Canadian Academy of Audiology
Academie Canadienne d'audiologie

New Electrophysiological Methods to Assess Hearing Function in Young Children Using Engaging Stories

Speaker: Melissa Polonenko, Assistant Professor
Department of Speech-Language-Hearing Sciences, University of Minnesota

Host: Dr. Karen Gordon, University of Toronto

2023-03-23

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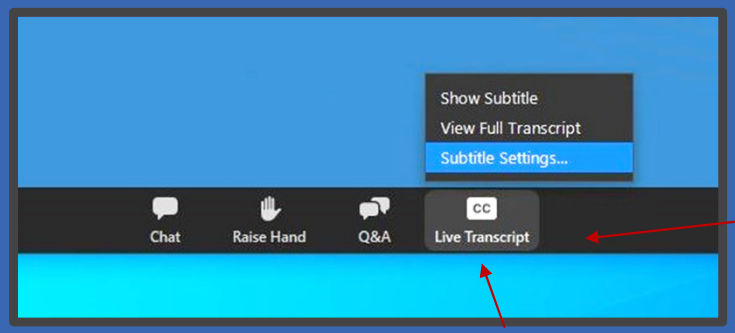

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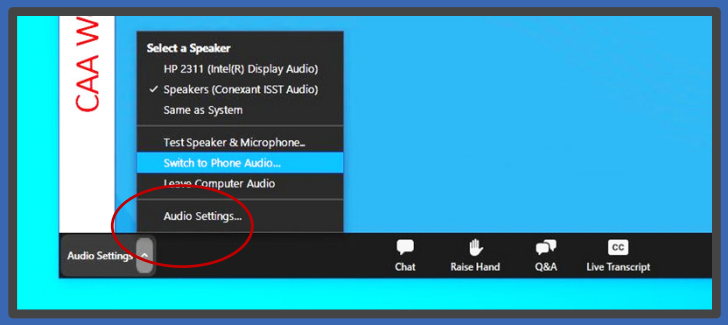

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Canadian Academy of Audiology is a professional association dedicated to enhancing the role of audiologists as primary hearing health care providers through advocacy, education and research.

Moderator – Dr. Karen Gordon, Senior Scientist SickKids, University of Toronto

Dr. Karen Gordon is a professor in the Department of Otolaryngology-Head & Neck Surgery and a graduate faculty member in the Institute of Medical Science at the University of Toronto. She works at SickKids as a Senior Scientist in the Research Institute and as Director of Research of Archie's Cochlear Implant Laboratory.

She is a member of the Cochlear Implant team, which is responsible for determining candidacy for cochlear implantation of children applying to the program and monitoring children who are using either a single cochlear implant or bilateral cochlear implants.

Speaker: Melissa Polonenko, Assistant Professor Department of Speech-Language-Hearing Sciences, University of Minnesota

Dr. Melissa Polonenko is an Assistant Professor in the Department of Speech-Language-Hearing Sciences at the University of Minnesota. She worked as an Audiologist in Edmonton Alberta before pursuing her PhD from the University of Toronto at SickKids Hospital.

Her current research focuses on auditory development in children with hearing loss who use hearing aids and cochlear implants, auditory-visual integration following hearing or vision loss, and new electrophysiological paradigms to assess hearing function.

New electrophysiological methods to assess hearing function in young children using engaging stories

March 23, 2023 · CAA Webinar

UNIVERSITY OF MINNESOTA
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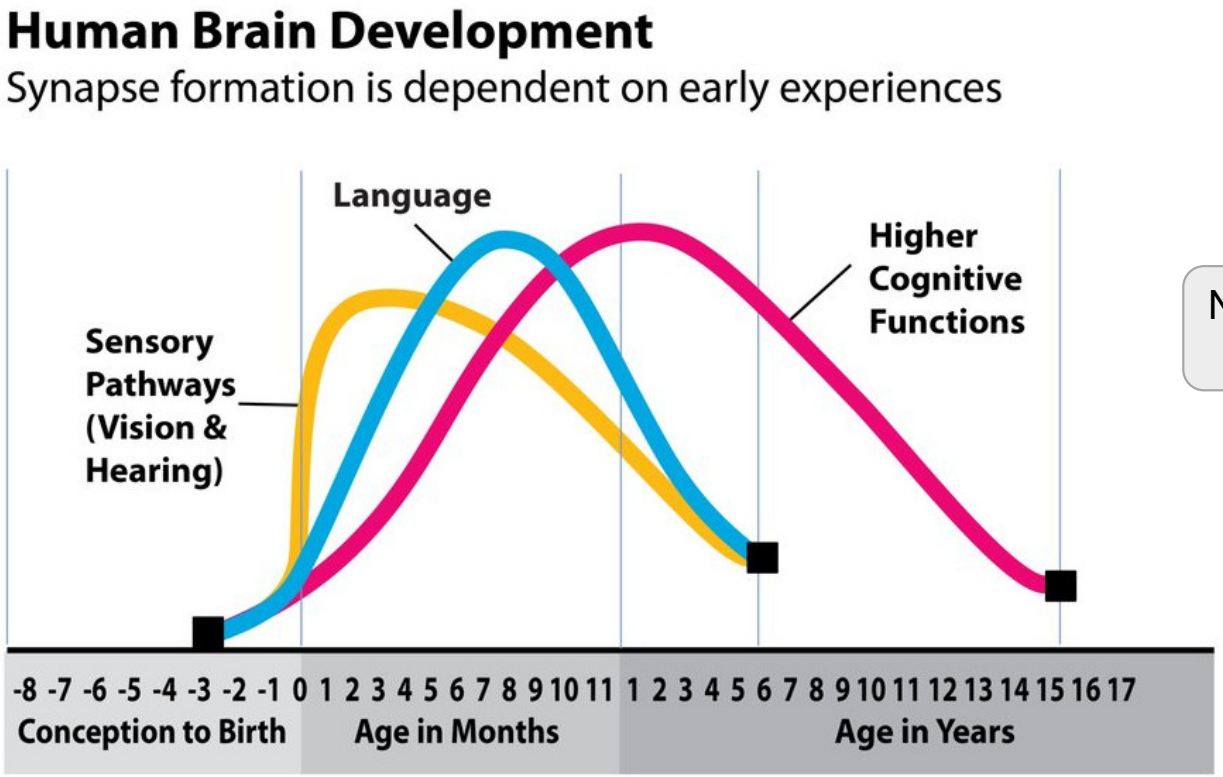
Melissa Polonenko, PhD, AUD(C)

Hearing and Multisensory Development Lab
Department of Speech-Language-Hearing Sciences

Early hearing experience influences development



Neurons build connections with each other

Kral & O'Donoghue (2010)
https://www.leelanauearlychildhood.org/brain-development

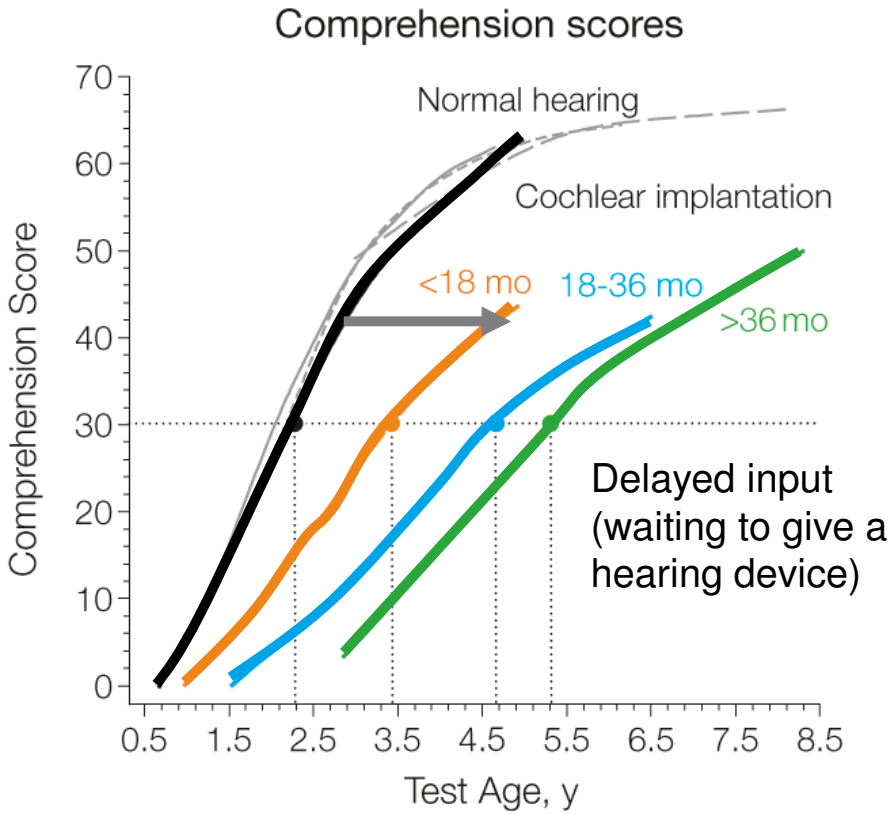
What does this mean for an infant with hearing loss?

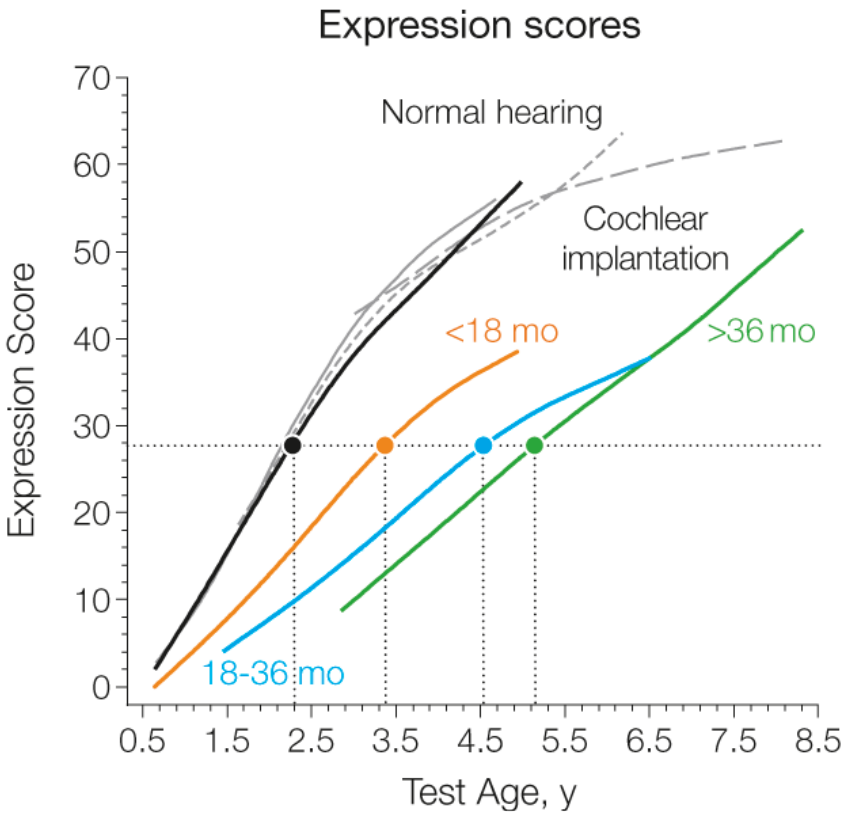
Building blocks are there but we need experience to refine and mature our hearing skills

What about congenital hearing loss?

