Maintaining fine temporal resolution when visualizing beamforming results

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Introduction

The main goal of this work has been to visualize event related neural response while maintaining fine temporal resolution. The primary output of beamformers is virtual sensors (VS) which reflect the time-course of estimated brain activity for selected locations. When VS are calculated for a grid of points filling the whole volume of the brain, a functional map can be created based on the VS traces. In order to display smooth images, typically the power of the activity is averaged over time in specific time-windows for every VS, thus losing the fine temporal resolution. Visualizing every time point separately in a movie like fashion yields noisy images due to momentary peaks for noisy sources. In order to overcome this problem two strategies were explored, normalization and masking.

The data used here is taken from a silent verb generation experiment. SAM beamforming was applied on the raw data to calculate covariance and weights (spatial filter). The weights where then multiplied by the average of 54 trials, similarly to SAM(erf) procedure (Robinson, 2004), thus creating VS for every point in the head. Although some virtual sensors showed evoked response, imaging the whole brain with unprocessed VS yielded noisy images.

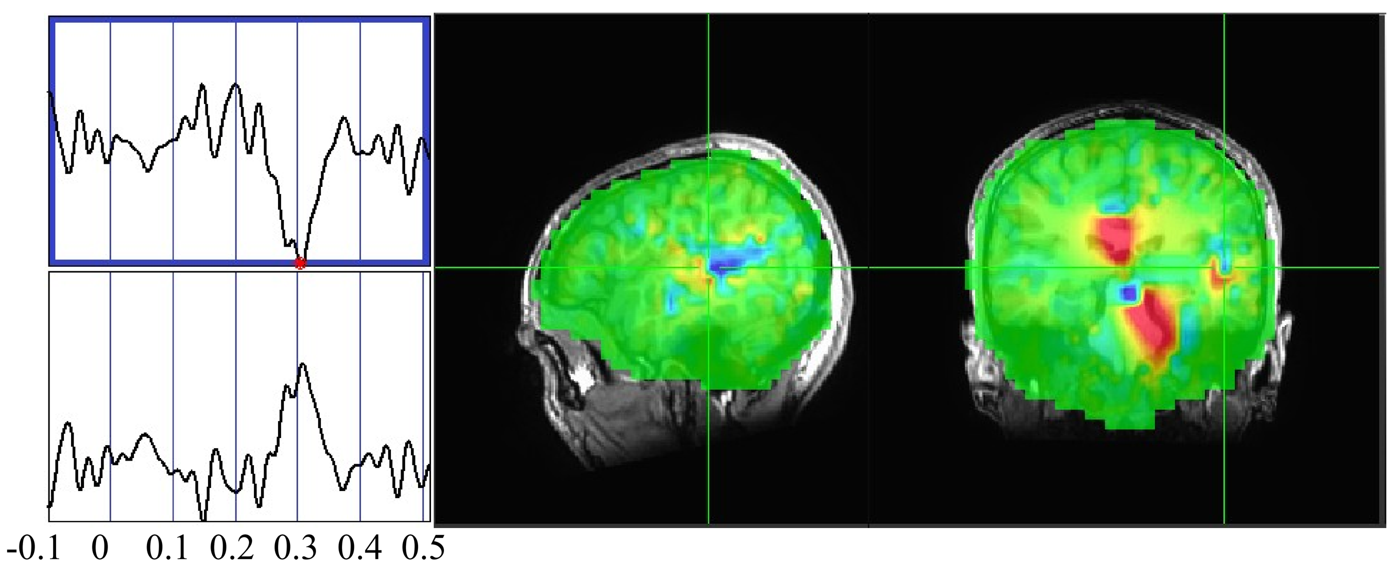


Figure 1. Imaging raw VS. The crosshairs (middle and right) points to the location for which the VS is delineated (top left). The red dot at the dip of the VS trace (top left) marks the time for which the imaging was performed. Positive and negative are arbitrary and there is a bias for deep sources.

One problem is that positive – negative amplitude is arbitrary. Displaying absolute values can solve this issue. The other problem is that some VS, and deep ones in particular are noisy. To overcome this issue some normalization is required.

