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Rethinking Speech Perception Challenges in Adults Without Hearing Loss, presented in partnership with AVAA

Jacie R. McHaney, PhD
Research Assistant Professor
Roxelyn and Richard Pepper Department of Communication Sciences and Disorders
Northwestern University

Jacie McHaney, PhD

Dr. Jacie McHaney is a Research Assistant Professor in Roxelyn and Richard Pepper Department of Communication Sciences and Disorders at Northwestern University. She is interested in the neural mechanisms underlying speech processing. She received her PhD from the University of Pittsburgh where she studied self-perceived listening difficulties in adults with normal hearing. Jacie uses a combination of neurophysiological, behavioral, and cognitive computational neuroscience approaches to study speech perception challenges in adults without overt hearing loss.

Disclosures

- **Presenter Disclosure**: Financial: Jacie McHaney is an employee of Northwestern University. Non-financial: Jacie McHaney has no relevant non-financial relationships to disclose. In lieu of an honorarium, a donation has been made to AVAA in the form of AudiologyOnline CEU memberships.
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Learning Outcomes

After this course, participants will be able to:

1. Explain 3 potential sources of speech perception problems in adults with normal hearing.
2. Discuss how to analyze pupillary responses as an index of effortful listening.
3. Describe why accuracies on speech perception tests do not provide the full picture of listening abilities.

Speech Perception Challenges As We Age

Photo by Norbert Braun on Unsplash

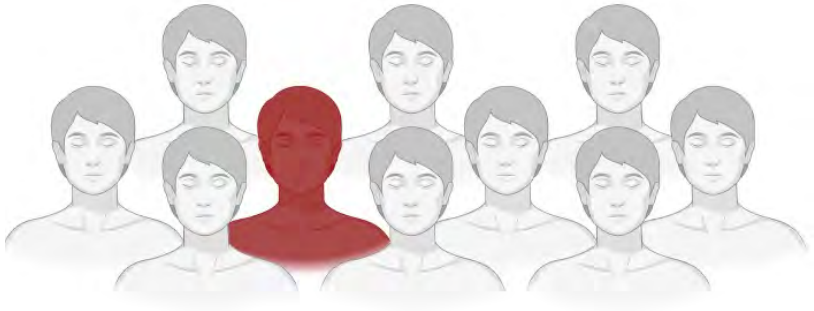
Why?

- Hearing loss
- Cognitive function
- Auditory processing abilities

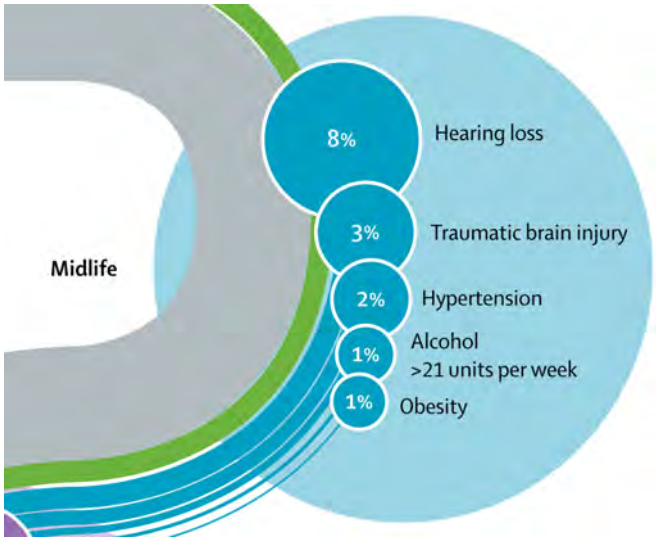
At the clinic

- Elevated audiogram thresholds/presbycusis
- Poor scores on speech in noise tests

Speech Perception Challenges Yet Normal Hearing



Modifiable risk factors for dementia



Livingston et al. (2020). Dementia prevention, intervention, and care: 2020 report of the Lancet Commission. *The Lancet Commissions.*

- 10% of adult patients with complaints of speech perception difficulties have normal hearing thresholds
  (Cancel, McHaney et al., 2023; Hind et al., 2011; Parthasarathy et al., 2020; Pryce & Wainwright, 2008; Spankovich et al., 2018; Tremblay et al., 2015)
- Speech perception challenges often arise in middle-age (~40-55 years)
  - Even in the absence of hearing loss
    (Demeester et al., 2012)
- Listening difficulties have significant implications on quality of life and associated with an increased risk for cognitive decline
  (Bainbridge & Wallhagen, 2014; Huddle et al., 2017; Lin & Albert, 2014)
- Hearing loss in middle-age is the largest modifiable risk factor for dementia in later life
  (Livingston et al., 2020)

Sources of Speech Perception Challenges in Normal Hearing

Cochlear synaptopathy (CS)

- Loss of neural synapses between auditory nerve fibers and inner hair cells, beginning primarily at the base of the cochlear (corresponding to high frequencies). (Kujawa & Liberman, 2009)
- Relationship between CS and speech perception challenges is unclear

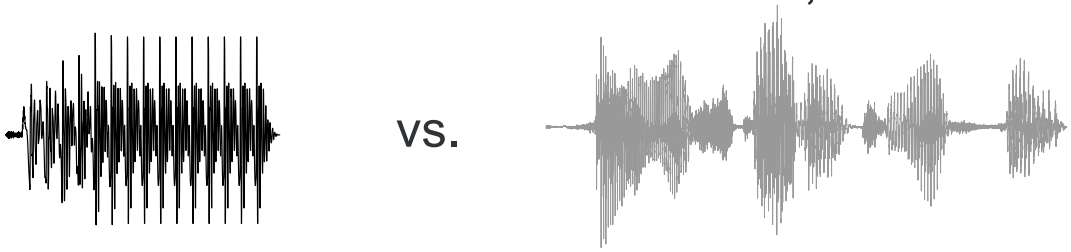
Critical need to develop diagnostic tests to capture sources of speech perception challenges in adults with normal hearing.

