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Response to Own Name in Children: ERP Study of Auditory Social Information Processing

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Abstract

Auditory processing is an important component of cognitive development, and names are among the most frequently occurring receptive language stimuli. Although own name processing has been examined in infants and adults, surprisingly little data exist on responses to own name in children. The present ERP study examined spoken name processing in 32 children (M=7.85 years) using a passive listening paradigm. Our results demonstrated that children differentiate own and close other's names from unknown names, as reflected by the enhanced parietal P300 response. The responses to own and close other names did not differ between each other. Repeated presentations of an unknown name did not result in the same familiarity as the known names. These results suggest that auditory ERPs to known/unknown names are a feasible means to evaluate complex auditory processing without the need for overt behavioral responses.

Keywords

name; P300; social; memory; familiarity

Auditory processing is an important component of cognitive development. Numerous studies have demonstrated that deficits in auditory processing are associated with learning disabilities, specific language impairment, and some of the social-communication difficulties in autism (e.g., Hämäläinen et al., 2013; McArthur & Castles, 2013; O'Connor, 2012). Evaluating auditory processing beyond hearing and basic speech sound discrimination can yield insights about more complex processes including language, attention, memory, and social-emotional functioning.

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Names are among the most frequently occurring receptive language stimuli (Holeckova et al., 2006, 2008) known for their attention-grabbing characteristics, and therefore would be an effective means to assess the extent of inherent attention to and processing of the auditory input in children. Response to own spoken name can also serve as an indicator of social-emotional functioning (e.g., Baranek, 1999; Yurmiya et al., 2006; Zwaigenbaum et al., 2005) because names are typically used to initiate, maintain, or terminate social exchange. Furthermore, own names are one of the most basic forms of language and have comparable significance across all participants (Holeckova et al., 2008; Tamura et al., 2015).

Response to one's own name develops early in life. Infants as young as 4 months prefer to listen to their own rather than other names (Mandel et al., 1995), which can help guide attention to events in their environment (Parise et al., 2010). By adulthood, own names elicit a highly preferential response that may be detected even without explicit instructions to attend (e.g., Eichenlaub et al., 2012) and in subjects with altered state of consciousness (e.g., asleep: Perrin et al., 1999; brain damage: Perrin et al., 2006; Laureys et al., 2007; Wang et al., 2015). Conversely, the lack of consistent response to own name has been frequently reported in individuals with developmental disabilities (e.g., autism: Nadig et al., 2007, Cygan et al., 2014; severe intellectual disability: Tamura et al., 2015). Thus, spoken names are an attractive stimulus for examining auditory processing across the lifespan and range of functioning.

Although own name processing has been examined in infants and adults, surprisingly little data exist on responses to own name in children. In infancy, own name offers a gateway to language learning (e.g., Bortfeld et al., 2005) and communicative development (Csibra, 2010) because it is one of the most frequently experienced and therefore recognizable spoken words. By adulthood, one's name becomes intrinsically meaningful through its connection to self-concept. However, it is unknown whether significant developmental changes in social, communicative, and cognitive skills that occur during childhood also affect processing of own names. The present study was designed to address this gap in knowledge.

Behavioral responses could provide general information about the children's reaction to their own name, but could also be confounded by motivational, attentional, and social factors. Therefore, we chose to examine brain responses to names. Event-related potentials (ERPs) reflect changes in ongoing electrical brain activity in response to a stimulus. They offer a non-invasive and relatively inexpensive (e.g., compared to other neuroimaging methods) means to examine information processing with high temporal precision across multiple stages, from sensory detection and perception to more complex attention, memory, and affective processes. Prior ERP studies of name processing using both visual (printed names) and auditory (spoken) stimuli examined multiple ERP responses and concluded that own name detection is most consistently reflected in the increased amplitude of the parietal P300.