- Miss key milestones in early development while awaiting appropriate input from auditory devices
- Distorted or abnormal hearing
- Brain pathways do not develop the same way

Delays to input affect speech understanding and production



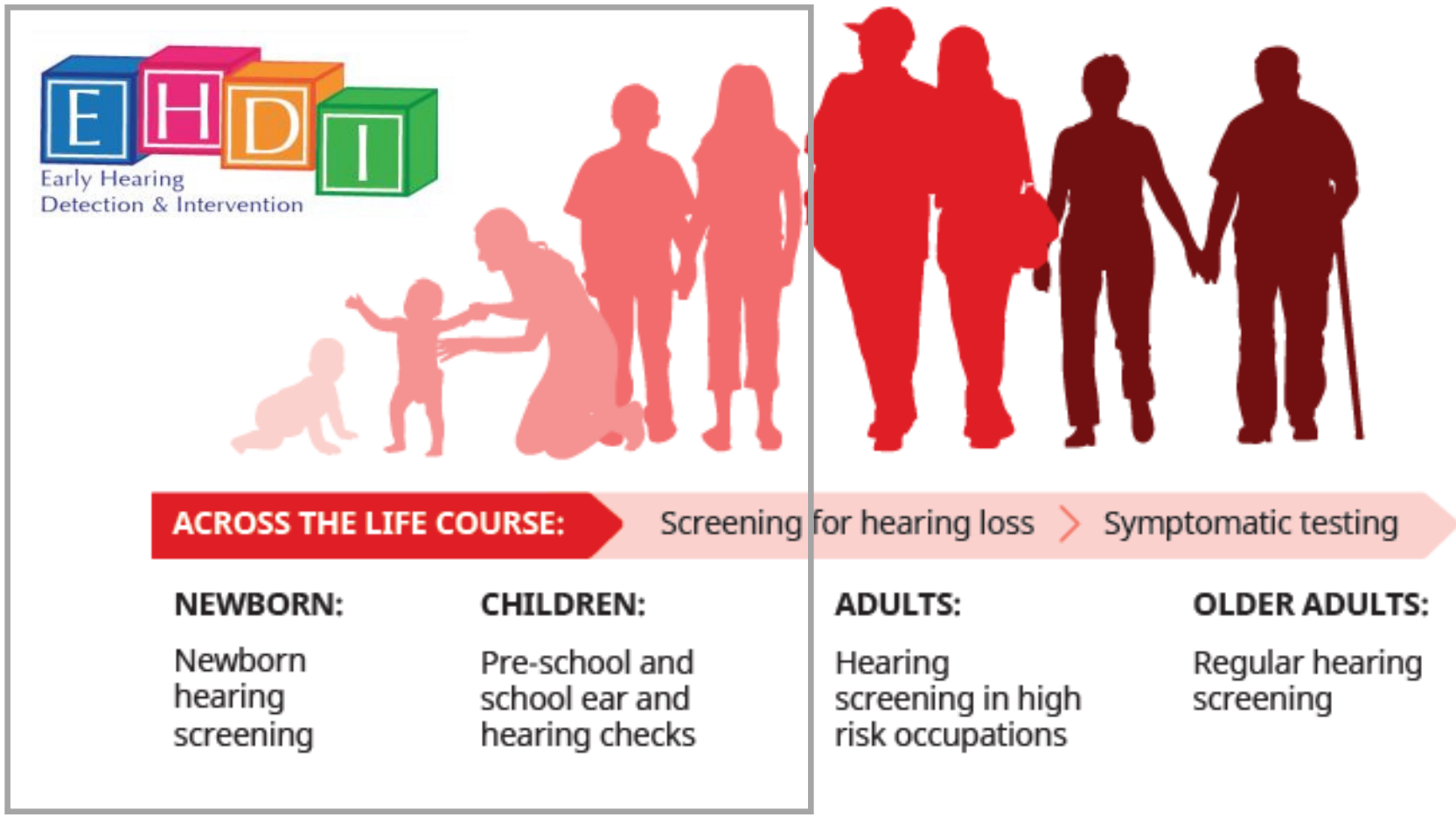


Niparko et al (2010)

Listening with hearing loss is effortful and impacts education

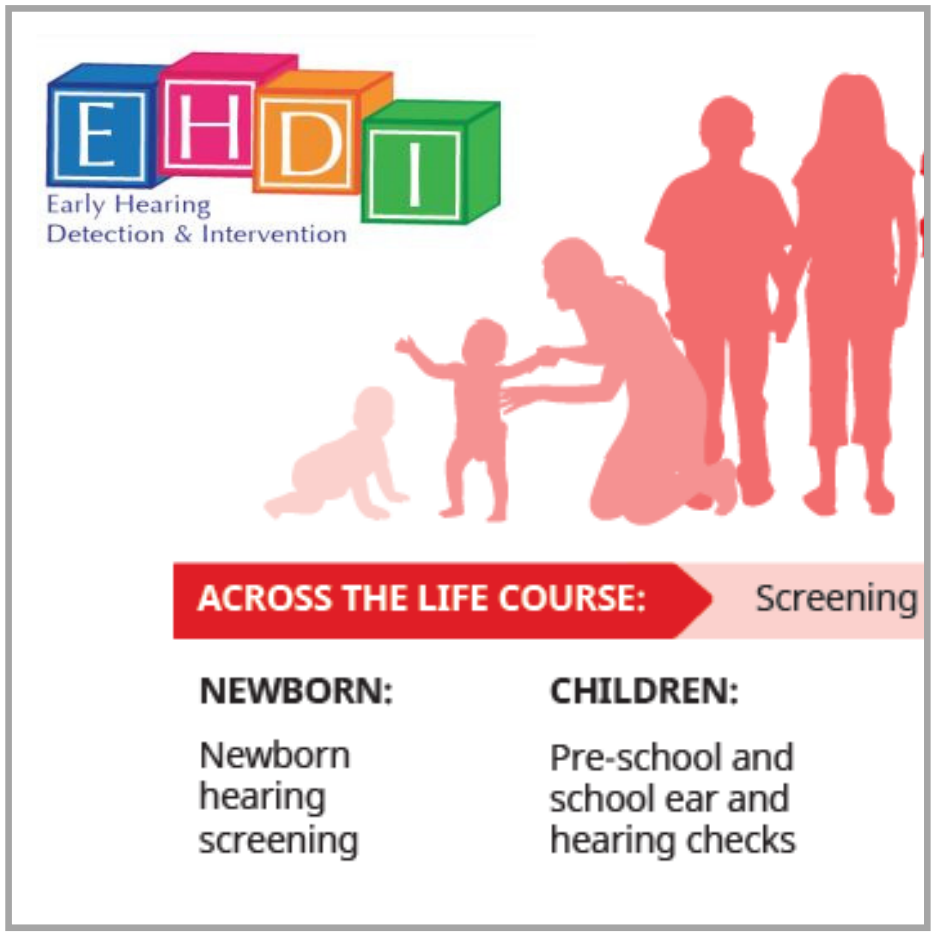
e.g.,
Winn et al (2015)
Bess and Hornsby (2014)
Hughes and Galvin (2013)
Lieu et al (2010, 2013)

2021 WHO world report: screening across the lifespan



https://www.who.int/publications/i/item/world-report-on-hearing

2021 WHO world report: screening across the lifespan



EHDI Goals

1 month	3 months	6 months
Screen for HL	Diagnose HL	Enroll in early intervention

https://www.who.int/publications/i/item/world-report-on-hearing

Why hearing loss is an “important health problem”

~3.7 million infants are screened yearly for hearing loss

~60,000 are referred for testing

~6,500 are identified with permanent hearing loss by 3 months

Prevalence of permanent HL doubles by the time children enter school
(5-6/1000 infants screened)

CDC (2018)

The challenges with early hearing testing

- We have an objective test – the “ABR” – but needs to be done while the infant sleeps, usually <5 months old

- Our objective test uses brief “click/pop” sounds and do not assess speech perception → what we want to facilitate

- Children 6-24 months are difficult to test behaviorally
  - ~40% of children with hearing loss have co-exiting conditions that also make testing challenging (Braun et al, 2015)


New ways to assess hearing function


Parallel ABR
Improving infant threshold estimation to facilitate earlier identification of hearing loss (Polonenko & Maddox, 2019, 2021)
New ways to assess hearing function
Continuous Speech ABR
Understanding speech processing to naturalistic, continuous speech such as audiobooks (Polonenko & Maddox, 2021)

Parallel ABR Improving infant threshold estimation to facilitate earlier identification of hearing loss (Polonenko & Maddox, 2019, 2021)

Further develop efficient tests that screen and diagnose hearing loss

Needs identified by US EHDI program

Create objective tests that assess speech perception and validate outcomes of hearing aid fittings

The Joint Committee on Infant Hearing, 2019

Continuous Speech ABR Understanding speech processing to naturalistic, continuous speech such as audiobooks (Polonenko & Maddox, 2021)

Key Take-Aways

1. Many hearing skills develop in early childhood, but we usually must wait until children are able to talk and perform longer behavioral testing before we can assess these skills.

2. Electrophysiological measures that use continuous speech can be measured and may provide insights into hearing function during development and in more complex environments than our traditional objective measures.

3. Having audiobook-based ABR tests may provide useful information for screening hearing loss and validating hearing aids in young children in the future.

Outline

- Current tests of hearing
- Creating a test using continuous speech
- Clinical uses for audiobook-based objective tests

How do we test hearing (sensitivity) in infants and children?

Physiologic measures (don't need them to respond)

- Acoustic immittance ("tymps")
- Otoacoustic emissions (OAE)
- **Auditory brainstem response (ABR) (<5 months)**

Behavioral measures (need a reliable response)

- Validated parent questionnaires
- Visual reinforcement audiometry (6 months – 2 years)
- Conditioned play audiometry (> 2 years)

Using EEG to assess hearing function

Cortical

Auditory cortex

Thalamo-cortical

Primary auditory cortex

Medial Geniculate Body

Brainstem

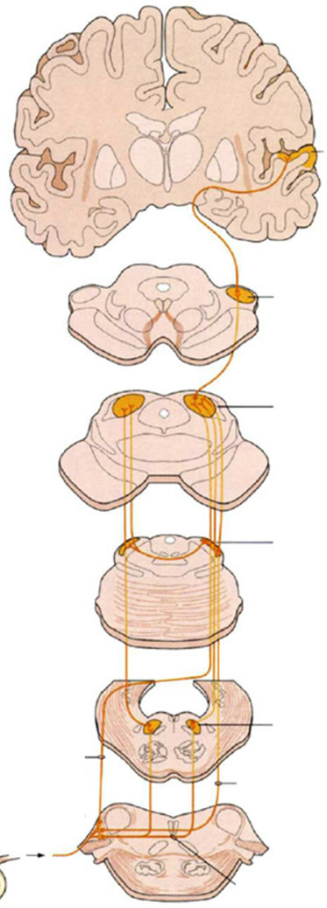
Inferior Colliculus

Lateral Lemniscus

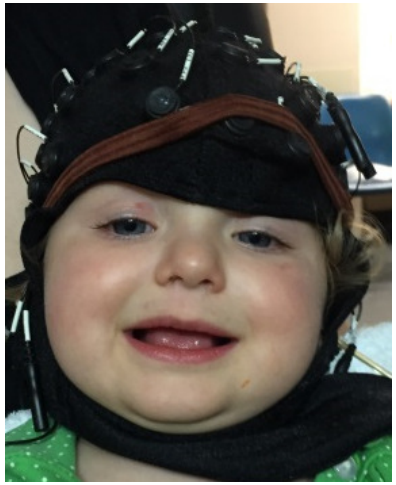
Superior Olivary Complex

Cochlear Nucleus

Auditory Nerve



Scalp potentials



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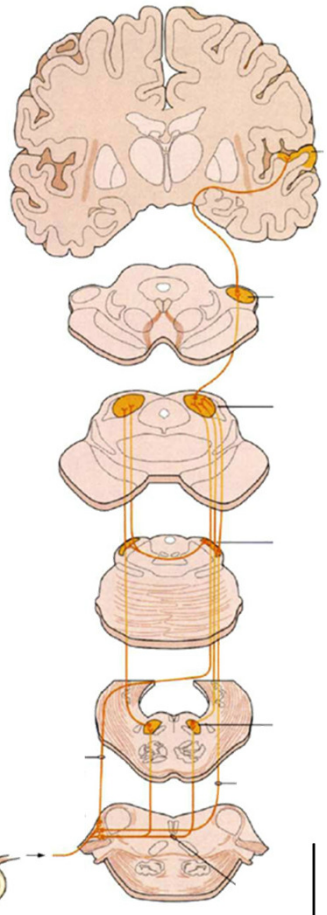

