THE RELATIONSHIP BETWEEN AUDITORY BRAINSTEM RESPONSES, COGNITIVE ABILITY, AND SPEECH-IN-NOISE PERCEPTION

Mishaela DiNino, Ph.D.
Department of Communicative Disorders and Sciences
University at Buffalo, Buffalo, NY, USA

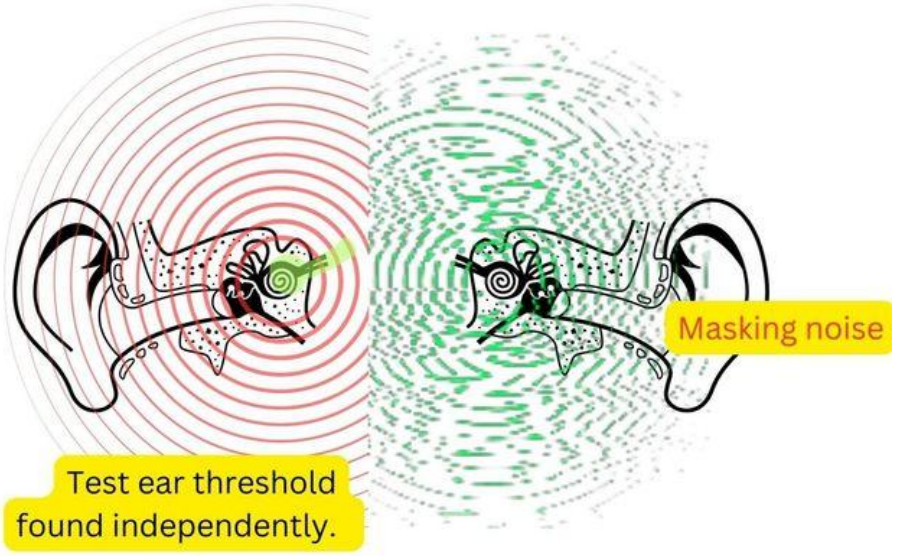
Presentation outline

- What is “noise”? Why is it difficult to listen in noise?
- Measuring auditory neural function
- The role of cognitive abilities in speech-in-noise perception
- Implications for clinical practice

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What is “noise”?

Noise is interference

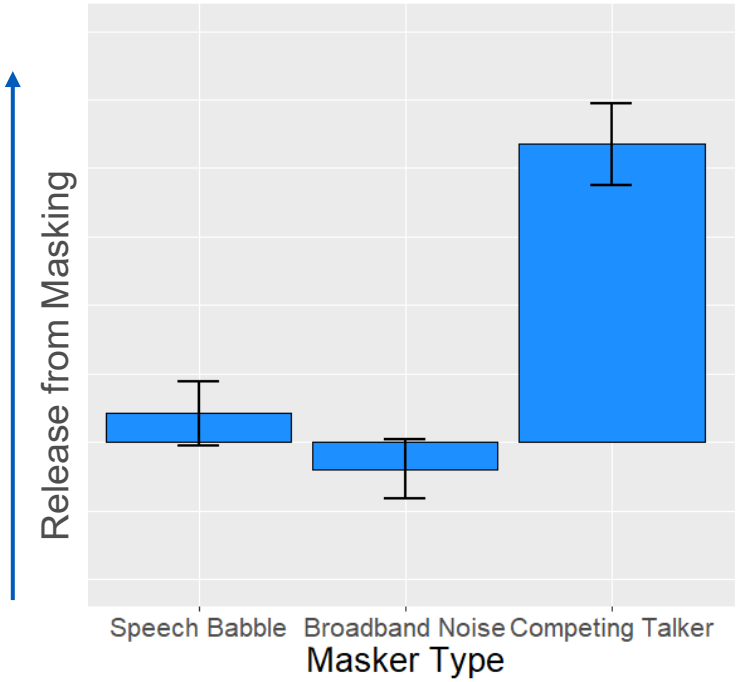


Noise is something you need to separate from what you want to hear



All “noise” is not the same

- Participants heard a target sentence in the presence of a masker
- Two conditions: 1) spatial separation between target and masker, 2) no spatialization
- Noise is the most detrimental when it consists of intelligible competing talkers



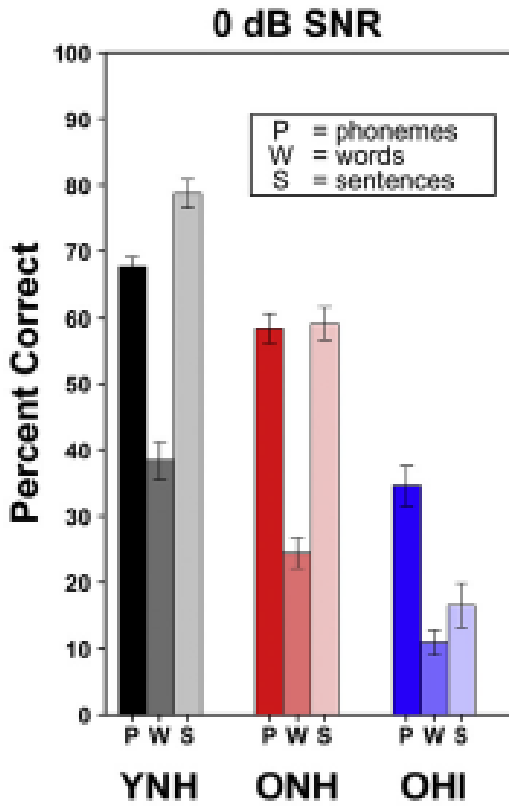
DiNino & Shinn-Cunningham, 2023

Separating speech from noise requires perceiving the acoustic differences between the two sounds

- This is very difficult for an individual with hearing loss
  - Reduced ability to discriminate frequencies
  - Cannot take advantage of the lower-intensity “dips” in noise

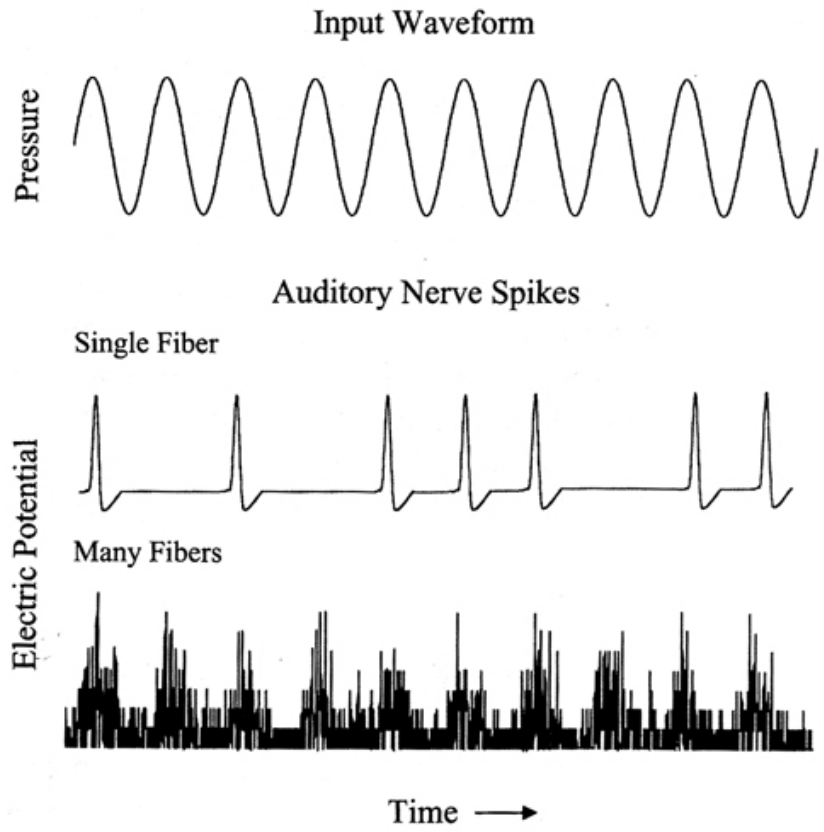


Hearing loss does not explain all difficulties understanding speech in noise



Billings & Madsen, 2018

Older adults exhibit neural changes that may contribute to difficulties hearing in noise



