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The Neural Representation of Auditory Modulations Relevant to Speech

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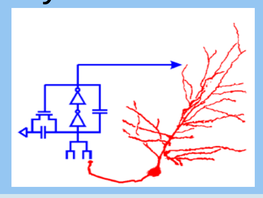
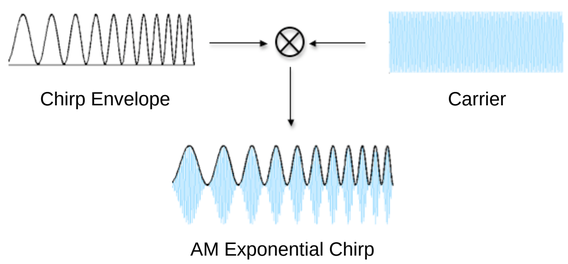


Introduction

- Speech signals contain a wide range of modulation rates, with most power below 15 Hz
- Neurons in the auditory cortex track the envelope of amplitude modulated (AM) sounds
- Magnetoencephalography (MEG) is a brain imaging technique that non-invasively measures neurally-generated magnetic fields
- Modulation transfer function (MTF) captures the relationship between the neural response and the modulation frequency

Methods

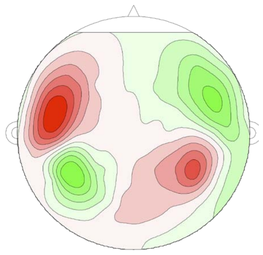
- 157 channel whole head MEG system
- 7 subjects (3 female, 4 male) passively listen to AM auditory stimuli
- Exponential AM chirps (6)
  - 10 s AM frequency sweep from 3-60 Hz
  - Carrier frequencies – 250 Hz, 707 Hz, 2 kHz
  - Upward and downward sweeps
  - Time-frequency analysis tracks the magnitude and phase of the neural response



- Constant AM stimuli (3)
  - 10 s AM signal at 3 Hz, 13 Hz, 37 Hz
  - Carrier frequency – 707 Hz
  - Fourier analysis extracted power and phase of the neural response at target AM frequencies to compare with the exponential chirp response

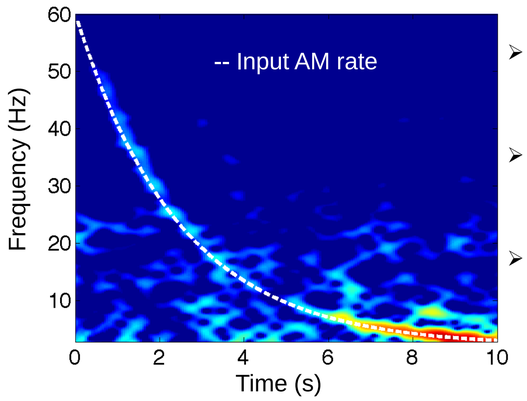
Results

Distribution of Magnetic Fields on Head



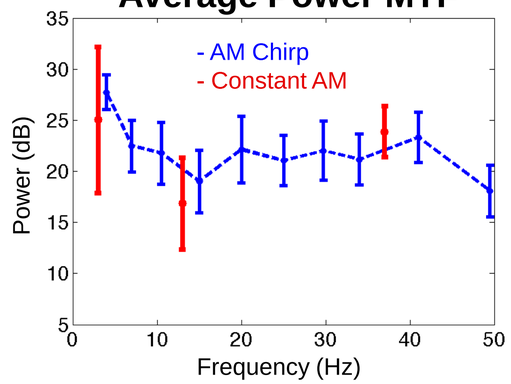
- The red and green patterns in each hemisphere represent a magnetic dipole
- The source of each dipole is located in each auditory cortex

Spectrogram of Neural Response



- Typical response to exponential AM chirp
- Strong 40 Hz and low frequency response
- Neural response closely tracks the input AM rate

Average Power MTF*

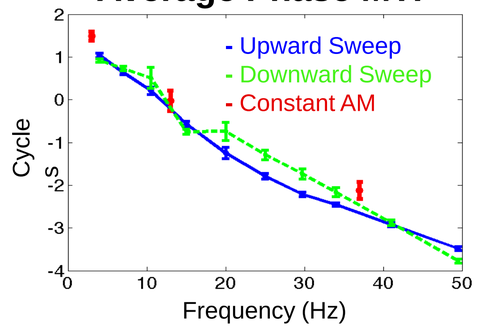


- AM chirp response is averaged over all stimuli and subjects and constant AM response is averaged over all subjects
- AM chirp response is strongest at low modulation rates
- Constant AM neural response closely matches AM chirp neural response with a slightly increased 37 Hz response

* Error bars are ±2 x standard error

More Results

Average Phase MTF**



- AM chirp response is averaged over subjects for each sweep direction and constant AM response is averaged over subjects
- AM chirp response has linear phase for both sweep directions
- Constant AM response closely matches the AM chirp response
- Upward and downward sweeps differ by approximately ½ cycle for modulation rates between 15 Hz and 25 Hz

**Error bars are ±2 x circular standard error

Conclusions

- An exponential AM chirp gives a successful estimate of the neural modulation transfer function (MTF)
- The brain responds maximally to low rate modulations
- The shape of the MTF is that of a shallow low-pass filter
- The phase of the neural response to AM frequencies is approximately linear, consistent with an 80 ms delay
- Neural phase responses to upward and downward AM chirps differ by ~1/2 cycle (15 Hz – 35 Hz)
- Neural phase responses agree at 40 Hz (where signal-to-noise ratio (SNR) is highest)

References

- Artieda, J. et al. “Potentials evoked by chirp-modulated tones: a new technique to evaluate oscillatory activity in the auditory pathway.” *Clinical Neurophysiology*. (2004): 1-11.
- Baillet, Sylvain, Mosher, John C., and Leahy, Richard M. “Electromagnetic Brain Mapping.” *IEEE Signal Processing Magazine*. November 2001: 14-30.
- Purcell, David W, and John, Sasha M. “Human temporal auditory acuity as assessed by envelope following responses.” *Journal Acoustical Society of America*. 116.6 (2004): 3581-3593.
- Ross, Bernhard et al. “A high-precision magnetoencephalographic study of human auditory steady-state responses to amplitude-modulated tones.” *Journal Acoustical Society of America*. 108:2 (2000): 679-691.