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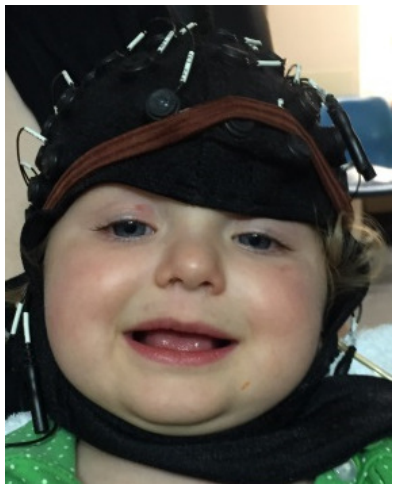
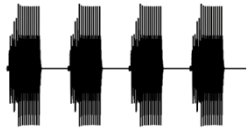


Audio stimuli

clicks



“da”

Adapted from Khuwaja et al (2015)

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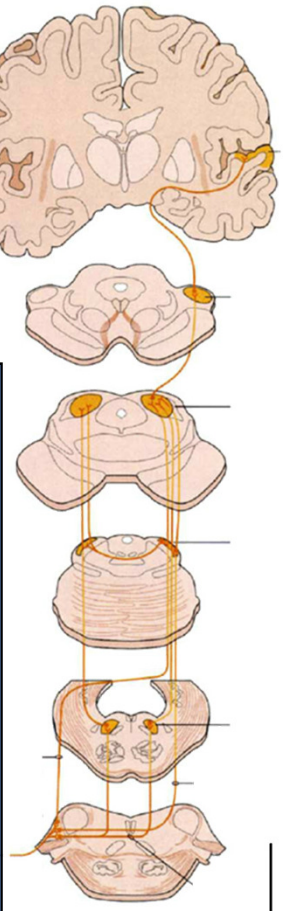
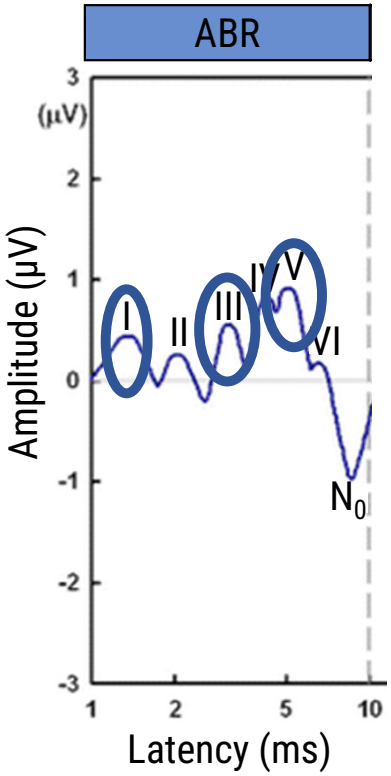
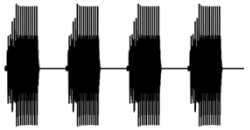




Timing ties to anatomy

clicks



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Using EEG to assess hearing function

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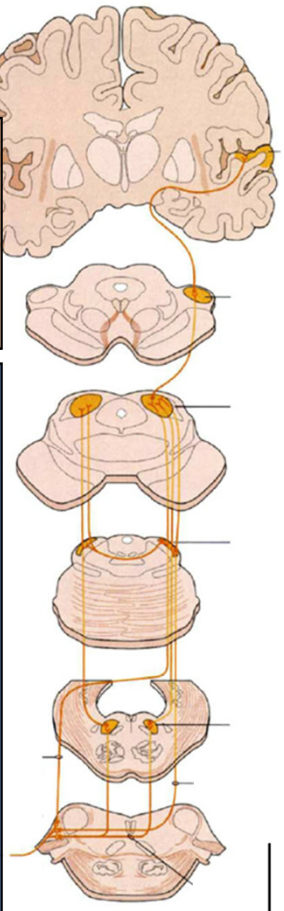
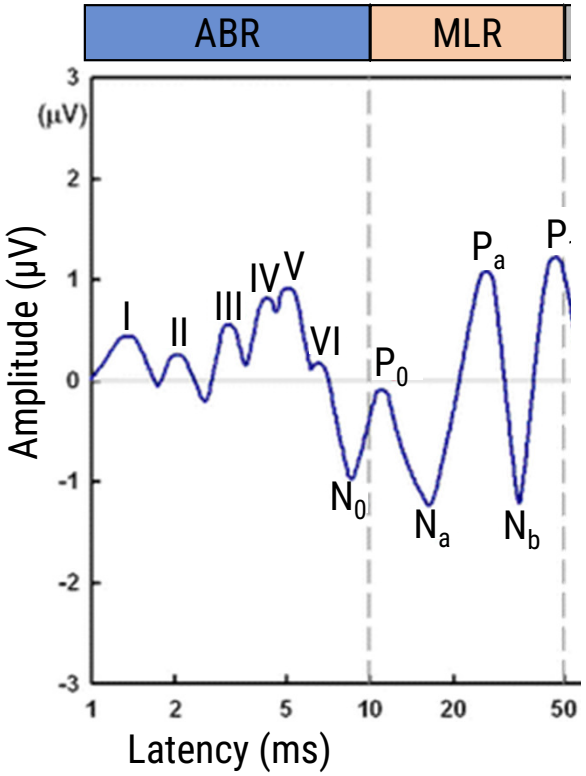
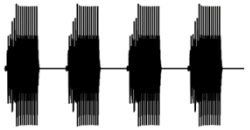




clicks



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Using EEG to assess hearing function

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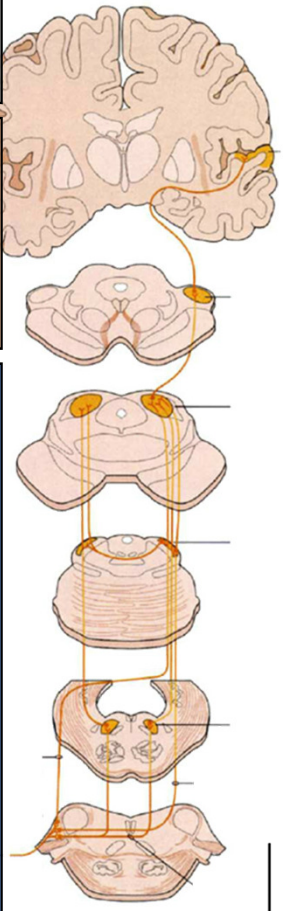

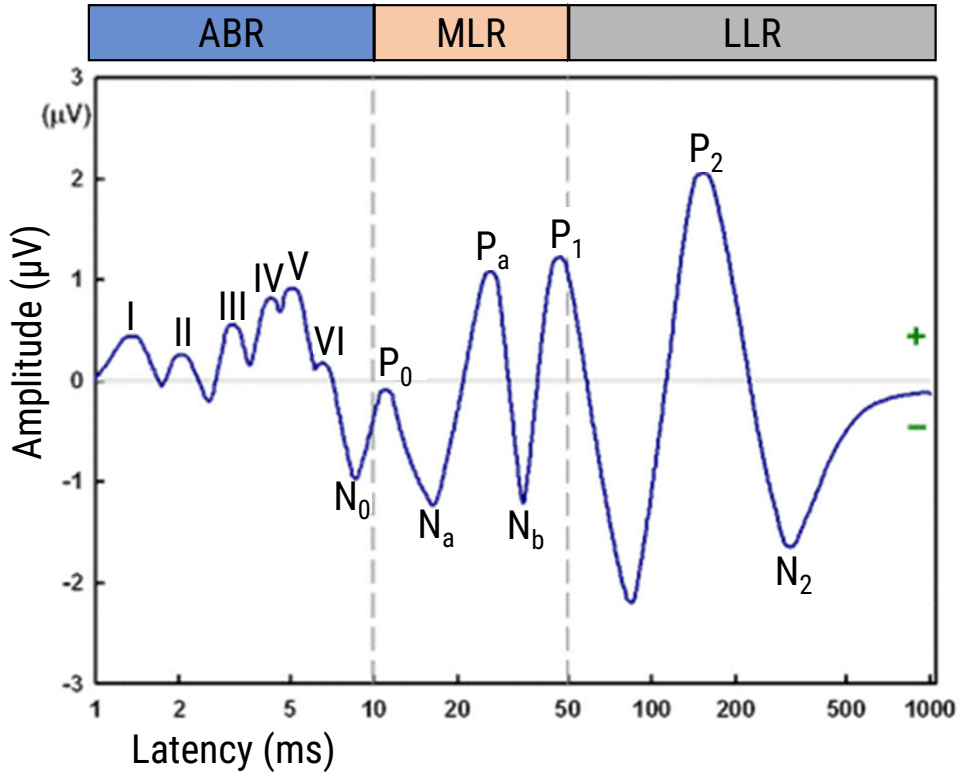

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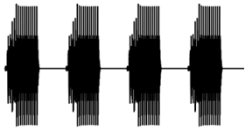
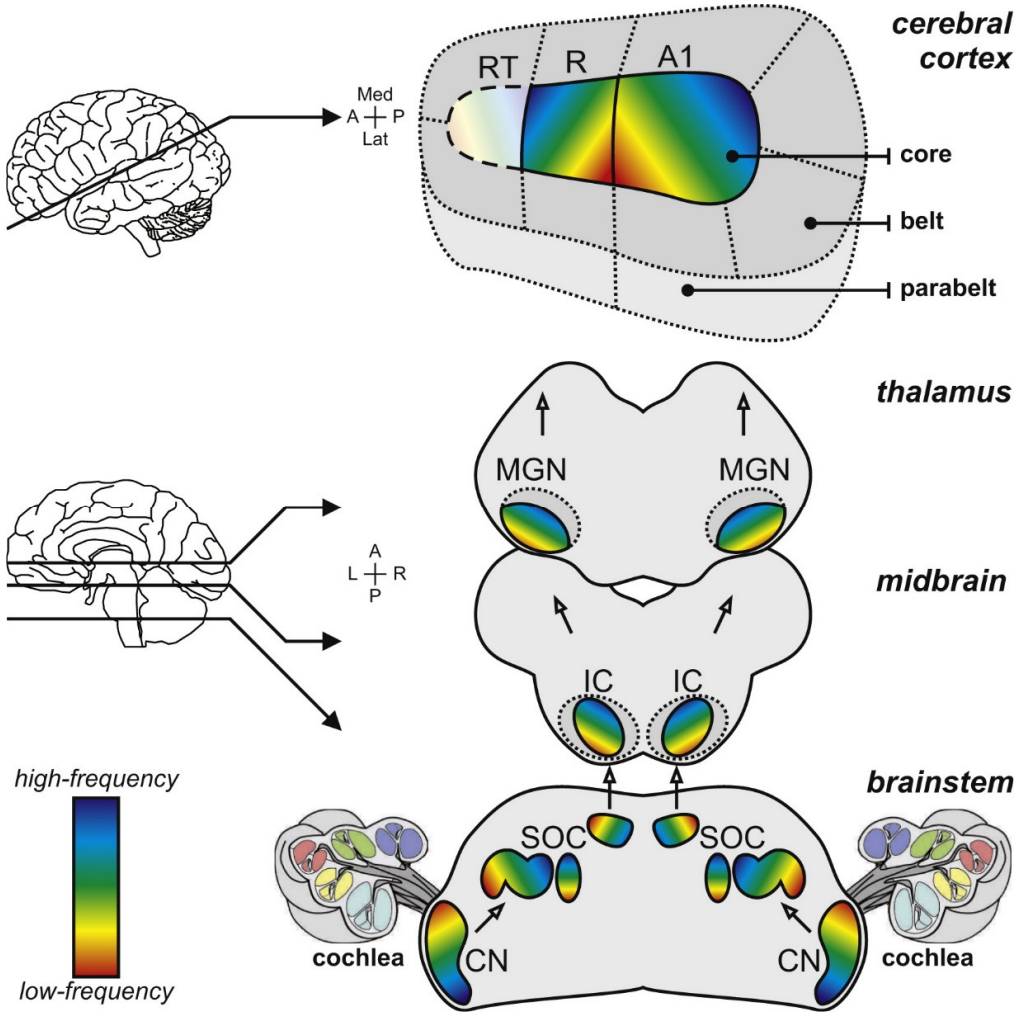


