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Hearing Aid Technologies for Supporting Teenagers' Unique Listening Needs

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Erin Picou is an associate professor in the Department of Hearing and Speech Sciences at Vanderbilt University Medical Center. She currently directs the Hearing and Affect Perception Interest (HAPI) laboratory, which is funded through a variety of industry and federal sources. Her research interests are related to hearing aid technologies for adults and children, with specific focuses on speech recognition, listening effort, and emotion perception. Erin is currently serving as the Editor in Chief of the American Journal of Audiology and as a section editor of Ear and Hearing. In addition to her research activities, Erin is involved with teaching and mentoring clinical and research doctoral students.

Disclosures

- **Presenter Disclosure:** Financial: Erin Picou is employed by Vanderbilt University. She received an honorarium for this presentation. Non-financial: Erin Picou has no relevant non-financial relationships to disclose.
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- Healthcare providers should apply cultural competence and sensitivity to ensure effective and respectful care based on their patients' diverse needs.
- Providers should always evaluate the limitations of diagnostic and screening tools, considering their potential for false results as well as any ethical implications.
- It is the responsibility of course participants to critically evaluate the evidence from multiple sources to guide professional practice.

Learning Outcomes

After this course, participants will be able to:

- Summarize unique listening needs of adolescents.
- Describe the benefits and limitations of tap control for adolescents.
- Summarize the benefits and limitations of noise reduction for adolescents.

Thank you!

- External support and collaboration
 - Lisa Standaert, Andrea Hillock-Dunn, Johanna Nelson, Jean Anne Schnittker
- Internal support and collaboration
 - Anne Marie Tharpe, Hilary Davis, Kathleen Healy, Kjersten Branscome, Kayleigh Pletch
- Funding provided by
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Today's Context (Mostly)

- Bilateral hearing loss
- Teenagers
- Hearing aid users with mild to severe sensorineural hearing loss
- Technological solutions

Listening Needs of Teenagers



What is Unique About Teenagers?

- If you've seen one, you've seen them all
- If you've seen one, you've seen one
- If you've seen one, you've seen one side of one

Lilian*

- 13-year-old girl
- Bilateral, sensorineural hearing loss
- Lives in a suburban town with her parents and brother

Typical Day

- 6:45 – catch the bus
video text video text
- 7:10 – arrive at school
text video text
- 2:55 – catch bus home
video text text
- 3:15 – homework
text video video text
- 4:00 – trombone practice
video video video video
- 4:45 – family dinner
text
- 5:15 – soccer practice
text
- 7:00 – snack/ homework/ screen time
text text text video video video video

Any Given Tuesday for Lilian

7:40 – Social studies

4-minute passing period

8:40 – Science

4-minute passing period

9:35 – Study hall

4-minute passing period

10:09 – English

4-minute passing period

11:04 – Lunch

4-minute passing period

11:59 – Math

4-minute passing period

12:54 – PE

4-minute passing period

1:49 – Band

4 minutes to get to the bus

Example Day Highlights...

- Growing autonomy
- Rapid speed of transitions
- Diversity of listening needs
 - Music
 - Streamed videos
 - Speech in quiet
 - Speech in noise
 - Speech from a distance
 - Speech and music in reverberation

Implications for Teenagers

- Need for autonomy
 - Give them control
- Diversity of listening situations
 - Flexible technology
 - Address noise, distance, music listening
- Rapid transitions
 - Tap control
 - Smartphone app
- Variability within and across teenagers
 - Get their perspective

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How to Solicit a Teenager's Perspective?

- Catch them at the right time
- Use teen-focused counseling techniques (English (2012))
 - Keep conversation going
 - Keep the conversation open
- Questionnaires
 - Self-Assessment of Communication – Adolescents (SAC-A; Elkayam & English, 2003)
 - Vanderbilt Classroom Assessment Short Survey (VCLASS; Picou et al 2025)

Vanderbilt Classroom Assessment Short Survey (VCLASS)

- Initially developed to explore the school-based listening challenges faced by adolescents with unilateral hearing loss
- Used questions from scale developed by Dr. Todd Ricketts
- Each question includes a picture and an item stem describing a listening situation

Example VCLASS Question

15 questions

- Look at each picture below
- Pretend you do NOT have hearing devices
- How easy is to understand?
 - Very EASY (5)
 - A little EASY (4)
 - Not easy or hard (3)
 - A little HARD (2)
 - Very HARD (1)
 - Does not apply.
 - I am never in that situation (NA)

VCLASS Items

- I am eating lunch at school; my friend across the table is telling a story.
- I am in a classroom in the front. The teacher in the front is telling the class what to do.
- I am in a classroom in the back. The teacher in the front is telling the class what to do.
- I am in a quiet place talking to my friend who is talking right in front of me.

VCLASS Items

- I am listening to the teacher in class and classmates start talking quietly behind me. I want to know what they are saying.
- I am in the classroom and the teacher walks behind me. She tells the class what to do.
- In class, we are working in a group. I want to know what someone in another group is saying.
- I am in a lunchroom. I am trying to understand a person talking at a table behind me.
- I am in a quiet room talking to my friend who is talking behind me.
- I am outside playing. My friend is talking behind me.
- My teacher asks me a question while standing behind me in the classroom.