Own names elicited larger parietal P300 responses than stranger names across paradigms that required an active response (e.g., familiar/unfamiliar classification or simple detection; e.g., Cygan et al., 2014; Kotlewska et al., 2015; Tacikowski et al., 2010) or passive exposure (e.g., Eichenlaub et al., 2012; Folmer et al., 1997), including during sleep (Perrin et al., 1999). Earlier components, such as P200 and N250, showed sensitivity to own vs. other names using visual stimulus presentation (e.g., Tacikowski et al., 2011, 2014), while P1/N1 response did not vary across specific name categories in either auditory or visual paradigms (Höller et al., 2011; Perrin et al., 1999; 2006; Tacikowski et al., 2014). The auditory mismatch negativity (MMN) responses were observed for names contrasted with tones (Holeckova et al., 2006, 2008), but this effect could be driven by differences in the stimulus type (speech vs. tone) in addition to the name-specific effects.

The increased positive parietal amplitude to own vs. other names overlaps in time and space with several ERP components, including the P300 (aka P3b) known to be sensitive to the attentional and memory demands (Polich, 2007), the late positive potential (LPP), reflecting affective processing (Hajcak et al., 2010; Sabatineli et al., 2013), and posterior old/new effect (Rugg & Curran, 2007), associated with stimulus recognition and recall processes. Indeed, the reported parietal response to own vs. other names could be driven by greater familiarity of one's own name, the perceived self-relevance of the stimuli (Fan et al., 2013) as well as by the number of repetitions during the study (Hirata et al., 2011; Höller et al., 2011; Tacikowski et al., 2011). While keeping these possible different functional interpretations in mind, we will refer to the parietal response as the "P300" for the ease of comparison with the previously published results.

Because comparable P300 effects were observed in studies requiring active participation and passive listening, we selected a passive listening paradigm for the present study. Our choice was motivated by the desire to examine the inherent attention to auditory inputs and by the need to keep the task simple enough to be suitable for future use in younger children, infants, and individuals with limited motor and/or intellectual abilities.

Although several prior studies used a combination of the first and last name as the stimuli (Cygan et al., 2014; Tacikowski et al., 2010, 2013), we chose to include just the first name because it had been more commonly used in auditory studies of name processing and is more likely to be familiar to children. The children's parents also provided the name of a close other person, with whom the child has a positive relationship. We did not use the parents' names because children rarely address or hear others address their parents by the first name. This choice also was expected to contribute to more comparable levels of familiarity of the close other name across subjects.

In the context of existing evidence demonstrating that repeated exposure within a test session may lead to increased brain responses to novel and unfamiliar names (e.g., Tacikowski et al., 2011), our paradigm included two unknown name conditions: repeated presentation of a single stranger name and a diverse set of novel names presented once. This design allowed to control for the possible repetition effects, examine the effects of pre-experimental familiarity vs. within-session familiarization due to stimulus exposure, and consider the impact of the number of unknown names on the ERPs to one's own name. In 5-month-old infants, the use of multiple unknown names as a contrast to the subject's own name resulted in the loss of the significant ERP enhancement for the own name compared to the single stranger name condition (Parise et al., 2010). However, the older children enrolled in our study were expected to have more experience with their own names as compared to infant participants. Additionally, including multiple unknown names provided greater variability in the auditory input, which was expected to maintain subjects' interest and reduce habituation to the stimuli. The resulting combination of the stimuli (own name, close other, repeated stranger, and novel names) also led to the relatively less frequent presentation of the own name compared to all other stimuli. This was expected to increase the likelihood of observing the increased P300 response to own name, as several prior studies in adults using a passive paradigm with equiprobable presentation of own, familiar, and novel names reported no significant condition differences in the ERPs (e.g., Höller et al., 2011; Hirata et al., 2011).

In line with the previously reported data, we hypothesized that in children, own and close other's names will elicit larger parietal P300 responses than unknown names. If name processing reflects personal emotional connection, then the repeated stranger name should be associated with smaller P300 amplitudes than own or close other name. Conversely, comparable responses to all repeated names vs. unknown names presented once will indicate general attention to and familiarization with the stimulus content.

