Magnetoencephalography (MEG) Response to Speech and Speech-like Modulations

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Introduction

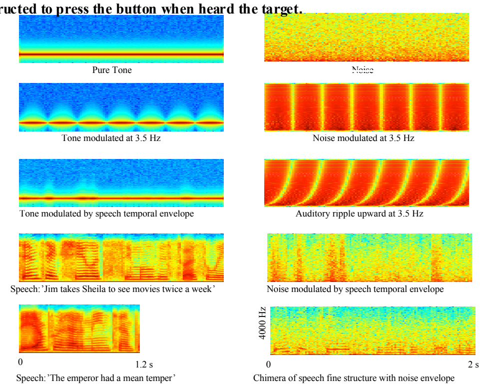
Hierarchical Processing

Anatomic and physiological research on non-human primates motivates the general hypothesis that there are three broad subdivisions in the auditory cortex: the core, belt and parabelt (Rauschecker et al., 1998; Kaas, 2000; Romanski et al., 1999). Within each larger region, cortical fields are identified by their sensitivity to stimulus complexity. For example, core auditory cortex cells tend to prefer tonal signals, while belt area cells respond more vigorously to complex sounds (bandpassed noise and species-specific vocalizations). The PET and fMRI studies based on the human auditory cortex also suggest the existence of the hierarchical processing and the belt is implicated in higher-order processing as well as speech analysis (Scott et al., 2000; Binder et al., 2000). These key observations connect human data to known structures and mechanisms in non-human primates.

While the imaging data reflects the location of the activated neuron, magnetoencephalography (MEG) is used to investigate the dynamic (temporal) neural response. MEG is the best way to record electrophysiological signals from the human auditory cortex at high temporal resolution (< 1 ms) and reasonably high spatial resolution (~5-10 mm).

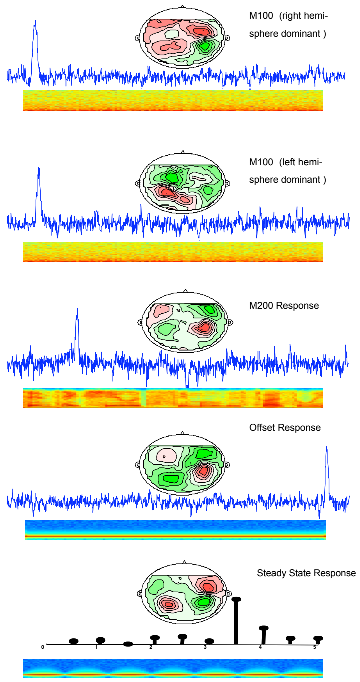
Stimuli

Ten stimuli with varying temporal and spectral complexity were used. To decrease subject drowsiness, an additional 10% stimuli were presented as "target" stimuli in which an extra segment of static noise or silence was inserted into the original stimulus; subjects were instructed to press the button when heard the target.



