (Brain Products, Munich, Germany). Ag-AgCl electrodes were mounted on an elastic cap (ActiCAP, Munich, Germany) and positioned according to the extended 10–20 system. Electrode impedance was kept below 5 kΩ. The EEG signal was recorded against an average of all channels calculated by the amplifier hardware. The sampling rate was 500 Hz.

2.5. Data analysis

2.5.1. Behavioral data

Responses were scored as correct if the appropriate key was pressed within a 100–2000 ms period after the stimulus onset. Pressing the wrong key or pressing no key at all was treated as an incorrect response. To analyze the behavioral data statistically, we used a two-way repeated-measures MANOVA, where the type of stimuli (two levels: names and faces) and the type of name/face (three levels: own, famous and unknown) were the factors. *T*-tests with Bonferroni correction for multiple comparisons were applied on post hoc analyses. The results are reported, with significance at $p < 0.05$.

2.5.2. ERP analysis

Off-line analysis of the EEG was performed using BrainVisionAnalyzer® software (Brain Products, Gilching, Germany). The first step in data preprocessing was the correction of ocular artifacts using Independent Component Analysis, ICA (Bell and Sejnowski, 1995). After the decomposition of each data set into statistically maximally independent components, based on visual inspection of the component map, the components representing eye blinks were rejected (based on Jung et al., 2001). The ocular-artifact-free EEG data was obtained by back-projecting the remaining ICA components by multiplying them with the reduced component mixing matrix. Butterworth zero phase filters were then implemented: high-pass—0.5 Hz, time constant—0.3 s, 12 dB/oct; low-pass—30 Hz, 12 dB/oct; notch filter—50 Hz. Next, the EEG was segmented to obtain epochs extending from 200 ms before to 1000 ms after the stimulus onset (baseline correction from −200 to 0 ms). It is worth noting that we analyzed only the trials in which subjects correctly recognized a name or face that was presented (special 'macro' was run to select those epochs). In the automatic artifact rejection, the maximum permitted voltage step per sampling point was 50 μV. In turn, the maximum permitted absolute difference between two values in the segment was 300 μV. The minimum and maximum permitted amplitudes were −200 and 200 μV, respectively, and the lowest permitted activity was 0.5 μV. Finally, the EEG was re-referenced to the mean of the recordings from the left and the right mastoids.

In order to prevent the loss of statistical power of the MANOVA (Gevins et al., 1995, 1996), instead of 62 electrodes, we analyzed three midline electrodes (Fz, FCz and CPz), where the P300 is typically evaluated (Johnson, 1993). As a consequence, peak detection procedure (global maxima search) was run on the above-mentioned electrodes and it encompassed the interval between 350 and 850 ms after the stimulus onset. Peak amplitudes and latencies were analyzed using a three-way repeated-measures MANOVA, where the type of stimuli (two levels: names and faces), the type of name/face (three levels: own, famous and unknown) and the electrode (three levels: Fz, FCz and CPz) were the factors. *T*-tests with Bonferroni correction for multiple comparisons were applied on post hoc analyses. The results are reported, with significance at $p < 0.05$.

3. Results

3.1. Behavioral data

The accuracy of responses was very high: the rate for self-name recognition was 99 ± 1, for famous names: 95 ± 5 and for unknown names: $93 \pm 7\%$, whereas, for self-face it was 98 ± 2, for famous faces: 96 ± 3 and for unknown faces: $95 \pm 5\%$. No significant differences in the accuracy rate were found among experimental conditions.

Fig. 1 shows that reaction times to self-name and self-face were generally shorter than to other names and faces. The MANOVA car-