Three potential avenues:

1. Electroencephalography (EEG) to examine neural representations of speech sounds in the brain
2. Pupillometry as a metric of effortful listening
3. Cognitive computational models of decision-making during speech perception

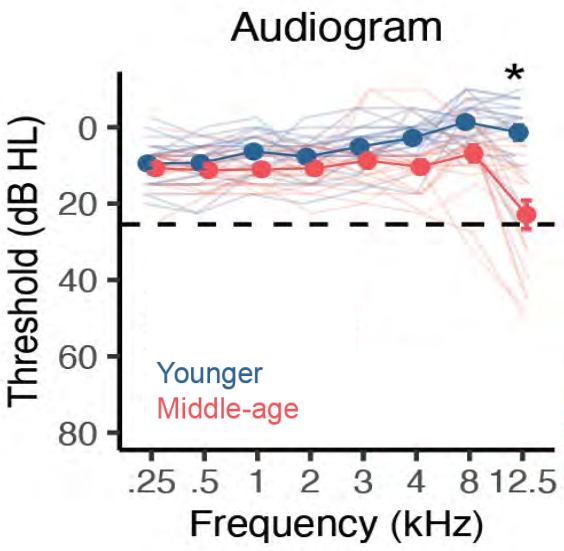
EEG to Continuous Speech

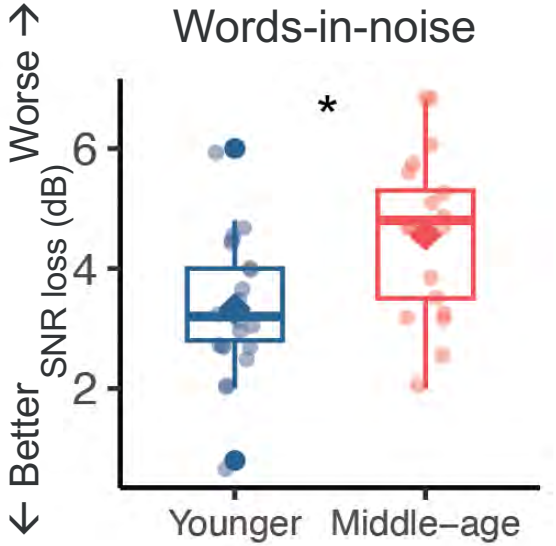
Shifting from discrete stimuli to more naturalistic, continuous speech



- Data conclusions collected to highly controlled stimuli may not apply to data using naturalistic stimuli (Hamilton & Huth, 2018)
- Using naturalistic stimuli allows us to efficiently examine auditory and speech processing
  - Envelope tracking, voice pitch tracking, phoneme encoding
- We use continuous speech from audiobooks to understand whether any of these metric may be indicative of “hidden hearing loss” in patients with normal hearing.

