Investigating the Effect of Selective Attention on Speech Encoding from Auditory Nerve to Cortex

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Introduction

Motivation

- Selective attention is critical for communication in noisy environments, yet several disorders can make this task difficult
- We do not fully understand at what neural processing stage attention first affects the encoding of sounds
- This experiment measured auditory evoked potentials to competing naturalistic speech stimuli in an attention task to test for attentional effects at several stages of the human auditory pathway

Background

- The compound action potential (CAP) is recorded from the tympanic membrane and originates from the auditory nerve[1]
- The auditory brainstem response (ABR) is an evoked response with a series of peaks which correspond to specific subcortical neural generators[2]
- While attention clearly modulates cortical responses [e.g., 3, 4], studies investigating attention in the subcortex have produced mixed results [e.g., 5-11]
  - With few exceptions[11], previous work has been limited to simple stimuli such as clicks or single syllables
- Our recently developed peaky speech stimuli allows for the calculation of canonical ABRs to running speech[12]

Methods

Subjects

- We have recruited 10 subjects (2 male, 8 female) aged 26 ± 5.9 (20-38) years (of a planned 24 subjects)
- Audiometric thresholds ≤ 20 dB HL were verified with pure tone audiometry at octave intervals from 250 to 8000 Hz for all subjects

Stimuli

- Peaky speech stimuli were generated from two audiobooks, one male narrator ("The Alchemyst") and one female narrator ("A Wrinkle in Time"), individually set to 60 dB SPL, and summed together
  - Subjects were instructed to attend only one audiobook on each trial
  - Multiple choice questions were asked at the end of each trial

Simultaneous Recording of Responses Throughout the Auditory System

- To increase SNR of auditory nerve responses, we used a lab built tympanic membrane (TM) electrode based on a design from Simpson et al.[1], referenced to the ipsilateral earlobe
- Passive electrodes placed on vertex and referenced to the earlobes were used to record the ABR
- All responses were recorded simultaneously to explore attention throughout the entire auditory pathway in one experiment

Analysis and Metrics

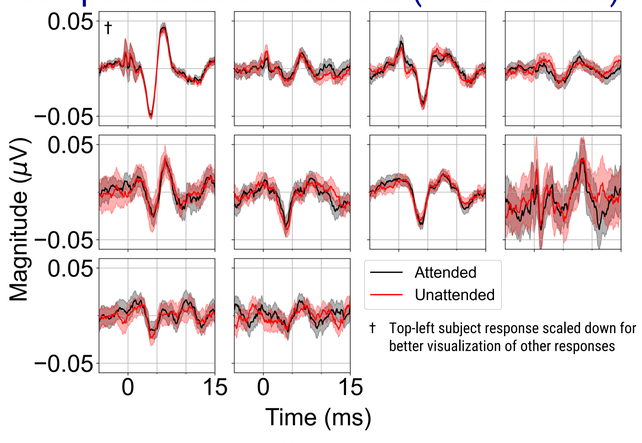
- Responses were calculated through deconvolution with the glottal pulse train at each site, as described previously[12]
- The TM electrode provides the compound action potential (CAP), which originates from the auditory nerve
- ABR wave V provides a measure of the encoding in the rostral brainstem
- Cortical responses can be examined from the passive ABR electrodes, as well as from a 32 channel montage

Results

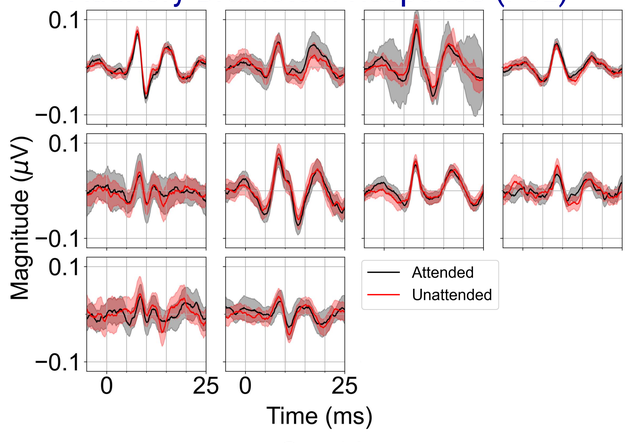
Attention modulates cortical, but not subcortical, responses

- No effects of attention are observed in the CAP (auditory nerve) or ABR wave V (rostral brainstem)
- The cortical response, evaluated from the same electrodes as the ABR, shows attentional effects and indicates that subjects were performing the task correctly

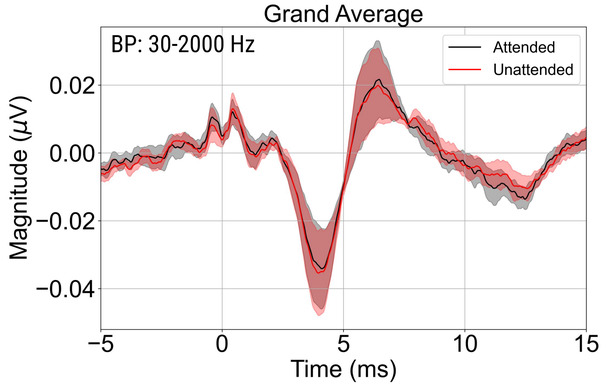
Compound Action Potential (TM Electrode)



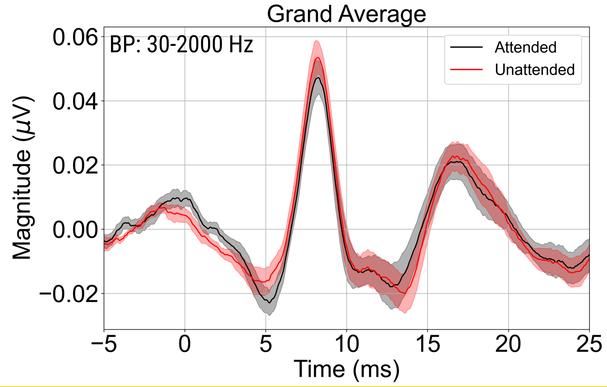
Auditory Brainstem Response (FCz)



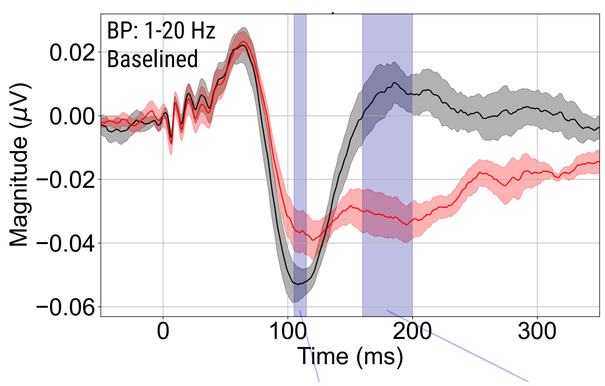
Grand Average



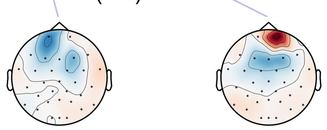
Grand Average



Late Latency Response (FCz)



Attended − Unattended:



Summary

- We used EEG to measure responses from the auditory nerve, brainstem, and cortex simultaneously while subjects performed an attention task with naturalistic speech stimuli
- A clear effect of attention was present in later cortical potentials
- No effect was observed in responses from the auditory nerve and brainstem

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