"da"

Adapted from Khuwaja et al (2015)

The auditory system is tonotopic



Structures are tonotopic

Hearing loss often differs by frequency

Saenz & Langers (2014) *Hearing Research*

Using EEG to assess hearing function (sensitivity)

Cortical
Auditory cortex

Thalamo-cortical
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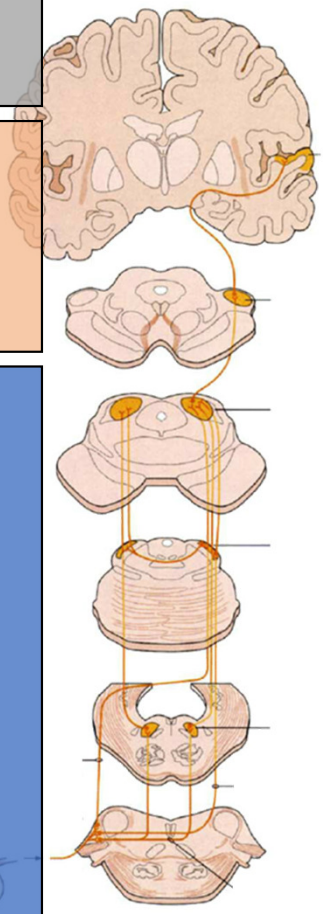
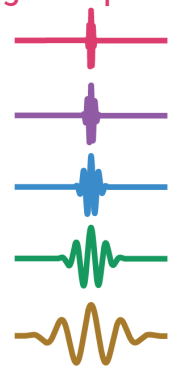


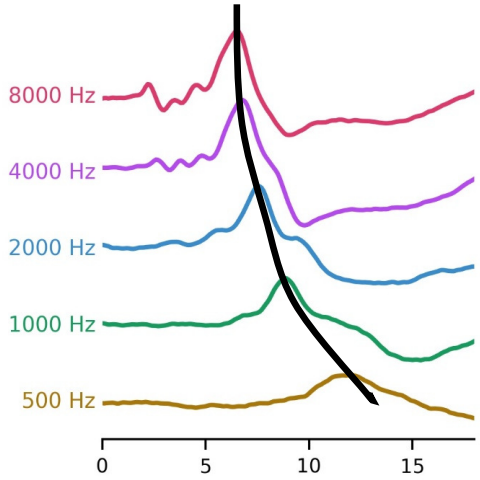
Tonotopic **Frequency ties to anatomy**

High frequency



Low frequency

Tone pips



Finding hearing thresholds

Goals of the speech ABR

Evoke responses with activity reflecting distinct neurogenerators

Evoke frequency-specific responses

Link between subcortical responses to ongoing speech and speech understanding?

Clinical Utility of the speech ABR

Evoke responses with activity reflecting distinct neurogenerators

- Assess speech processing and development.

Evoke frequency-specific responses

- Assess hearing and verify changes with amplification.

Link between subcortical responses to ongoing speech and speech understanding?

- Assess speech processing in noise.

Move beyond sensitivity to outcomes

Clinical Utility of the speech ABR

Evoke responses with activity reflecting distinct neurogenerators

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Evoke frequency-specific responses

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Link between subcortical responses to ongoing speech and speech understanding?

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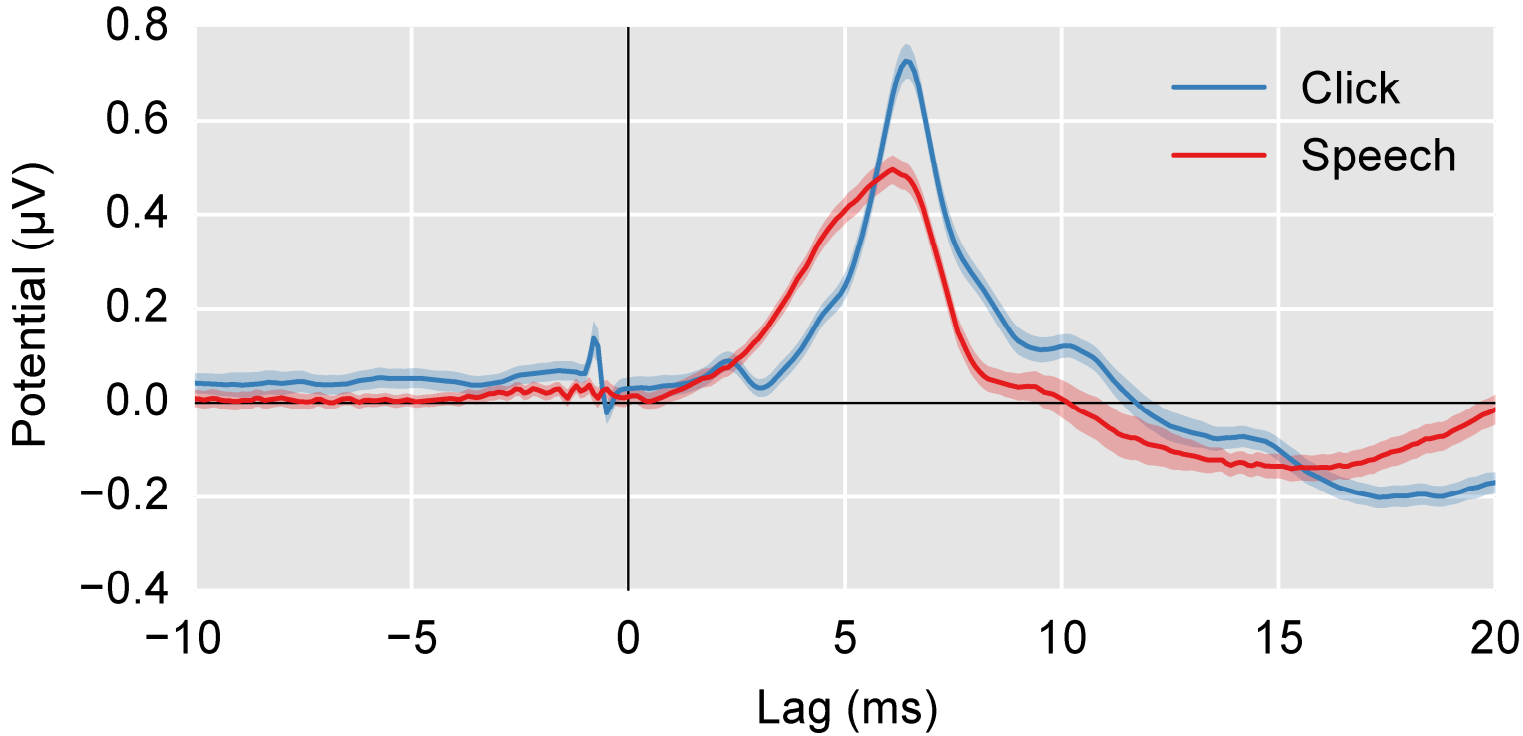
Similar click and speech-derived ABRs



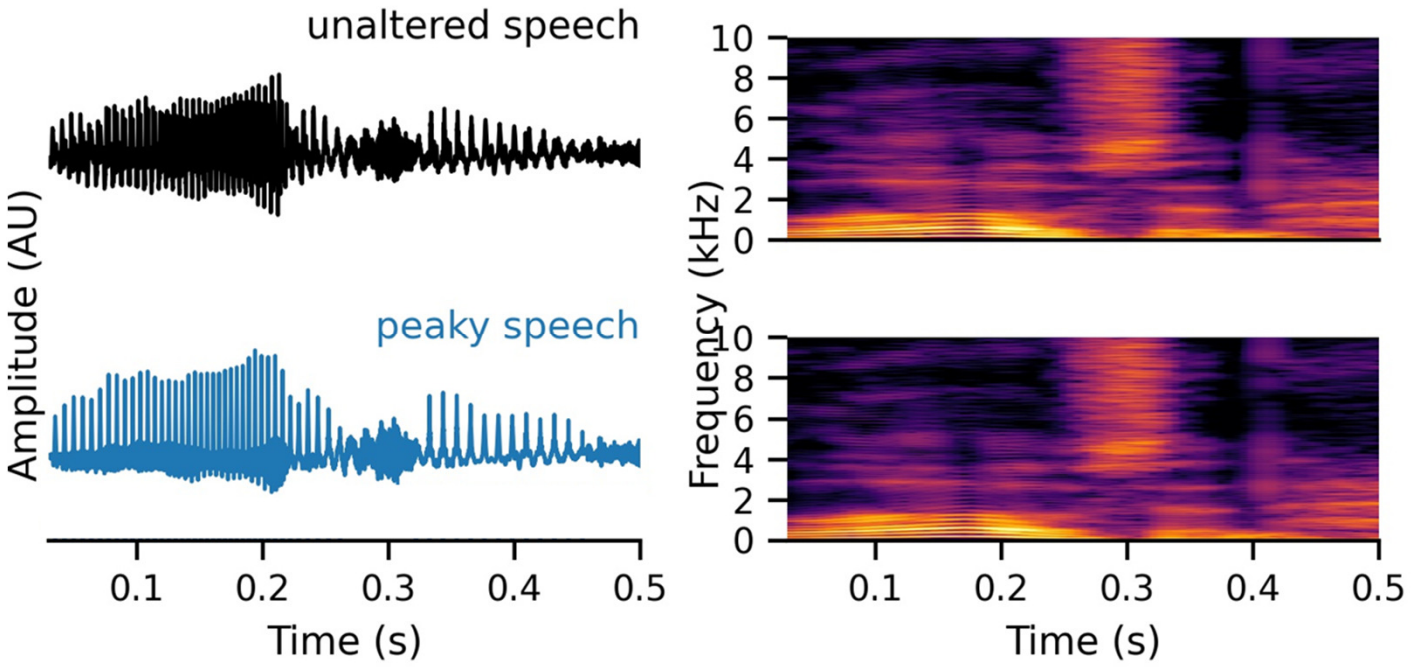
Metric of subcortical processing to ongoing speech with a characteristic but broad wave V.