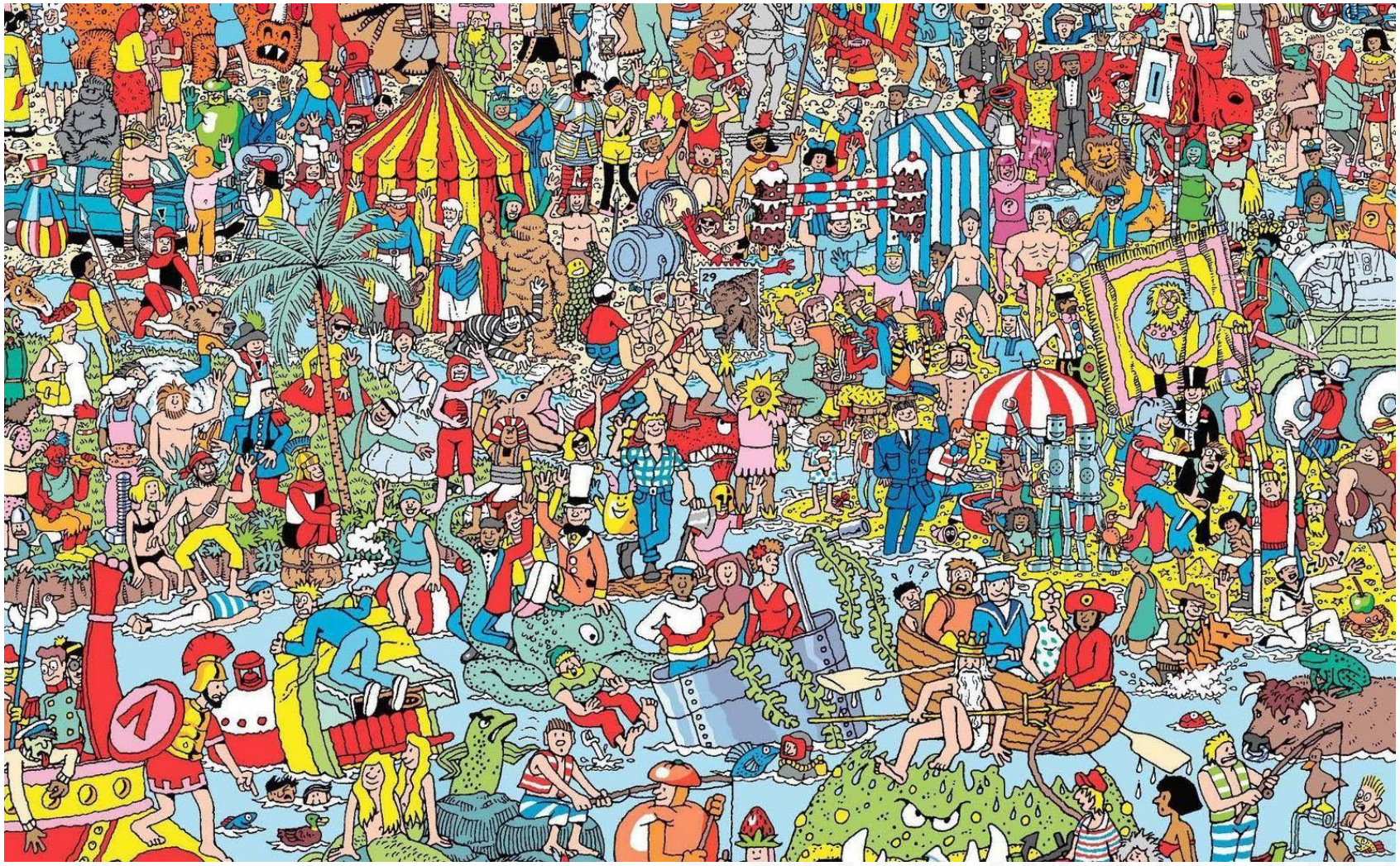
- Slower neural processing
- Fewer neurons to transmit sound
  - Auditory signals sent to the brain are not as precise
  - Not really an issue in quiet, but a huge issue when encoding multiple signals simultaneously
    - e.g., a sound in background noise

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In quiet



In noise



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In quiet

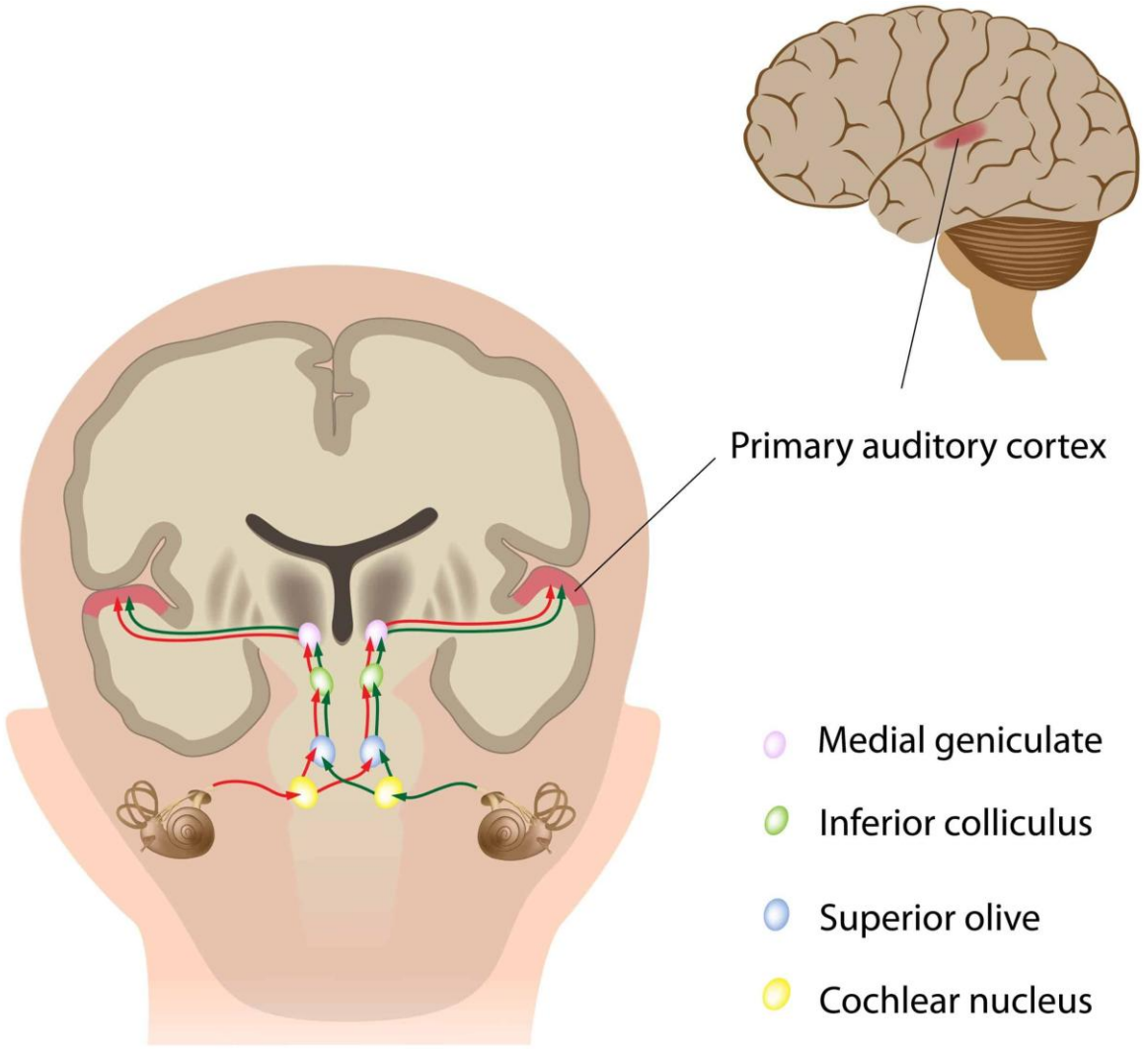


In noise



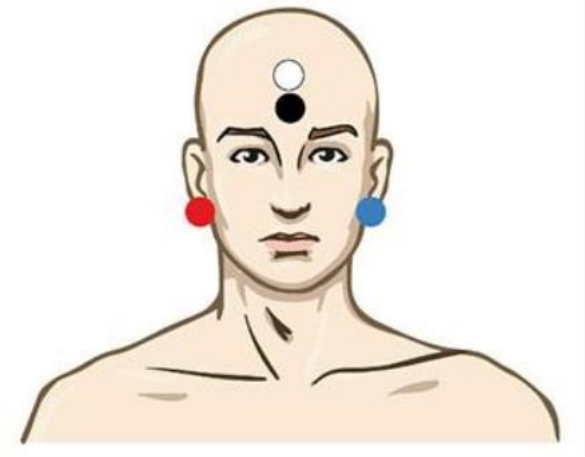
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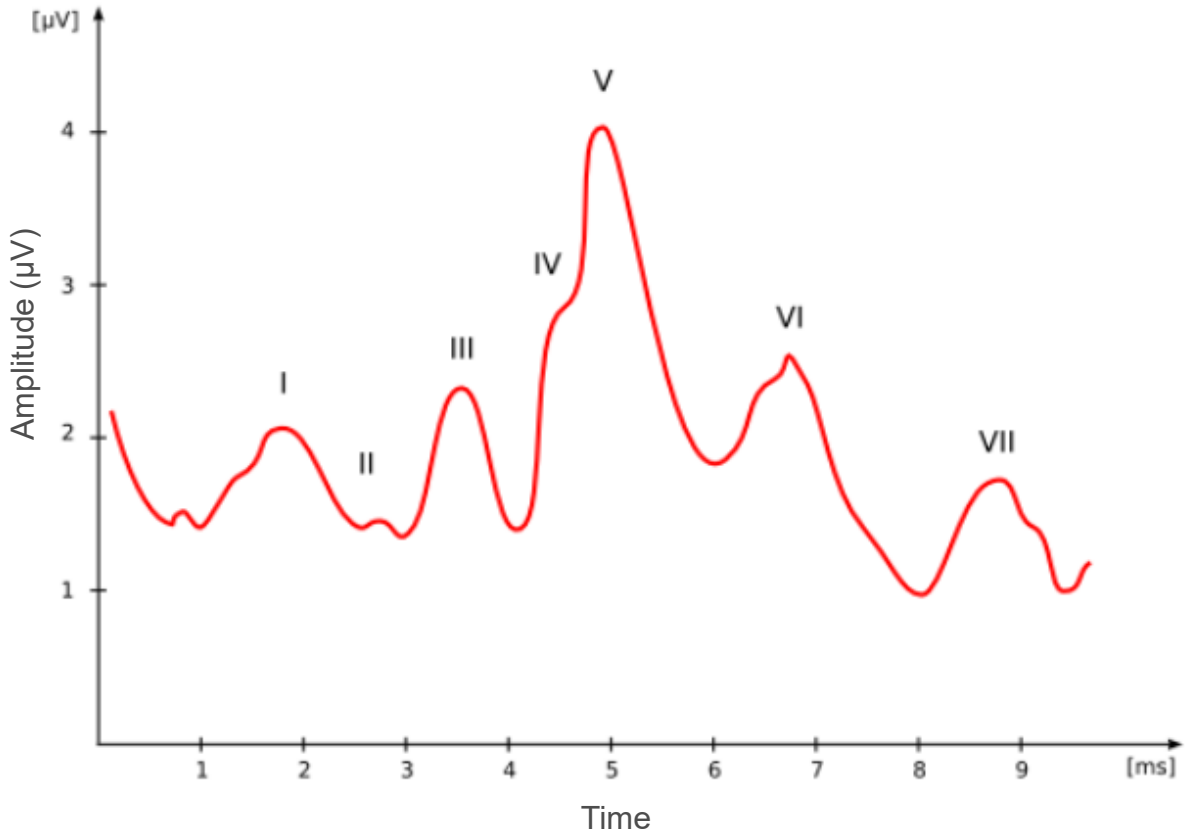
How can we measure function of the central auditory system?