VCLASS Items

- I am in a noisy gym and I hear someone say my name. I want to find where they are.
 - I am hanging out with my friends. Someone's phone starts to ring and I want to figure out where the ringing is coming from.
 - I am hanging out with my friends. Someone's phone starts to ring and I want to figure out where the ringing is coming from.
 - I am on a sidewalk at a busy intersection. I am trying to listen for traffic coming from all directions to know the best time to cross the street.
- 

Example Questions with Pictures



I am eating lunch at school; my friend across the table is telling a story



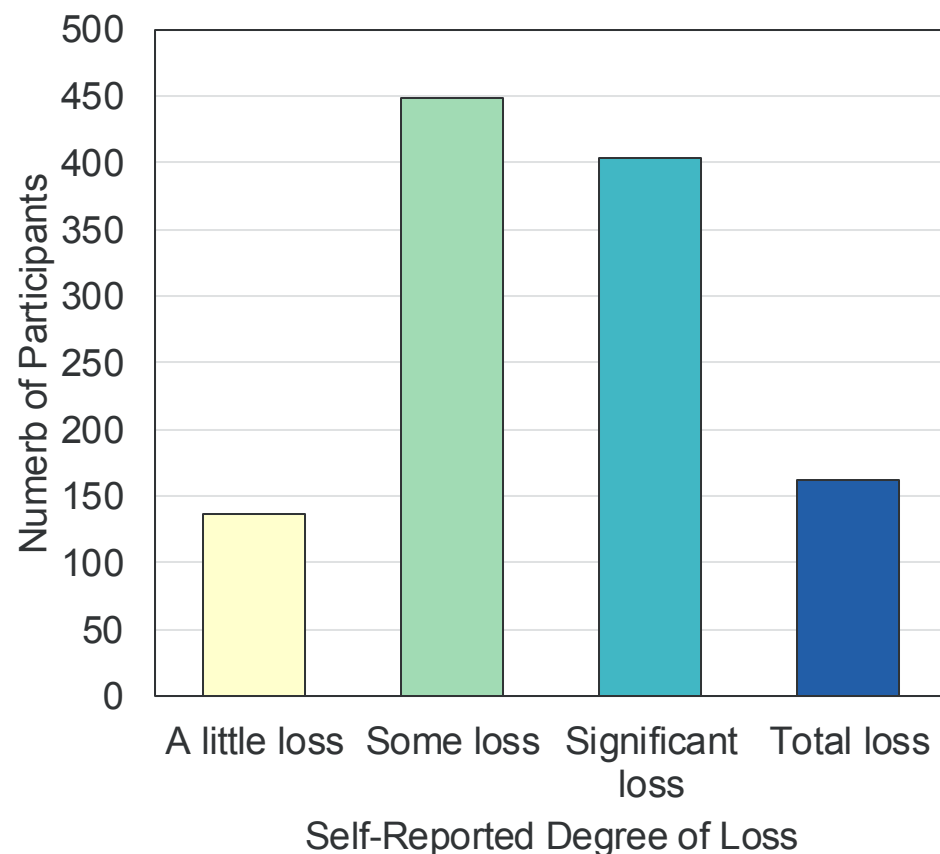
I am in a quiet room talking to my friend who is studying behind me



I am hanging out with my friends. Someone's phone starts to ring and I want to figure out where the ringing is coming from.

Validation of VCLASS with Pre/Teenagers with UHL

- Survey distribution
 - Hands and Voices
 - Research Match
 - Word of mouth
- Participants
 - Mean age = 13.3 years (range: 9 – 17 years)
 - Mothers mostly had college education
- VCLASS response rate
 - 1826 completed
 - 1148 deemed 'useable'



Subscale Creation of the VCLASS

- Responses analyzed using exploratory factor analysis
- Result was 3 subscales with good internal reliability
 - Far (listener and talker far apart)
 - Student in the back of a classroom
 - Near inside (listener and talker close together and inside a building)
 - Student in the front of a classroom
 - Near outside (listener and talker close together and outside)
 - Student and friend in a park



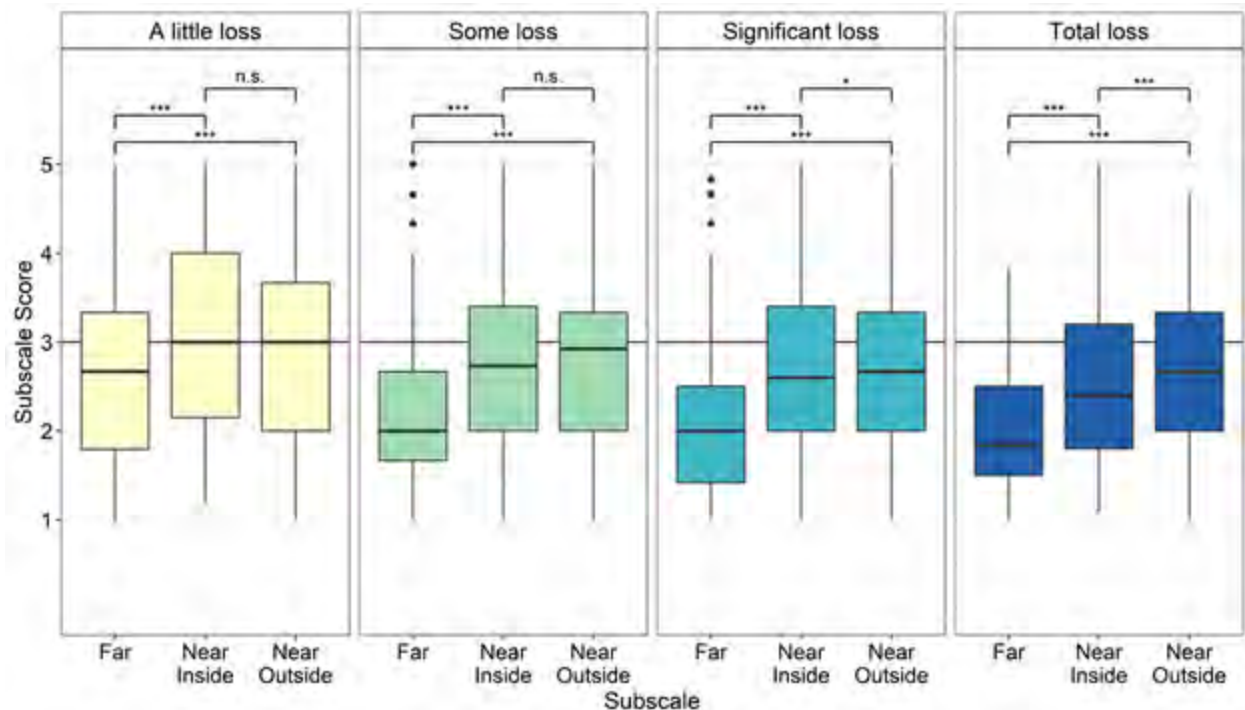
Self-reported Degree of Hearing Loss is Related to Difficulties in Real Classrooms