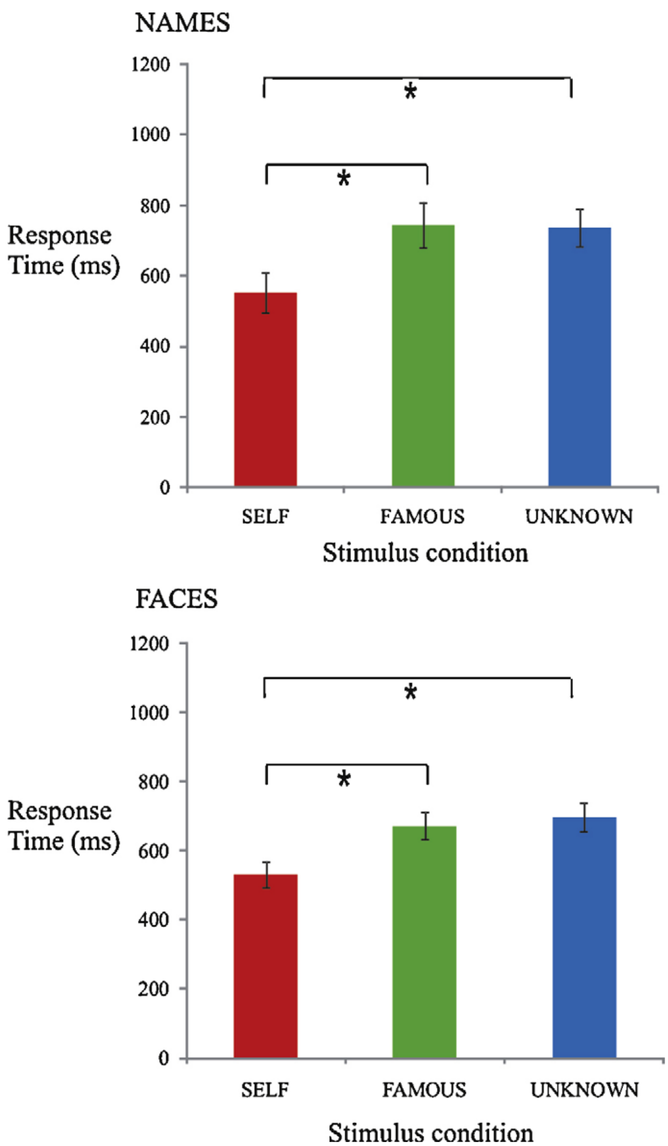

Fig. 1. Reaction times (RTs) and standard deviations to self-, famous and unknown names and faces. Significant Bonferroni corrected post hoc comparisons have been marked with the (*) symbol. Subjects, in general, responded faster to self- than to other-related cues. RTs to famous and unknown faces were significantly shorter than RTs to famous and unknown names. However, no significant differences were found between RTs to self-name and self-face.

ried out on the RTs revealed the main effects of the name/face type [$F(2, 25) = 70.2$, $p < 0.0001$, $\eta^2 = 0.93$] and the type of stimuli [$F(1, 26) = 14.7$, $p < 0.001$, $\eta^2 = 0.36$], as well as the type of stimuli × type of name/face interaction [$F(2, 25) = 10.8$, $p < 0.0001$, $\eta^2 = 0.46$]. The post hoc analyses revealed that RTs to self-name were shorter than to famous ($p < 0.0001$) and unknown names ($p < 0.0001$). The difference between the two latter was not significant. Similarly, RTs to self-face were shorter than to famous ($p < 0.0001$) and unknown ($p < 0.0001$) faces. Again, the difference between the RTs to famous and unknown faces did not reach significance. Moreover, faces were generally recognized faster than names ($p < 0.0001$). As far as the type of stimuli × type of name/face interaction is concerned, famous and unknown faces were recognized faster than famous and unknown names ($p < 0.0001$ and $p < 0.05$, respectively). However, no significant differences between the RTs to self-name and self-face were found.

3.2. Electrophysiological data

Fig. 2A shows the grand average ERPs to three types of names (self-, famous and unknown). The neural activity between 350 and 850 ms after the stimulus onset – encompassing the P300 component – was the most positive for self-name, less positive for famous names and the least for unknown names. Fig. 2B illustrates that an analogous pattern of neural responses occurred in the face-recognition part of the experiment. As the main interest of this study was the comparison between the processing of self-name and self-face, the ERPs to these two types of stimuli were presented separately on Fig. 2C. It should be noticed that the P300 responses to both of these cues were very similar across the whole scalp.

