Cortical Over-representation of Speech in Older Listeners Correlates with a Reduction in both Behavioral Inhibition and Speech Intelligibility

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Introduction

Aging is associated with an exaggerated representation of the speech envelope in the auditory cortex[1][2]. However, whether this over-representation is related to decreased speech intelligibility for older listeners is an open question. Source space analysis has shown the over-representation originates (at least) from early responses (~50 ms latency) in the auditory cortex[3].

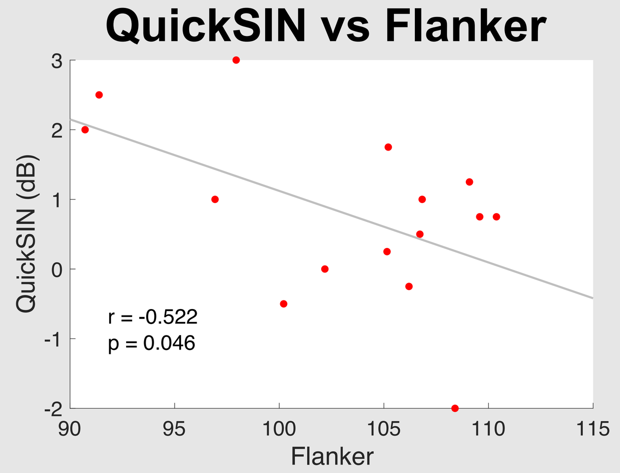
- The abnormally strong response to low-frequency speech envelope in older listeners may be related to speech processing problems
- Reanalysis of earlier experiment[1][2] using mutual information

Methods

Experiments

- 1-min speech segment (male speaker), both clean and masked with a competing female speaker, presented for 4 trials for each condition (quiet and 4 SNRs: 3, 0, -3 and -6 dB)
- Neural responses to continuous speech recorded by magnetoencephalography (MEG) at sampling frequency 1 kHz
- 17 younger adults (age: 18-27) and 15 older adults (age: 61-73), native English speakers with clinically normal hearing
- Visual inhibitory ability measured by Flanker score (higher is better)
- Listeners' ability to understand speech in noise measured by QuickSIN test (quick speech in noise, higher is worse)
- Weak negative correlation between the two behavioral scores seen for older listeners

QuickSIN vs Flanker



Temporal Mutual Information Function (TMIF)

- MEG recording denoised by TSPCA[4], and the first DSS component (1-8 Hz) extracted[5] from MEG signal as auditory response
- Low-frequency (1-8 Hz) speech envelope extracted
- Both response and speech envelope binned into 8 bins based on amplitude
- Temporal Mutual Information Function (TMIF) estimated by mutual information between speech envelope and response delayed at different time points
- At one time point t, the mutual information is estimated by

$$I_t(X;Y) = \sum_{i \in S, j \in S} p(x(\tau) = i, y(\tau + t) = j) \log \frac{p(x(\tau) = i, y(\tau + t) = j)}{p(x(\tau) = i) p(y(\tau + t) = j)}$$

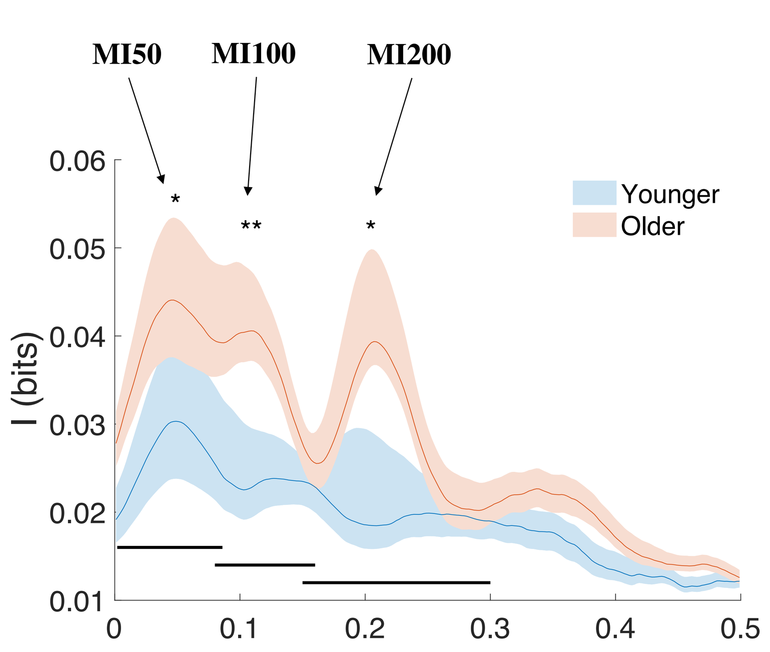
- $S = \{1,2,\ldots,8\}$, the set of amplitude bins from which i, j are drawn
- X and Y: random variables denoting stimulus and response. The joint probability distribution of X and Y estimated by amplitude of speech envelope and shifted response