Very EASY

“Far” subscale results in the lowest ratings of easy listening

More significant self-reported hearing loss associated with:

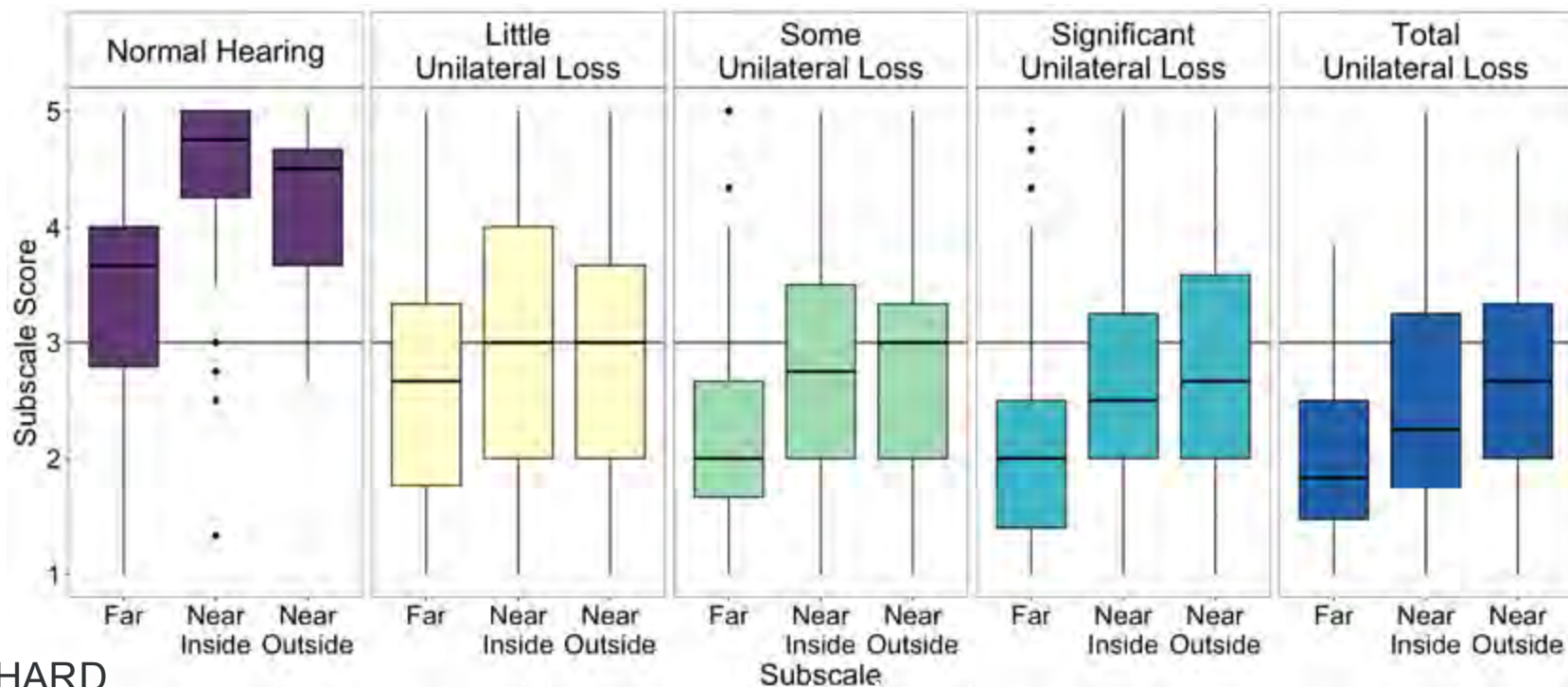
- More difficulty overall
- Bigger difference between “inside” and “outside” subscales



Very HARD

Students with Normal Hearing Report that Classroom Listening is Easy

Very EASY



Very HARD

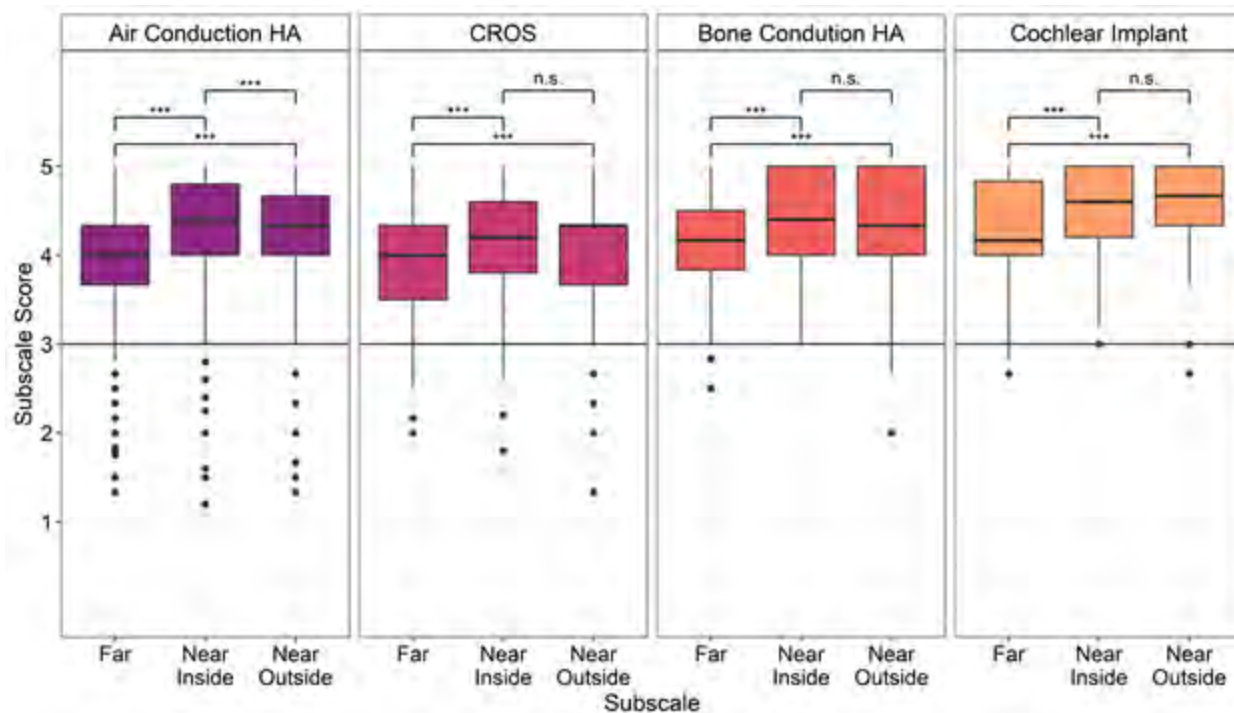
Personal Hearing Devices Improve Classroom Listening for Teenagers with UHL