The MANOVA on peak amplitude values revealed main effects of the electrode [$F(2, 25) = 14.7$, $p < 0.0001$, $\eta^2 = 0.54$], the name/face type [$F(2, 25) = 79.5$, $p < 0.0001$, $\eta^2 = 0.86$] and the electrode × type of name/face interaction [$F(4, 23) = 12.2$, $p < 0.0001$, $\eta^2 = 0.68$]. Post hoc analyses showed that P300 amplitude for self-name and self-face was greater than for famous names and faces ($p < 0.0001$) as well as for unknown names and faces ($p < 0.0001$). The two latter also differed between each other—P300 amplitude for famous names and faces was greater than for unknown names and faces ($p < 0.0001$). Moreover, neural activity to all types of stimuli was generally greater in CPz than in Fz ($p < 0.001$) and FCz ($p < 0.001$). The difference between Fz and FCz was not statistically significant. As far as the electrode × type of name/face interaction is concerned, we found that P300 was greater in CPz than in Fz and FCz, only in case of self- and famous names and faces. There were no such topographical differences in response to unknown names and faces.

The MANOVA on peak latencies, in turn, revealed the main effect of the name/face type [$F(2, 25) = 25.5$, $p < 0.0001$, $\eta^2 = 0.67$] and the electrode × type of name/face interaction [$F(4, 23) = 5.7$, $p < 0.01$, $\eta^2 = 0.49$]. The post hoc analyses showed that P300 latencies for self-name and self-face were significantly shorter than for famous ($p < 0.0001$) and unknown ($p < 0.0001$) names and faces. The difference between famous and unknown names/faces was also statistically significant ($p < 0.05$). The post hoc analyses of the interaction, in turn, revealed that the effect of shorter latencies for self vs. famous, self vs. unknown and famous vs. unknown names and faces was the strongest in the FCz location. In Fz the difference between self- and famous names and faces was not statistically significant. In CPz, in turn, the difference between the latencies for famous vs. unknown names and faces did not reach significance.

To investigate similarities in neural processing of different names and faces we calculated Pearson's correlation coefficients between P300 amplitudes for self-name and self-face, famous names and famous faces, as well as for unknown names and unknown faces. Based on Fig. 2D, where scalp topography of P300 is presented, the electrodes where the amplitude of this waveform was the highest – CP1, CPz, CP2, P3, P1, Pz, P2, P4, PO3, POz and PO4 – were selected for this analysis. As far as self-name and self-face are concerned, we found significant correlations in the CP1 ($r = 0.48$, $p < 0.05$), CP2 ($r = 0.62$, $p < 0.01$), CPz ($r = 0.45$, $p < 0.05$), P1 ($r = 0.5$, $p < 0.01$), P4 ($r = 0.44$, $p < 0.05$) and PO4 ($r = 0.4$, $p < 0.05$) electrodes. None of the correlations between famous names and faces or unknown names and faces reached significance. Fig. 3 illustrates the correlations between P300 amplitudes for self-name and self-face at the electrode sites where this effect was the strongest.

4. Discussion

The aim of this study was to investigate whether self-name and self-face engage person's attentional resources to a similar extent. We found no significant differences between the processing of self-name and self-face, neither in the behavioral nor in neural (P300) responses. Moreover, P300 amplitudes for self-name and self-face were significantly correlated. In order to interpret these findings, first, the broader context of previous research will be shown, and then, more specific theoretical propositions will be discussed.

The preferential status of self-name in attentional processes has been extensively investigated in many studies. However, they provided equivocal results. More specifically, it was shown that even if the participants were engaged in another cognitive task, they could still detect their own name in the unattended ear or visual field (Cherry, 1953; Moray, 1959; Wolford and Morrison, 1980; Wood and Cowan, 1995). Moreover, it was discovered that one's own name is particularly resistant to attentional blink (Shapiro et al., 1997) and to repetition blindness during rapid serial visual presentations when compared to other names and nouns (Arnell et al., 1999). At the same time, however, when self-name was presented as a distracter it did not impair subjects' performance more