TMIF in neural source space

- Neural source space response via minimum norm estimation[6] (MNE)
- TMIF of each neural source is estimated

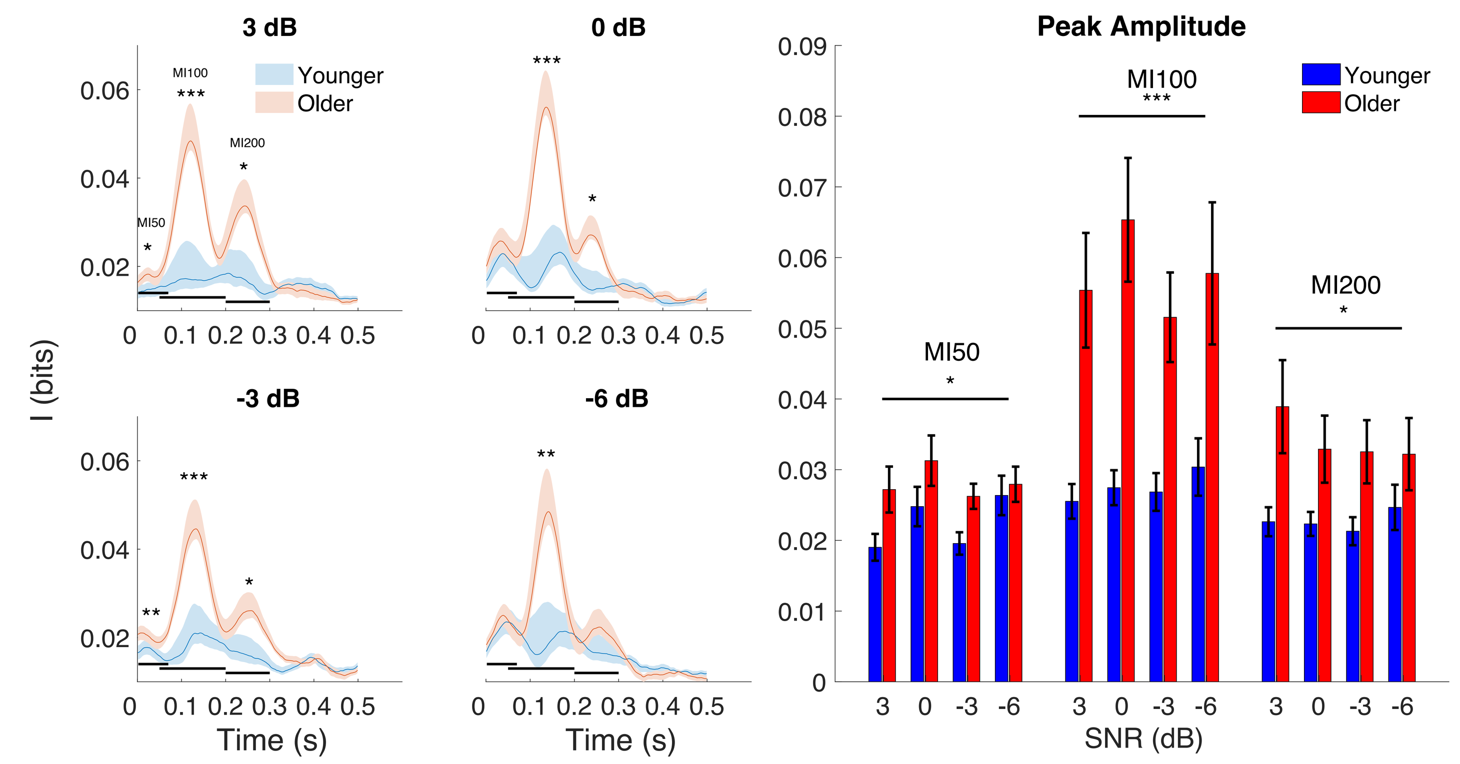
Results

TMIF of speech in quiet



- TMIF = information theory analog of linear Temporal Response Function (TRF)
- Amplitude response in older listeners is larger than younger listeners in quiet
- Older listeners have higher MI50, MI100 and MI200
- For older listeners, over-representation not only occurs early, but occurs for three different latencies
- *p<.05, **p<.01, ***p<0.001