Primary auditory cortex
Medial geniculate
Inferior colliculus
Superior olive
Cochlear nucleus

Auditory brainstem responses (ABRs)

- Loud clicks are played to elicit responses by auditory neurons

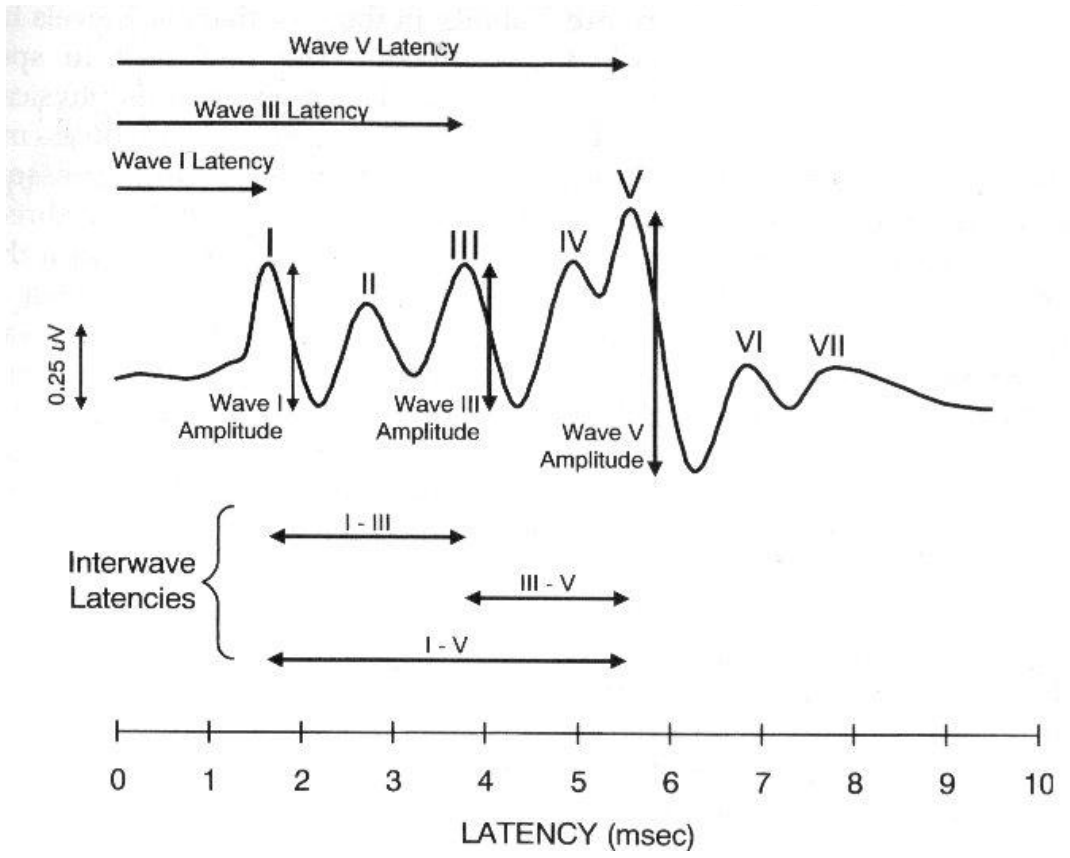




ABR wave amplitudes and latencies

Amplitude: strength of response

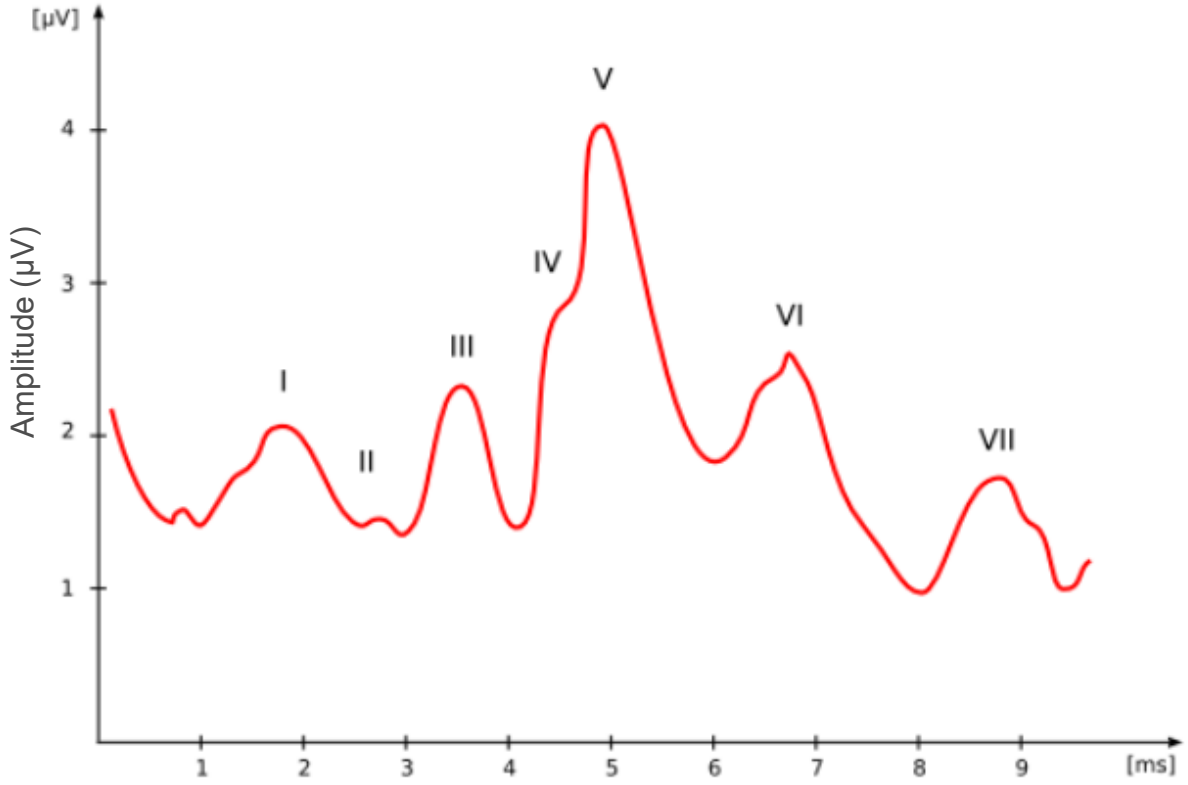
Latency: timing of response



ABR generators

- Waves I and II: auditory nerve
- Wave III: cochlear nucleus
- Wave IV: superior olivary complex
- Wave V: lateral lemniscus/inferior colliculus

- Wave VI: medial geniculate nucleus
- Wave VII: auditory cortex



… we know this primarily from animal studies

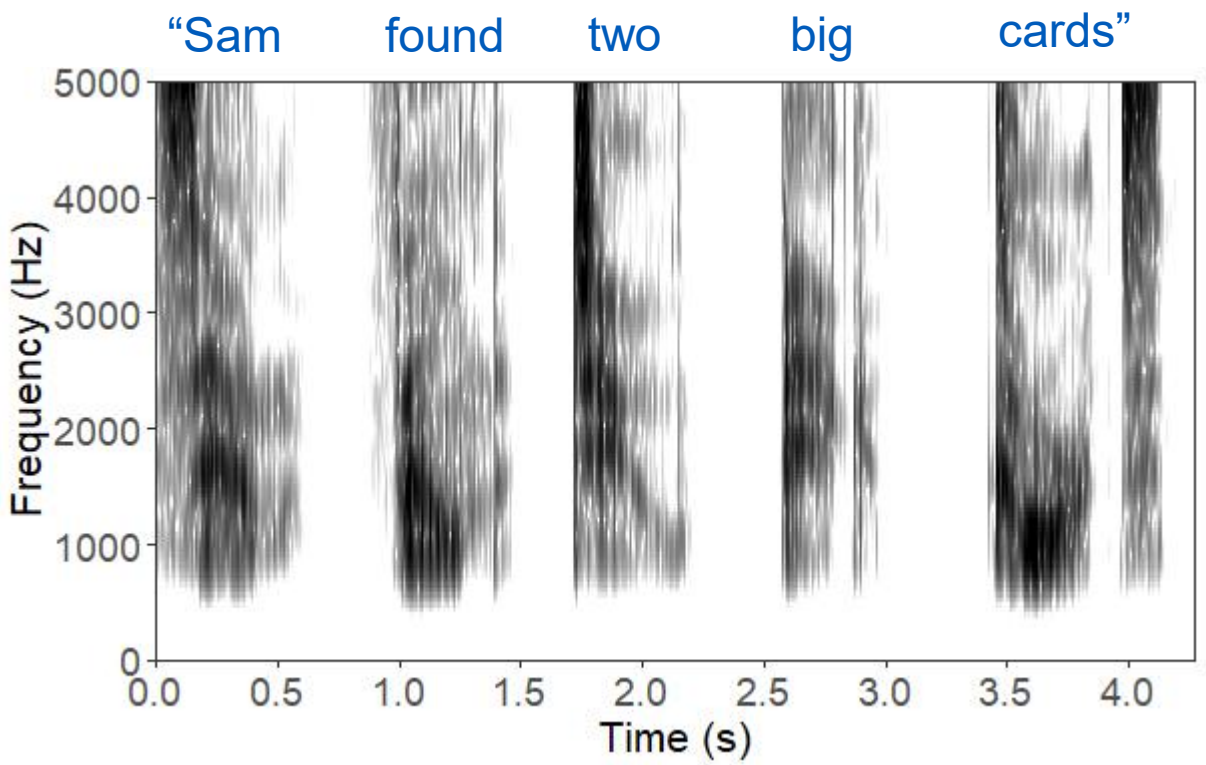
Challenges understanding speech in noise are theorized to result from neural issues

- Some studies have found that ABR metrics predict speech-in-noise perceptual difficulties
  - Bramhall et al., 2015; Liberman et al., 2016; Valderrama et al., 2018; Grant et al., 2020