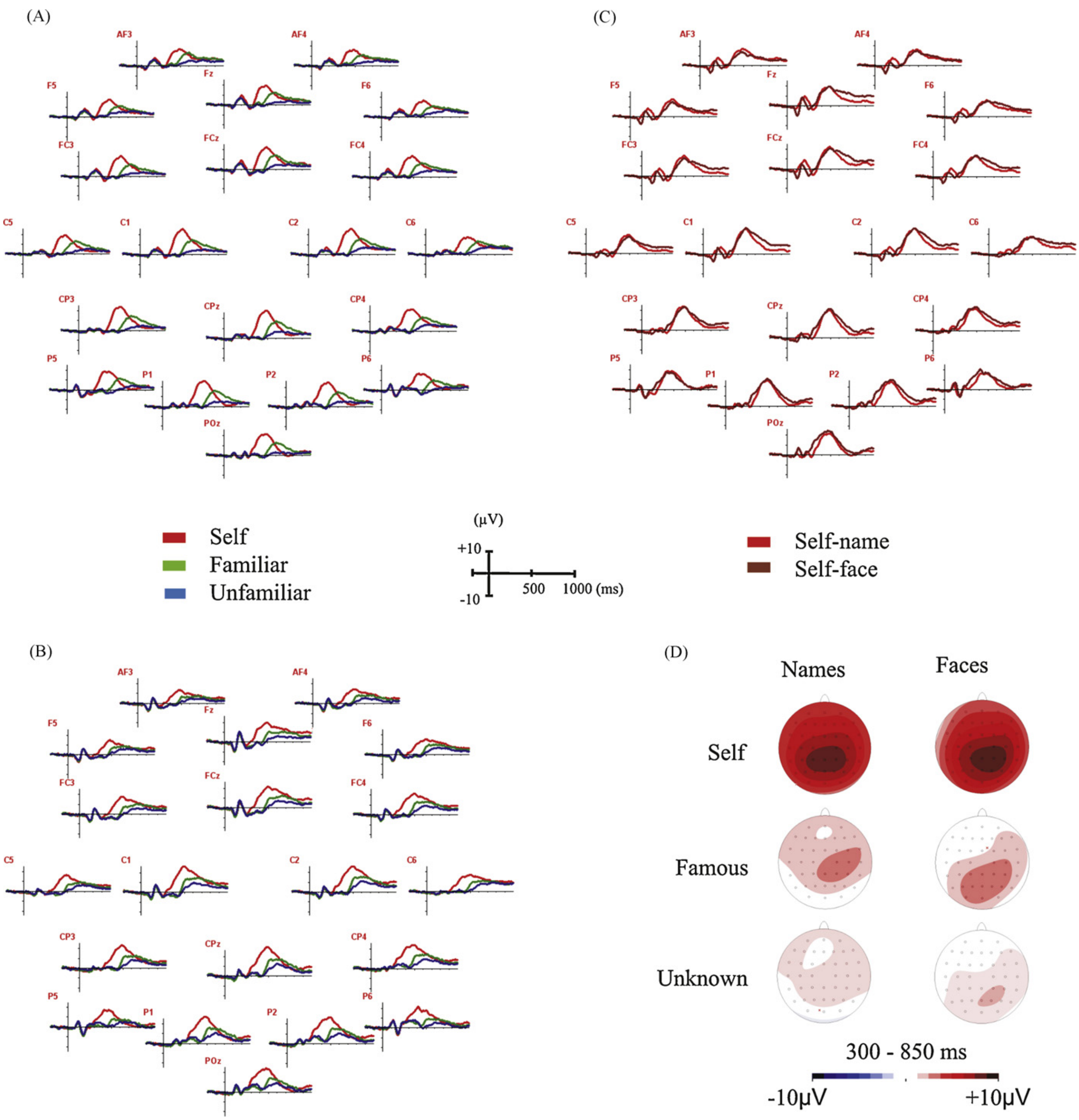

Fig. 2. Grand average event-related potentials (ERPs) to self-, famous and unknown names (A) and faces (B). For the ease of visual inspection we arbitrarily selected 20 (out of 62) representative electrodes covering left to right and anterior to posterior regions of the scalp. A similar pattern of ERPs was present both for names and for faces—in the 350–850 ms interval (encompassing the latency of P300) brain activity was the most positive going for the subject's own name and the subject's own face (red lines), the least—for unknown names and faces (blue lines) and in between the two for famous names/faces (green lines). All of the differences were statistically significant. Moreover, the P300 responses to self-name and self-face seemed to be very similar (C). The MANOVA on P300 amplitudes and latencies did not reveal any differences between the processing of self-name and self-face. As the maps show (D), the topography of P300 for self-name and self-face was also analogous. The maps were computed using interpolation by spherical splines method (order of splines, 4; maximal degree of Legendre polynomials, 10; lambda, 1e−5).

than other names, suggesting that the stimulus does not automatically capture the participants' attention (Bundesen et al., 1997). Harris and Pashler (2004), in turn, found that the number of trials in which self-name is presented is also crucial: after many repetitions, self-name no longer seemed to attract the subjects' attention. Moreover, Kawahara and Yamada (2004) reported that one's own name caused distraction only if it was directly associated with the task. Gronau et al. (2003) showed a similar regularity: task-relevance and location of the distracters (central vs. peripheral) were found to affect performance and skin conductance resistance more than the intrinsic significance of self-name.