Maddox and Lee (2018) *eNeuro*

Create continuous speech stimuli that evoke ABRs that reflect **distinct** subcortical stages

"Peaky speech" paradigm

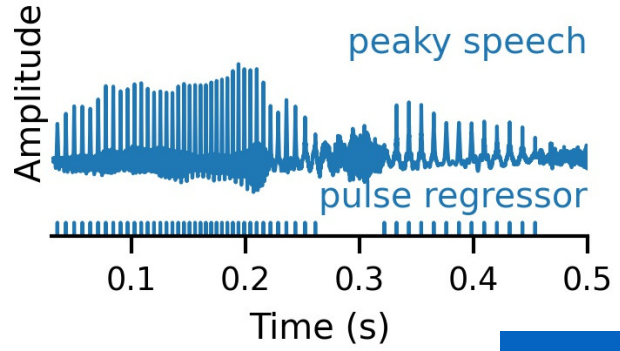
Make the speech waveform click-like while preserving spectral-temporal properties

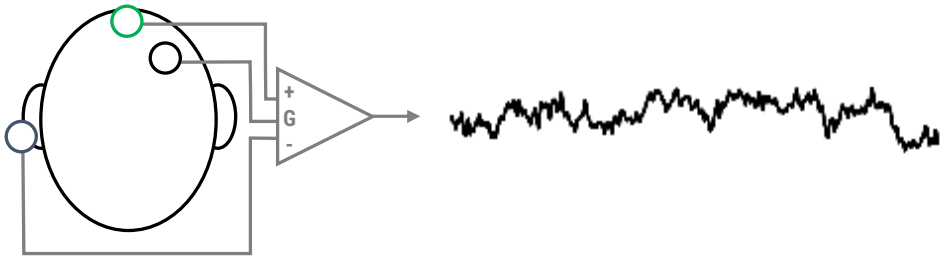


Yellow color = higher amplitude

Polonenko & Maddox (2021) *eLife*

“Peaky speech” paradigm

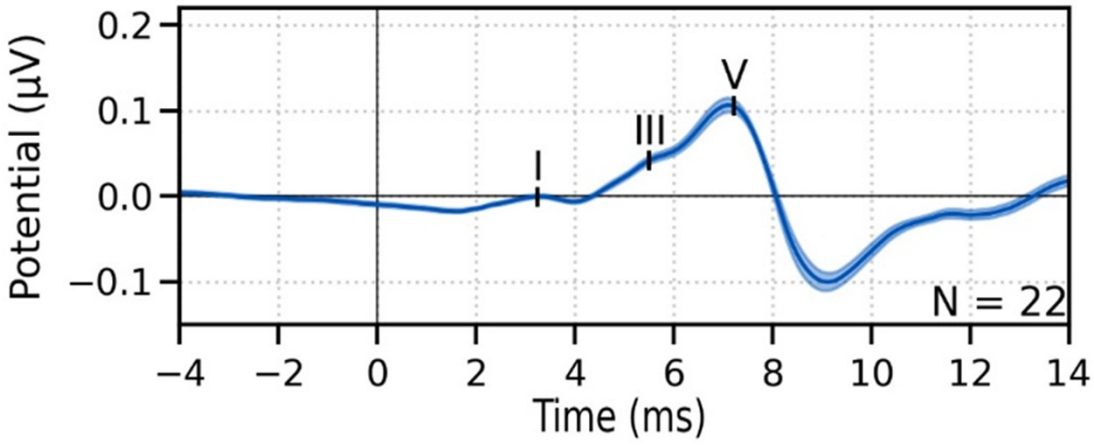




Speech stimulus → Glottal pulses → Auditory system → EEG data

x_i w_i y_i

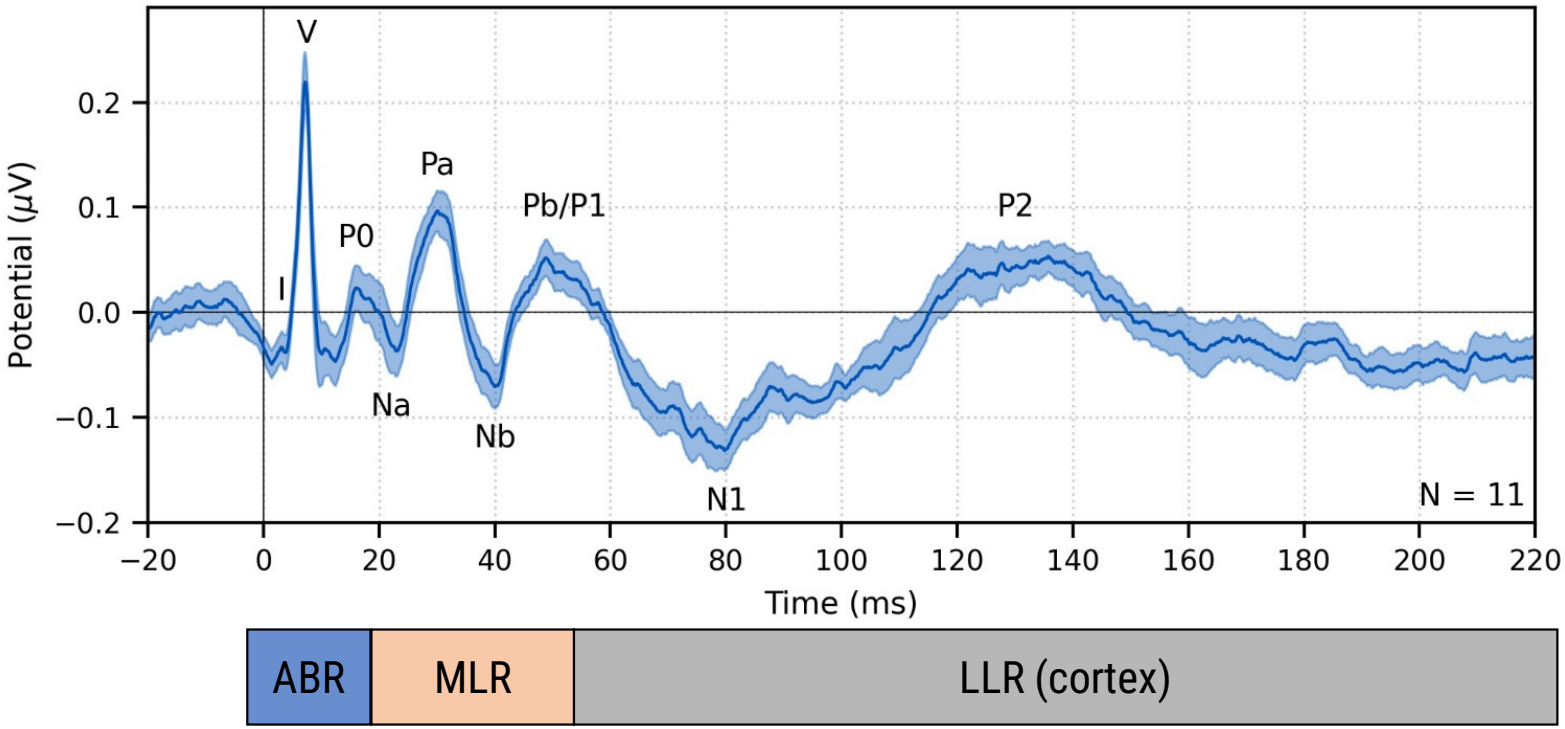
Deconvolution



Responses have components that reflect activity from distinct subcortical structures

Polonenko & Maddox (2021) *eLife*

Responses have components that reflect activity from distinct structures

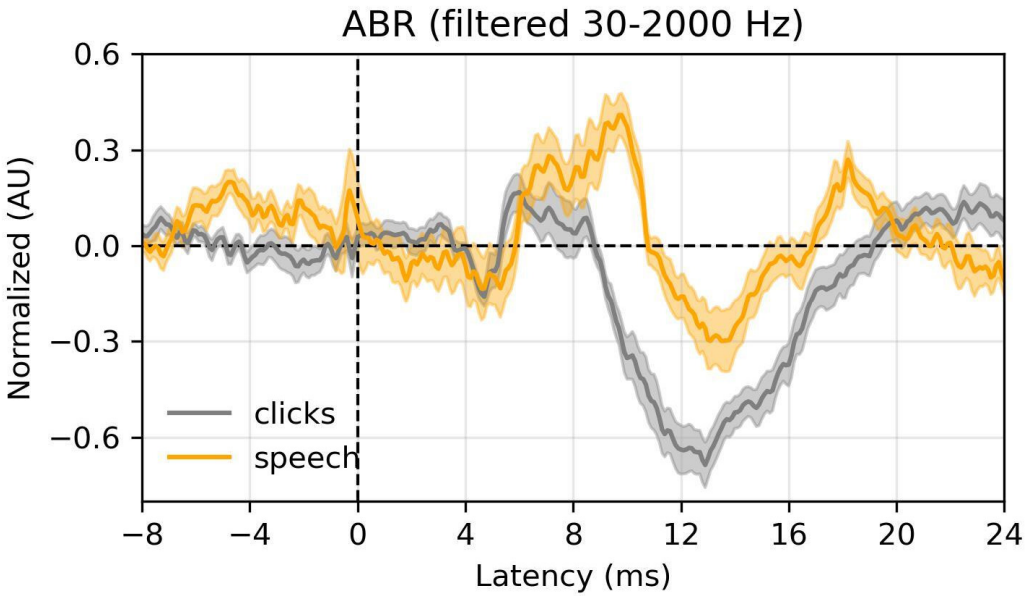


Polonenko and Maddox (2021)

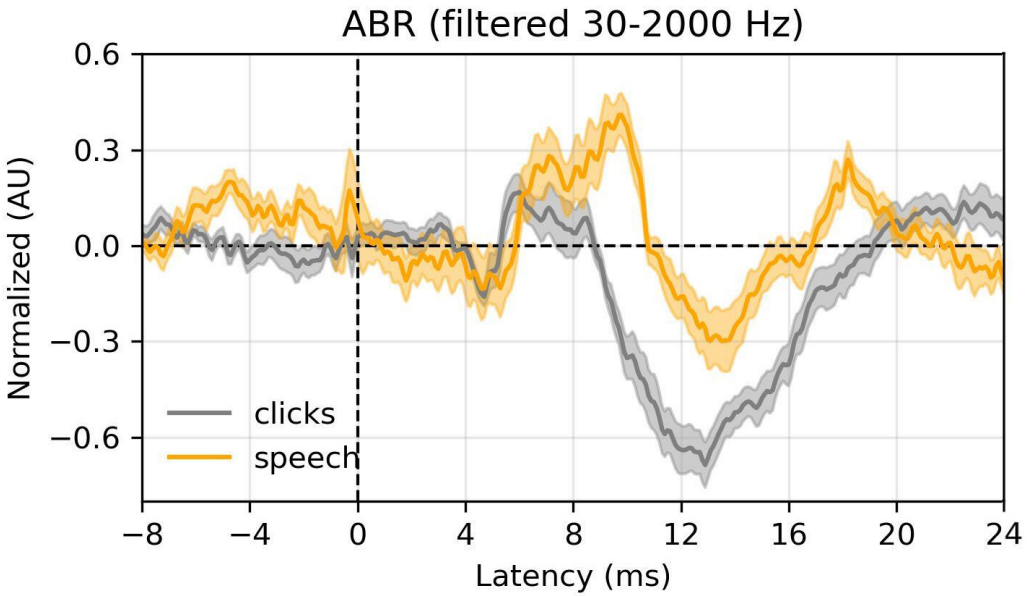
Identify risks of developing communication challenges

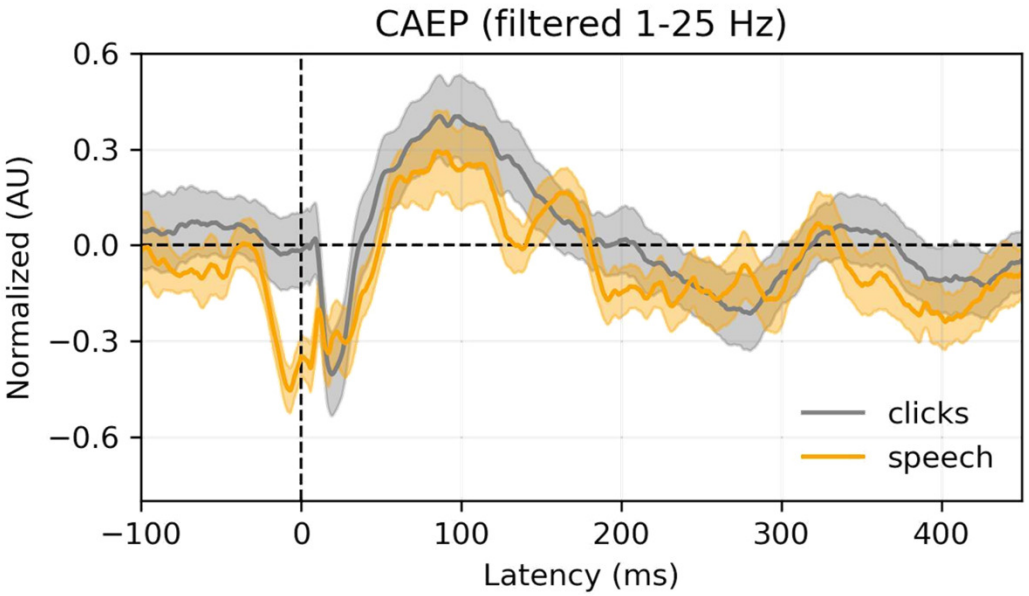
Apply this to other populations at risk of developing speech difficulties.

