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Short communication

# Pre-articulatory electrical activity associated with correct naming in individuals with aphasia

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Picture naming is a language task that involves multiple neural networks and is used to probe aphasia-induced language deficits. The pattern of neural activation seen in healthy individuals during picture naming is disrupted in individuals with aphasia, but the time-course of the disruption remains unclear. Specifically, it remains unclear which anatomical and temporal aspects of neural processing are necessary for correct naming. Here, we tested two individuals with stroke induced aphasia, and compared the differences in the event-related potentials (ERPs) and current sources when they made correct vs. erroneous responses during picture naming. The pre-articulatory ERP activity was significantly different between the two responses. Current source analysis revealed that the ability to recruit left temporal and frontal areas within a 300–550 ms time window after stimulus onset contributed to correct responses. These results suggest that targeted neuromodulation in these areas could lead to better treatment outcomes in patients with aphasia.

## 1. Introduction

Brain lesions secondary to stroke can lead to language disorders, such as aphasia, in approximately 40% of stroke survivors (Berthier, 2005; Pedersen, Vinter, & Olsen, 2004; Wade, Hewer, David, & Enderby, 1986). One of the most persistent symptoms in aphasia relates to difficulty in naming common objects, anomia. Interestingly, overall accuracy on naming tasks across testing sessions is fairly consistent (Naeser et al., 2010; Vitali et al., 2007). However, the individual items incorrectly named will often vary across sessions, suggesting that the person with aphasia has the capacity to name most items, but some aspect of processing is incomplete or erroneous at times, and leads to inconsistent errors. Such errors are not item dependent (i.e., the participant does not need to re-learn the item), but rather, stochastic in nature. It remains unclear what the mechanism supporting correct versus incorrect naming is, but it is likely that a disruption of time- and region- dependent neuronal communication plays a major role (Piai, Meyer, Dronkers, & Knight, 2017).

Picture naming task involves a network of brain regions in the occipital, temporal, parietal and frontal cortices (DeLeon et al., 2007; Gleichgerrcht, Fridriksson, & Bonilha, 2015; Salmelin, Hari, Lounasmaa, & Sams, 1994). Different components of this network are involved in distinct cognitive processes but language specific areas play a particularly important role. Electrophysiological studies have shown that the left posterior temporal lobe shows strong activation approximately 200–350 ms after picture presentation (Eulitz, Hauk, & Cohen, 2000; Levelt, Praamstra, Meyer, Helenius, & Salmelin, 1998). This time window is perhaps critical for picture naming because patients with lesions in these areas are less likely to show treatment-related improvements in anomia (Fridriksson, 2010).

Previously, using functional brain imaging, we have shown that activation of the perilesional left frontal and temporal cortices is associated with an increase in the number of items named correctly by patients with aphasia (Fridriksson, Richardson, Fillmore, & Cai, 2012). However, because the hemodynamic response is relatively slow, the temporal role of neural activation in these areas remains unclear. In this pilot study, using high-density electroencephalography (EEG) and source analysis, we tracked and compared the spatiotemporal dynamics of cognitive processing between correct and incorrect responses made by two individuals with post-stroke aphasia during a picture naming task. We first computed event-related potentials for the *Correct* and *Incorrect* responses and performed a topographic ANOVA analysis

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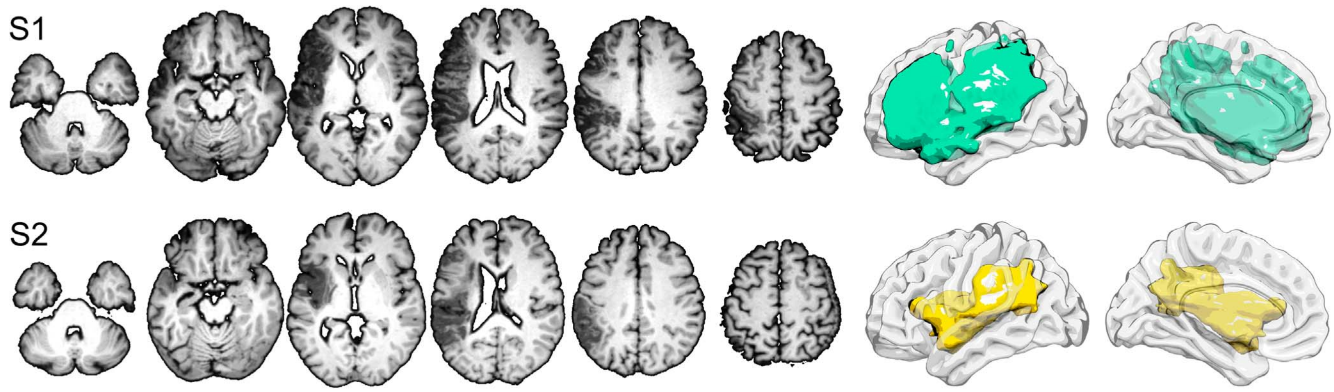


**Fig. 1.** Lesion locations and volumes for S1 (top) and S2 (bottom).

(Murray, Brunet, & Michel, 2008) on the potentials between the two types of responses. We then modeled the activated cortical areas using current source estimation and we expected distinct neural signatures in the frontal and temporal lobes when the pictures were named correctly versus incorrectly. Our results show that within a 300–550 ms window, current sources in the left temporal and frontal lobes contributed to better picture naming performance.