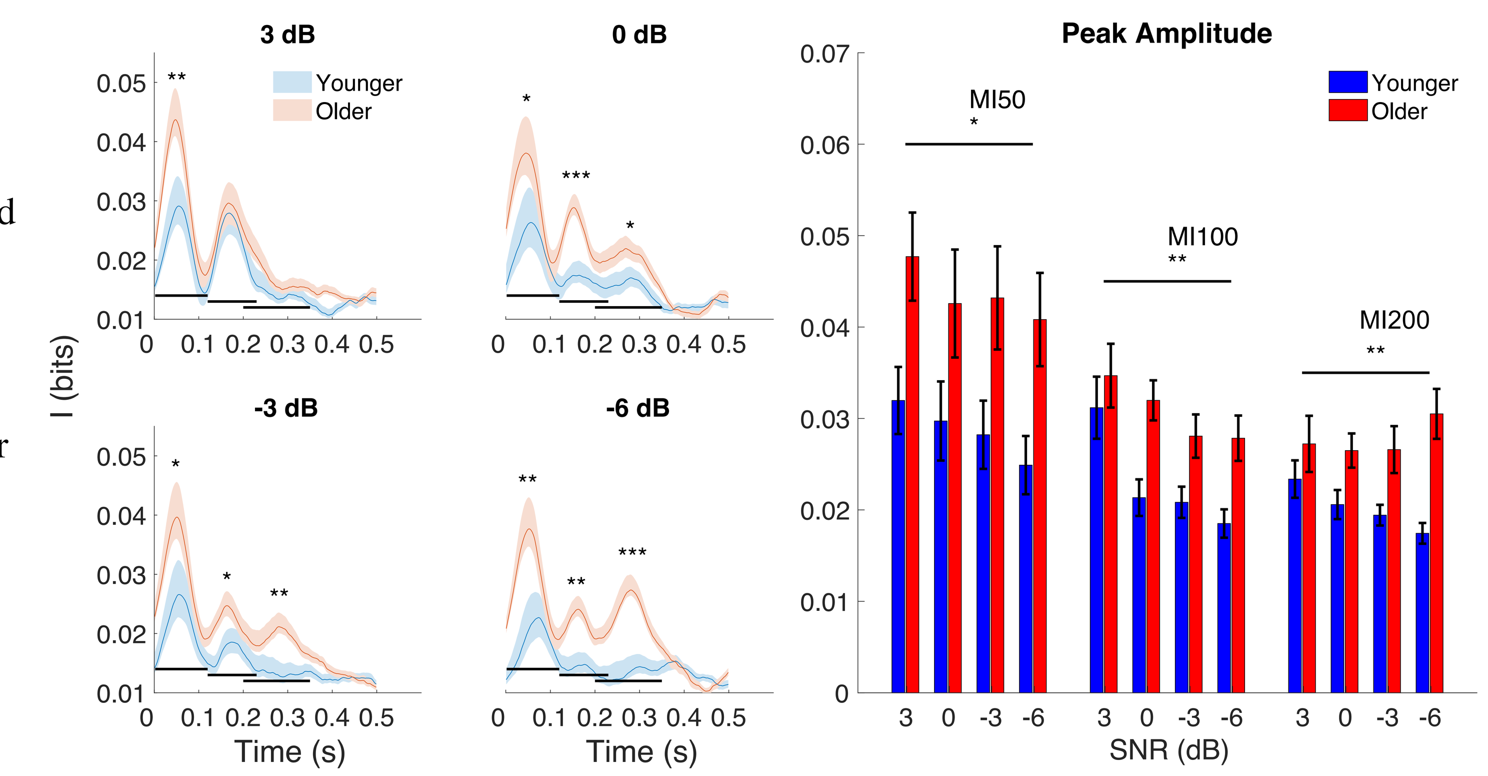
TMIF of foreground speech in noisy conditions