Despite similar thresholds, middle-aged adults showed poorer speech in noise

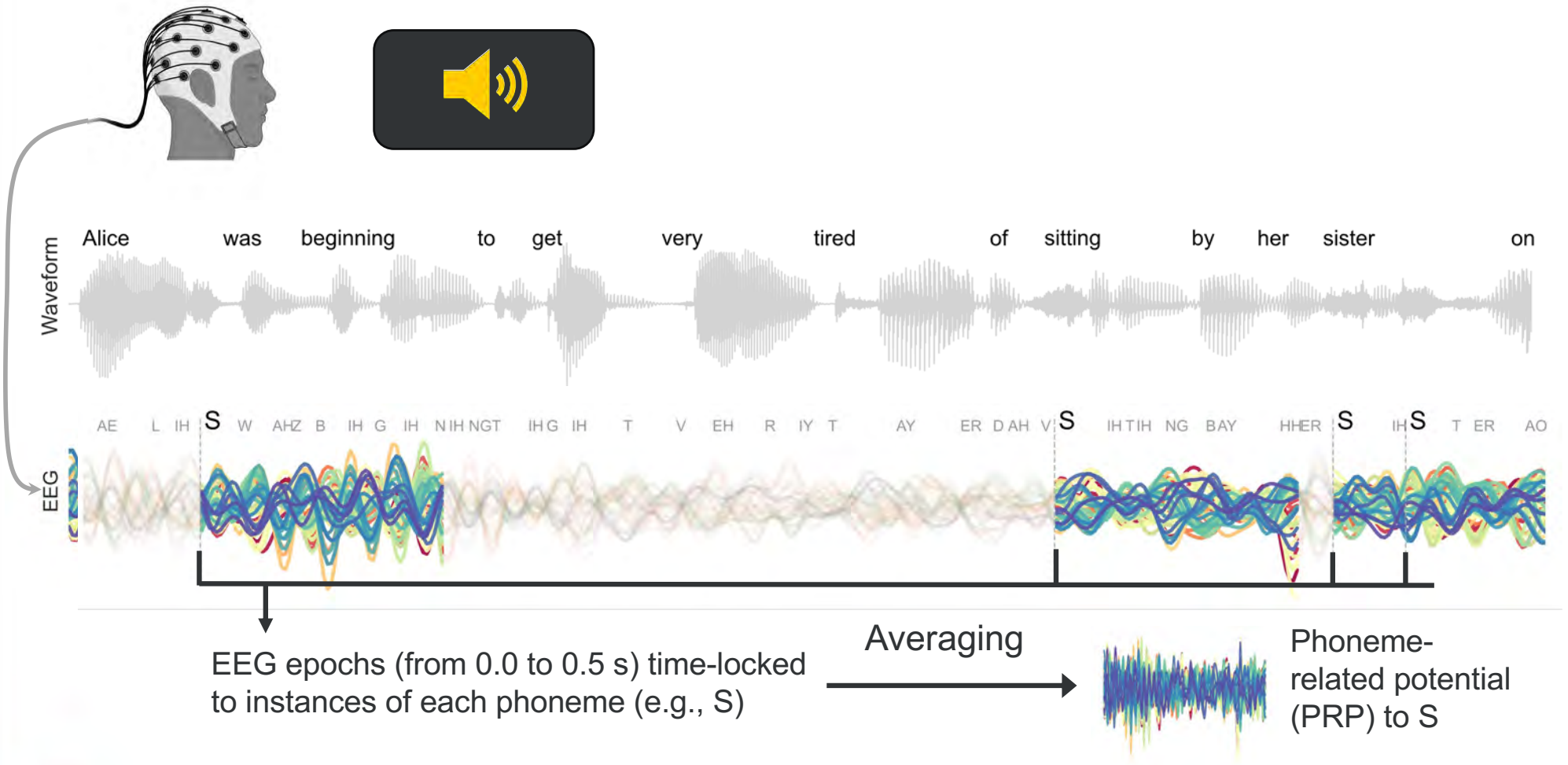




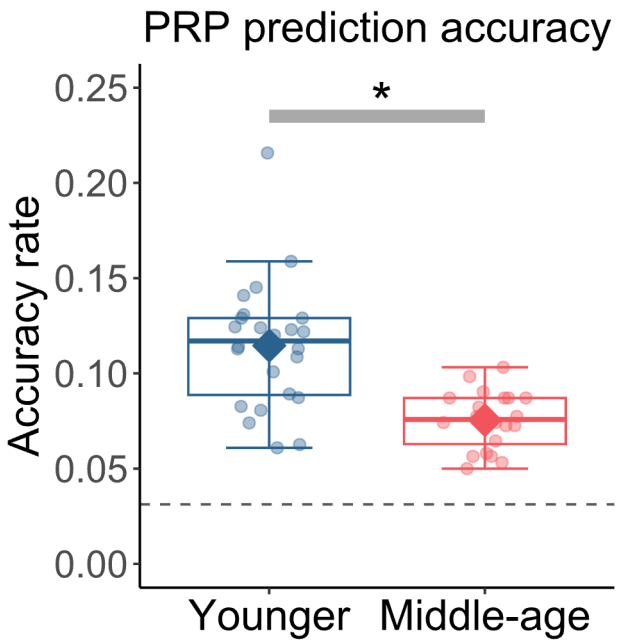
- 21 younger adults ages 18-25 years
- 18 middle-aged adults ages 40-52 years
- Thresholds ≤25 dB HL at 250-4000 Hz
  - Middle-aged adults showed some hearing loss at extended high frequencies (> 8kHz)
- Middle-aged adults had worse words in noise recognition than younger adults

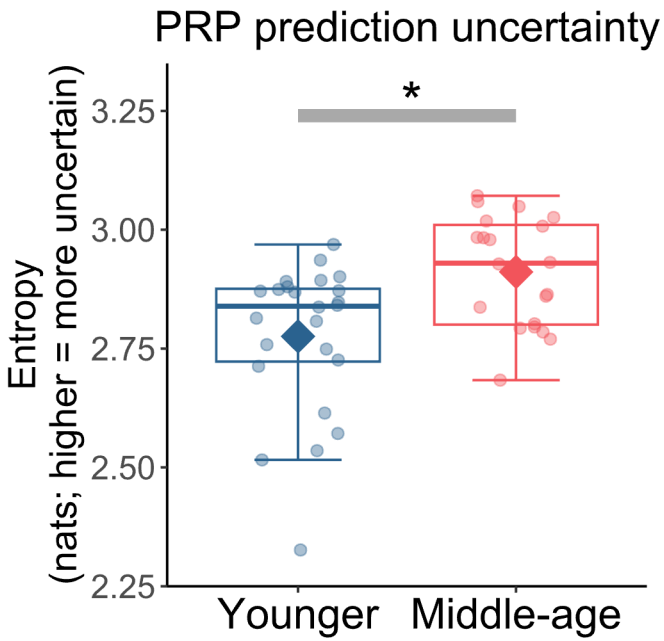
Guo & McHaney et al. (2024). *bioRxiv.*

Cortical Representations of Phonemes



Cortical Representations of Phonemes in Middle-aged Adults





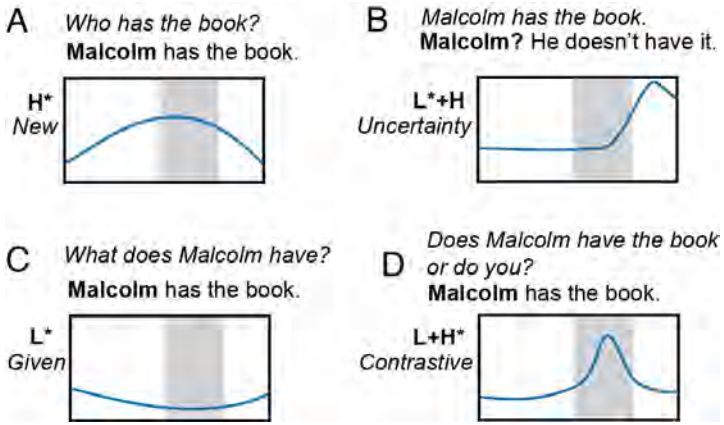
- Trained a neural network model to classify phoneme-related potentials into the correct category
- Middle-aged adults had worse prediction accuracy
- The model was less certain when classifying middle-aged adult responses

