Neural source dynamics of brain responses to continuous stimuli with MEG: speech processing from acoustics to comprehension

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**Introduction**

The high temporal resolution of electro- and magnetoencephalography (EEG/MEG) makes them ideal tools to study brain responses to rapidly evolving continuous stimuli such as speech. Linear kernel estimation has been used to decompose EEG and MEG responses to continuous stimuli (see box: “Linear kernel estimation”). However, this analysis is typically applied to sensor space data, not using the full neural source localisation power of MEG. To localise responses anatomically, we computed distributed minimum norm source current estimates of continuous MEG data and estimated a separate response function for each virtual current source dipole. We then used permutation testing to determine whether or not specific regions of the brain displayed significant spatio-temporal patterns in the responses. To demonstrate this method, we analysed the MEG responses of participants listening to segments of a story. We used predictor variables representing different processing stages in comprehension to show differences in anatomical localisation.

**Methods**

**MEG Data**

- 17 Participants (10 left-handed) were recorded while listening to a 43.9-min long story (based on Sleepy Hollow) while wearing a 128-channel MEG system (Magnes 3300, Elekta, Stockholm, Sweden).
- Time series were low-pass filtered at 0.125 Hz and convolved with the tip of the Hilbert transform of the current dipole
- All participants had normal or corrected-to-normal vision.

**Predictor variables**

- Three factors were used to model the predictor variables: face, space, and sound.
- Face: a 1-bit binary vector indicating whether a picture of a face was present or not.
- Space: a 1-bit binary vector indicating whether a location was present or not.
- Sound: a 1-bit binary vector indicating whether a sound was present or not.

**Point spread function**

The theoretical accuracy of MEG source localisation can be evaluated using the point spread function. Since both the forward model and the inverse operator operate on linear matrix operations, the source estimate of a hypothetical source current vector can be computed by combining both operations. The source estimate for a hypothetical point source is the “point spread function”. Hypothetical sources are indicated by the yellow outline.

**Linear kernel estimation**

-Convolving the same kernel with a more dense signal:

**Results**

**Acoustic envelope**

**Word frequency**

- Bilateral early response
- Auditory cortex (<50 ms)
- Sensorimotor parietal and frontal cortices (<90 ms)
- Right-lateralised later response
- Auditory cortex (<100 ms)

- Strong left-lateralized response in auditory cortex (<170 ms)
- Lateral, weaker bilateral frontal response

**Clustering response functions**

Because of the smoothness of MEG source estimates (see box: “Point spread function”), response functions are composed of multiple overlapping responses. To find independent sources we used hierarchical clustering of dipoles based on their time-course (separately for each predictor variable).

**Discussion**

- Results confirm viability of analyzing continuous stimuli
- Allows anatomically separating brain responses to different stimulus properties
- Localization preserves temporally precise response functions (cluster of tens of milliseconds)
- Simultaneously sensitive to variable related to higher cognitive levels in speech comprehension as well as basic acoustic properties
- Robust responses from just 6 minutes of data
- Broaden the possibilities for studying speech comprehension with natural stimuli
- Applicable also to other continuous stimuli

**References**