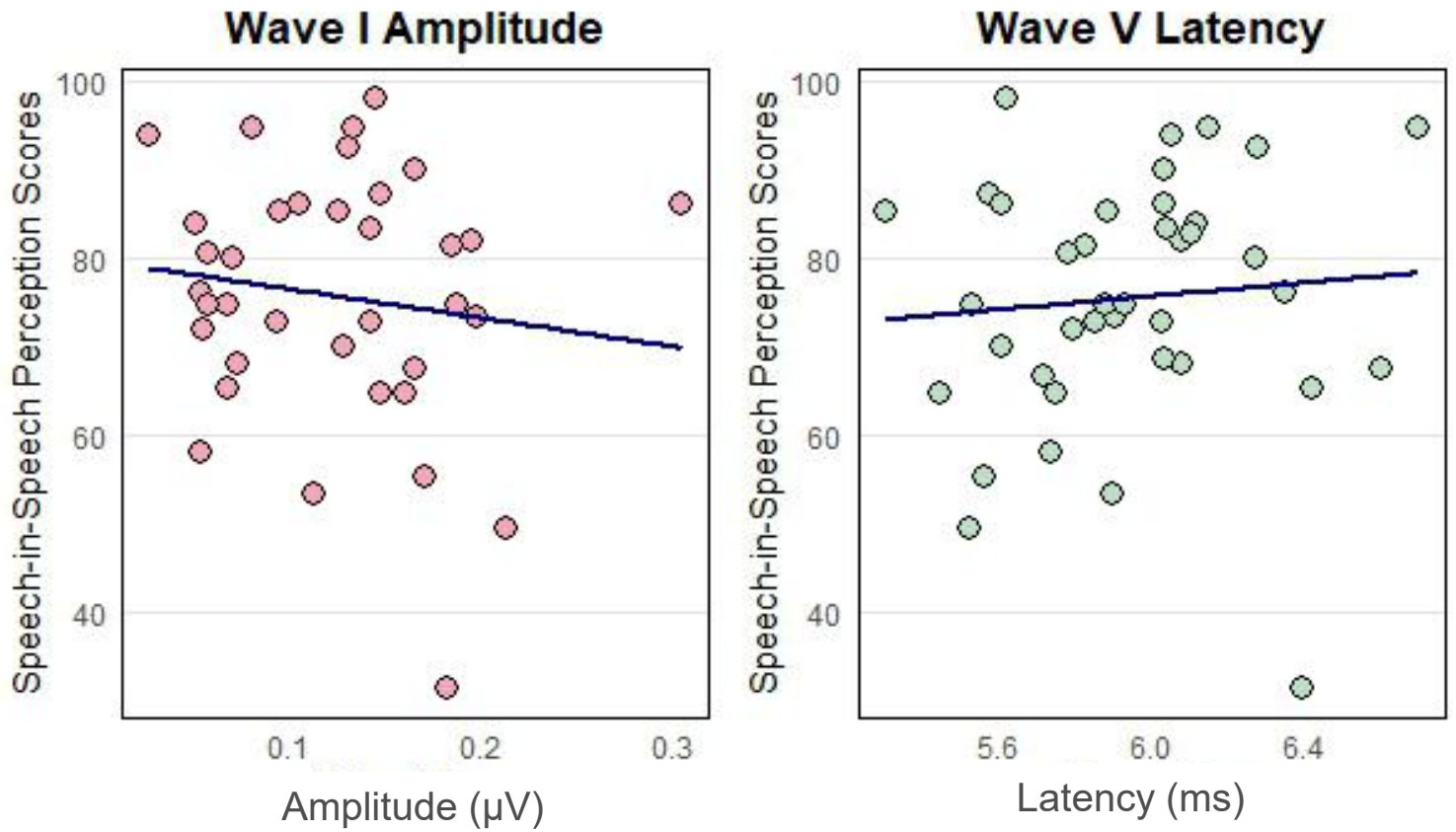
- …But many others have not observed this relationship
  - Grose et al., 2017; Prendergast et al., 2017; Prendergast et al., 2019; Johannesen et al., 2019; Couth et al., 2020; Carcagno & Plack, 2022

We designed a speech-in-speech perception task that is specifically sensitive to auditory nerve function

- Stimuli were high pass filtered at 800 Hz to remove pitch cues that create clear cochlear excitation peaks
  - Emphasizes neural pitch encoding
- Middle-aged and older adults listened to a target talker while ignoring a distractor talker
- The target talker spoke “AND” at the beginning of each trial
- But pitch cues were degraded, increasing the difficulty of identifying the target talker

