Effects of Aging on the Cortical Representation of Continuous Speech

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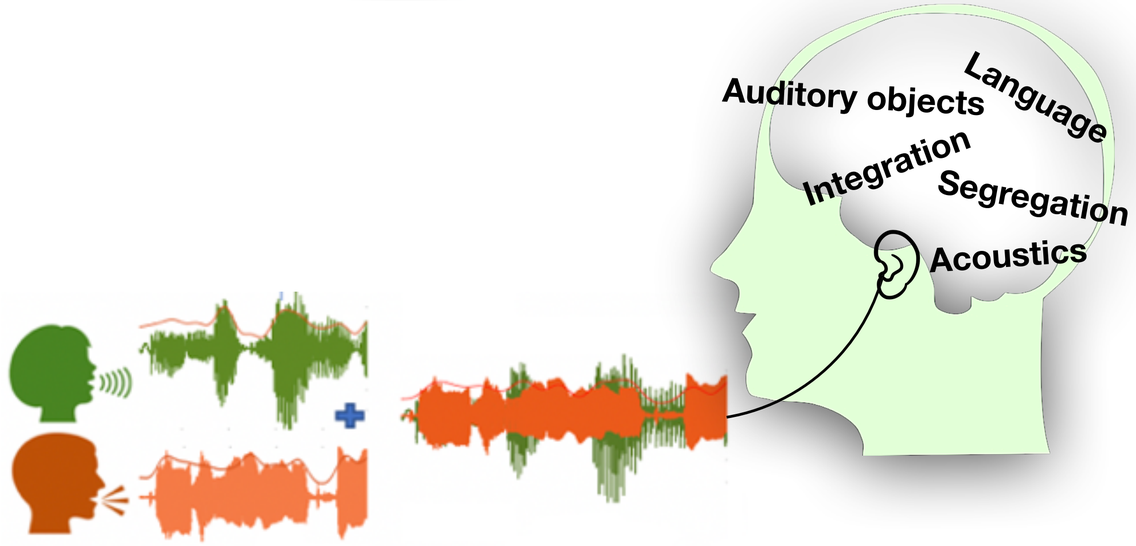
Introduction

- Older adults often report difficulty in understanding speech in noise [1]
- Difficulties may arise from age-related physiological changes and temporal processing deficits
- Previous work has shown that older adults exhibit exaggerated cortical responses

Motivation

- At what latencies, age related processing differences occur?
- How does the task difficulty change the neural responses?
- How are the foreground (FG) and background (BG) speakers represented neurally?



1. Gordon-Salant, S., Fitzgibbons, P. J., & Yeni-Komshian, G. H. (2011). Auditory temporal processing and aging: Implications for speech understanding of older people. *Audiology Research*, *1*(1S), e4. https://doi.org/10.4081/audiores.2011.e4

Method

Participants: Native English speakers

- 18 younger adults (age: 17-26 y)
- 17 older adults (age: 65-78 y)
- Normal hearing (125-4000 Hz thresholds $\leq$ 25 dB HL)

Task: Listening to 1 minute long speech segments from an audio book

- Clean speech
- Mixed speech (Male speaker vs female speaker) [0 dB, -6 dB]
- Attend to male or female speaker ignoring the other

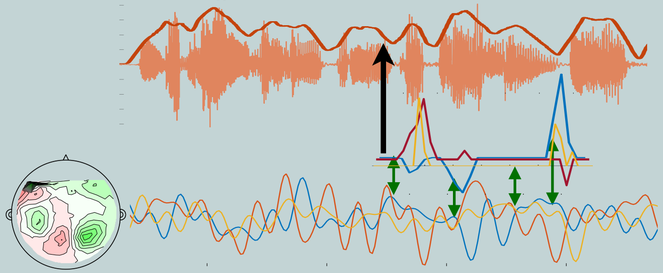
Data: MEG data

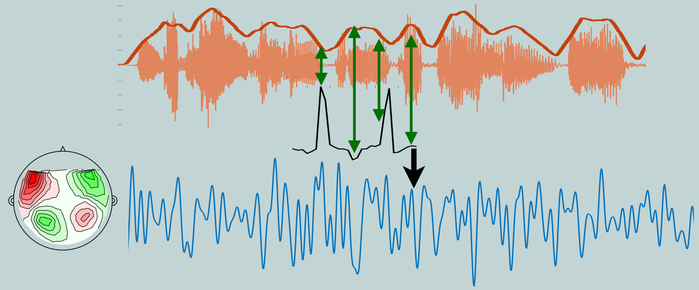
- Band pass filter 1-10 Hz

Preprocessing: Denoised by Time-Shift PCA (TSPCA), Sensor noise suppression (SNS) and Denoising Source Separation (DSS)