Method

Participants

Thirty-two typically developing children (15 female), age 4-12 years (M=7.85, SD=2.41) participated in the study. Data for two additional children were excluded due to the lack of cooperation with the testing procedures (n=1) or insufficient number of artifact-free trials (n=1). Typically developing status was verified by Peabody Picture Vocabulary Test –IV (PPVT-IV, Dunn & Dunn, 2007), and all children scored between the average to superior range (M=137.03, SD=32.77). The choice of this particular assessment of cognitive function was due to the design of a larger ongoing study that involves children with developmental disabilities for whom the PPVT is the most commonly used standardized assessment because it does not require a verbal or motor response. All children had normal or corrected-to-normal vision and hearing. Three children were left-handed, the rest were right-handed (M=0.66, SD=0.63) as determined by Edinburgh Handedness Inventory (Oldfield, 1971).

Parents/guardians of the participants provided written informed consent, and all participants provided their assent. The study was conducted with approval from the university Institutional Review Board.

Stimuli

First names of the participant (own name), his/her close other (e.g., sibling, friend), and strangers served as the stimuli. The preferred version of the child's name (e.g., "Billy" vs. "William") served as the own name stimulus. All names were one to four syllables long. There were no significant differences in length among the conditions: participants' own names M=2.06, SD=.72, close other M=2.10, SD=.70, repeated stranger M=2.11, SD=.51. For the entire database from which a subset of stranger names was randomly selected for each participant, M=2.09, SD=.63.

The stimuli were recorded by an adult female native English speaker unfamiliar to the participants and spoken with a friendly intonation, digitized at 44,100 Hz, and equalized in loudness. Although several prior studies suggested that own names spoken by a familiar voice may elicit more pronounced brain responses (e.g., Holekova et al., 2006; 2008; del Giudice et al., 2014), the use of the same unknown adult speaker across all participants reduced the possibility of confounding effects due to personal familiarity with the names or differences in personal experience of each child with the speaker.

Electrodes

Auditory ERPs were recorded using a 128-channel Geodesic sensor net (EGI, Inc., Eugene, OR). The electrode impedances were kept at or below 40 kOhms. The ERP signals were sampled at 250 Hz with filters set at 0.1 Hz - 100 Hz. During data collection, all electrodes were referred to vertex (Cz). Average reference was used for data analyses.

ERP procedure

Each participant was tested individually in a sound dampened room. They were told that they would hear different names and asked to sit quietly and watch a silent video of slow moving geometric figures and abstract shapes (Baby Smart Start, Babyscapes, Inc., Las Vegas, NV) presented on a computer monitor positioned approximately 1 m in front. The spoken stimuli were delivered as a passive auditory paradigm that required no behavioral responses from the participants. Participant’s own name and the name of the close other were presented 32 times each. To control for potential memory effects due to repeated exposures, one stranger name (selected by the caregiver from the unknown set) was also presented 32 times. The three repeated names were interspersed among 96 unique names of strangers (randomly selected from a list of 160+ possible options). Thus, the repeated- and single-presentation names were delivered equally often within a test session. Each participant’s caregiver reviewed the list of possible stimulus names prior to the test session and identified all names that their child may know based on personal experiences (e.g., neighbors, classmates, etc.). These names were excluded from the test run. Stimuli were delivered using an automated presentation program (E-prime 2.0; PST, Inc., Pittsburgh, PA) at an average intensity of 75 dB SPL from a single overhead speaker positioned above the participant’s midline. The interstimulus interval varied randomly between 1800-2800 ms to prevent habituation to stimulus onset. The entire task included 192 trials and lasted approximately 12 minutes.

Data analysis

The EEG data were filtered offline using a 30Hz lowpass filter. Individual ERPs were derived by segmenting the ongoing EEG on stimulus onset to include a 100-ms prestimulus baseline and a 900-ms post-stimulus period. All trials contaminated by ocular and movement artifacts were excluded from further analysis using an automated screening algorithm in NetStation (Electrical Geodesics, Inc; Eugene, OR) followed by a manual review. Data for electrodes with poor signal quality within a trial were reconstructed using spherical spline interpolation procedures. If more than 20% of the electrodes within a trial were deemed bad, the entire trial was discarded. For a data set to be included in the statistical analyses, individual condition averages had to be based on at least 10 trials. The retention rates were comparable across the three repeated names conditions (own=13.63+/−3.22; close other=13.44+/−3.59; stranger repeated =13.72+/−3.64; *p*'s >.58); however, slightly fewer trials contributed to the unique unknown names average (33.94+/−10.50) than to the combined repeated category (40.74+/−9.05), *p*<.01.