Previous investigations of self-face attention-grabbing capacity also produced rather inconsistent results. For instance, self-face flanking a classmate's name in a face-name interference paradigm generated a stronger interference than the reverse condition (i.e., when a classmate's face flanked the participant's own name) (Brédart et al., 2006). Similarly, self-face was more quickly detected among distracters than strangers' faces, even if it was presented in atypical orientations and after hundreds of trials (Tong and Nakayama, 1999). In contrast, in another study, only 18% of participants reported the presence of their own face in the background while they were performing a matching task on two faces presented at foreground (Laarni et al., 2000). Devue and Brédart (2008), in turn, showed that self-face fails to produce interference when presented outside of the focus of attention. In another study, interferences caused by self-face and famous faces did not differ significantly, which again suggests that self-face processing might not have such a preferential status as previously assumed (Devue et al., 2009).

Our study seems to support the hypothesis of attention-grabbing properties of self-relevant cues. Using two types of self-related cues, the same experimental procedure, the same modality and with the same group of subjects we found shorter reaction times and increased P300 responses to self-name and self-face when compared to other names and faces. These findings are consistent with previous electrophysiological studies on subject's own name and face recognition (Berlad and Pratt, 1995; Folmer and Yingling, 1997; Perrin et al., 1999, 2005; Scott et al., 2005; Sui et al., 2006; Holeckova et al., 2006). It is of interest how the P300 sensitivity to self-related cues may be explained.

As outlined in the Introduction section, the P300 component has been mainly associated with the processes of attention (for review see: Polich, 2007). In dual-task performance, as primary task difficulty increases, P300 amplitude from the secondary task decreases regardless of modality or the motor requirements of the primary task (Isreal et al., 1980; Wickens et al., 1983; Kramer et al., 1985). These results suggest a close relationship between the level of attentional resources engaged in a task and the P300 amplitude

