MEG Response to Speech and Stimuli with Complex Modulations

Juanjuan Xiang (ECE, ISR), Jonathan Z. Simon (ECE, Biology, NACS, ISR)

Computational Sensorimotor Systems Lab

Introduction

By Hilbert transformation, an auditory signal can be decomposed into the product of an envelope and fine structure. Mammals have neurons in the auditory brainstem sensitive to these features. The goal of this study is to explore the neural response properties in the human auditory cortex.

The neural activity was recorded by a whole-head Magnetoencephalography (MEG) 160-channel, axial gradiometer system (KIT, Kanazawa, Japan, Figure 1) stored in a magnetically shielded room. The MEG system has very good temporal resolution (1ms) and moderate spatial resolution (1cm).

Figure 1 KIT-UMD whole head MEG system & shielded room

A new method to separate brain activity from artifacts is Independent Component Analysis (ICA), which is based on the assumption that the brain activity and the artifacts, e.g. heart beat or eye movements, are anatomically and physiologically separate processes, and this separation is reflected in the statistical independence between the magnetic signals generated by those processes. It also can separate independent neural sources.

Experiment

- ***Recording***

The MEG data was sampled at 1000 Hz, filtered between 1 Hz and 200 Hz with notch at 60 Hz and then was denoised by a Block-LMS adaptive filter with 3 reference channels.

- ***Stimuli***

(1) Figure 2 shows waveforms of 5 different stimuli (1000 ms duration). The first two stimuli are same sentence fragment ("she washed her darks") spoken by two different speakers; The third and fourth stimuli are pure tone and broadband noise modulated by the sentence fragment's envelope; The fifth one is the sentence's auditory ripple approximation.

(2) Each stimuli is presented 80 times in pseudorandom order; random inter-stimulus intervals are uniformly ranged from 800 to 1200 ms; loudness is approximately 70dB SPL.

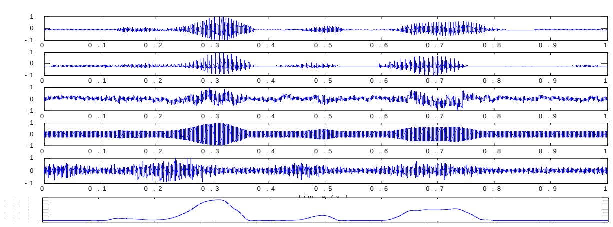
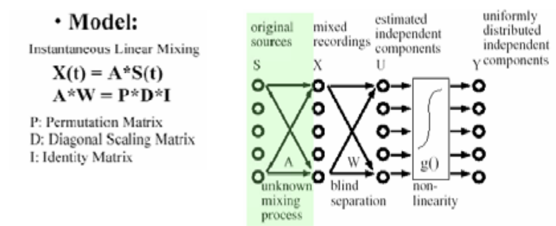


Figure 2 Waveforms for experiment's 5 stimuli and the bottom one is speech's envelope

ICA model

We use ICA to unmix the separate sources' activity.



- ***Assumption***

  Sources are independent and mix linearly

- ***Method***

  Estimate weights in order to maximize output entropy H(Y)

  ⇔ Minimize mutual information I(Y**)**

- ***Goal***

  Learn the transform which can unmix the recorded signal so that the output is as independent as possible

Results

(1) After applying ICA to the MEG recording, the unmixed components are extracted. Figure 3 presents some components' spatial weights for the response to stimulus 1. The first one is the left auditory independent component and the second one is the right one. The third one is heartbeat artifact. The spatial weights of auditory components can be considered as the magnetic field distribution of an equivalent-current dipole. The location, intensity and orientation of the dipoles are shown in Figure 4.

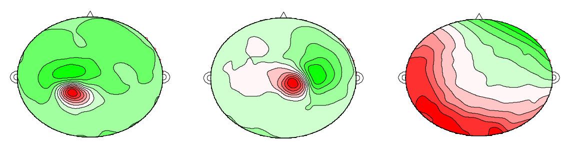


Figure 3 Left auditory component (left), right auditory component (middle) and heartbeat artifact (right)

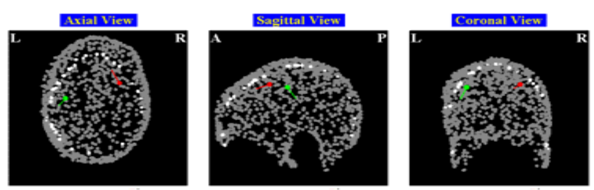


Figure 4 Left auditory dipole (green) and right auditory dipole (red)

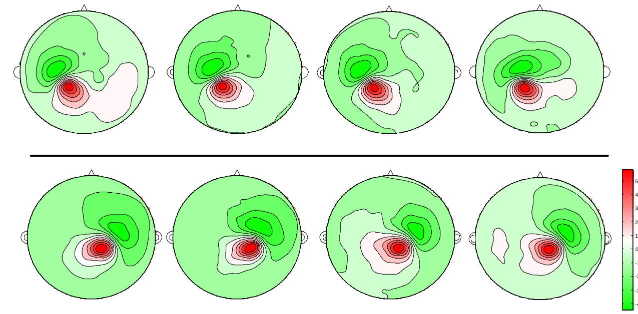


Figure 5 Spatial weights of the left auditory components for the response to the other 4 stimuli (above) and spatial weights of the right auditory components for the response to the other 4 stimuli (bottom)

(2) For responses to each of the five stimuli, there is always one distinct independent component localized over the left auditory cortex and another localized over the right cortex. This pattern is consistent across stimuli. The spatial weights are shown for the response to the other 4 stimuli in figure 5. Figure 6 shows the location, intensity and orientations of the corresponding 10 dipoles, all of them are tightly grouped.

(3) Figure 7 shows the correlation coefficients between auditory response component and stimulus envelop for stimulus 1. The value are in reasonable range, from 25% to 32%, which is evidence of phase-locking.

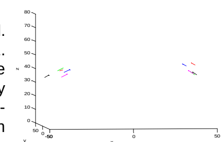


Figure 6 Location, intensity and orientation of 10 dipoles

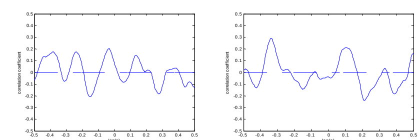


Figure 7 Correlation coefficients between left auditory response and stimulus envelope (left) and correlation coefficients between right auditory response and stimulus envelope (right)

Conclusion

(1) ICA is a powerful way to enhance the MEG signal. In addition to extracting non-neural artifacts, ICA can be used to identify auditory related responses, which are localized over left and right auditory cortex independently.

(2) The location and the orientation of auditory dipoles are robust across stimuli,

(3) There is evidence that neurons in the auditory cortex can phase-lock to stimuli with complex temporal and spectrotemporal envelopes.

References

[1] What is MEG, http://www.geocities.com/Tokyo/1158/meg.html

[2] Anthony J. Bell and Terrence J. Seinowski, An Information-Maximization Approach to Blind Separation and Blind Deconvolution, Volume 7, Issue 6 (November 1995) Pages: 1129 – 1159

[3] Ehud Ahissar, Srikantan Nagarajan, Merav Ahissar, et al, Speech Comprehension is Correlated with Temporal Response Patterns Recorded from Auditory Cortex