Wavelet Analysis of MEG Auditory Response

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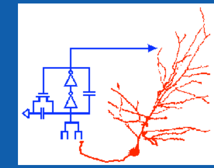


Introduction

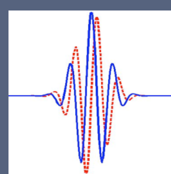
What is MEG?

Magnetoencephalography (MEG) is a powerful, non-invasive technique for detecting neural activity in the brain. The UMD system is capable of high temporal and relatively high spatial resolution, and takes data from 157 superconducting sensors around the head. It can detect a magnetic field as small as 10 fT, generated by as few as 10000 synchronously activating neurons.

Each sensor is a tiny superconducting loop. Ionic currents in the brain create magnetic fields, which in turn induce currents in the sensors.

What is wavelet analysis?

The Morlet wavelet is the product of a Gaussian and a complex sinusoid. In a wavelet transform, the wavelet is multiplied by the signal over a range of frequencies and times: the result is a two-dimensional graph of the power.



$$Signal\,(t) \Rightarrow Power\,(f, t)$$

There is a trade-off between resolution in the time and frequency domains, depending on the wavelet's width.

Methodology

Four different stimuli: each was a one-second pure tone at 400 Hz, modulated in amplitude at 16, 32, 48, or 64 Hz, and each was presented 100 times via headphones to a subject in the MEG system. The resulting data was analyzed in two ways.

PART 1 - The transient response consists both of activity phase-locked to the stimulus (***evoked***), as well as non-phase-locked activity (***induced***). If it is found, consistent induced activity in the gamma band (20-50 Hz) is important because it is believed to indicate the formation of abstract constructs in the brain. A short wavelet (~1 ms) was used to improve temporal resolution.

PART 2 - The steady state response to an AM tone is known to be strongly phase-locked to the stimulus, so only the evoked response was considered. A longer wavelet was used, to emphasize longer features.

Results

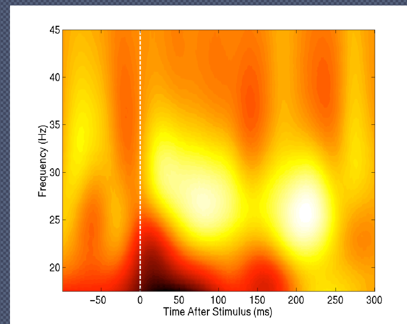


Fig 1 - Induced onset response to the 16 Hz modulated stimulus.

PART 1 - TRANSIENT RESPONSE

Figure 1 shows the induced response to the onset of the 16 Hz stimulus, which contains two major peaks, at 82 ms and 213 ms post-stimulus. No corresponding evoked activity was observed at these times.

The induced responses to the onsets of the other stimuli was somewhat similar to Figure 1. No consistent pattern was found in response to the offset of the stimulus.

Figure 2 shows the sensor readings at one of the peaks. The area medial and anterior to the auditory cortex, where higher-order processing occurs, is very active.

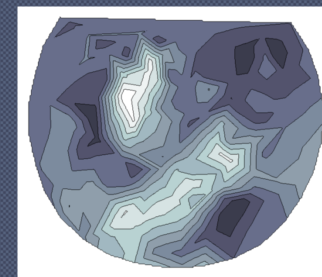


Fig 2 - Looking downward on the head, the MEG signal during the peak at 213 ms.

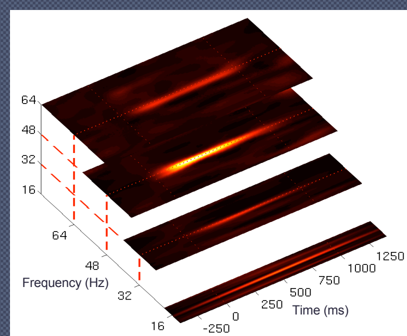


Fig 3 - Steady state response to each stimulus.

PART 2 - STEADY STATE RESPONSE

Figure 3 shows that the SSR is very strong in a narrow band around the modulation frequency of each stimulus. It lasts from approximately 50 ms post-onset until 50 ms post-offset, although with this particular wavelet temporal resolution is low.

Figure 4 shows a contour map of the 48 Hz response, exhibiting peaks over the auditory cortices. Contours of the other SSRs show similar results.

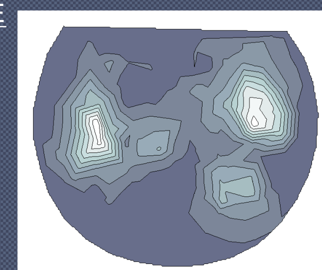


Fig 4 - Looking downward, the MEG signal at 48 Hz.

Discussion and Conclusions

In Part 1, a possible transient, induced response was found; however, it was not present for every stimulus and the noise background was very high. Perhaps with better tools for identifying and eliminating noisy trials, this induced response can be confirmed. Or perhaps these stimuli do not generate induced responses in the brain after all. These results are not conclusive.

In Part 2, a very strong steady state response was identified. It is phase-locked to the stimulus (although ~50 ms delayed), and narrowly banded in frequency, independently confirming the results of previous analyses.

The next step in continuing this research is to estimate the neuronal currents that generate the MEG contours shown above. This information is necessary to understand the actual mechanisms behind the brain's processing of auditory information.

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