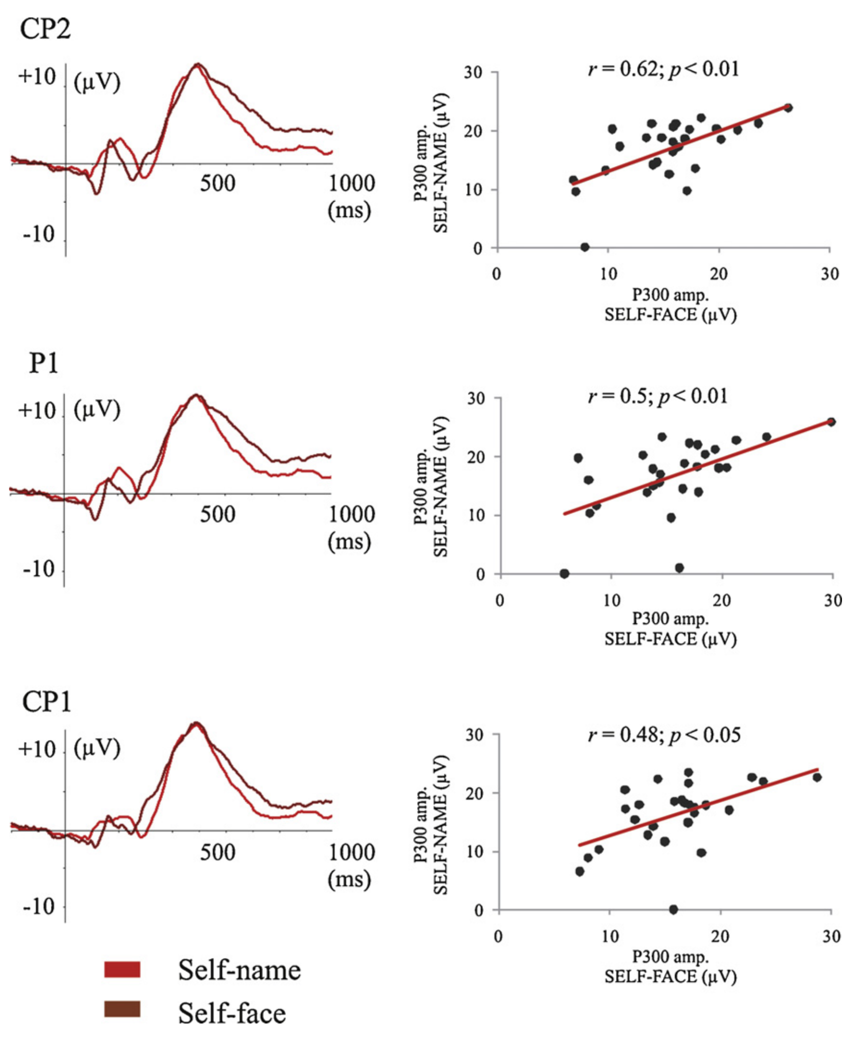

Fig. 3. Grand average ERPs to self-name and self-face and correlations between the P300 amplitudes to these cues in three electrodes where the correlations were the highest. Noteworthy, self-name and self-face produced different early (occurring before 300 ms) ERP responses. However, these differences did not seem to be self-specific, i.e., within the same type of stimuli P300 was the earliest waveform sensitive to the self-relevance feature. Because the aim of this study was to compare self-specific responses to different types of self-related cues, we did not analyze those early differences. Most probably they reflect variations in the processing of names and faces in general.

(Johnson, 1988). In line with this attention-related interpretation, our study showed that self-name and self-face engage attentional resources to a similar extent.

Going beyond purely cognitive interpretations, the P300 also seems to vary with the emotional value of the stimulus—emotionally charged stimuli (regardless of their valence) produced larger P300 then neutral ones (Johnston et al., 1986). Also Dietrich et al. (2001) revealed significantly enhanced P300 for emotionally charged words as compared to neutral ones, suggesting that this ERP waveform is influenced by the emotional content of the experimental material. What is more, Johnston and Oliver-Rodriguez (1997) reported that the P300 amplitude was correlated with the evaluation of the observed person's facial attractiveness (the more attractive the face, the higher the P300).

Obviously, these two interpretations – seeing the P300 amplitude as an index of attention or as an index of emotional arousal – are not mutually exclusive, and could even complement one another. According to Lang et al.'s (1997) model of motivated attention, emotional cues (regardless of their valence) prompt motivational regulation and draw attentional resources. In fact, many behavioral (e.g., Mogg and Bradley, 1997; Öhman et al., 2001; Armony and Dolan, 2002) as well as electrophysiological (e.g., Cuthbert et al., 2000; Keil et al., 2002; Schupp et al., 2003; Briggs and Martin, 2009; Foti et al., 2009) studies support this relationship between emotions and attention. The question that arises at this point is whether self-name and self-face could be regarded as emotional stimuli. Recent definitions of emotions emphasize their subjective character, i.e., emotions could be conceptualized as psychophysiological states that reflect an organism's *appraisal* of the meaning, relevance, and value of events in the world (Dolan, 2002). In this context, it is the motivational relevance of a particular stimulus, to a particular person that determines the emotional vs. neutral evaluation. Without doubt, being oblivious to our own name or face could have serious consequences in our social life and, therefore, these stimuli, among objects such as blood, mutilation, threat or erotic scenes, could be treated as highly emotional. Our results are in line with this interpretation—the RTs and P300 responses that we showed may be attributed to the level of attention engaged in response to emotionally/motivationally different stimuli, with the subject's own name/face being the most emotionally/motivationally relevant, the unknown names/faces being neutral and the famous names/faces—in between.

The present study's novel contribution is the finding that different kinds of self-related cues, such as self-name and self-face, activate a similar amount of attentional resources. Apparently, the social/adaptive value of these stimuli is also similar. We found that it is the meaning of the stimuli, i.e., the fact they denote us ('It's me!'), not their physical features (faces or names), that is crucial for the involvement of the attentional resources.

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