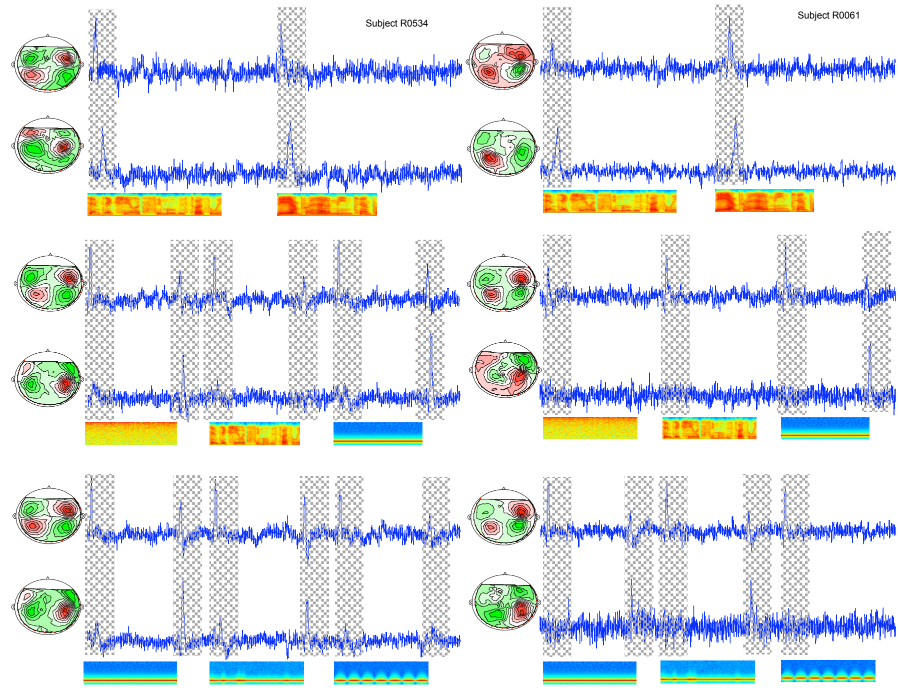
Individual response ICA

ICA was applied separately to the averaged response to each stimulus. The following figure shows a variety of example auditory response components from a variety of stimuli.



Concatenated Responses ICA

The contour map and the temporal waveform of the onset/offset response were consistent across stimuli, indicating that they are produced by same neural population. When ICA was applied to the concatenated responses, these consistent components were put into one component.

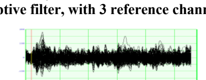


Methods

Recording

- Magnetic signals recorded using a 160-channel whole-head axial gradiometer system.
- Sampling rate 500 Hz, bandpassed between 1 Hz and 200 Hz, with notch at 60 Hz.
- 157 neural channels denoised with a Block-LMS adaptive filter, with 3 reference channels.
- Three human subjects thus far.

Stimuli



- 10 stimuli, 2000 ms duration.
- 80 stimulus presentations; inter-stimulus intervals from 1500 to 1900 ms; loudness 70 dB SPL.

Analysis

- Averaging responses from 100 ms pre-stimuli to 2800ms post-stimuli for response to each stimulus.
- Applying Independent Component Analysis (ICA) for response to each stimulus.
- Applying ICA for concatenated response to different stimuli.

Independent Component Analysis (ICA)

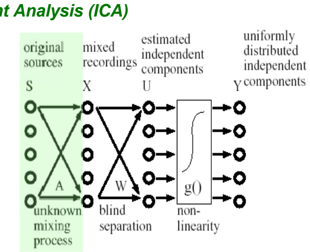
• **Model:**

Instantaneous Linear Mixing

$X(t) = A*S(t)$

$A*W = P*D*I$

P: Permutation Matrix
D: Diagonal Scaling Matrix
I: Identity Matrix



Conclusions

- ICA, applied to a response to a wide variety of stimuli, including continuous speech, produces physiological meaningful auditory components, such as onset, offset, and steady state responses.
- ICA, applied to concatenated responses, groups similar responses to different stimuli into one component, makes comparison across stimuli and subjects easier.

Reference

[1]Josef P Rauschecker, Cortical processing of complex sounds, Current opinion in neurobiology 1998,8: 516-521

[2]Romani, L. M.,B. Tian,et al., Dual streams of auditory afferents target multiple domains in the primate prefrontal cortex, Nature Neuroscience 2(12),1999:1131-1136

[3]Jon H.Kaas, Troy A. Hackett,Subdivisions of auditory cortex and processing streams in primates, PNAS,Vol97,No. 22,2000,11793-11799

[4]Cathy Price,Gauillaume Thierry and Tim Griffiths, Speech-specfic auditory processing: where is it,Trends in Cognitive Sciences, Vol. 9, No. 6,June 2005 271-276

[5]Zachary M.Smith,Bertand Delgutte and Andrew J.Oxenham,Chimaeric sounds reveal dichotomies in auditory perception, Letters to nature, March 2002,87-90

[6]Sophie K. Scott, Ingrid S. Johnsrude, The neuroanatomical and functional organzation of speech perception, Trends in neurosciences, Vol. 26, No. 2, February 2003,100-107