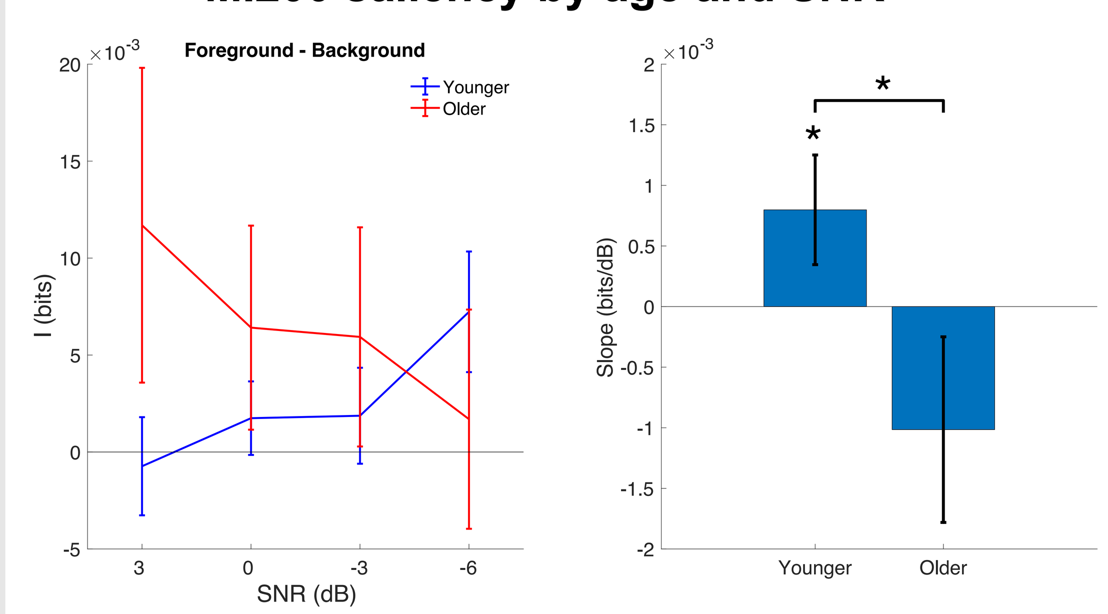
- The TMIFs of foreground contain larger peaks of MI50, MI100 and MI200 for older listeners measured by average across SNR conditions
- Over-representation at ~50, ~100 and ~200 ms also maintained for speech in noise

TMIF of background speech in noisy conditions

- Over-representation also occurs for background speech at ~50, ~100 and ~200 ms for older listeners measured by average across SNRs
- MI200 shows changes with worsening SNR: increasing for older listeners but decreasing for younger