Cortical representation analysis

- Low frequency (1-10 Hz) log speech envelope
- Boosting algorithm with 5-fold cross validation
- 500ms integration window
- Statistical significance was evaluated by Linear mixed effect models





Stimulus Reconstruction

- First 6 DSS components filtered data for the reconstruction
- Attended and Unattended speaker envelopes reconstructed separately
- Reconstruction accuracy is estimated by the Pearson correlation coefficient between the reconstructed and the true speech envelope

Temporal Response Function (TRF) [2]

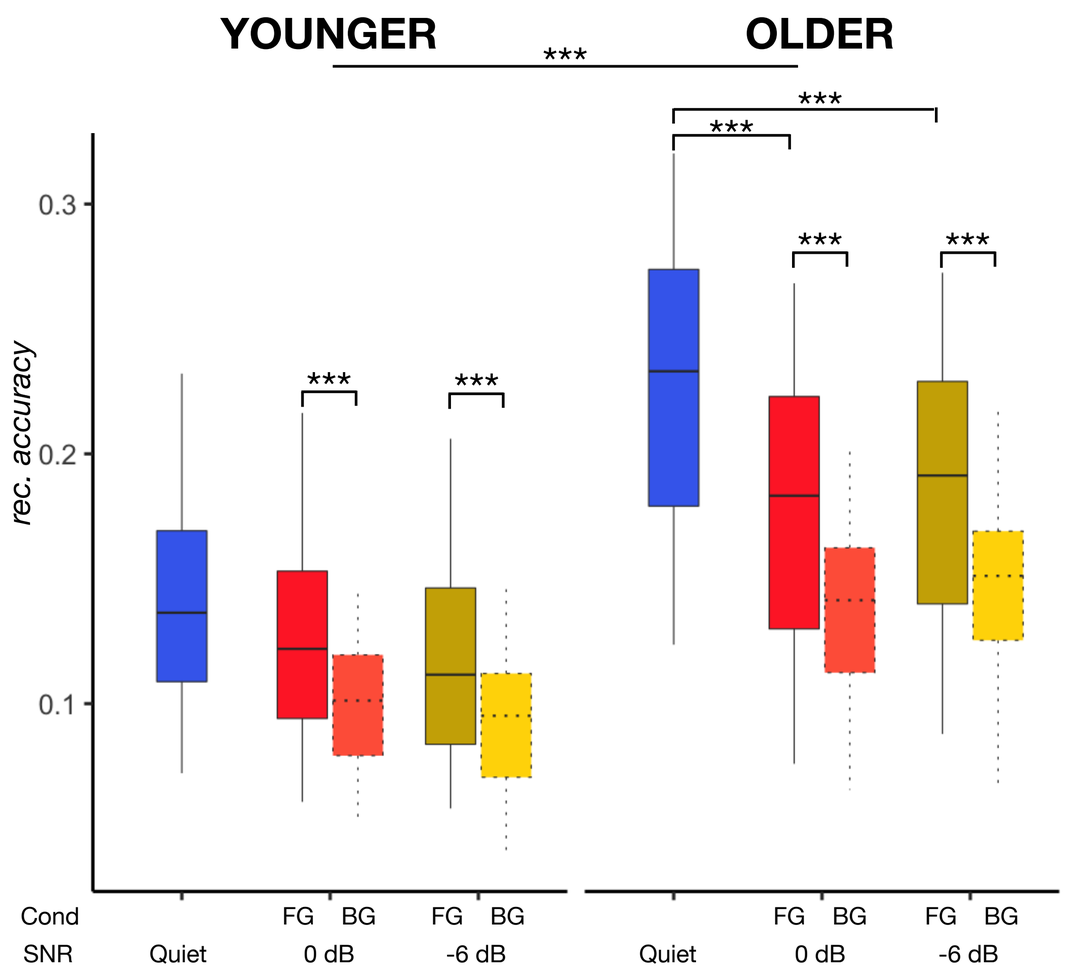
- 1st DSS component filtered neural data is used as the auditory response
- TRF is estimated as the linear filter that transforms the speech envelope to the neural response

