THE ROLE OF OSCILLATORY BRAIN ACTIVITY IN THE BETA AND ALPHA BAND DURING LANGUAGE COMPREHENSION

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Background
Event-related potentials (ERPs) have been intensively explored in language research. ERPs have provided important insight into language processing. However, relevant information might also be contained in induced oscillatory responses. Even though many theories predict oscillatory brain activity to play an important role in neuronal processing, limited work has been done on brain oscillations and their relation to language. The aim of this study was to explore oscillatory responses elicited by semantically incongruent words in a classical sentence comprehension paradigm. In particular we focused on modulation in the alpha (8 – 13 Hz) and beta (14 – 35 Hz) band.

Methods
We recorded the magnetoencephalogram (MEG) from 10 subjects using a 151-sensor CTF system. Auditorily presented sentences in which the last word was inappropriate to the sentence context (semantically incongruent) were compared to congruent sentences. The MEG signals from the axial gradiometers were transformed to the planar gradient. In the planar gradient, the strongest signals are typically observed directly above the source. Time-frequency representations were calculated for the individual trials and then averaged using a wavelet method. The sources of oscillatory responses were identified using the beamformer technique SAM and mapped to the individual subjects structural MRIs.

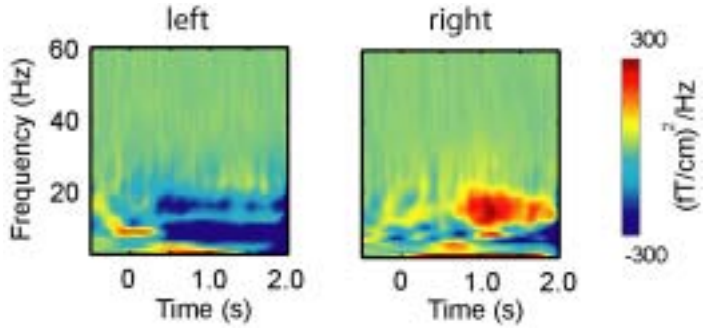

Figure 1. Time-frequency representations of the brain activation following the final-sentence word for incongruent sentence endings. The grand-averages for two typical sensors over the left and right hemisphere are shown. Over the left hemisphere we observed a suppression in the beta band. This was followed by a beta increase over the right hemisphere.

Results
As reported in several previous studies on semantic violations we observed a left lateralized event related field (ERF) over left and right temporal regions peaking ~300-500 ms after the onset of the last word in the sentence. This N400m component was stronger for incongruent compared to congruent words (the N400m effect).

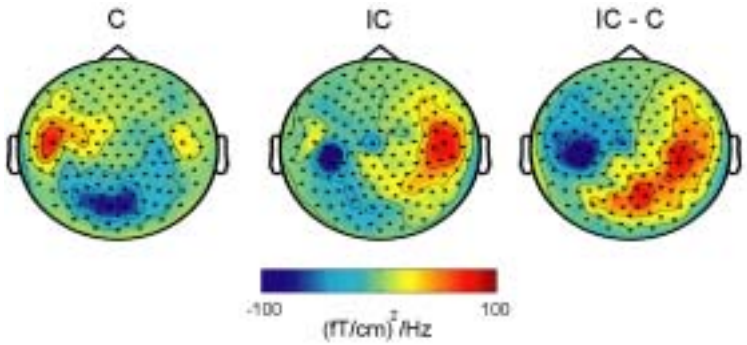

Figure 2. The topography of the beta band response (18 - 25 Hz) for congruent (C), incongruent (IC) and incongruent minus congruent (IC-C) sentence endings. The reponse was calculated 0.8-1.5 s after the onset of the last word.

The wavelet analysis revealed strong modulation of oscillatory signals in the 18-25 Hz beta band (Figure 1). Over the left hemisphere the beta activity was clearly depressed ~500 ms after the onset of the final-sentence word. Over the right hemisphere, the beta activity increased ~1 s after the onset. Both the left hemisphere decrease and the right hemisphere increase were significantly stronger for the incongruent compared to the congruent sentence endings (Figure 2). The SAM analysis identified the oscillatory source of the beta decrease to left prefrontal areas around Broca's areas. The oscillatory sources of the beta increase were identified to the right hemisphere around the posterior part of the Sylvian fissure (Figure 3). Over posterior areas we found a strong modulation in 9-12 Hz alpha band. The alpha activity was suppressed following the onset of the final-sentence word. A stronger depression of the alpha activity was observed for congruent compared to incongruent sentence endings.

Figure 3 . The beta response following incongruent sentence endings localized by SAM in a representative subject.

Discussion

We suggest that the early suppression of beta oscillations in the left prefrontal cortex in response to incongruent sentence endings is explained by increased processing demands to language specific areas. The subsequent increase in beta oscillations in the right hemisphere areas reflects suppression. Likewise we suggest that the reduced suppression of posterior alpha activity following incongruent sentence endings is due to a higher degree of inhibition of posterior areas reflecting the higher processing demands in prefrontal areas. Several lessons can be learned from these results. First, a signal increase in a given frequency band does not necessarily reflect an increase in computational demands. Second, the source modelling allows us to interpret the functional role of the observed oscillatory signals.