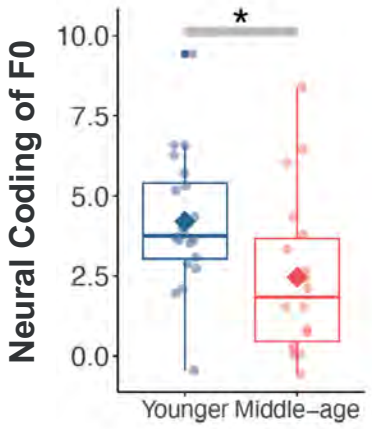
Middle-aged adults have less distinct cortical encoding of phonemes, which may contribute to speech in noise difficulties.

Guo & McHaney et al. (2024). *bioRxiv.*

Voice Pitch Representations and Pitch Accents

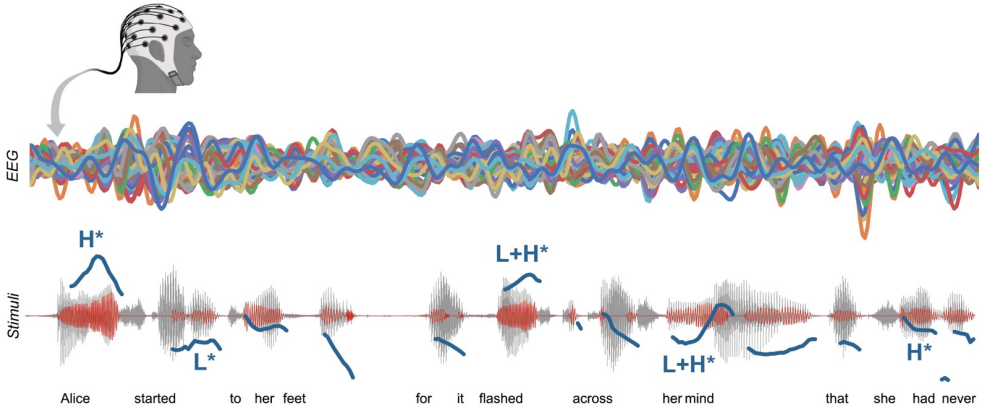
- Voice pitch (fundamental frequency) is a critical cue for speech perception
  - Multitalker scenarios
  - Cues emotion
  - Linguitic pitch accents
- 4 pitch accents in English that speakers use changes in fundamental frequency to communicate important information (Pierrehumbert & Hirschberg, 1990)
- Neural coding of fundamental frequency is reduced in middle-aged adults (Van Canneyt et al., 2020; McHaney et al., in prep.)
- If neural coding of fundamental frequency is reduced, then are neural representations of pitch accents also affected in middle-age?

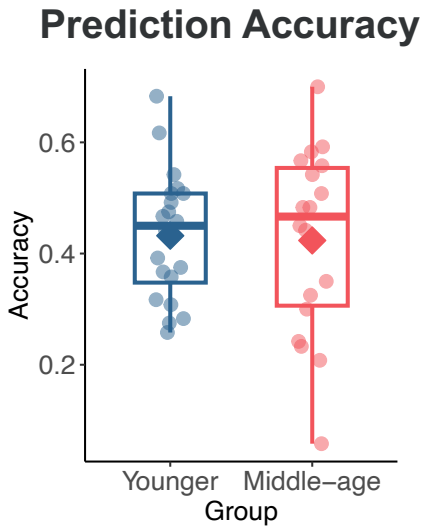


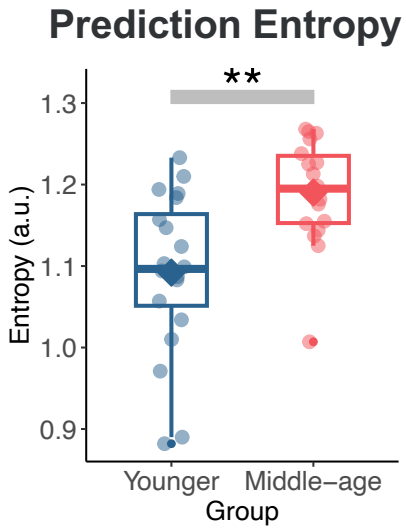


McHaney et al. (in preparation).

Pitch Representations in Middle-age are Reduced







- Trained a neural network model to classify accent-related potentials into the correct pitch accent category
- Middle-aged adults and younger adults had similar prediction accuracy levels
- The model was more uncertain when classifying middle-aged adult responses

Neural coding of voice pitch may lead to troubles encoding pitch accents—may cause trouble with speech perception