Very EASY

Classroom listening is reported to be easy or very easy WITH personal devices

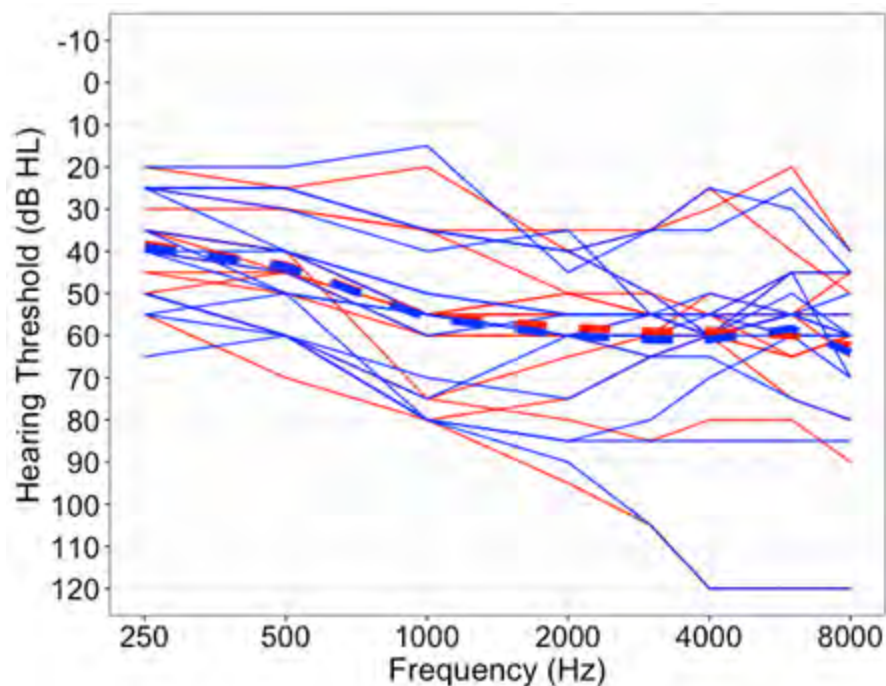
“Far” subscale still most difficult

Very HARD



Use of VCLASS for Teenagers with Bilateral Hearing Loss

- Participants in a lab-based study about digital noise reduction
 - 17 adolescents (12-17 years)
 - Existing hearing aid users
- Completed the VCLASS as if they were not wearing hearing aids (unaided) and after wearing study hearing aids for 1 week (aided)

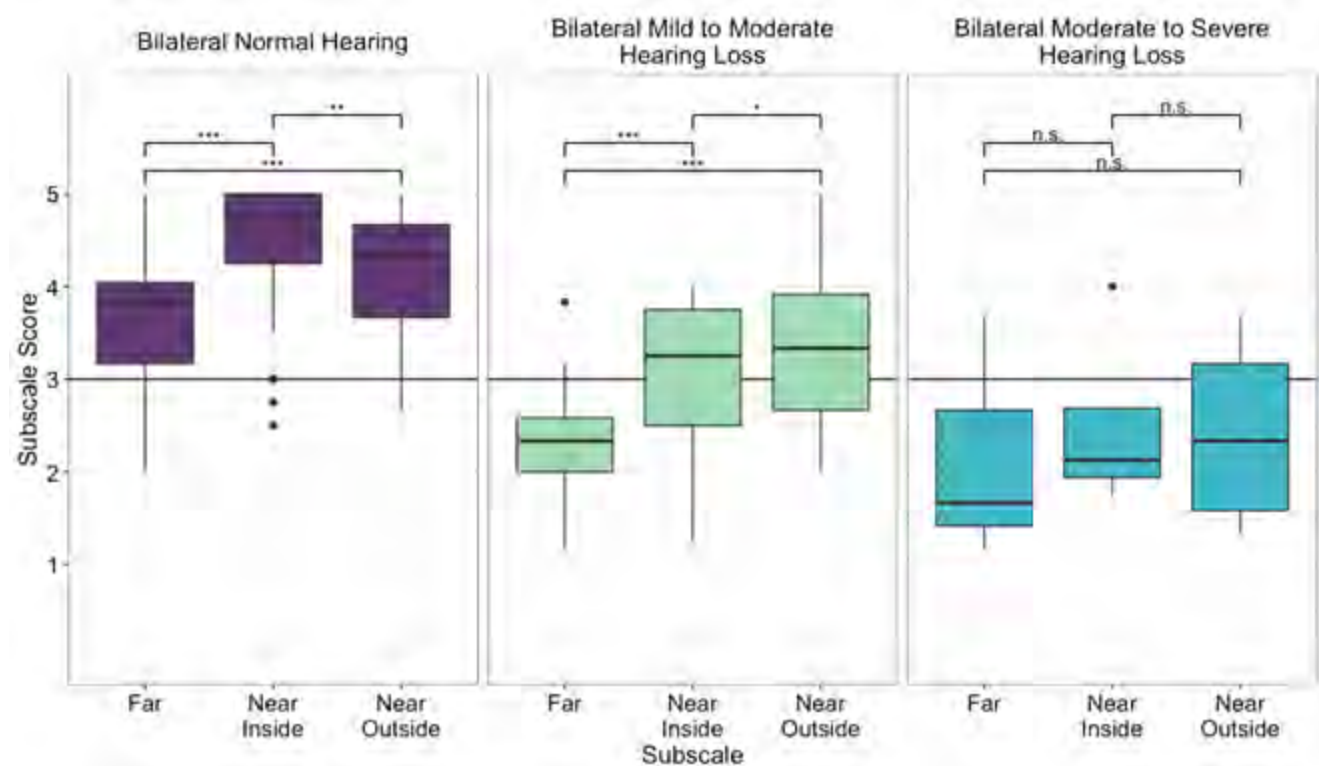


Audiometric Hearing Loss is Related to Self-Reported Difficulties in the Classroom