$$DSS_1'(t) = \sum_{\tau} TRF_{FG}(\tau) Env_{FG}(t-\tau) + \sum_{\tau} TRF_{BG}(\tau) Env_{BG}(t-\tau) + \varepsilon(t)$$

- TRF has three prominent peaks
  - ~50 ms ; M_{50} (a positive peak)
  - ~100 ms; M_{100} (a negative peak)
  - ~200 ms; M_{200} (a positive peak)

2. Ding, N., & Simon, J. Z. (2012). Emergence of neural encoding of auditory objects while listening to competing speakers. *Proceedings of the National Academy of Sciences*, *109*(29), 11854–11859. https://doi.org/10.1073/pnas.1205381109

Stimulus Reconstruction



$$rec.accuracy \sim 1 + Age + SNR + Age * SNR + Cond + (1 + Cond \mid Subj)$$

*p<0.05, **p<0.01, ***p<0.001

Younger vs Older

Older reconstruction better than younger

- Confirms the previous results [3,4]

Possible Explanations:

- Age related changes e.g., excitation/ inhibition imbalance
- Recruitment of additional top-down resources
- Increased attention

Task Difficulty

Age*SNR is significant
Quiet reconstruction better than 0 dB/-6 dB only in older adults

Related finding:

- Background noise significantly worsens speech intelligibility in older listeners

Foreground vs Background

Foreground reconstruction better than Background for both groups

Possible Explanations:

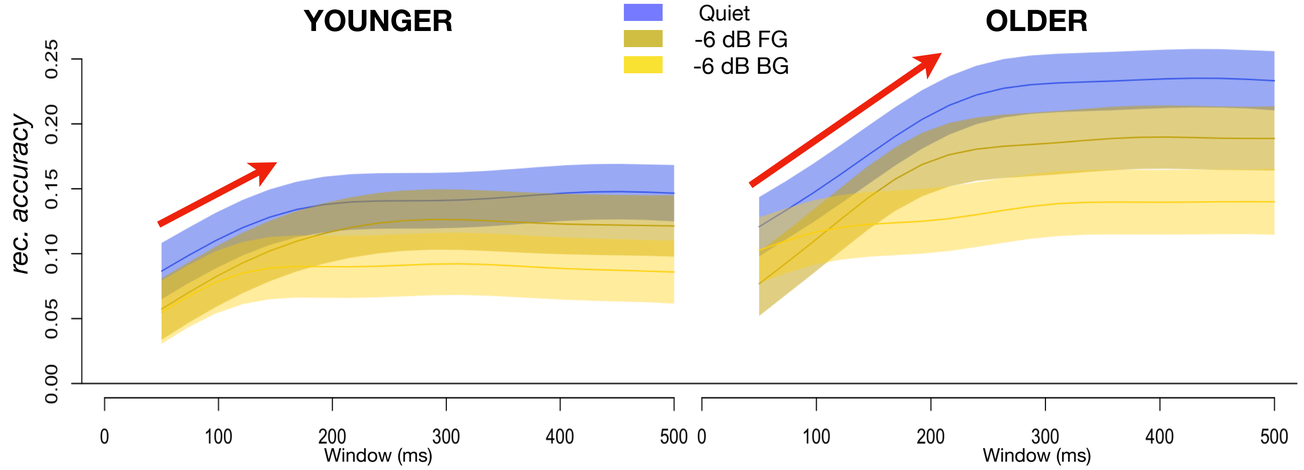
- Selective attention
- Separation into distinct sources