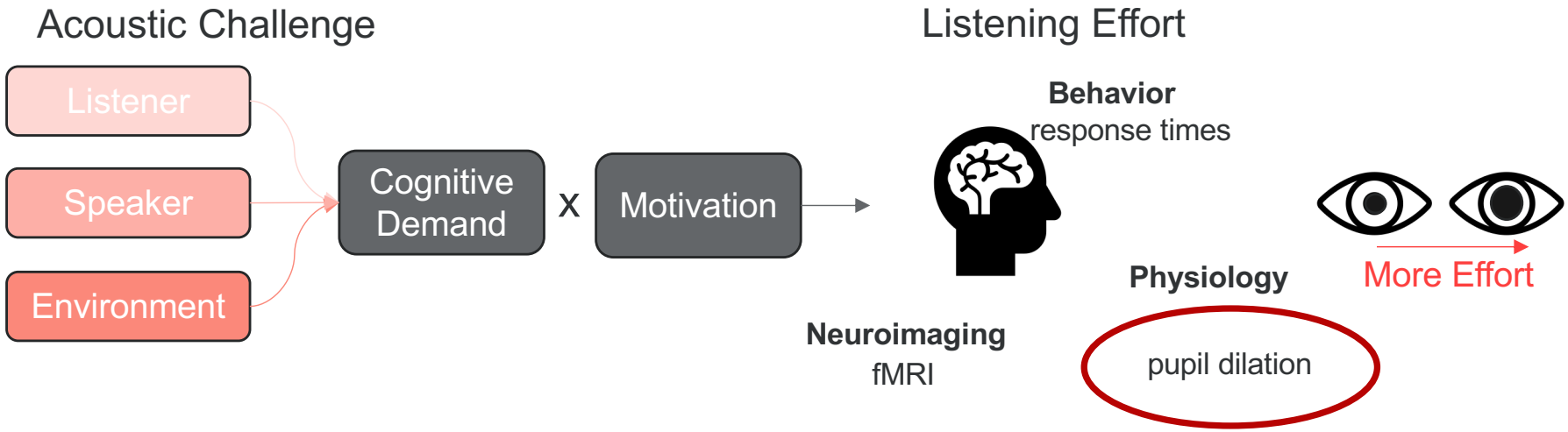
McHaney et al. (in preparation).

Interim Summary on Neural Representations of Phonemes and Voice Pitch

1. Middle-aged adults have fuzzier representations of phonemes and reduced neural coding of linguistic pitch accents, despite similar hearing sensitivity as younger adults
2. Age-related neural dedifferentiation may be the underlying mechanism
    1. Previously only applied in older adults—posits that reduced specialization in the sensory cortex and more distributed, correlated activity across the cortex drives age-related processing challenges (Koen & Rugg, 2019; Park et al., 2004)
    2. Our two studies suggest this may occur in middle-age, and may contribute to speech processing challenges
3. Our two metrics may serve as an early indicator of “hidden hearing loss” in middle-aged adults with complaints of speech perception difficulties, yet have normal hearing

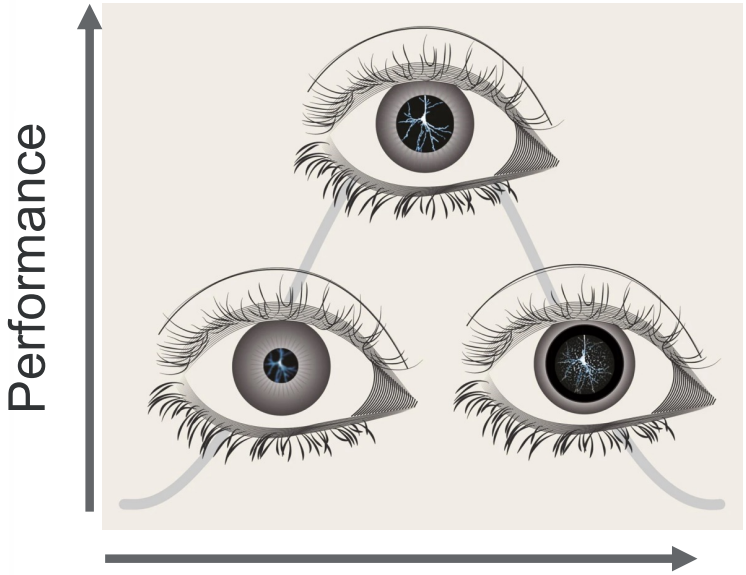
Listening Effort

- Listening Effort: the deliberate reallocation of mental resources to overcome obstacles in pursuit of listening
(Pichora-Fuller et al. 2016)



Peelle, 2018. *Ear and Hearing.*

Pupillometry as a Metric of Listening Effort



(Illustration by Kresley Singson; from: https://news.yale.edu/2015/06/11/eyeing-top-performance-look-pupil)

Pupil dilation driven by the release of norepinephrine
(Aston-Jones & Cohen, 2005)