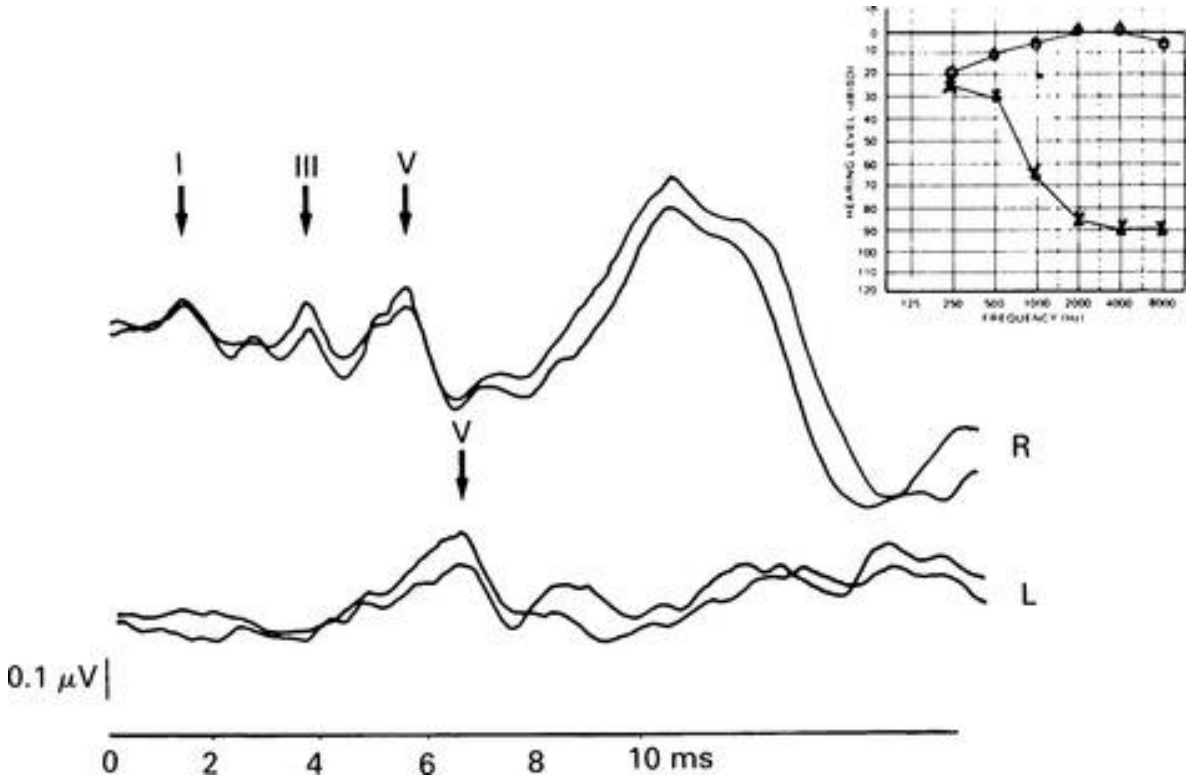


Still, ABR metrics did not predict speech-in-speech recognition task scores



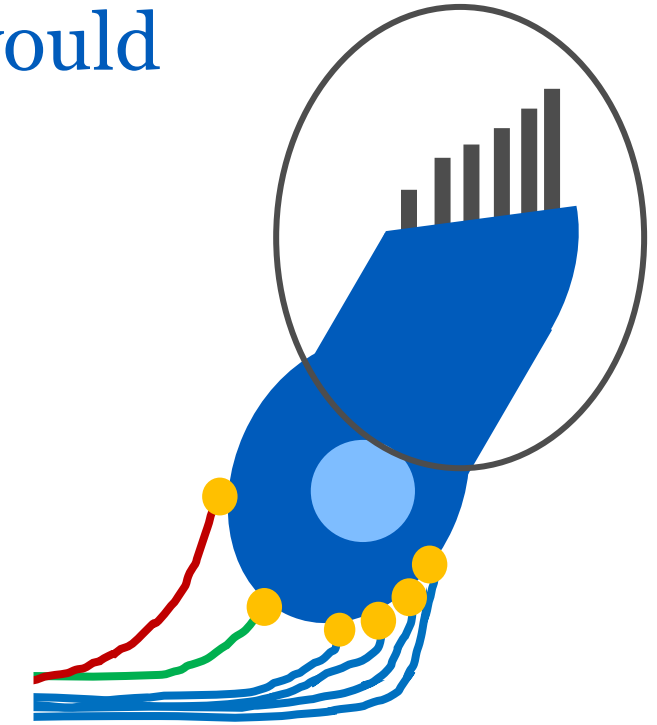
Deremiah & DiNino, 2026

Possible reason: hearing loss confounds measures of neuronal function



Most young adults do not have hearing loss that would confound ABR metrics

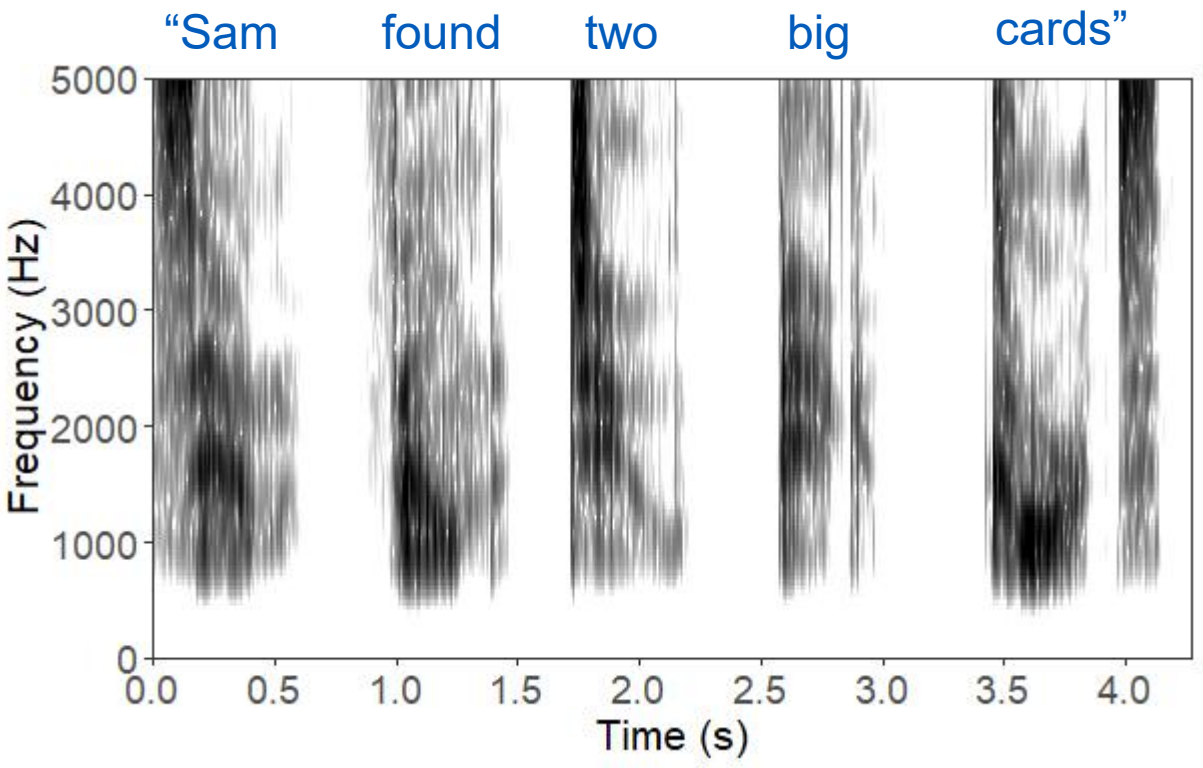
- Would we expect individual differences in neural function?
  - Some young adults experience exceptional difficulty hearing in noise but have normal audiograms
    - Kumar et al., 2007; Hind et al., 2011
  - Noise-induced cochlear synaptopathy has been proposed to explain this
    - Plack et al., 2016; Liberman et al., 2016; Resnick & Polley, 2021



Cochlear synaptopthy
(especially connections to AN fibers that encode high-intensity sound)

Young adults performed the same speech-in-speech perception task as older adults

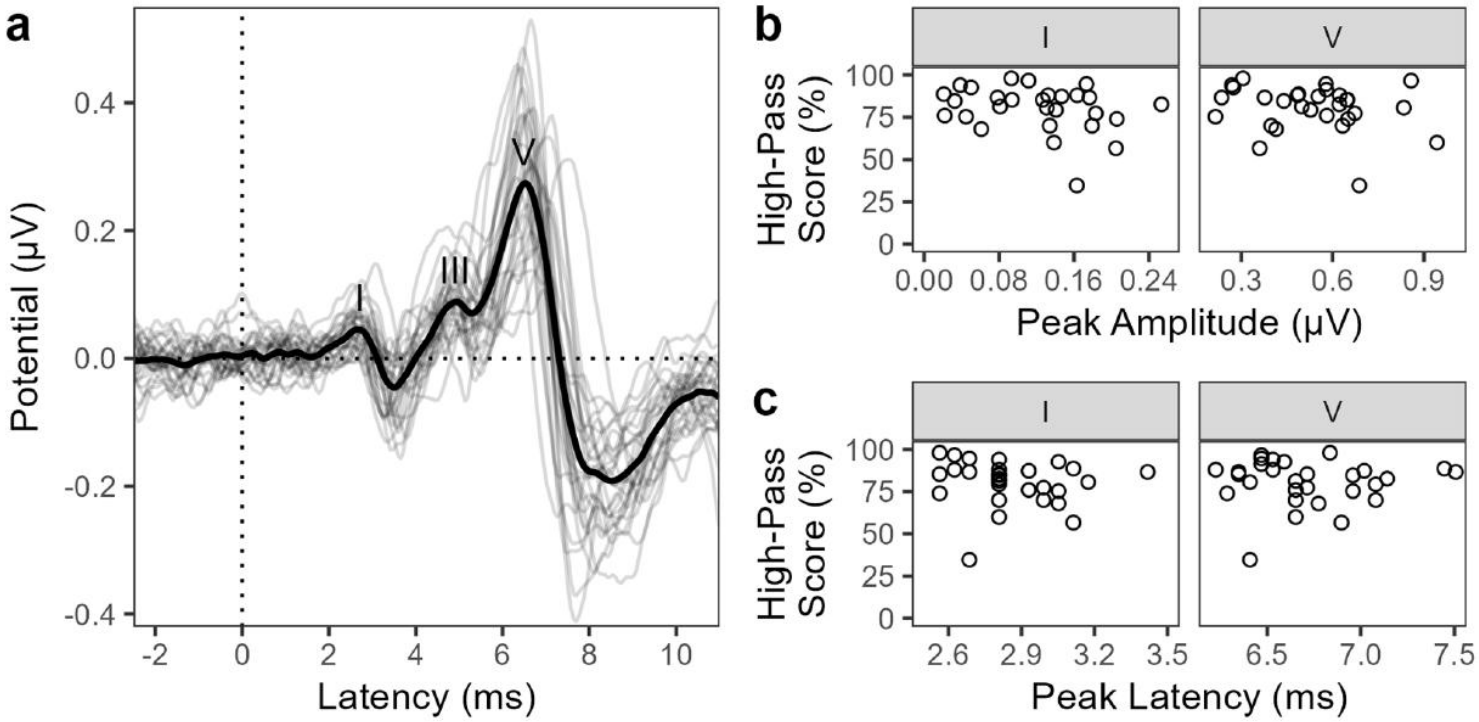




- In collaboration with Dr. Melissa Polonenko at the University of Minnesota
- The task should be sensitive to individual differences in auditory nerve function
- Individuals with poor performance should demonstrate lower ABR wave I amplitudes and/or other altered ABR metrics

First experiment: clicks played at speech levels

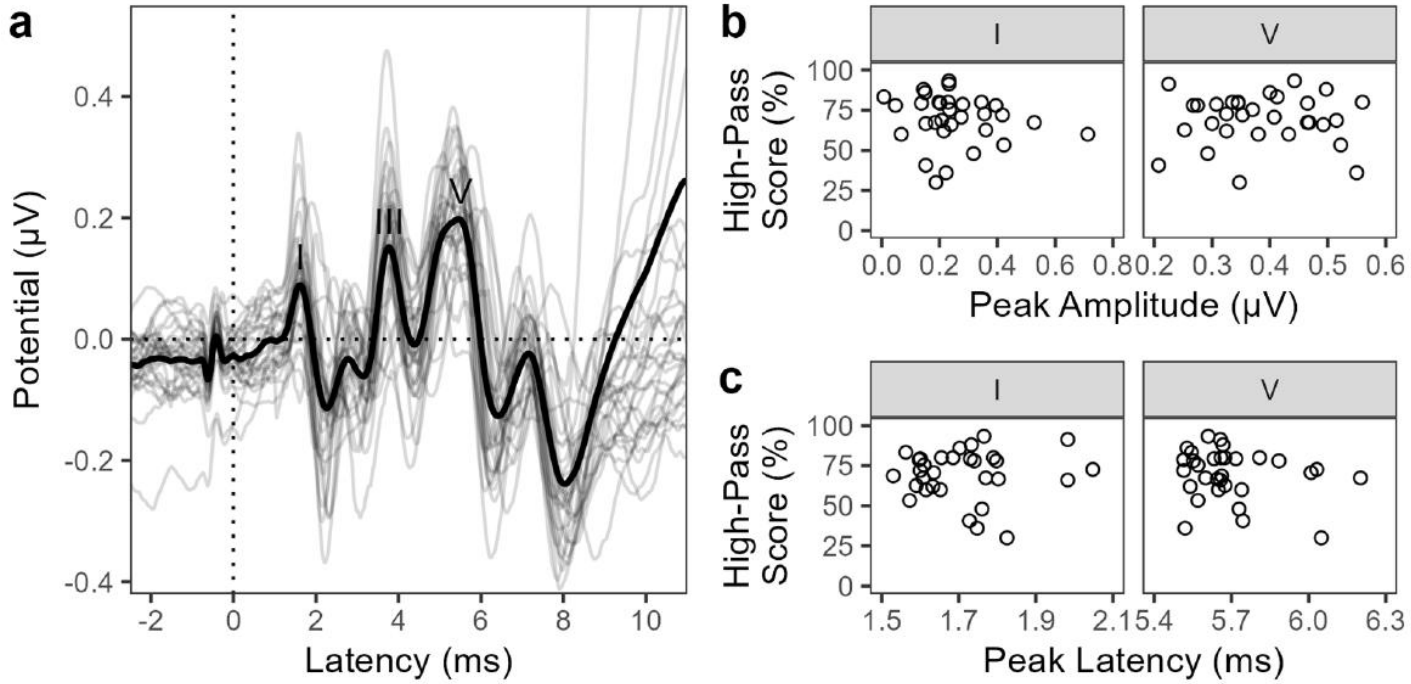




DiNino et al., 2025

Second experiment: clicks played at high intensities





DiNino et al., 2025

ABR metrics did not explain individual differences in speech-in-speech perception

- What might this be?
- Adaptation mechanisms: if sensory processing is decreased, cognitive reliance increases
- Important to consider in clinical practice

- Do cognitive abilities better explain an individual's ability to understand speech in noise?