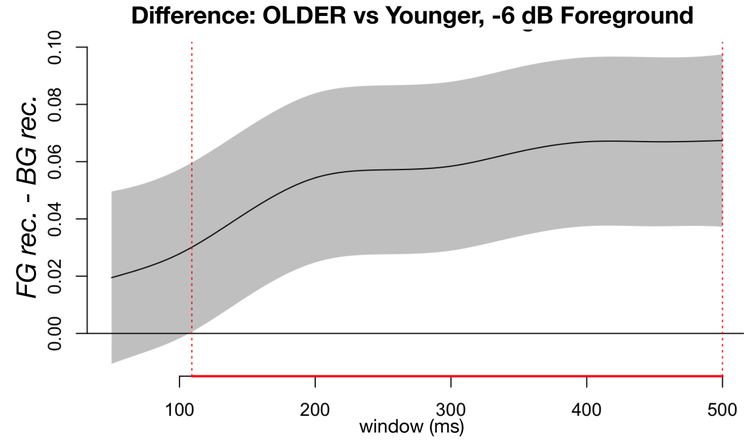
3. Presacco, A., Simon, J. Z., & Anderson, S. (2016). Evidence of degraded representation of speech in noise, in the aging midbrain and cortex. *Journal of Neurophysiology*, *116*(5), 2346–2355. https://doi.org/10.1152/jn.00372.2016
4. Decruy, L., Vanthornhout, J., & Francart, T. (2019). Evidence for enhanced neural tracking of the speech envelope underlying age-related speech-in-noise difficulties. *Journal of Neurophysiology*, *122*(2), 601–615. https://doi.org/10.1152/jn.00687.2018

Stimulus Reconstruction - Integration window analysis

- Method:- Speech envelope reconstruction using 50-500 ms integration windows
- Statistical Analysis:- Generalized additive Mixed models (GAMMs) time series

$$Rec \sim \beta_0(Age * SNR * Attn) + s(Window, Age * SNR * Attn) + (s(Window) \mid Subj)) + (Window \mid Item) + \epsilon$$





Younger vs Older

Reconstruction takes more time for older adults

Possible Explanations:
- Recruitment of additional top-down resources
- Attentional gain

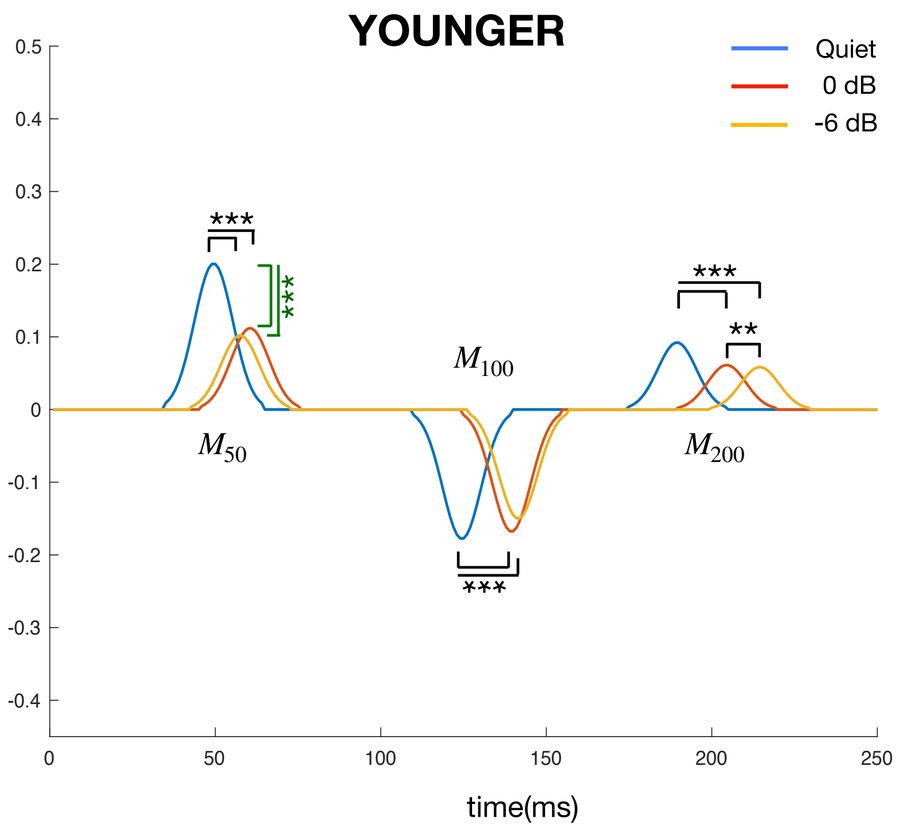
Over representation starts as early as ~100ms in older adults