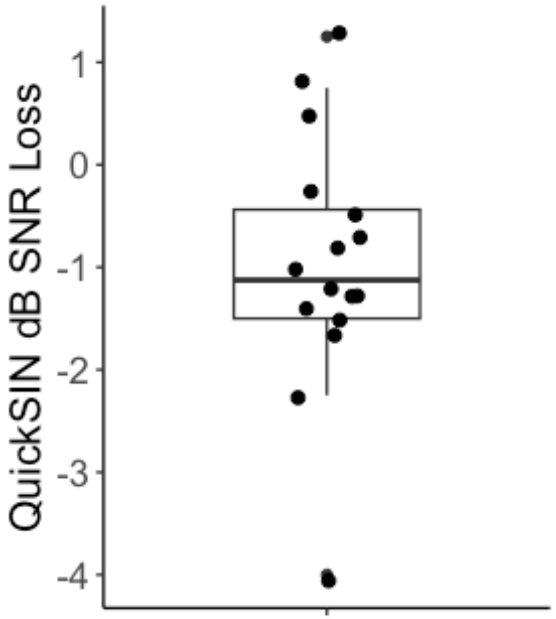
Listening Effort in Context

1dB SNR Loss on QuickSIN

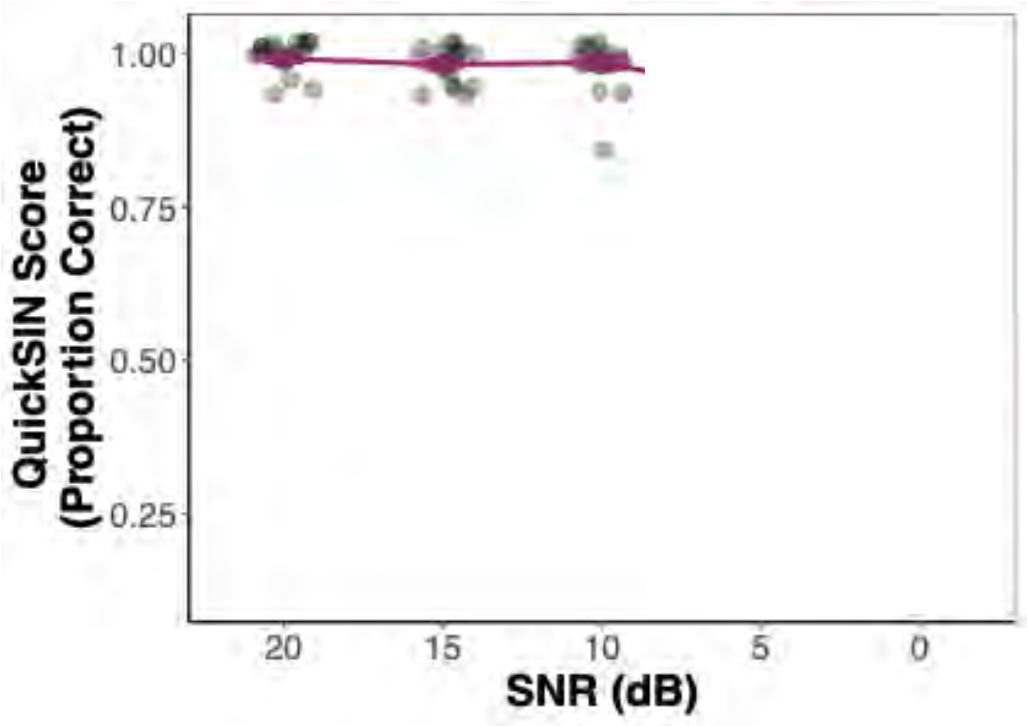
1dB SNR Loss on QuickSIN

Exerted more listening effort to achieve the same score

Listening Effort During QuickSIN in Adults with Normal Hearing



SNR loss all within normal limits

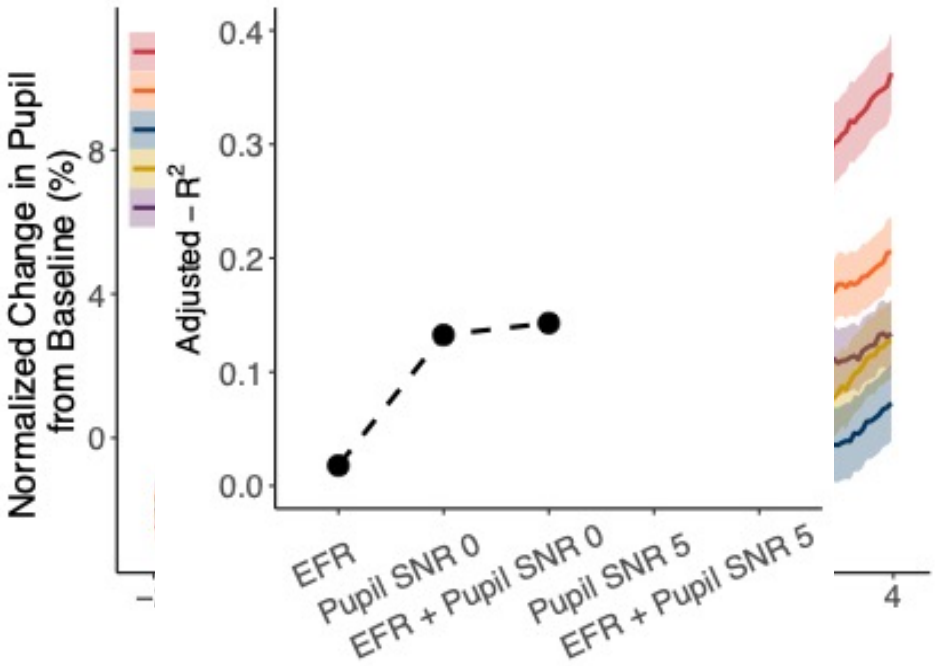


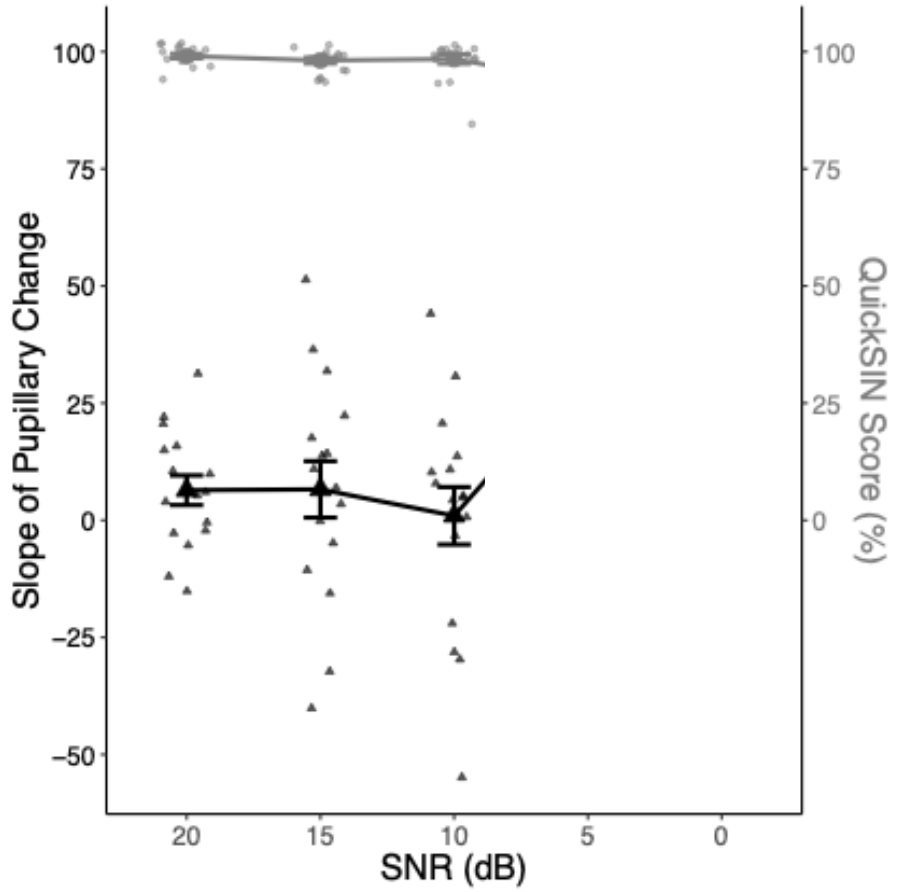
Individual variability at hardest SNR level.
Not captured by SNR loss score.

McHaney et al., 2024. *Scientific Reports.*

Listening Effort During QuickSIN in Adults with Normal Hearing

Model of Speech in Noise Performance at SNR 0



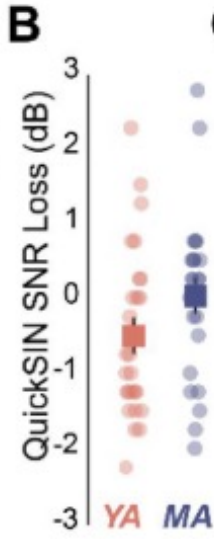


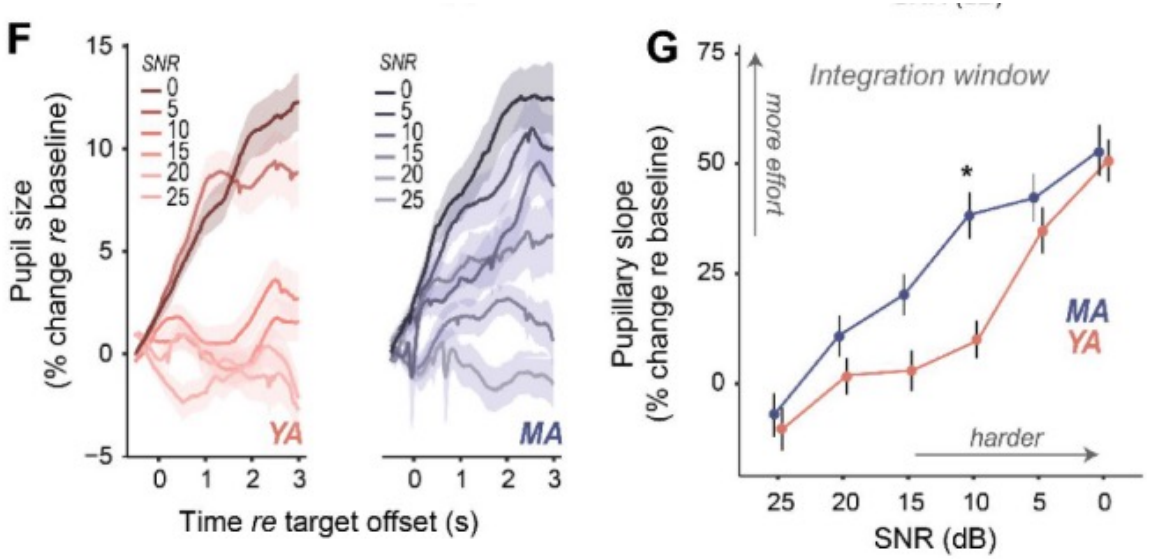
Listening effort at SNR 5 better explains performance at SNR 0

"sweet spot" at SNR 5 → poor performance at SNR 0

McHaney et al., 2024. *Scientific Reports.*