Following artifact screening, individual ERPs were averaged, re-referenced to an average reference, and baseline-corrected by subtracting the average microvolt value across the 100-ms prestimulus interval from the post-stimulus segment. To reduce the number of electrodes in the analysis, only data from selected electrodes corresponding to frontal, central, and parietal midline locations (see Figure 1) were used in the remaining statistical analyses. Averaging data within a small group of spatially contiguous electrodes improves signal-to-noise ratio and increases reliability compared to data from a single electrode. These electrode clusters were selected a priori and reflected scalp regions commonly identified as relevant to P300 topography in previous studies (see Polich, 2007 for review), including studies of name recognition (e.g., Hirata et al., 2011; Tacikowski et al., 2014).

Next, mean ERP amplitudes were derived for the P300 in the 450-750ms window. The specific time intervals were selected a priori based on temporal windows utilized in previously published ERP studies of own name processing (e.g., Eichenlaub et al., 2012; Tacikowski et al. 2010, 2014), and confirmed by visual inspection of the grand-averaged waveforms. The resulting mean amplitude values were averaged across the electrodes within the pre-selected electrode clusters (Fz, Cz, Pz; Figure 1) and entered into a repeated-measures ANOVA with Sex (2: male, female) as a between-subject factor and Name (4: own, close other, stranger repeated, unknown) x Electrode Cluster (3: Fz, Cz, Pz) as within-subject factors with Huynh-Feldt correction. Although our hypotheses were specific to the Pz region, including Fz and Cz in the analysis allowed us to confirm the parietal maximum of the anticipated ERP response, accommodate possible developmental differences in the topography, and capture possible additional name discrimination effects associated with the repeated and single presentations of the unknown names. Significant interactions were further explored using planned comparisons and post-hoc pair-wise t-tests with Bonferroni correction.

Results

There were no effects of sex. There was a main effect of electrode, $F(2,58)=88.672$, $p<.001$, partial eta sq. = .747, as well as Stimulus x Electrode interaction, $F(6,174)=5.568$, $p<.001$, partial eta sq. = .157.

Planned comparisons indicated that parietal ERP responses to the own and close other names (Figure 2) were not significantly different from each other, $t(31) = 1.07$, $p=.293$, and generated more positive amplitudes compared to the repeated stranger name (own: $t(31) = 2.184$, $p=.037$, $d=.39$, close other: $t(31) = 3.58$, $p=.001$, $d=.63$) and unknown names (own: $t(31) = 2.92$, $p=.007$, $d=.52$, close other: $t(31) = 3.98$, $p<.001$, $d=.70$). There were no significant differences between repeated stranger and unknown names, $t(31) = .87$, $p=.389$.

Post-hoc pairwise t-tests revealed no significant stimulus-related effects at the Cz, while at the Fz location, ERPs differentiated repeated vs. single presentations, with unknown names eliciting more positive responses that own, $t(31) = 2.41$, $p=.022$, $d=.42$, close other, $t(31) = 2.92$, $p=.007$, $d=.54$, and repeated stranger names, $t(31) = 2.05$, $p=.049$, $d=.36$; however, only the close other vs. unknown difference remained significant following Bonferroni correction.

As an exploratory analysis, the effect of age on the observed ERP responses to names was examined using bivariate correlations. Only ERP amplitudes to unknown names were associated with age where more positive parietal amplitudes, $r(31)=.438$, $p=.012$, and more negative frontal amplitudes, $r(31)=-.483$, $p=.005$, were observed in older children. However, neither correlation remained significant following Bonferroni correction.

Discussion

The purpose of this study was to evaluate auditory processing in children using ERP responses to own and other names. While previous findings in adults established that written and spoken own names attract attention both in active and passive tasks (e.g., del Giudice et al., 2014; Tacikowski et al., 2014), this is the first study demonstrating similar processing in typically developing children.