Responses from 13 babies in the neonatal intensive care unit (NICU)



Responses from 13 babies in the neonatal intensive care unit (NICU)





Next: well baby versus premature babies

Clinical Utility of the speech ABR

Evoke responses with activity reflecting distinct neurogenerators

- Assess speech processing and development.

Evoke frequency-specific responses

- Assess hearing and verify changes with amplification.

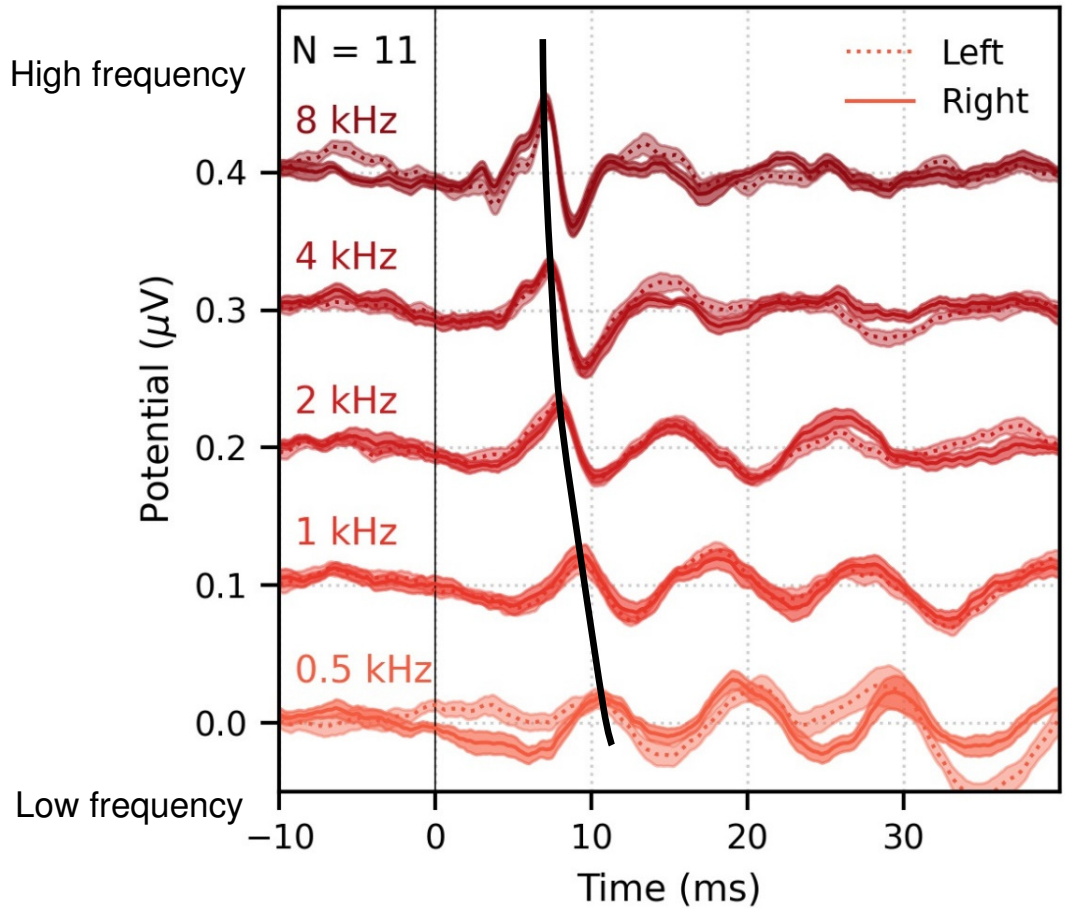
Link between subcortical responses to ongoing speech and speech understanding?

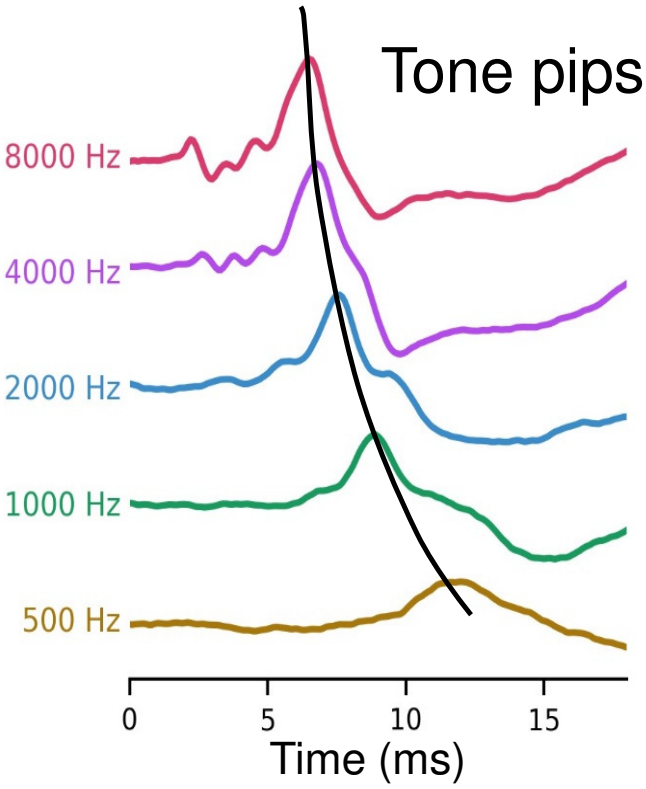
- Assess speech processing in noise.

Frequency-specific brainstem responses to speech

Multiband peaky speech:

Manipulate fundamental frequencies of each band so that they are slightly different



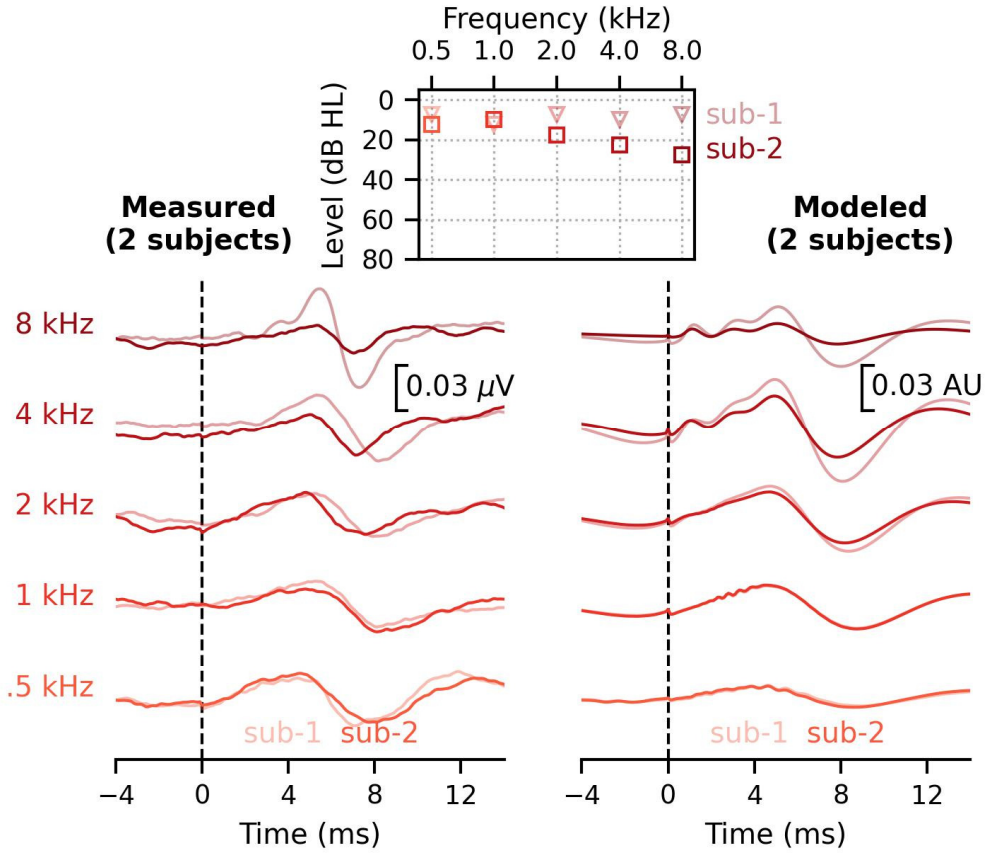


Polonenko & Maddox (2019, 2021)

Applications of multiband peaky speech

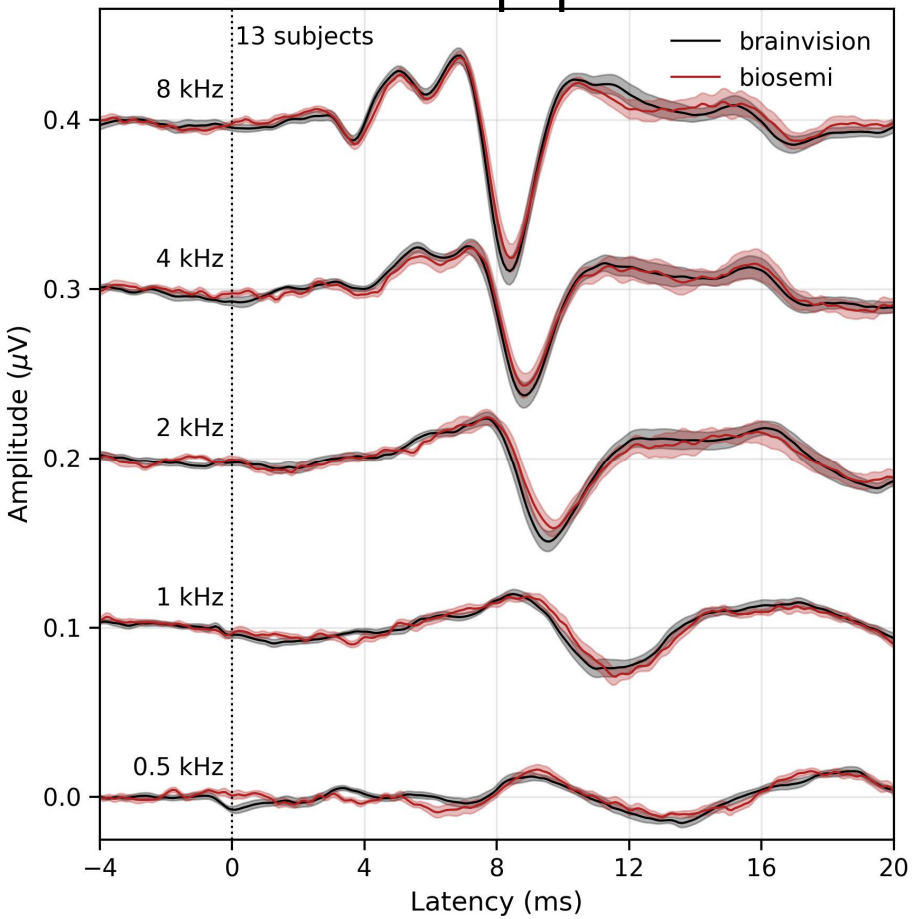
Verifying neural responses to amplification