Teenagers with more significant hearing loss are reporting more difficulties

Trend towards “far” talkers to also be the most difficult situations

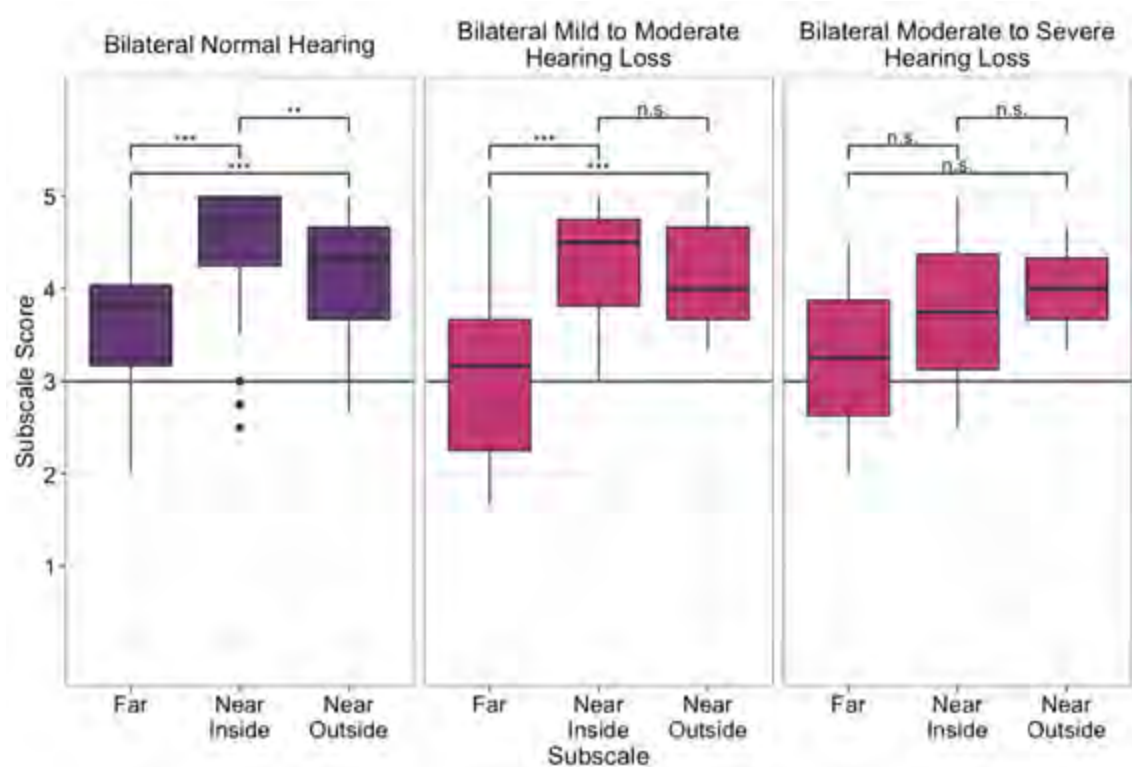
Overall pattern is similar to children with unilateral hearing loss



With Hearing Aids, Teenagers with Bilateral Hearing Loss Report Classroom Listening to be Easy

Ratings are significantly better than the unaided ratings

Difficulties for the “far” talkers persist, even with hearing aids



Summary of VCLASS

- Validated, empirically-derived, internally consistent questionnaire to evaluate and monitor school-based listening situations for teenagers (and pre-teenagers)
- Data suggest listening to a talker far away most challenging for teenagers
 - With unilateral hearing loss
 - With bilateral hearing loss
 - While wearing hearing aids

Potential Uses of the VCLASS

- Continuing research
- Identifying students who have difficulties
- Identifying listening specific listening situations that are challenging
- Monitoring device success

<https://redcap.vumc.org/surveys/?s=MHYJTDCY9XTCN7JR>

Example VCLASS

- Lilian scores a 3.5 total score on the VCLASS with her hearing aids
- Largely driven by the 'near inside' subscale score (2)
- Indicates listening is difficult even with hearing aids
- Consider exploring
 - Remote microphone technology
 - Advanced noise cleaning algorithms

Implications for Teenagers

- Need for autonomy
 - Give them control
- Diversity of listening situations
 - Flexible technology
 - Address noise, distance, music listening
- Rapid transitions
 - Tap control
 - Smartphone app
- **Variability within and across teenagers**
 - **Get their perspective**

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Tap Control



Typical Day

6:45 – catch the bus

video text video text

7:10 – arrive at school

text video text

2:55 – catch bus home

video text text

3:15 – homework

text video video text

4:00 – trombone practice

video video video video

4:45 – family dinner

text

5:15 – soccer practice

text

7:00 – snack/ homework/ screen time

text text text video video video video

More About Lilian

- Wears bilateral hearing aids
- Has iPhone 13
- Loves streaming
- Has a YouTube account
- Is allowed to keep phone on her at school for hearing aid control
- Makes (mostly) good decisions at school about streaming and connectivity