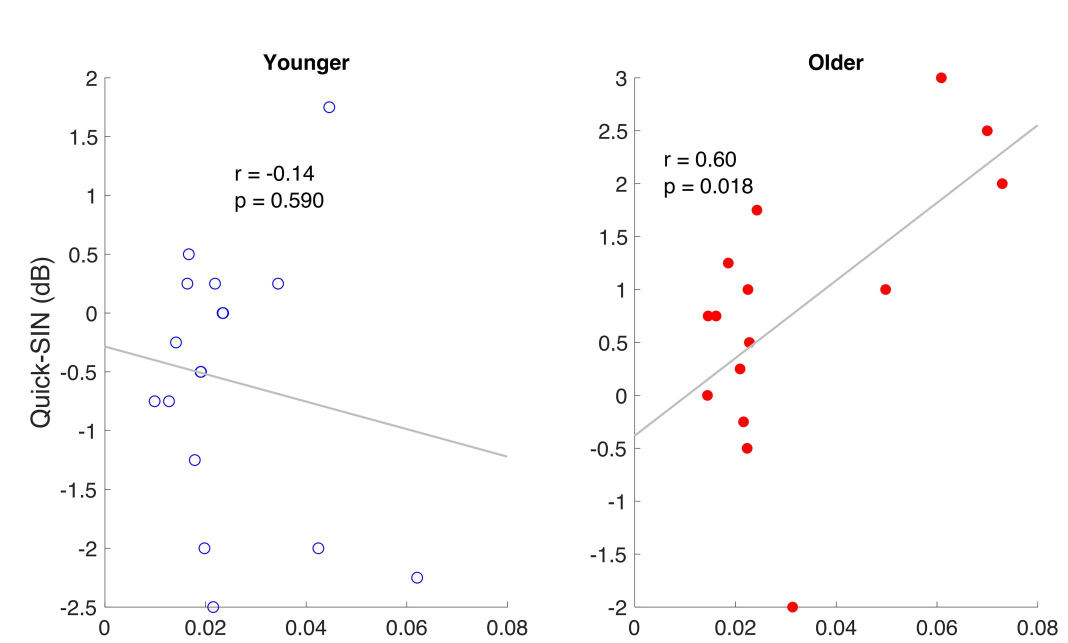


MI200 saliency by age and SNR

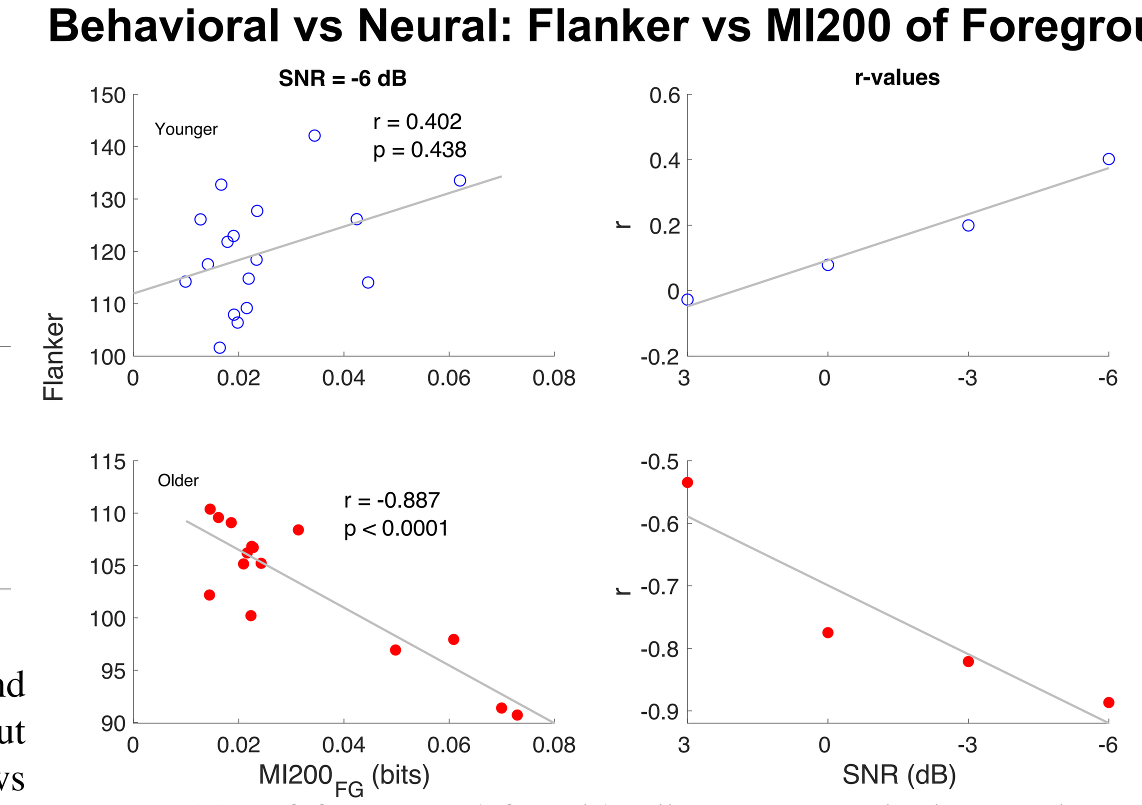


- MI200 saliency, measured by MI200 foreground and background difference, shows decrease as noise worsens for older listeners but increase for younger (asterisk above younger errorbar shows significance)
- The MI200-by-SNR slope is significantly larger for younger listeners than for older, illustrated by the top asterisk