Listening Effort "Sweet Spot" Occurs at Easier SNRs in Middle-age





SNR Loss all within normal limits

Individual variability at harder SNRs, and middle-aged adults performed worse at SNR 0 than younger adults

Listening effort steadily increased in middle-aged adults, with "sweet spot" occurring at SNR 10.

Zink, Zhen, **McHaney** et al., 2024. *eLife.*

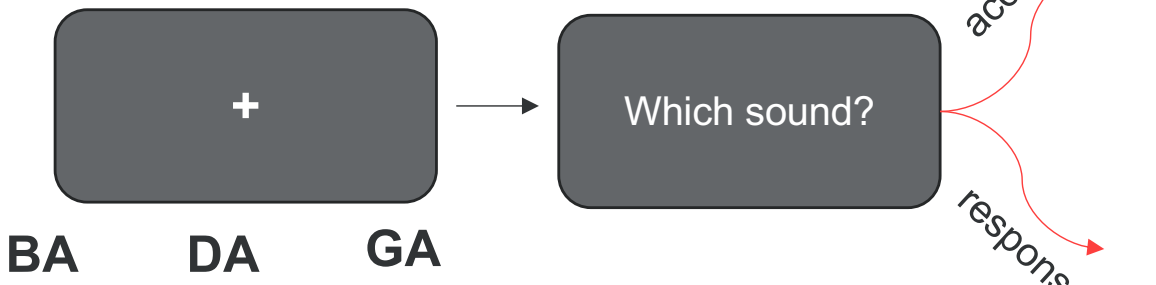
Interim Summary: Pupil to Measure Listening Effort

1. Listening effort follows an inverted U-shaped curve, with maximal performance during speech in noise occurring at intermediate effort levels.
2. With increasing age, there is a shift in the “sweet spot” for effort, even without a change in hearing sensitivity.
    1. Middle-aged adults hit their sweet spot at easier SNR levels compared to younger adults
3. Listening effort should be considered when working with patients who have normal hearing but complain of speech in noise difficulties.