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The role of cognition in speech-in-noise perception

Holding a conversation is a cognitive challenge

- It involves:
  - Attention
  - Working memory
  - Inhibitory control
  - Processing speed
  - Cognitive flexibility
  - Executive function



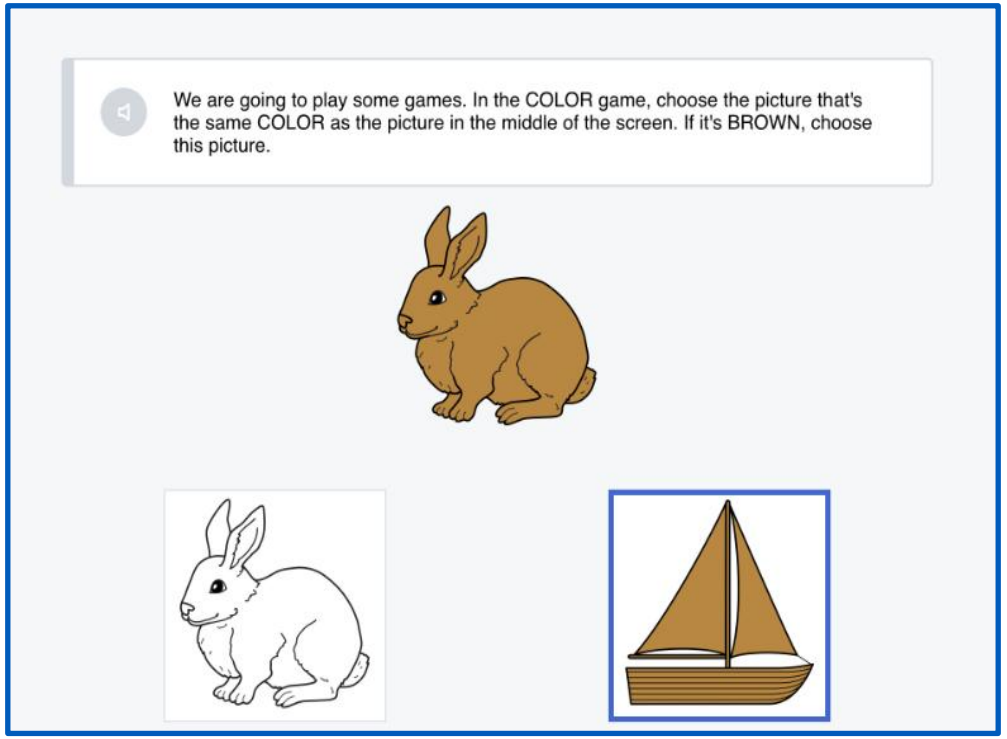
Young adults performed measures from the NIH cognitive toolbox

- Three tasks assessed domains important for speech-in-noise perception
  - Executive function
  - Inhibitory control and attention
  - Working memory



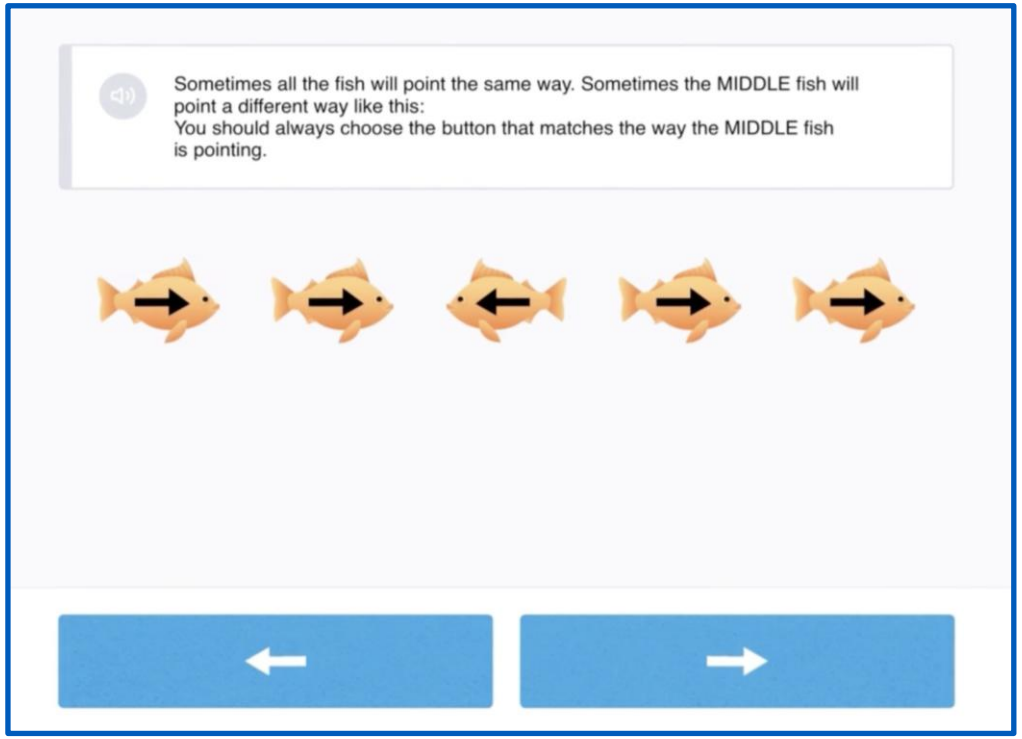
Dimensional Change Card Sort (DCCS)

- Match a series of picture pairs to a target picture



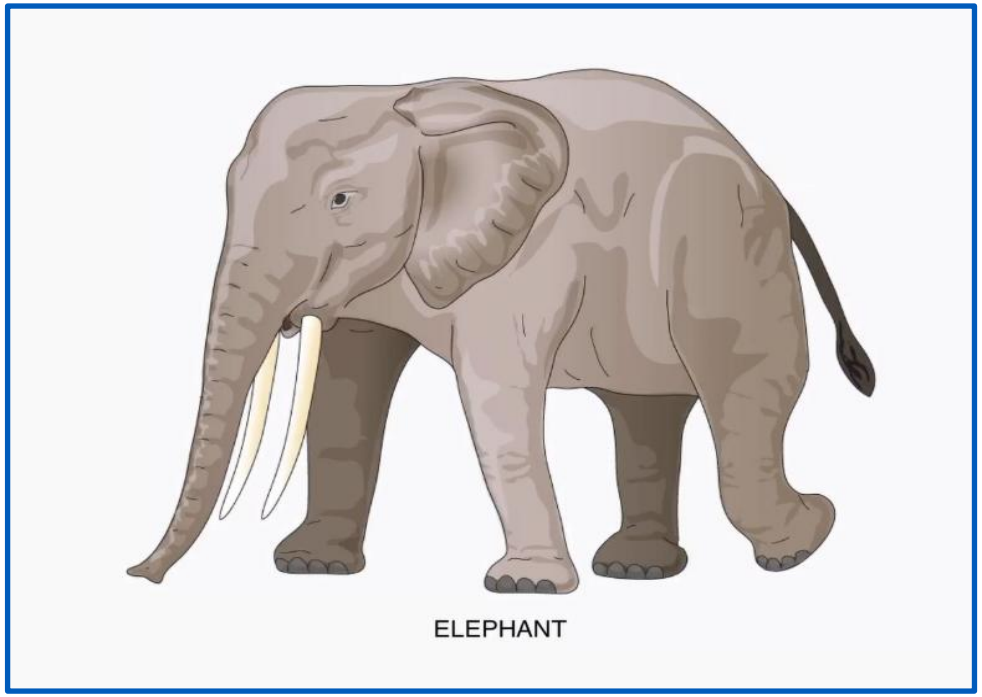
Flanker Inhibitory Control and Attention

- Focus on the center stimulus while ignoring other stimuli

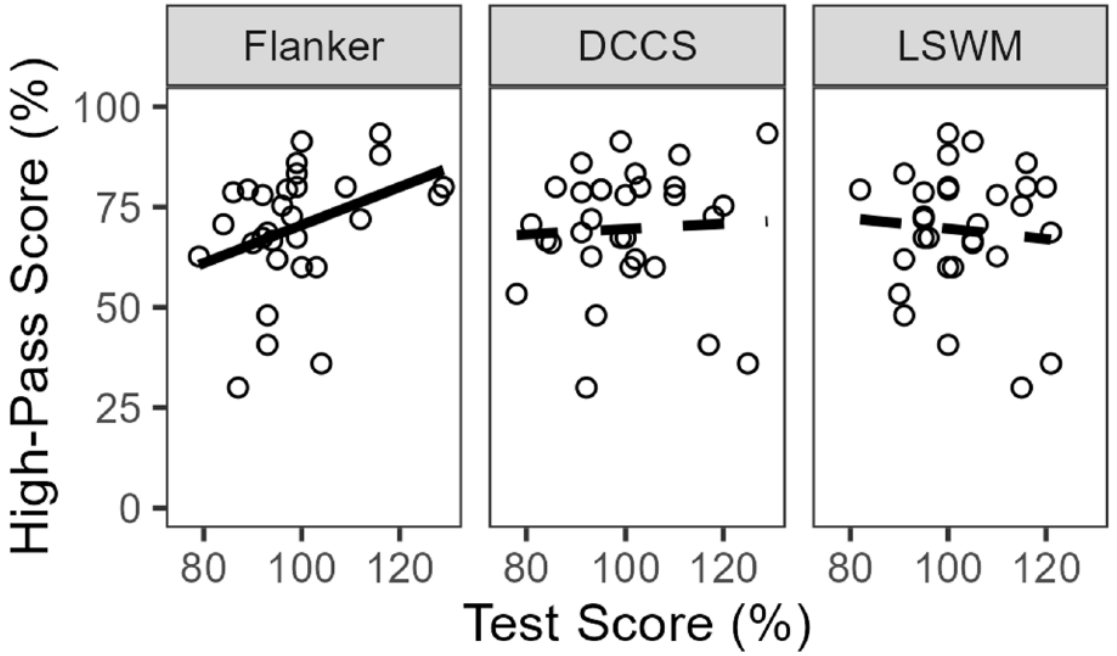


List Sorting Working Memory

- Recall and sequence different animals and food



Scores on the Flanker significantly predicted scores on the speech-in-speech perception task