Screen for hearing loss

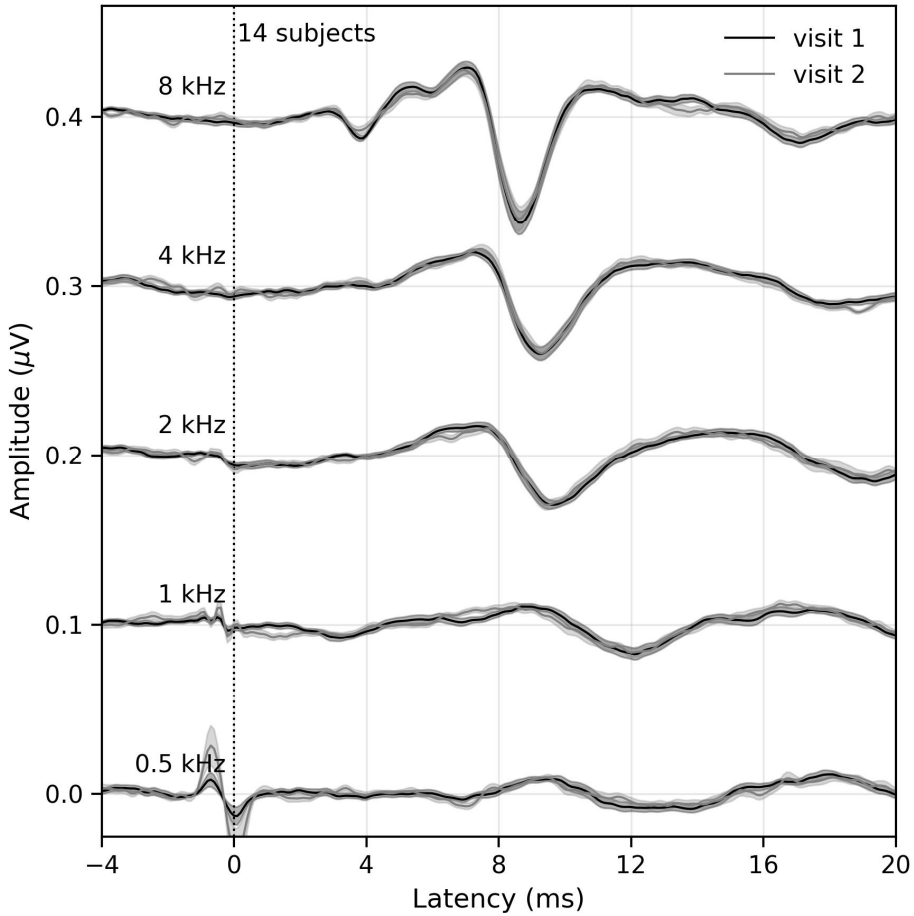


Multiband peaky speech responses are reproducible

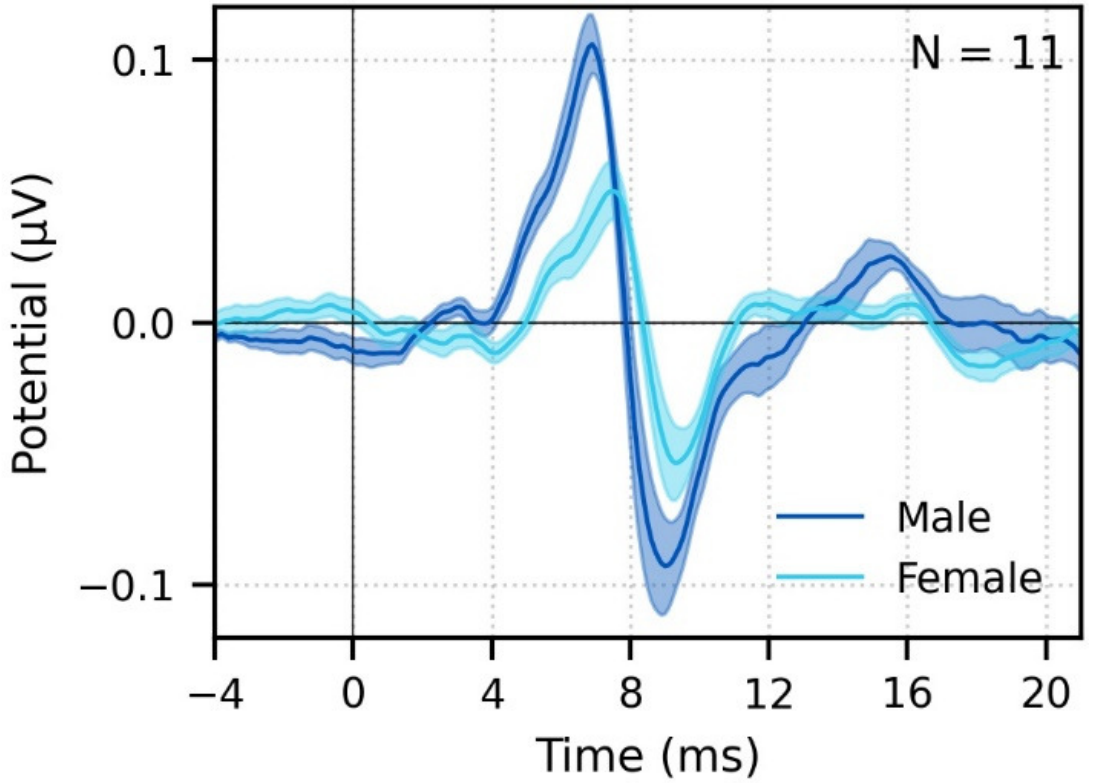
Across equipment



Across test dates



Consideration: Responses differ across talkers

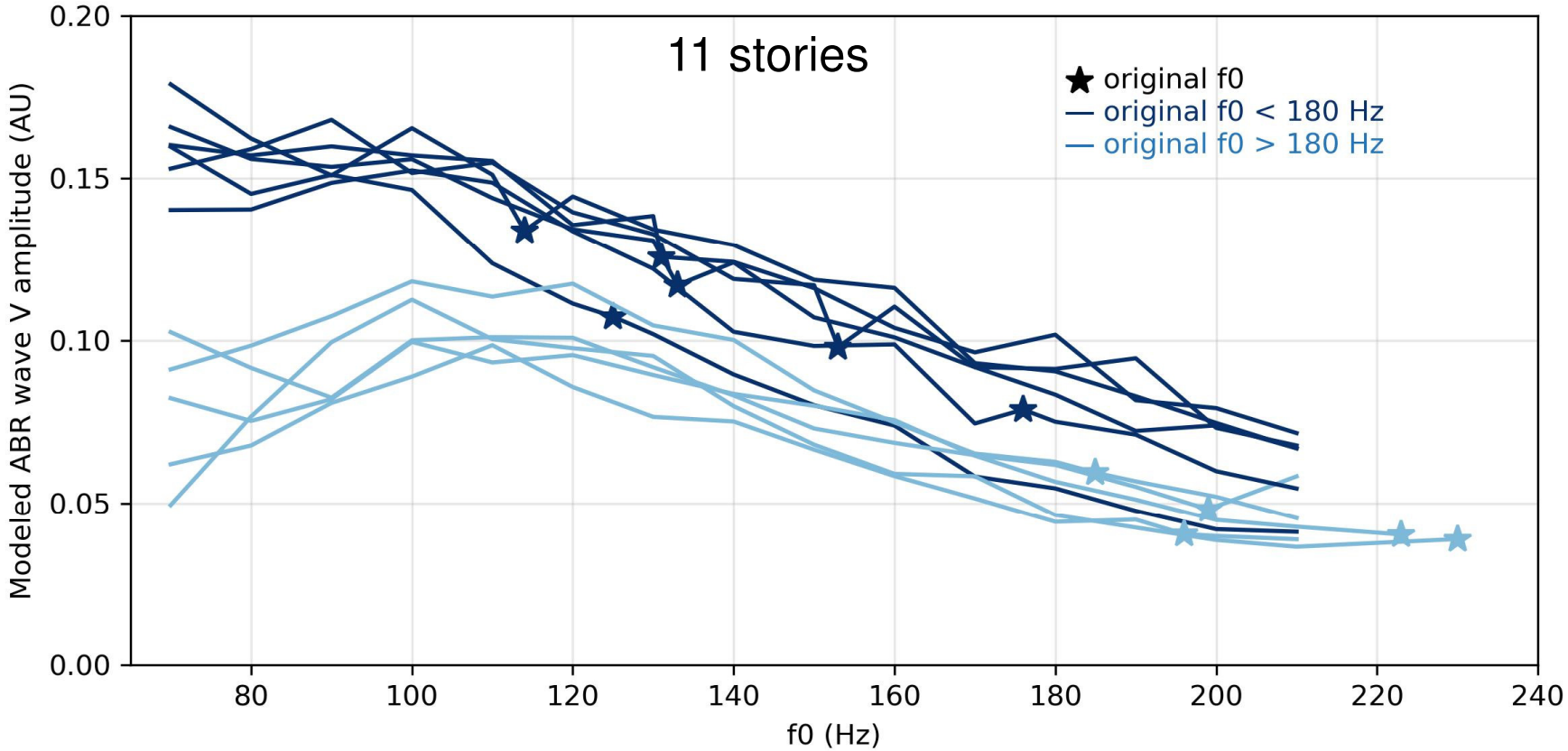


f_0:
115 Hz
198 Hz

Neural adaptation at higher stimulation rates (fundamental frequencies, f_0)

Polonenko & Maddox (2021) *eLife*

Computational models to simulate changes with fundamental frequency (f0) for different talkers



Next steps for multiband peaky speech

Make the test faster (<30 minutes)

- determine the optimal f0-phase combination for larger responses

Test the viability of multiband peaky speech to identify hearing loss

Long-term:

- Have an efficient, engaging speech-based test of hearing loss
- Facilitate testing in toddlers and evaluating amplified speech

Clinical Utility of the speech ABR

Evoke responses with activity reflecting distinct neurogenerators

- Assess speech processing and development.

Evoke frequency-specific responses

- Assess hearing and verify changes with amplification.