Options for Hearing Aid Control

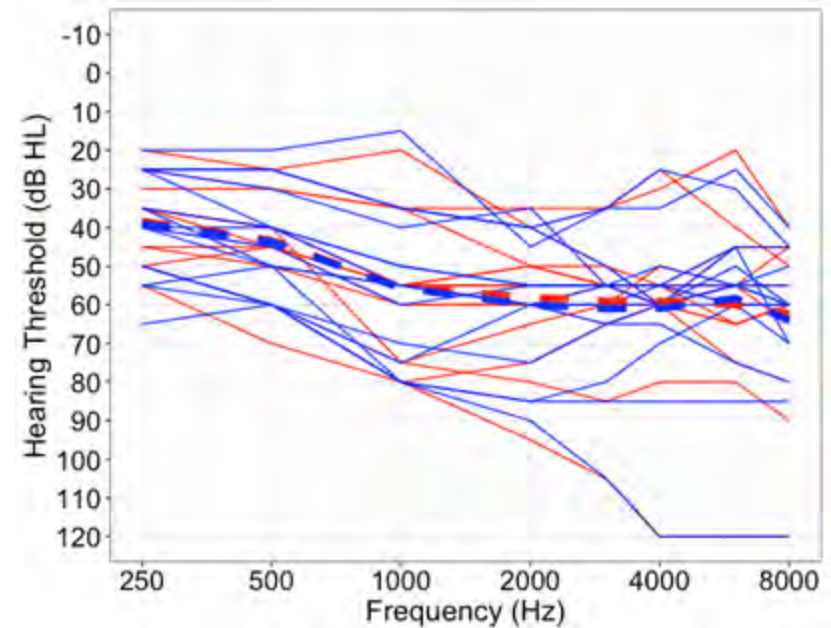
- Program button / remote control
 - + in most form factors
 - + many options for control
 - + can do bilateral control
 - - most teenagers don't use it (e.g., Ricketts et al., 2017)
- Smartphone application / control
 - + easy, comfortable, and natural
 - - offers *many* options for control
 - - requires interaction with phone

Tap Control

- Tap control can:
 - Accept/end call for streaming
 - Pause/resume streaming from a connected Bluetooth® device
 - Access smartphones' voice assistant (e.g., Siri or Alexa)
- Activate by double tap pinna
- Can control the strength necessary for double tap in programming software

Testing Tap Control

- Fit participants with Phonak Audeo L90-R
- Trained on Tap control
- Encouraged to use Tap during a second field trial
 - ~1 week
- Answered questions about ease of use, preferences

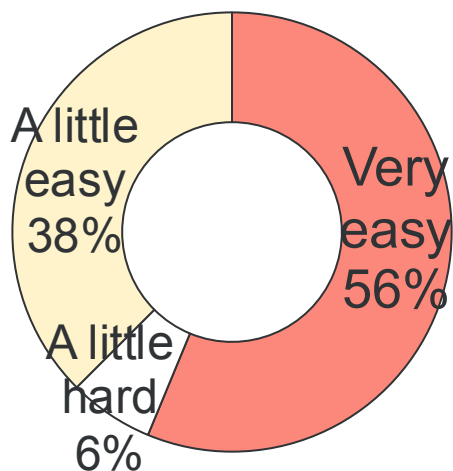


Participants were All Easily Trained on the Use of Tap Control

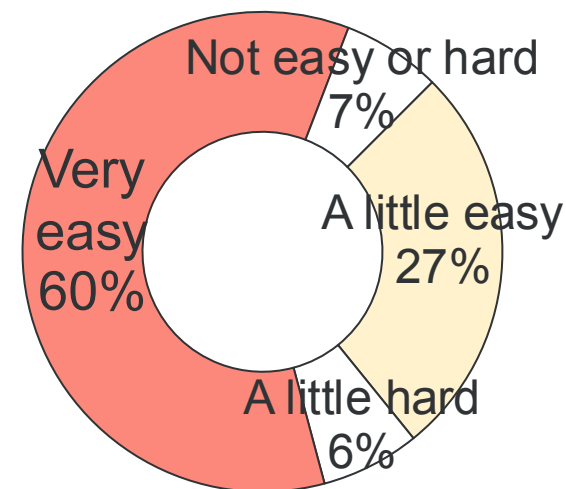
- 100% of participants demonstrated they could use Tap control
 - Immediately after training
 - At the end of the visit
- Could demonstrate
 - How to double tap successfully
 - Which ear controlled streaming
 - Which ear controlled phone
 - Which ear controlled voice assistant

Teenagers Reported Tap is Mostly Easy to Use

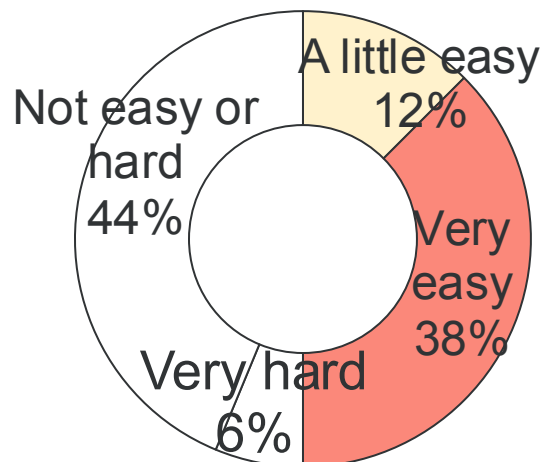
Stop/Start Streaming



Calling Voice Assistant



Answering Phone Calls



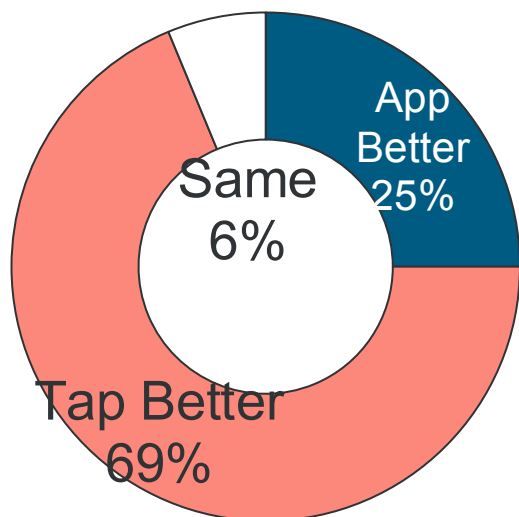
Reasons for Liking Tap Control

- “The tap was cool.”
- “Just a simple tap would do the trick well.”
- “When I got a call and I was busy it was very easy to just tap my ear instead of stop what I’m doing to answer the call it was very nice.”
- “It's faster than taking out my phone and pressing pause.”