DiNino et al., 2025

Noise is something you need to separate from what you want to hear

- … which requires **attention and inhibitory control**

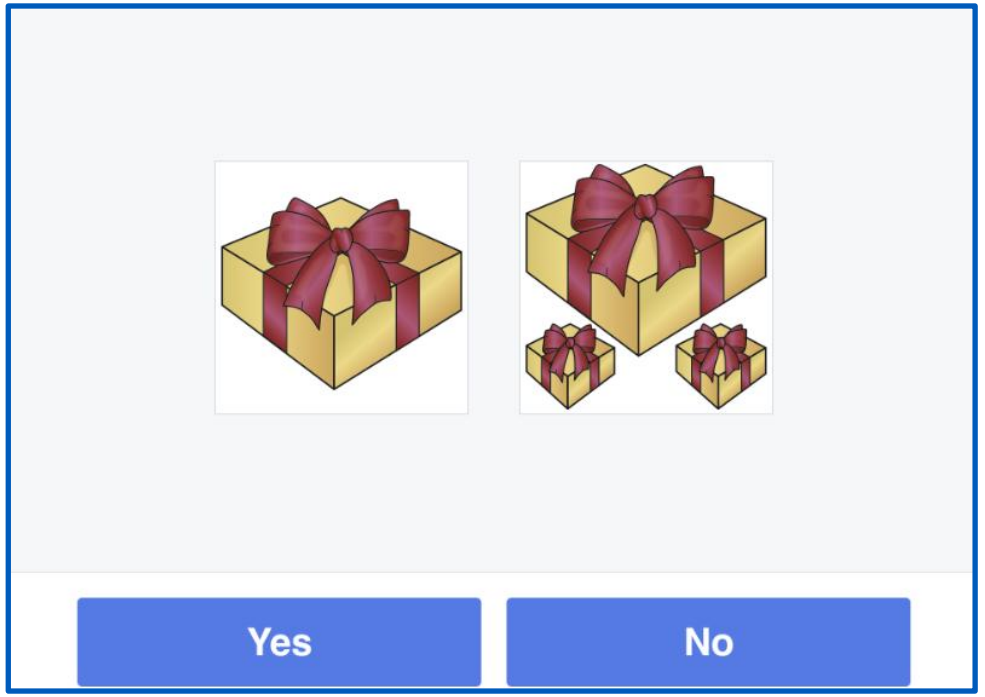


Do older adults' cognitive abilities predict their speech-in-noise recognition?

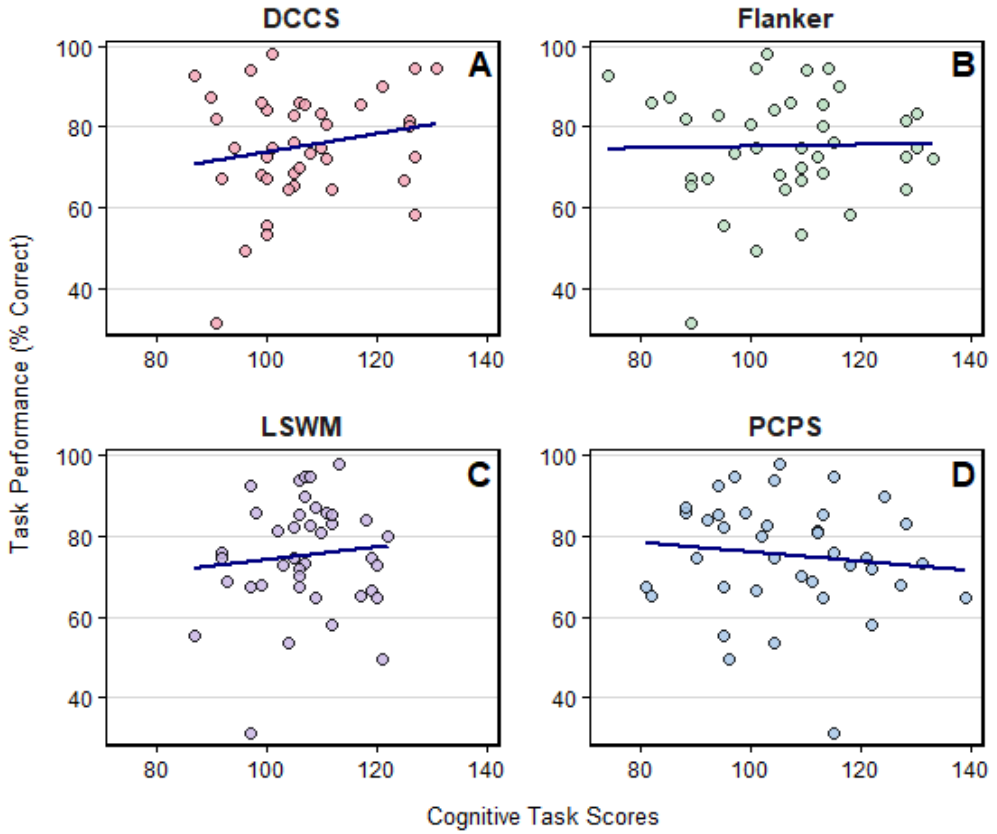
- Middle-aged and older adults performed the same cognitive battery as young adults, plus a test of processing speed

Pattern Comparison Processing Speed (PCPS)

- Quickly determine whether two images are the same or not the same

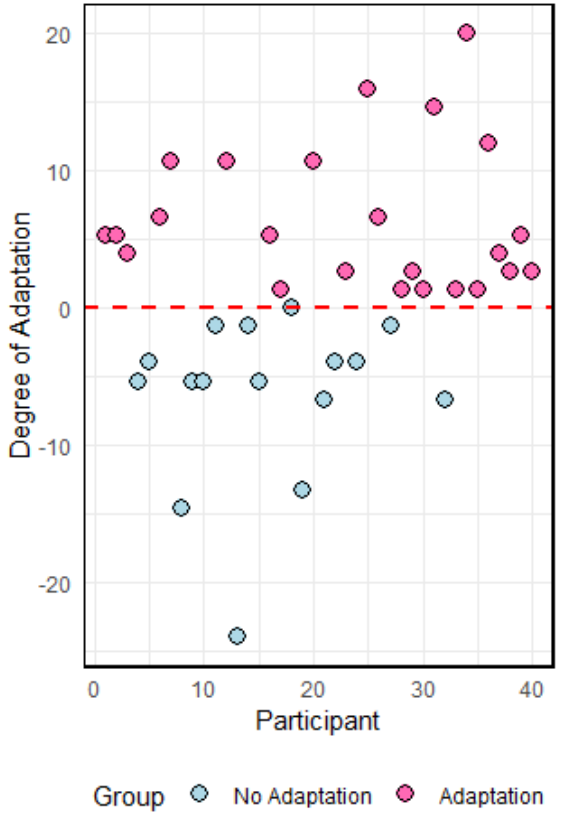


Scores on cognitive tasks did not predict speech-in-speech recognition in middle-aged and older adults



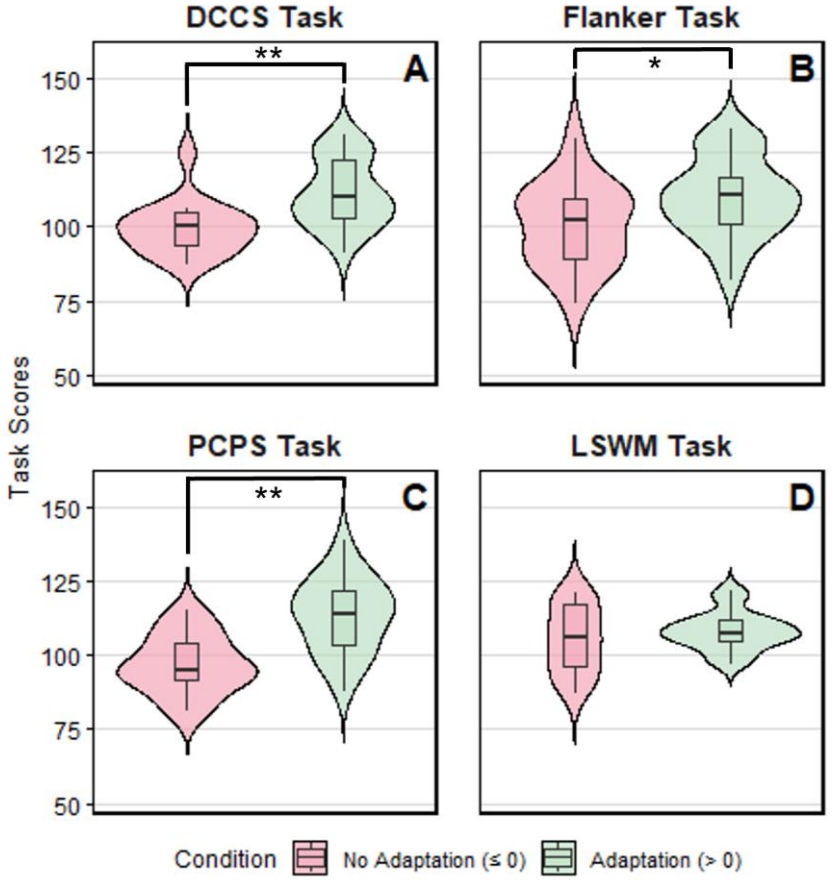
Deremiah, Fish, & DiNino, under review

However, many of these individuals exhibited adaptation as the task progressed



Deremiah, Fish, & DiNino, under review

We observed significant differences in cognitive ability between individuals who did and did not adapt



- Individuals who demonstrated speech-in-speech task adaptation had significantly higher scores on the DCCS, Flanker, and PCPS