Normalization

Pseudo Z is a common normalization method where the VS vectors are divided by their noise estimate. Here the mean μ and SD σ were calculated for a baseline period of 100ms. For each sample X of every virtual sensor the absolute pseudo Z score was calculated as: $\left|\frac{X-\mu}{\sigma}\right|$

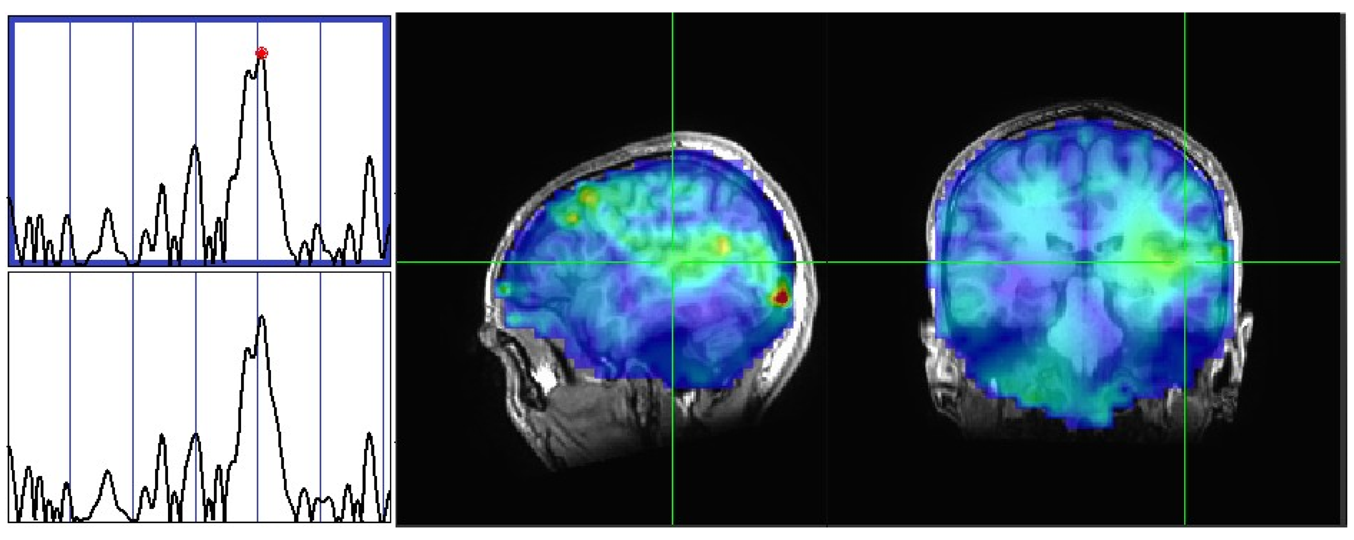
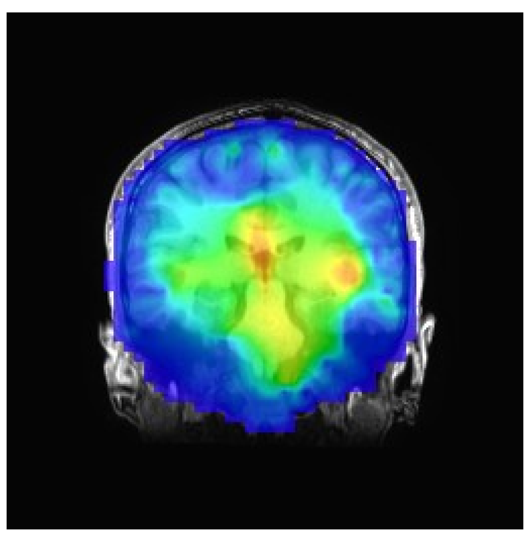


Figure 2. Pseudo Z VS. Channels with quiet baseline (red point in sagittal view) may seem more active than channels with evoked response.

Pseudo Z however depends on the baseline data and may bias the results towards channels with quiet baseline. We used an alternative approach for depth normalization which does not depend on the data. For each VS the root mean square (RMS) of the beamforming weights was calculated to serve as noise estimate.

Figure 3. RMS of beamforming weights is biased to the center and reflects the different scaling for deep and surface VS.



The RMS of VS weights is generally larger for deeper sources. The VS were therefore normalized by dividing each one by its weights' RMS value.

