Attention modulated neuro-markers extracted from listening to continuous speech

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Introduction

Cocktail party phenomenon

Auditory system can filter sounds being heard

• Selective attention
• Limited processing capacity
Background

Attention modulated neuro-markers can be used to understand how it fails in different clinical populations

- Hearing loss
- Age-related hearing impairments
- Schizophrenia
- Tinnitus
- ……..

Applications

- Brain-Computer interface systems
- Smart Hearing aids
Experimental Design

Continuous speech:

“In the bosom of one of those spacious coves which indent the eastern shore of the Hudson, at that broad expansion of the river denominated by the ancient Dutch navigators....”

The Legend of Sleepy Hollow - Washington Irving

Task

- Listening to 1-minute-long speech segments from an audio book
  - Clean speech
  - Mixed speech (Male talker vs female talker) [0 dB, -6 dB]

Participants

- 18 Younger adults (age: 17-26 y)
- 17 Older adults (age: 65-78 y)
- Normal Hearing (125-4000 Hz, ≤25 dB HL)
- Native English Speakers

Data

- MEG (magentoencephalography)
- Behavioral data
Speech Envelope Reconstruction Accuracy

How attended vs unattended speaker envelopes are represented in the neural response?

Reconstruction accuracy = correlation (True Env, Reconstructed Env)

- **Attended > Unattended**
  - Selective Attention

- **Task difficulty**
  - Task difficulty worsens speech reconstruction
Speech Envelope Reconstruction Accuracy

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- Selective Attention

- Task difficulty
- Task difficulty worsens speech reconstruction

- Older > Younger (!)
  - Age related changes e.g., excitation/inhibition imbalance
  - Recruitment of additional top-down resources
  - Increased attention

- Age*Attention not significant
Integration Window Analysis

How attended vs unattended speaker envelope representation build up over time?

Reconstruction accuracy for each lag with 5 ms step

This motivates the TRF analysis
Temporal Response Function (TRF)

How brain encodes acoustic envelope?

Three main peaks: M50, M100, M200

Attended > Unattended
- For both M100 and M200
- Suggests middle and late peaks are modulated by attention

M200: Attended Latency > Unattended Latency
- Attended talker is processed for longer time
How brain encodes acoustic envelope?

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Temporal Response Function (TRF)

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Younger vs Older
- Amplitudes: Older > Younger
- M100 amplitude: Age*Attention is significant
- M100, M200 Latency: Age*Attention is significant
Real Time attention Decoding

Real time estimation of attention modulated neuro-markers (TRF)

• Adaptive TRF estimation using previously proposed sparse adaptive filtering (Miran et al. 2018)

$\hat{\theta}_k = \arg\min_{\theta} \sum_{j=1}^{k} \lambda^{k-j} \left\| y_j - X_j \theta \right\|_2^2 + \gamma \left\| \theta \right\|_1, \quad k = 1, 2, \ldots, K$

L1 regularized least squares estimation with a forgetting factor ($\lambda$)

• Effective data length is 8 s
• Forward Backward splitting algorithm

Representative Subject - Trial 1

Real Time attention Decoding

Real time estimation of attention modulated neuro-markers (TRF)

- Adaptive TRF estimation using previously proposed sparse adaptive filtering (Miran et al (2018))
- Attended > Unattended
- Older > Younger
- Feasibility of real time attention marker extraction
Summary

• Both speech envelope reconstruction accuracy and some TRF features are modulated by attention.

• Integration window analysis shows the competition of auditory objects at early stages and segregation towards the late processing stage.

• Feasibility of using near real time algorithm to extract attention modulated neuro-markers from continuous speech.

Age related hearing loss

• Older adults show exaggerated neural response.

• Attention modulated neuro-markers are affected by aging.
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