Deremiah, Fish, & DiNino, under review

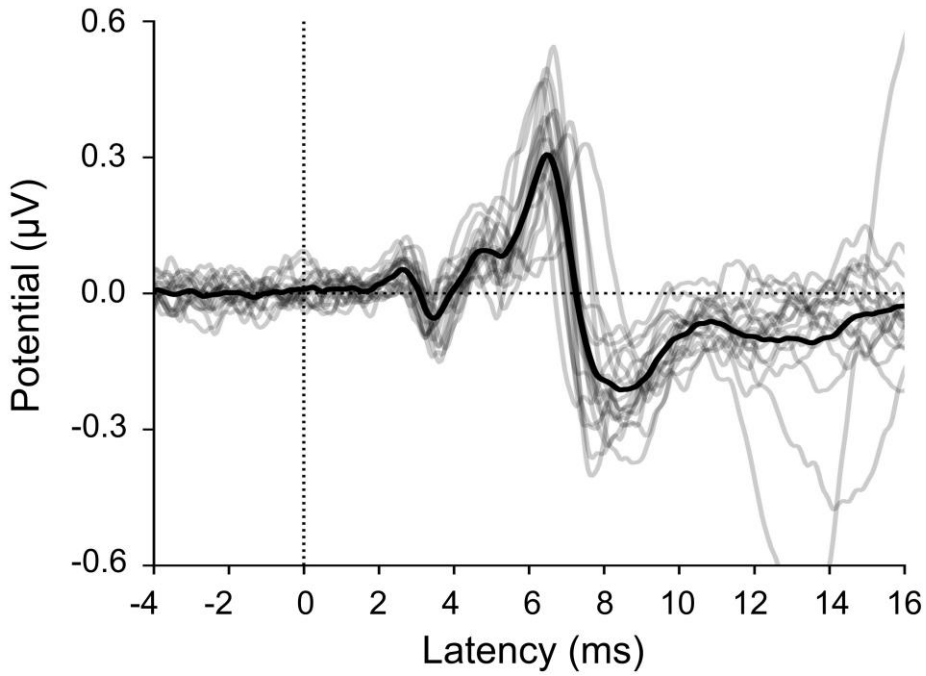
Research conclusions

- Cognitive abilities help adults of all ages perceive speech in noise
  - In young adults, an individual's attention and inhibitory control directly predict their ability to hear speech in noise
  - In middle-aged and older adults, adaptation to the challenging listening scenario plays a larger role
    - Cognitive abilities are connected to this ability to adapt

Implications for clinical practice

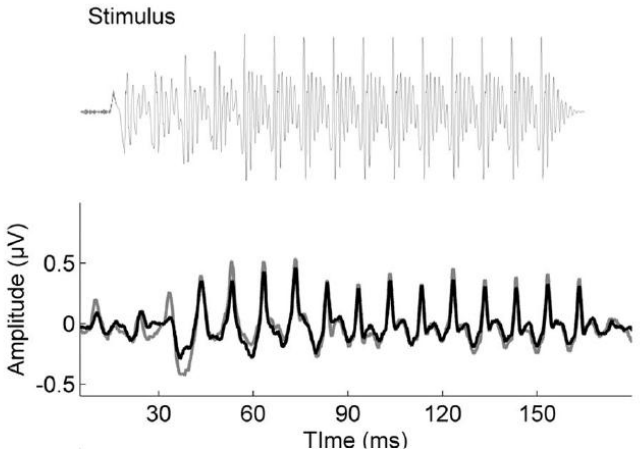
Are ABR metrics predictive of listening difficulties in noise?

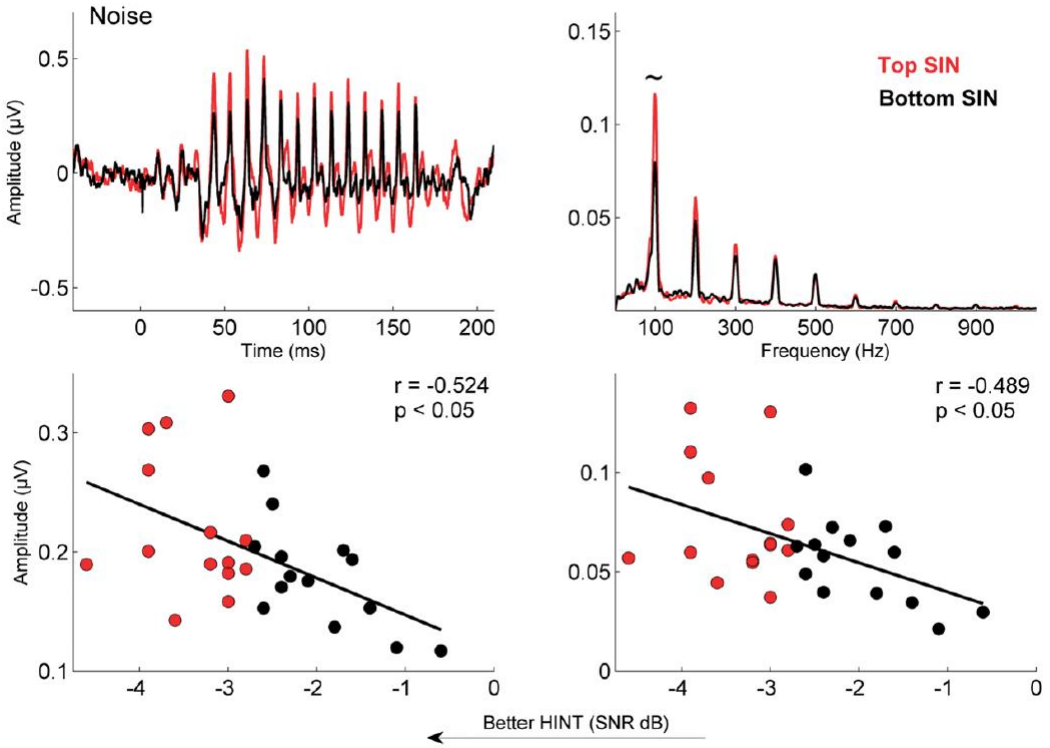
- There is not consistent evidence
- Challenges:
  - Hearing loss affects ABR amplitudes and latencies
  - ABRs are noisy!
  - Collection parameters can change the shape of the waves



ABRs are a measure of neuron onset responses

- … Not how well the auditory brainstem is tracking speech
- Frequency following responses (FFRs) may better predict an individual's ability to hear in noise





Anderson et al., 2011

Cognitive abilities play a role in speech-in-noise perception

- Can we assess cognitive function in clinic?
  - Montreal Cognitive Assessment (MoCA)
  - Mini-Cog
    - However, these tests will not identify subtle variations in cognitive ability
  - Cognivue
    - Overall composite score
    - Subscores
      - Memory, executive function, processing speed

Individuals with poor cognitive function might do poorly on speech reception testing

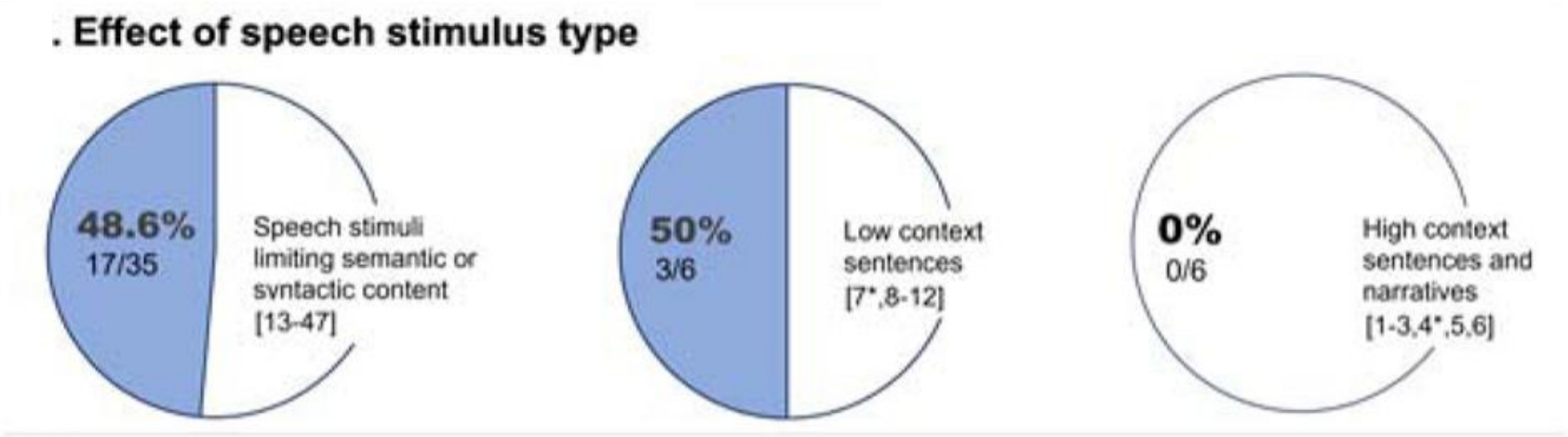
- Aging affects performance on both speech-in-noise perception tests and cognitive tasks
- Is it a sensory issue that can be addressed? Or a cognitive issue?
- If cognition is the primary factor, this will play a role in counseling the patient
  - Devices will not resolve their issue
  - Appropriate expectations should be discussed

Individuals may compensate for sensory deficits with enhanced cognitive ability

- Particularly on speech tests with sentences or passages as stimuli
- However, those stimuli are the most relevant to everyday listening

Assessing basic sensory function vs. ecological validity

Percent of studies finding a relationship between auditory neural function and speech-in-noise perception:



NASEM Measuring Meaningful Outcomes for Adult Hearing Health Interventions recommendation: **the Words in Noise test**

DiNino, Holt, & Shinn-Cunningham 2022

Conclusions

- ABRs assist with diagnosis of a pathology, but do not seem to consistently predict speech-in-noise perception
- Cognitive abilities play a significant role in speech-in-noise perception among adults of all ages
- Cognitive ability can be considered during clinical appointments
  - Direct assessment
  - Mindfulness that patients with poor cognitive abilities may do worse on higher-level tasks than assessments of auditory system function would predict
  - Conversely, awareness that a patient may be compensating for sensory deficits with good working memory or attention
    - Perhaps at the expense of listening effort

Thank you!

- Members of the Auditory Processing and Perception Lab
- Funding sources:
  - Hearing Health Foundation Emerging Research Grant
  - University at Buffalo start-up funding



Hearing Health Foundation
Prevention | Research | Cure

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Questions?