As predicted, children elicited more positive parietal P300 responses to their own and close other's names during the passive exposure to known and unknown names. The timing of this response is consistent with the adult data, suggesting that neural mechanisms supporting own name processing develop early in life. The absence of significant differences between the ERP responses to own and close other's names also replicates prior reports (e.g., Sugiura et al., 2008; Tacikowski et al., 2014; Shi, 2016) attributing this finding to comparable self-relevance and/or affective value of the two familiar stimulus types. Importantly, this replication across ages, modalities (auditory vs. visual), and task demands (passive exposure vs. active classification by color or by familiarity) suggests that the observed results are unlikely to be an artifact of the particular data processing or analysis procedures.

Differently from previous studies, our design included a repeated stranger name, a condition that allowed controlling for the effects of repeated exposure to a stimulus during the testing session. Although previous studies in adults noted that repeated presentations of an unknown name could lead to increased P300 amplitudes (e.g., Tacikowski et al., 2011), in our data set, repeated stranger names elicited smaller P300 responses than own and close other's names, suggesting that repeated exposure to a novel stimulus over a short period of time (i.e., 32 trials over 12 minutes) may not be sufficient to develop familiarity comparable to that associated with own or close other's name. Indeed, we observed no significant differences between the parietal P300 amplitudes elicited by the repeated stranger name and the varied unknown names presented once.

The use of a varied unknown name condition that included 96 unique names with which the participants had no personal experience allowed the auditory stimuli to be diverse and also likely increased the difficulty of the task compared to previously published studies. In 4-5-

month-old infants, using 10 unknown names resulted in the lack of significant ERP difference in response to own name, unlike the results for the group that used a single unknown name (Parise et al., 2010). The increased diversity of the stimuli in our study could be viewed as a better approximation of the daily listening experiences within school and the broader community, and the evidence of school-age children's ability to differentiate personally known from unknown names under such conditions likely reflects a more mature and experienced neural system.

One unexpected finding was the presence of the amplitude differences between repeated vs. single name presentations observed at the frontal locations. Based on the negative polarity and the relatively late time window of this effect, we interpret it to be a form of an FN400 response associated with stimulus familiarity. Similar frontal negativity has been reported in adults by Holeckova et al. (2006) in a study using names spoken in familiar and novel voices. While this finding was not predicted and therefore will need to be replicated, it does not detract from the overall utility of the paradigm as the means to evaluate complex auditory processing without the need for overt behavioral responses. It suggests that in addition to the detection of self-relevant stimuli (indexed by the parietal amplitude differences), our passive listening paradigm may be also tapping general discrimination between repeated and single stimulus events (reflected by the frontal amplitude differences).

The reported results have implications for future studies in individuals with autism and other developmental disabilities characterized by motor and/or social-communicative deficits that make behavioral evaluations of their language, social, and cognitive skills challenging. The use of auditory ERPs paired with experimental paradigms that do not require an overt behavioral response would be ideal for assessing these individuals since these tasks bypass the need for verbal and/or motor responses. Own names offer a particularly promising stimulus for assessing auditory processing because they are among the developmentally earliest recognizable meaningful words and attract attention even during passive exposure. Thus, differential neural responses to own vs. other names would index the participant's ability not only to detect the presence of a sound but also to orient to and process the auditory input enough to notice a familiar, salient stimulus. The contrasts between own and close other's or unknown names could provide additional information about the social-emotional and communicative functioning, including the sense of self and affective connections with others. In a currently ongoing study, we are using the same name task to evaluate the extent of independent auditory processing in children with Rett and MECP2 duplication syndromes. We predict that individuals with more advanced social-communicative skills and better attention will generate ERPs resembling those of the typical children.

While providing novel findings that will have implications for ongoing and future research in individuals with and without developmental disabilities, our study presents several limitations. The age range of participants was relatively wide for an ERP study. The choice was necessitated by the larger study involving children with Rett and MECP2 duplication syndromes, rare genetic disorders for which recruiting single-age samples is not feasible. We examined the effect of age on the analyzed ERPs and observed a non-significant trend toward larger parietal response to unknown names in older children. However, a larger sample with more participants of each age would be necessary to determine the effects of age on own name processing in children. Also, while we addressed the main goal of establishing the feasibility of using ERP responses to own name as measures of auditory processing during a passive listening paradigm, we are unable to evaluate the connections between the ability to detect personally familiar names and social-emotional functioning in children because no relevant standardized behavioral assessments were collected. In the future study, we will expand the repertoire of the behavioral assessments to include such measures.