## 2. Results

The lesion location and volumes for both participants are shown in Fig. 1. S1 had a much larger lesion compared with S2 (Fig. 1). S1's lesion encompassed most of the frontal, parietal and temporal lobes, whereas S2 had a large, albeit smaller lesion, in the perisylvian region. Both participants (S1 and S2) made a substantial number of errors during the picture naming task. Out of 80 total pictures, S1 and S2 named 50 and 49 pictures incorrectly, respectively. The average reaction times for S1 were 1840 (*Correct*) and 2269 (*Incorrect*) ms, respectively and for S2 were 1209 (*Correct*) and 1554 (*Incorrect*) ms, respectively. Overall, S1's reaction time was about ~600 to 700 ms slower than S2.

We found statistically significant differences in the ERPs between the *Correct* and *Incorrect* responses at different latencies in the two participants. This observation is consistent with previous literature suggesting that responses in individuals with aphasia is delayed compared with the neurologically intact population (Hurley et al., 2009; McCarthy & Kartsounis, 2000). For participant S1, the TANOVA analysis revealed that the ERP responses were significantly different ($p < .05$) in the time window spanning 346–366 ms. A topographical map of the averaged ERPs in the two conditions are shown for the *Correct* and *Incorrect* responses in Fig. 2A and B. Participant S2's ERP responses were significantly different ($p < .05$) in a 485–555 ms time window post stimulus presentation. Fig. 2C and D shows the averaged ERPs for the two types of responses for S2. For both the participants, the ERPs were stronger in the language processing areas (inferior frontal gyrus, anterior temporal lobes, superior gyrus and posterior portions of the temporal cortex) for the *Correct* responses compared to the *Incorrect* responses.

We then looked at the sources of the ERPs within the same time windows where we found significant differences in the averaged ERPs. For S1, the sources of the ERP activity for the *Incorrect* responses were focused in the frontal lobe only (see Fig. 3A). In contrast, for the *Correct* responses, the sources were more diffuse (including the language areas in the left temporal lobe) over the temporal, frontal, parietal and occipital lobes. For participant S2, the sources were focused over the left inferior temporal cortex for *Incorrect* responses and over the left frontal and temporal lobes for the *Correct* responses (see Fig. 3B). Thus, for both the participants, the current sources in the left temporal and frontal areas were stronger during the *Correct* responses versus the *Incorrect* responses.

## 3. Discussion

The behavioral performance of the participants in our study seem to be related to the size of the stroke lesion. Overall, S1's reaction time was about ~600 to 700 ms slower than S2. S1 also had a larger lesion encompassing most of the frontoparietal and temporal areas. The main finding of our exploratory study is that, even though there were substantial differences in the behavior and stroke lesions between the two subjects, there was a common underlying neurophysiological pattern supporting correct naming, i.e., the recruitment of the temporal regions, prior to the correct utterance.

One of the first EEG studies of picture naming conducted with neurologically intact participants showed that cortical activation underlying visual to symbolic transformation of the pictures progressed bilaterally from the occipital cortex towards the temporal and frontal lobes (Salmelin et al., 1994). Since then, other studies have replicated this finding (Levelt et al., 1998; Tanji, Suzuki, Delorme, Shamoto, & Nakasato, 2005; Wierenga et al., 2008). Specifically, these studies have shown that it takes about 200 ms for neural activation to advance from the occipital cortex to the parietal and temporal areas after stimulus presentation and about 400 ms to reach frontal regions.

In participants with aphasia, besides a suppression of ERP activity over the lesioned areas (Spironelli, Angrilli, & Pertile, 2008), differences have also been observed about 250–400 ms after picture presentation in the perilesional left posterior temporal areas (Laganaro, Morand, Michel, Spinelli, & Schnider, 2011; Laganaro, Python, & Toepel, 2013). In their studies, Laganaro and colleagues attributed the impairments in phonological processing and the reduction in the observed ERP activity in these areas to stroke-induced changes in language processes. However, these studies did not directly assess lesion location or compare the anatomical pattern of neural activations between the correct and erroneous responses. One possible reason was that the patients in their study produced too few errors (between 1% and 25%) for statistical comparison. In our study, both participants made ~67% to 75% erroneous responses. That allowed us to compare the ERPs and the sources between the *Correct* and *Incorrect* responses.

We found that the current sources in the left temporal and frontal areas were different between the *Correct* and *Incorrect* responses for both the participants. In addition, there were participant specific differences in the neural activation in the two conditions. These results underscore the importance of appropriately timed neural activation in the temporal and frontal areas for language processes and correct picture naming. Furthermore, stroke patients whose lesions damage dominant temporal areas involved in phonological processing are less likely to show treatment-related improvement in picture naming compared with patients who had suffered minimal damage to these areas (Fridriksson, 2010), especially when the left temporal lobe loses its