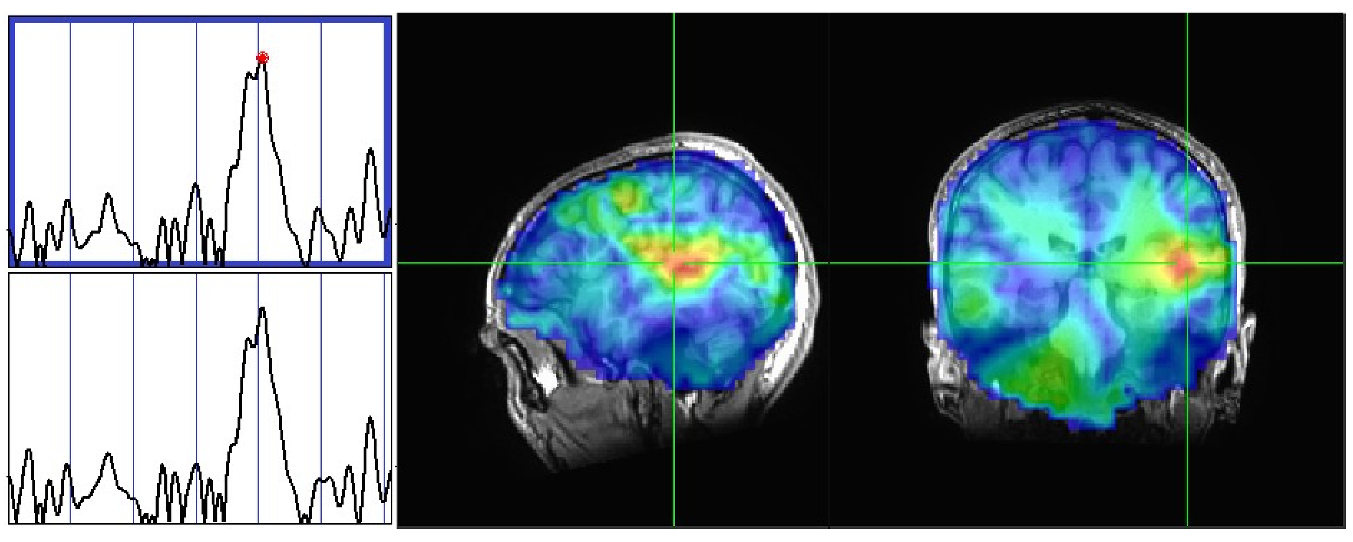


Figure 4. Imaging VS normalized by weights RMS is Similar to pseudo Z but does not depend on baseline data. The waveform is not identical to pseudo Z because the absolute value is computed without baseline correction of the VS.

Masking

Some channels did not show a clear response to the stimulus. In this paradigm this problem was more evident for right hemisphere locations, possibly because alpha rhythms, which were greater over the right, inactive hemisphere were not averaged out fully. In order to distinguish between channels with and without evoked response excess Kurtosis (g2) was calculated for each VS, similarly to spike detection procedure for epilepsy (Robinson et al., 2004).

$$g2=\frac{\frac{1}{n}\Sigma\left(Xi-\bar{X}\right)^4}{\left(\frac{1}{n}\Sigma\left(Xi-\bar{X}\right)^2\right)^2}-3$$

Oscillating VS with no evoked response yielded negative g2 values and were masked out.