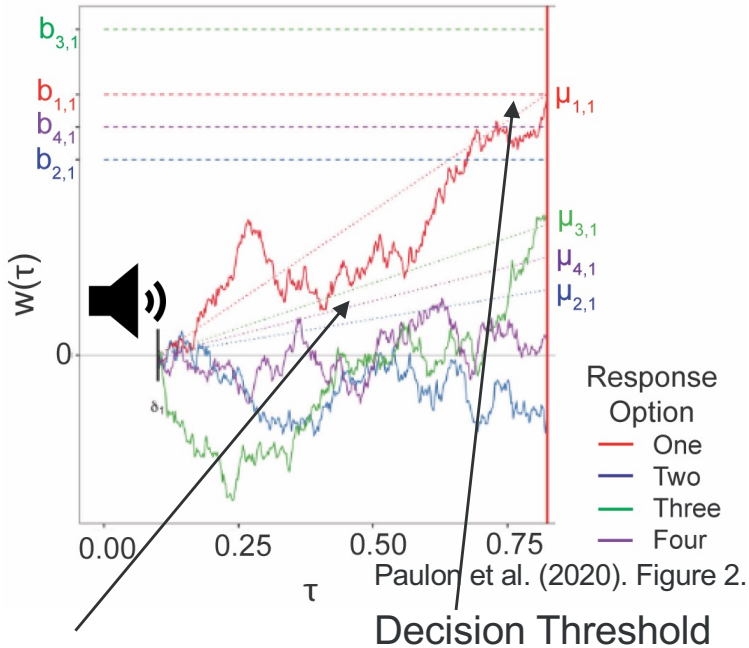
Back to the basics: Behavior Responses

- Many tests rely on patient responses through accuracies
- Accuracies alone may hide underlying issues
  - Effort
  - Cognitive processes
- Can incorporating response times help disentangle cognitive aspects of speech processing?

Computational Models of Behavior During Listening



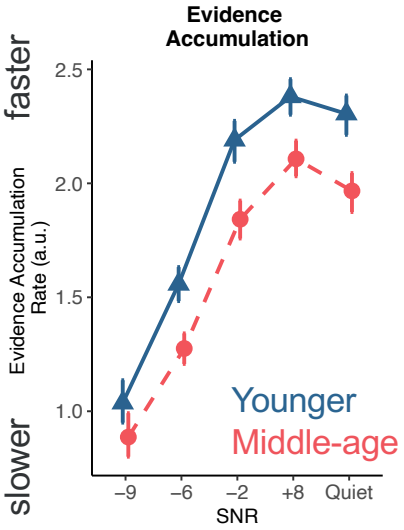
Drift Diffusion Model (DDM)

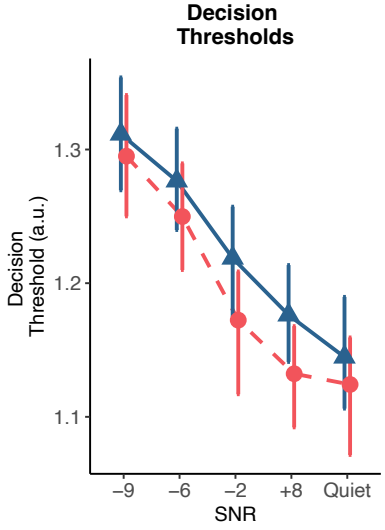


Paulon et al. (2020). Figure 2.

Evidence Accumulation Rate
- how much information is extracted from the sound

Decision Threshold
- how much information is needed before you can make a decision





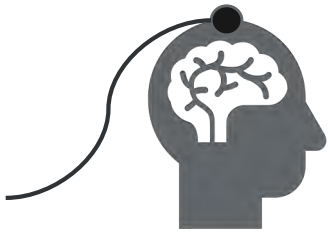
Middle-aged adults with normal hearing are slower to accumulate critical evidence from a stimulus during speech processing than younger adults but show no differences in decision thresholds.

McHaney et al., in prep.

Translating Our Science to the Clinic

- Making cortical representations of phonemes test clinically viable

15 minutes of listening



5 minutes of listening

- Validating behavioral test of cognitive decisional processes during listening

15 min test in person → 15 min test online → 5 min test in clinic

Key Takeaways

- Our research shows that cognitive changes during speech perception occur as early as middle-age
  - Poorer cortical representations of phonemes during listening
  - Greater listening effort
  - Slower evidence accumulation during listening
- These changes may contribute to listening challenges reported by 10% of adult patients with normal hearing thresholds
- Developing clinically viable tests to capture these sources of speech perception challenges is critical

Acknowledgements

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www.soundbrainlab.northwestern.edu

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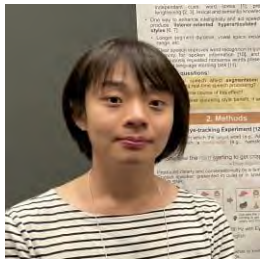

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