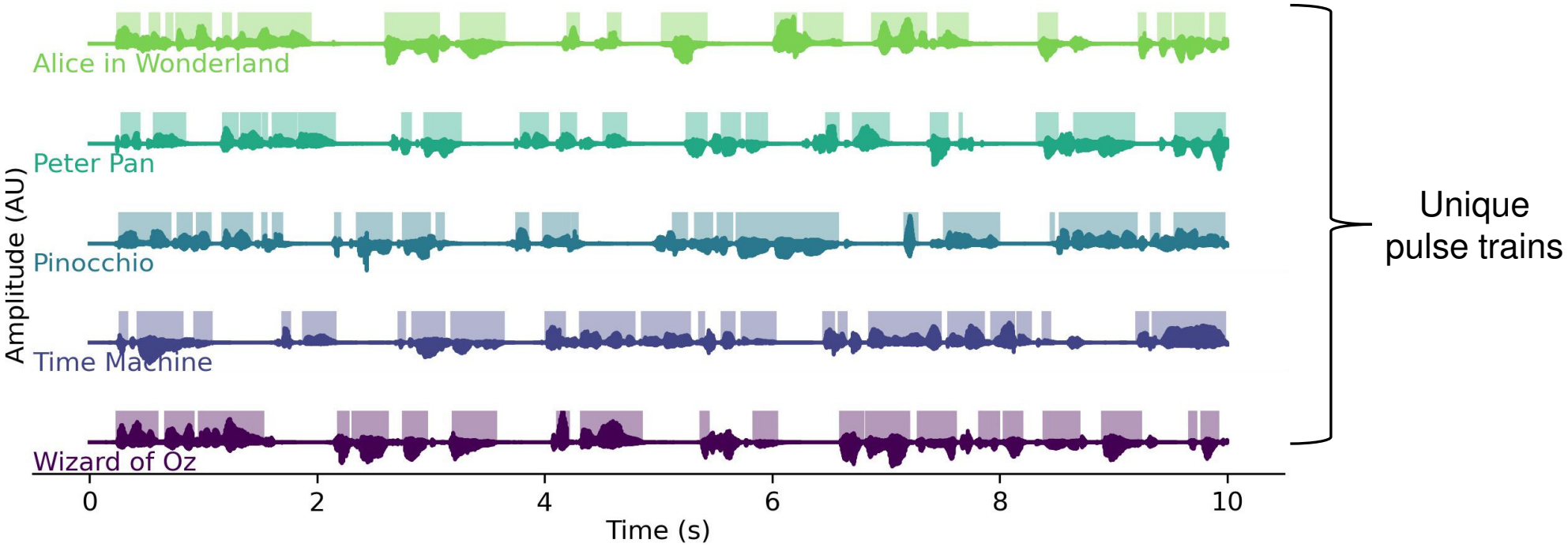
Link between subcortical responses to ongoing speech and speech understanding?

- Assess speech processing in noise.

Everyday communication often involves listening to someone talk while several other people are also speaking

The are many questions about the contributions of early stages of continuous multi-talker processing

Speech-in-speech processing



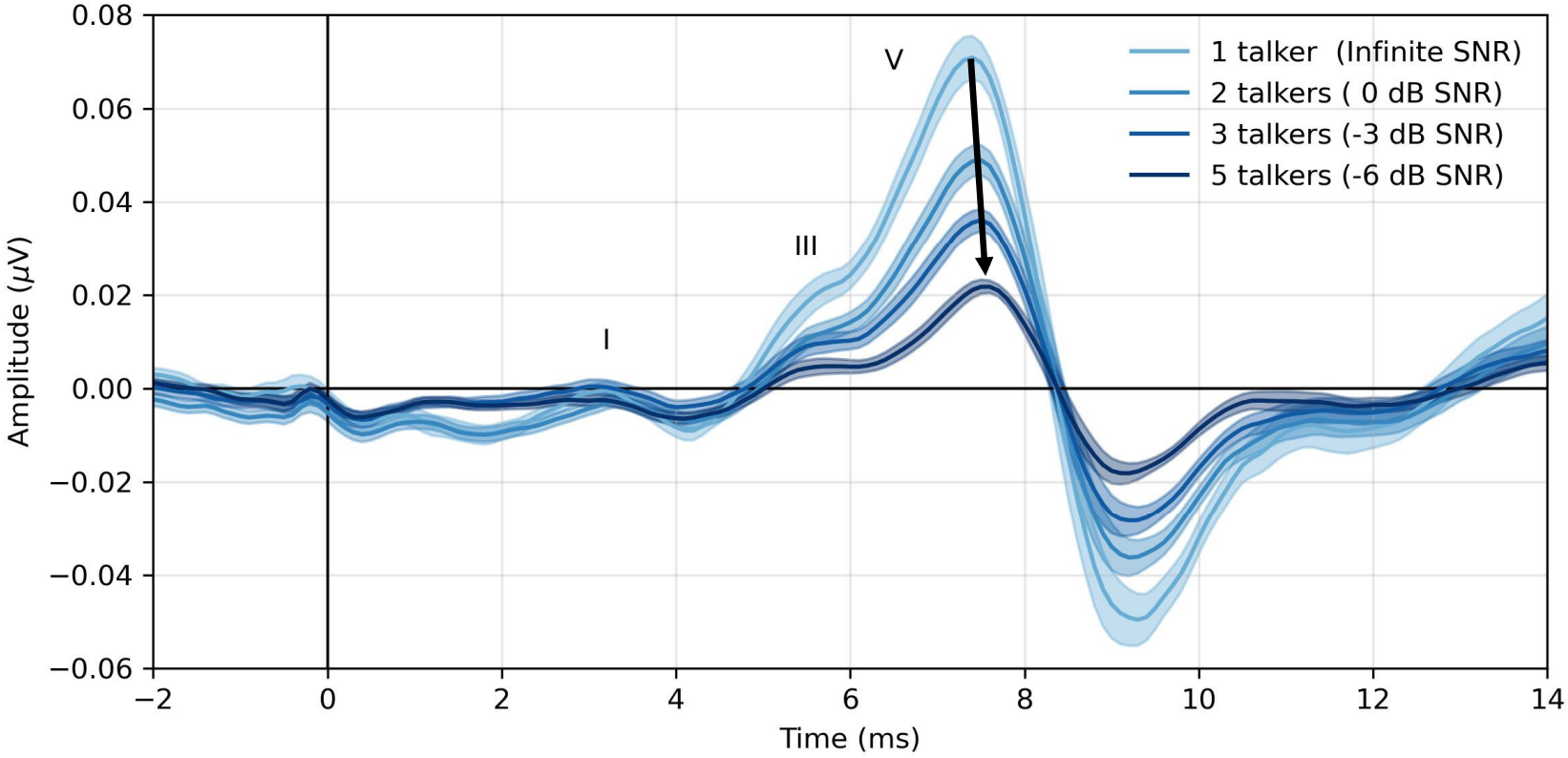
4 conditions, 30 min each

1 talker (Infinite SNR)
2 talkers (0 dB SNR)
3 talkers (-3 dB SNR)
5 talkers (-6 dB SNR)

Deriving responses

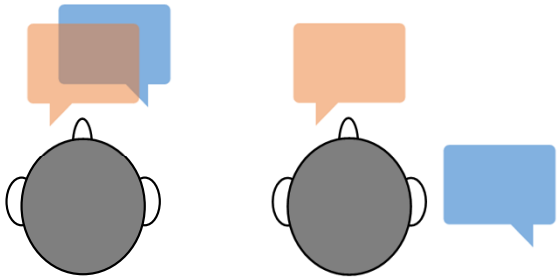
Epochs: mixtures of talkers
Response: deconvolve to each talker

Brainstem responses systematically change with number of simultaneous talkers (and lower SNR)

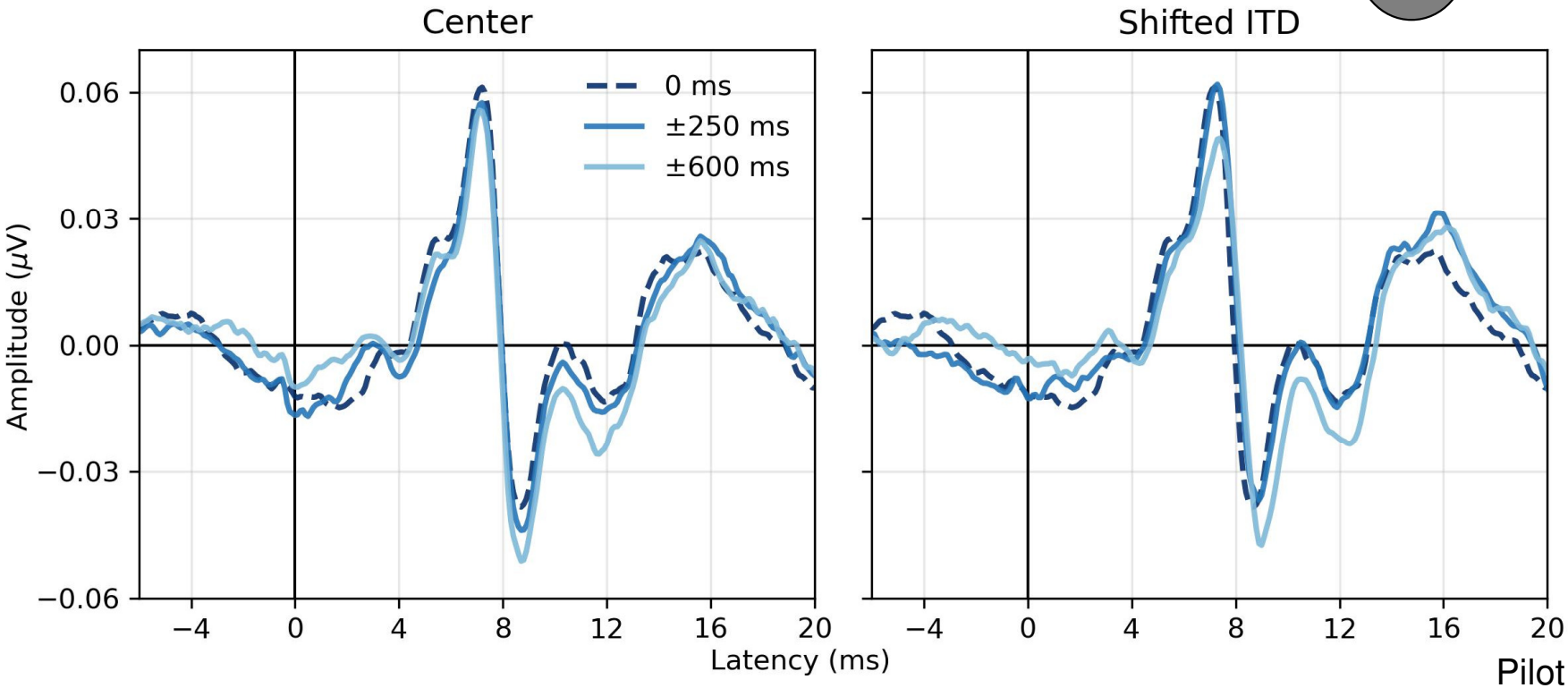


Next: Binaural / spatial speech-in-speech task

Present 2 stories simultaneously
Introduce a small timing difference between the ears to one of them so that the story is heard off-center (e.g., to the side)



Spatial benefit



Pilot study: 3 subjects

Summary: New ways to assess hearing function

Peaky speech ABR for potentially:

- measuring speech development
- screening hearing
- validating hearing aids
- studying speech processing in challenging environments

Better understand hearing *function*, and in young children

Key Take-Aways

1. Many hearing skills develop in early childhood, but we usually must wait until children are able to talk and perform longer behavioral testing before we can assess these skills.

2. EEG measures that use continuous speech can be measured and may provide insights into hearing function during development and in more complex environments than our traditional objective measures.

3. Having audiobook-based ABR tests may provide useful information for screening hearing loss and validating hearing aids in young children in the future.

Acknowledgments

Polonenko Lab:
Melissa Polonenko (PI)
Ben Eisenreich
Samantha Krocak
Natalie Falconer
Jenna Skare
Aviendha Helton
Eric Mitchell

Maddox Lab:
Ross Maddox (PI)
Yathida Anankul
Maddy Cappelloni
Thomas Stoll
Tong Shan
John Kyle Cooper
Tianruo Sun
Jin Dou

Prieve Lab:
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Questions?

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Questions?

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