In conclusion, our study provided the first evidence that during passive exposure to spoken stimuli, typical children respond to personally known names in a manner similar to that of adults. These results suggest that own names are a feasible means to evaluate complex auditory processing without the need for overt behavioral responses. Future studies will need to examine the associations between ERPs to own name and standardized measures of social-emotional and communicative functioning, but current data suggest that this experimental paradigm holds promise as a new approach to document higher-order processing in individuals with developmental disabilities.

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Highlights

- We examined ERP responses to own, known, and unknown names in children.
- We used a passive listening paradigm with no attentional demands.
- Personally known names elicited larger P300 than unknown names.
- P300 to repeated unknown names did not differ from unknown names presented once.
- ERPs to known/unknown names are a feasible marker of complex auditory processing.

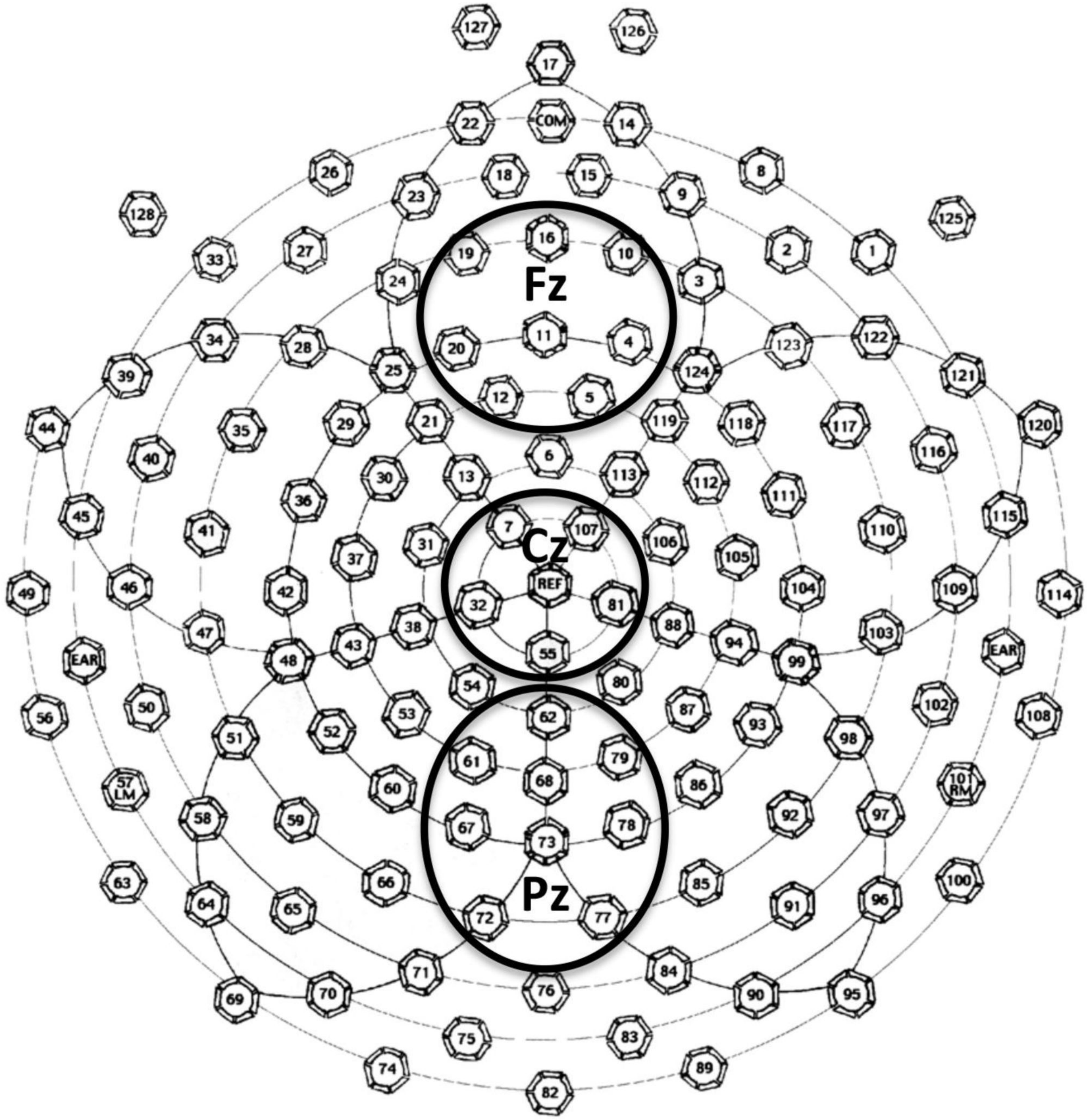

Figure 1.

Electrode layout of the 128-channel geodesic net (EGI, Inc) and the frontal, central, and parietal midline clusters used in data analysis.

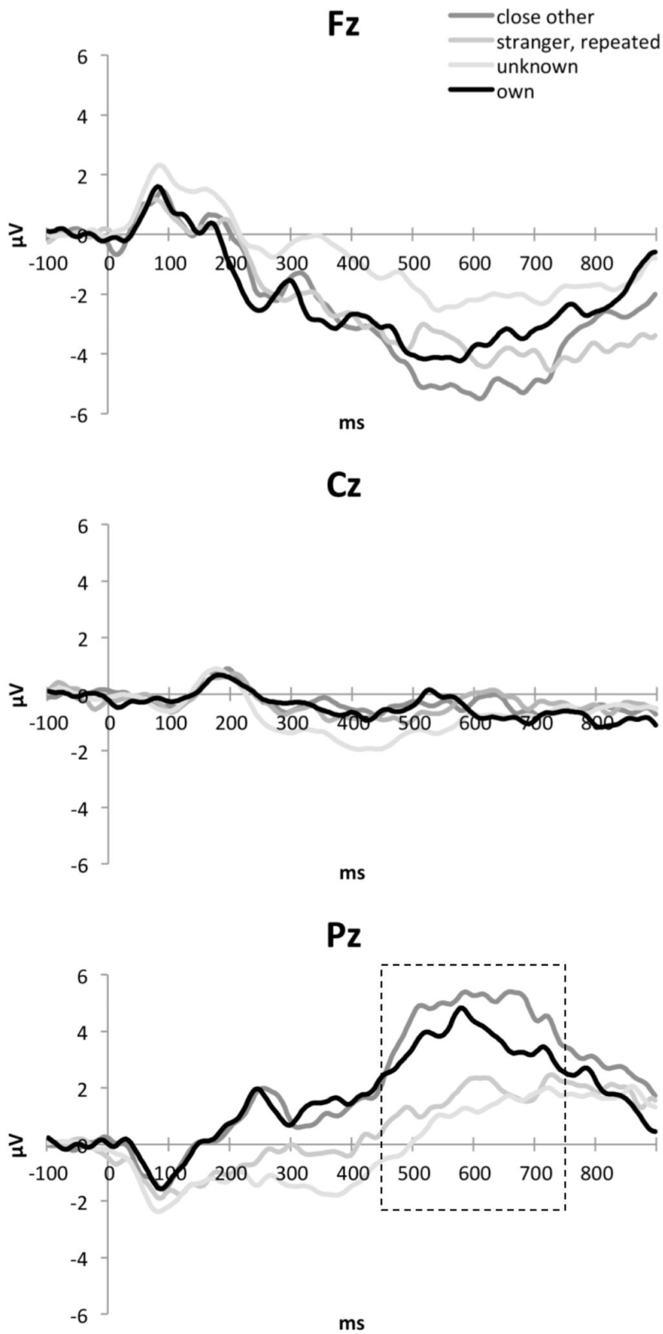

Figure 2.

Averaged ERP responses to names at Fz, Cz, and Pz scalp locations.