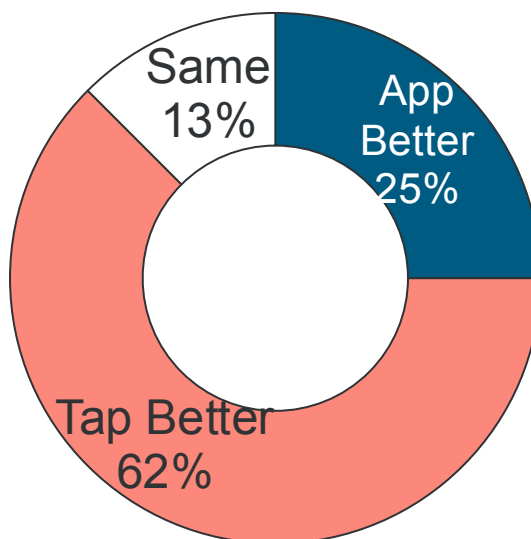


Most Teenagers Preferred Tap to Alternatives

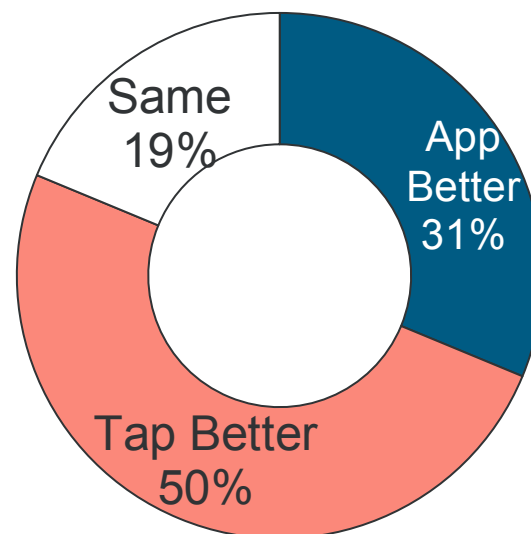
Stop/Start Streaming

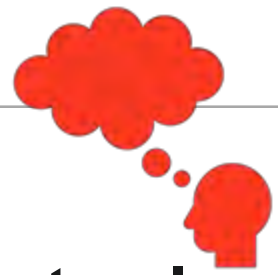


Answering Phone Calls



Calling Voice Assistant





Reasons for Not Liking Tap Control

- “Sometimes when I tapped it it did not work.”
- “It was confusing sometimes, because I would accidentally hang up on a call.”
- “I find it easier to press a button on my phone one time rather than try double tapping multiple times just to stream music.”
- “Sometimes something (like a pillow) touched my hearing aid and Siri answered.”
- “It was easy but when I was putting my hair behind my ear it <Siri> would come on.”

Options for Hearing Aid Control

- Program button / remote control
- Smartphone application / control
- Tap control
 - Training very easy and successful (100%)
 - Most teenagers reported liking to use it
 - Especially for phone and streaming
 - Less success with voice assistant
 - On by default in Phonak Audéo P- R and Audéo P-RT (performance level 70 and 90)

Implications for Teenagers

- **Need for autonomy**
 - **Give them control**
- Diversity of listening situations
 - Flexible technology
 - Address noise, distance, music listening
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Digital Noise Reduction

Benefits



Hunter*

- Bilateral hearing loss
- Wears RIC devices mostly full time
- Audiologist deactivated advanced features several years ago, including noise reduction options
- Tired at the end of the day
- Loves the mountain biking team, but has trouble making it to the practices because he's tired after school

Listening in Noise

- Difficult
 - Interfere with learning (e.g., Valente et al., 2012)
- Effortful
 - Especially for younger children (e.g., Hsu et al., 2021)
- Fatiguing
 - Even within 25 minutes, adolescents report 56% increase in fatigue while listening in noise (Picou et al., 2019)

Features that Could be Activated to Help Hunter at School

- Directional microphones (e.g., unilateral or bilateral beamformer)
- Digital noise reduction (e.g., single microphone, modulation-based)
- Advanced digital noise reduction (e.g., spatially based)

Features that Could be Activated to Help Hunter at School

- **Directional microphones (e.g., unilateral or bilateral beamformer)**
- Digital noise reduction (e.g., single microphone, modulation-based)
- Advanced digital noise reduction (e.g., spatially based)

Directional Microphones Improve Speech Understanding

- In adults, directional microphones improve speech recognition under right circumstances
 - Low reverberation
 - Spatial separation speech and noise
 - Oriented towards the talker
- In teenagers, also see directional benefits in the same circumstances (Gravel et al., 1999; Ricketts & Picou, 2013)
 - No age-related change in child's ability to orient toward talker of interest (Ricketts & Galster, 2008)

Directional Microphones Can Reduce Listening Effort

- Directional microphones reduce behavioral listening effort for adults
 - Especially in difficult, complex environments (Picou et al., 2017)
- Directional microphones can reduce behavioral listening effort for teenagers
 - For those who have high effort in omnidirectional setting (Gustafson et al., 2021)

Features that Could be Activated to Help Hunter at School

- Directional microphones (e.g., unilateral or bilateral beamformer)
- **Digital noise reduction (e.g., single microphone, modulation-based)**
- Advanced digital noise reduction (e.g., spatially based)