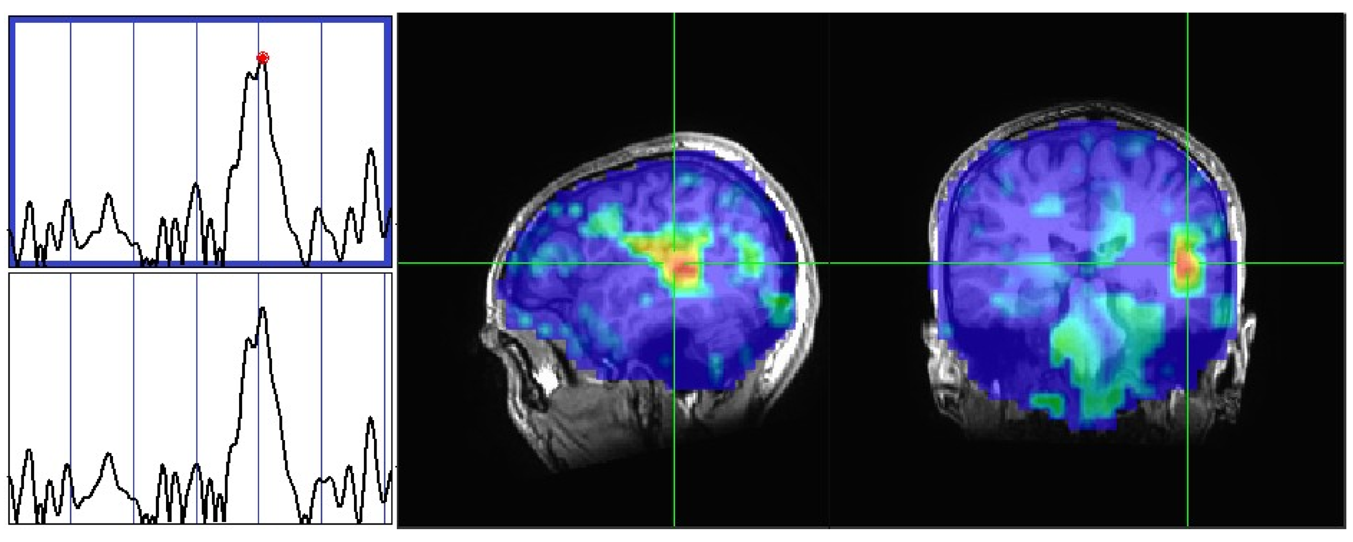


Figure 5. Image of VS normalized by the RMS of their weights after masking out negative Kurtosis (g2) VS.

Conclusions

Rescaling virtual sensors by weights RMS prove a useful normalization method. After normalizing a Kurtosis based mask can be applied in order to hide channels with no evoked response. This way a relatively clean movie can be generated, allowing the researcher to explore the data while maintaining the MEG fine temporal resolution.

For materials and scripts see:

https://github.com/yuval-harpaz/vsMovies

or contact Dr. Harpaz at yuvharpaz@gmail.com

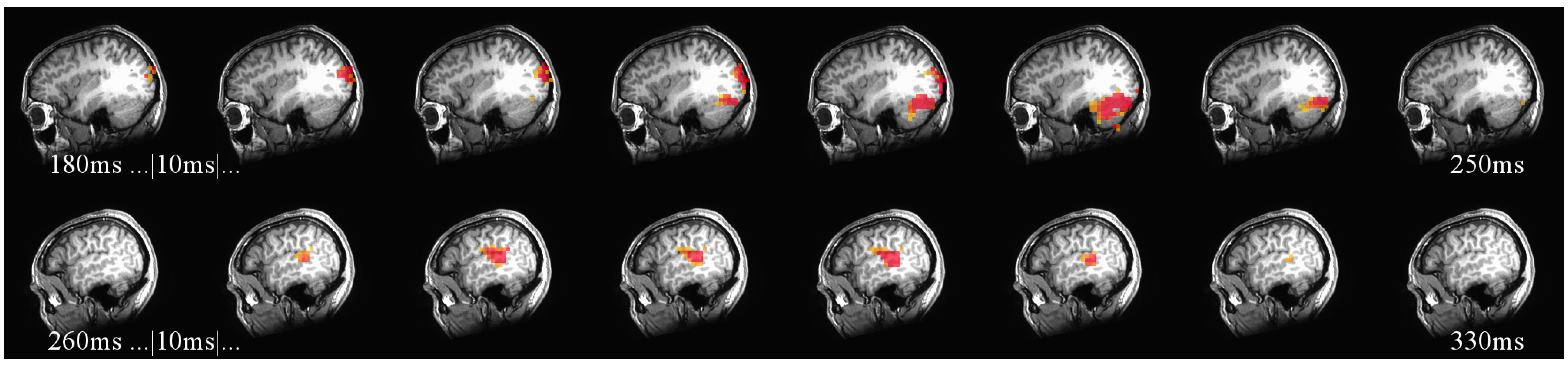


Figure 6. Movie frames of evoked response of the left hemisphere. The images show the spread of activity over the visual cortex (top) and Wernicke's area (bottom).

References

Robinson, S. E. (2004). Localization of event-related activity by SAM(erf). Neurology & Clinical Neurophysiology: NCN, 2004, 109.

Robinson, S. E., Nagarajan, S. S., Mantle, M., Gibbons, V., & Kirsch, H. (2004). Localization of interictal spikes using SAM (g2) and dipole fit. Neurology & clinical neurophysiology: NCN, 2004, 74.