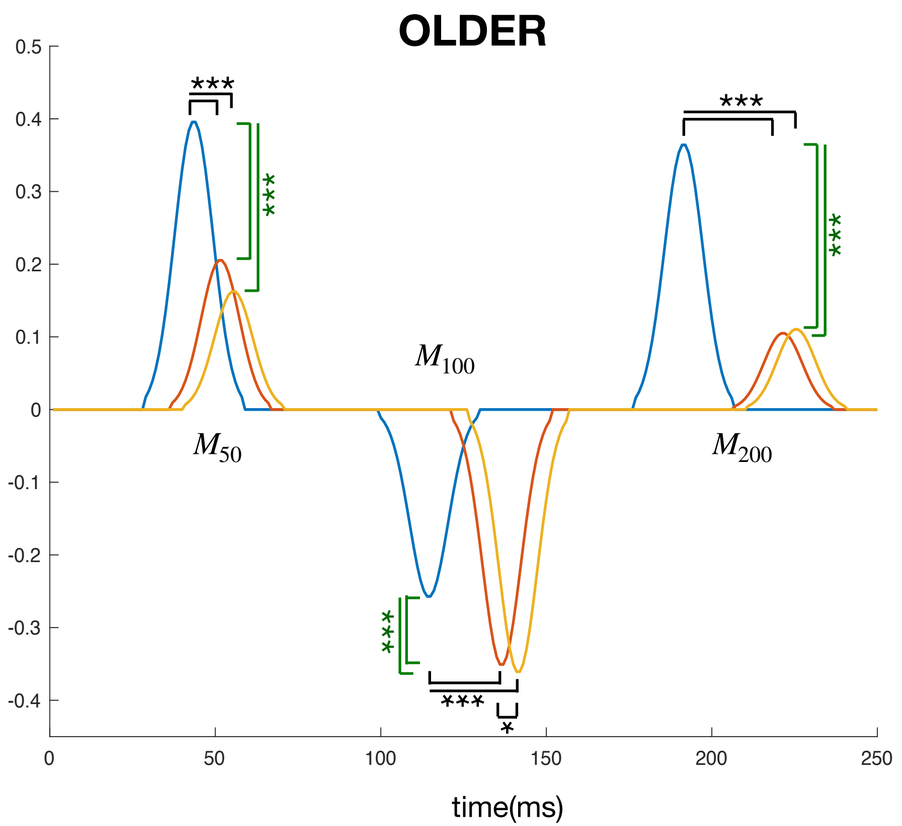
Possible Explanations:
- Excitation and inhibition imbalance

Ceiling: Younger (100-200 ms) < Older (200-300 ms)

Possible Explanations:
- Additional processing ~200ms in older adults to compensate for the temporal processing deficits

Temporal Response Function (TRF) - Foreground





Plots contain illustrative TRFs

**p<0.05, **p<0.01, ***p<0.001*

Younger vs Older

Older amplitudes bigger than younger amplitudes

Possible Explanations:

- Age related changes e.g., excitation/ inhibition imbalance

M200 peak difference

Possible Explanations:

- More resources being used for processing

Task Difficulty

M100 increases only in older adults

Possible Explanations:

- Greater attention
- Listening asymmetry

M200 amplitude decreases

Possible Explanations:

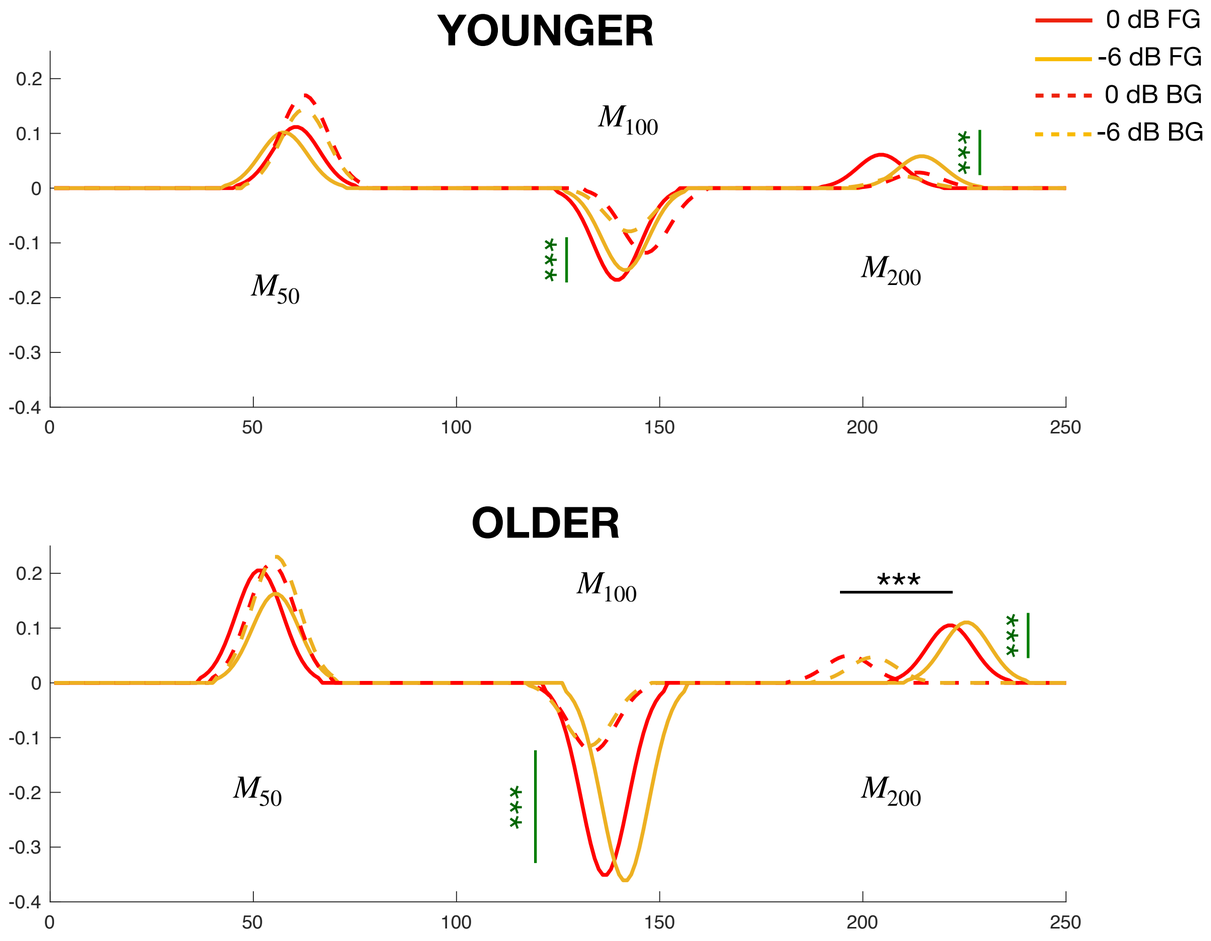
- Modulated by late neural mechanisms

Quiet peaks early than 0 dB/-6 dB peaks

Possible Explanations:

- Harder the task, takes more time to process

Temporal Response Function: Foreground Vs Background



Plots contain illustrative TRFs

**p<0.05, **p<0.01, ***p<0.001*

Younger vs Older

No difference in peaks

Foreground vs Background

No significant difference between M50 for both groups

Possible Explanations:

- Early response is shared between Foreground and Background

Foreground > Background for both M100 and M200 and both groups

Possible Explanations:

- Modulated by attention

Foreground M250 latency> Background M250 latency only in older adults

Possible Explanations:

- Foreground is processed for longer time by recruiting additional resources

Conclusion

- Older adults' neural response robustly tracks the speech envelope, and to a greater extent than younger adults, possibly due to several mechanisms
- M200 peak is late enough to be modulated by many compensatory mechanisms
- Early activity, i.e., the M50, is not modulated by attention, while late activity, M100 and M200, is
- More difficult tasks produce longer latencies
- Altogether, despite impaired speech intelligibility in noise, time locked speech responses are exaggerated in older adults compared to younger

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