QuickSIN vs MI200



Behavioral vs Neural: Flanker vs MI200 of Foreground

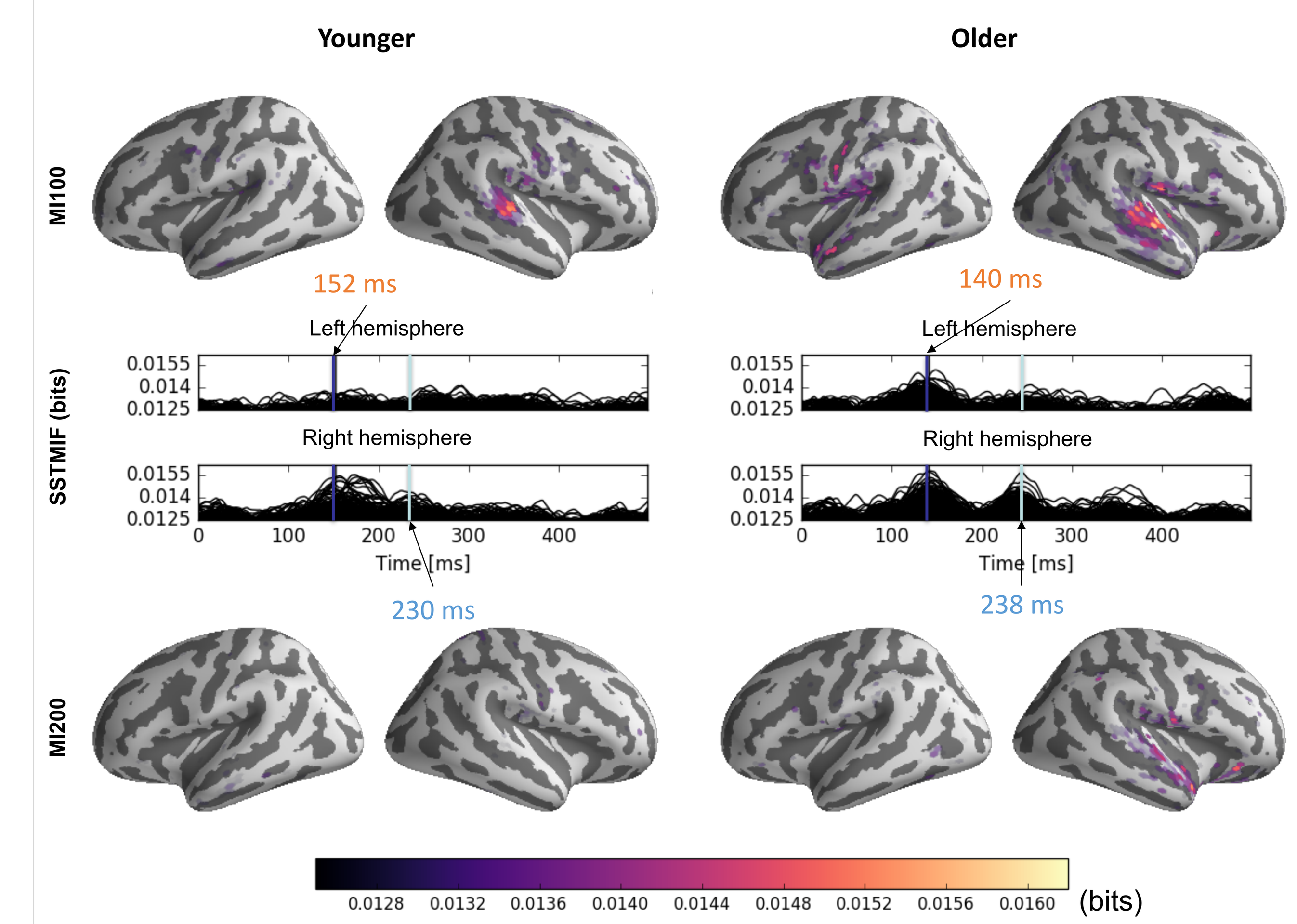


- MI200 of foreground for older listeners negatively correlates with Flanker score, and correlation grows more negative with more noise
- Even though flanker test measures behavioral visual inhibition, it reflects domain-general inhibition and correlates strongly with an auditory neural biomarker

- MI200 for older listeners is positively correlated to QuickSIN speech intelligibility score, while no correlation is seen for younger listeners
- Larger MI200 corresponds to worse speech intelligibility for older listeners
- Linear mixed effect model of MI200 ~ Flanker * QuickSIN shows significant effect from QuickSIN after ruling out interaction from Flanker

For mutual information analysis of midbrain response, see poster PS 236.

TMIF in neural source space



- Older listeners show a right-lateralized response in auditory cortex for MI200, while no significant response is seen for younger listeners
- Younger listeners show right-lateralized MI100 response in auditory cortex, while older listeners' response is bilateral
- Neural sources for MI200 localize to auditory cortex (despite correlation with visual Flanker score)

Conclusions

- An over-representation of low-frequency speech envelope is observed for older listeners illustrated by peaks in TMIF.
- At ~100 ms latency, older listeners engage additional areas (e.g., left hemisphere) over younger listeners; at ~200 ms latency, older listeners show new response (MI200) (dominantly right hemisphere) not shown by younger listeners.
- The over-representation in older listeners may be due to the loss of cortical synaptic inhibition, exaggerated attentional efforts, and processing of contextual or redundant speech information.
- The neural mechanism behind the exaggerated information representation may relate to the loss of behavioral inhibitory control, which affects speech intelligibility in challenging environments for older listeners.

Acknowledgments

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