Single-Microphone Digital Noise Reduction

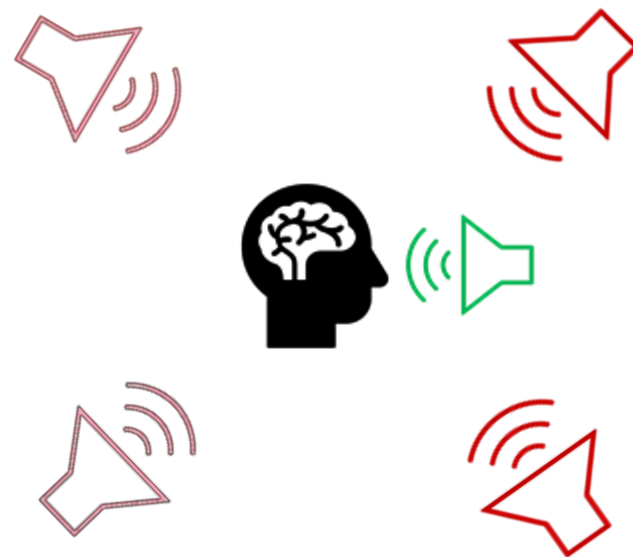
- Benefits for subjective preference and listening comfort
 - In adults (Lakshmi, Rout, & O'Donoghue, 2019)
 - In school-aged children (McCreery et al., 2012)
- Benefits for listening effort
 - In adults (e.g., Sarampalis, Kalluri, Edwards, & Hafter, 2009)

Features that Could be Activated to Help Hunter at School

- Directional microphones (e.g., unilateral or bilateral beamformer)
- Digital noise reduction (e.g., single microphone, modulation-based)
- **Advanced digital noise reduction (e.g., spatially based)**

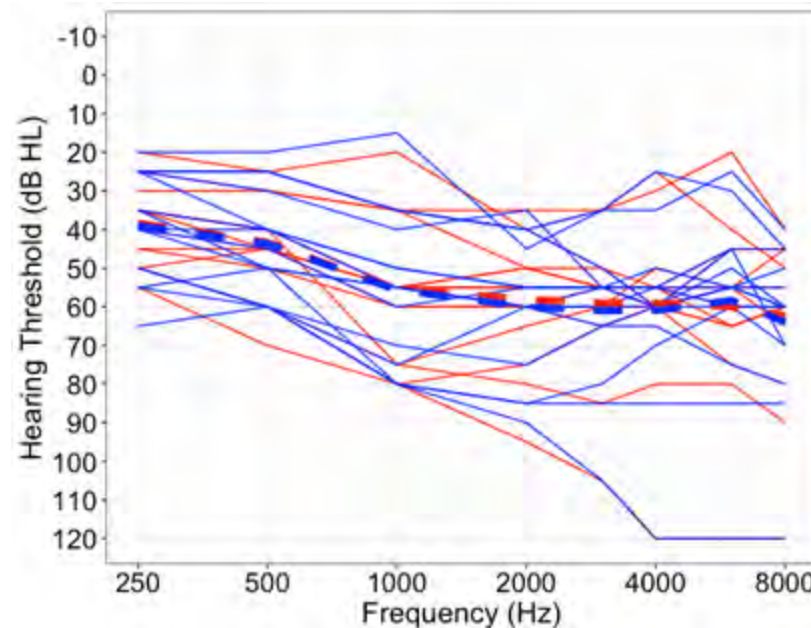
Advanced Digital Noise Reduction

- Spatial noise cancellation feature that works in combination with a directional beamformer to improve the signal-to-noise ratio in challenging situations
 - Reduces noise from behind and beside
 - Dynamic Noise Cancellation (Phonak)



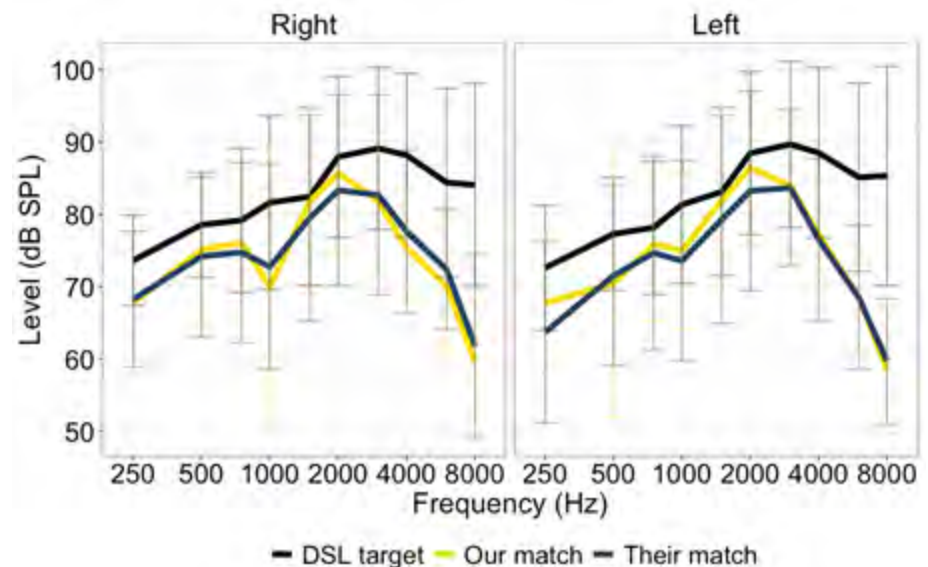
Testing Advanced Digital Noise Reduction

- Same participants as the Tap control study
- Laboratory testing
 - Double-blinded paired comparison testing
 - Sentence recognition in noise testing



Programs for Laboratory Testing

- All matched to the same frequency gain response
- 3 manually accessible programs
- Double blind assignment
- Advanced digital noise reduction setting strength
 - Off
 - Weak
 - Strong



Testing Advanced Digital Noise Reduction

- Blinded A-B paired comparison test
 - CST speech passage (70 dBA) in noise (68 dBA cafeteria noise)
 - Same two sentences repeatedly
 - Programs compared each other round robin
 - "Which was easiest to listen with?"
- Likert scale - How much easier was the program you chose?

Which setting makes it easier to listen to those sentences? A or B?

A

B

How much easier was the one you chose?

They're the same

It's a lot easier

1

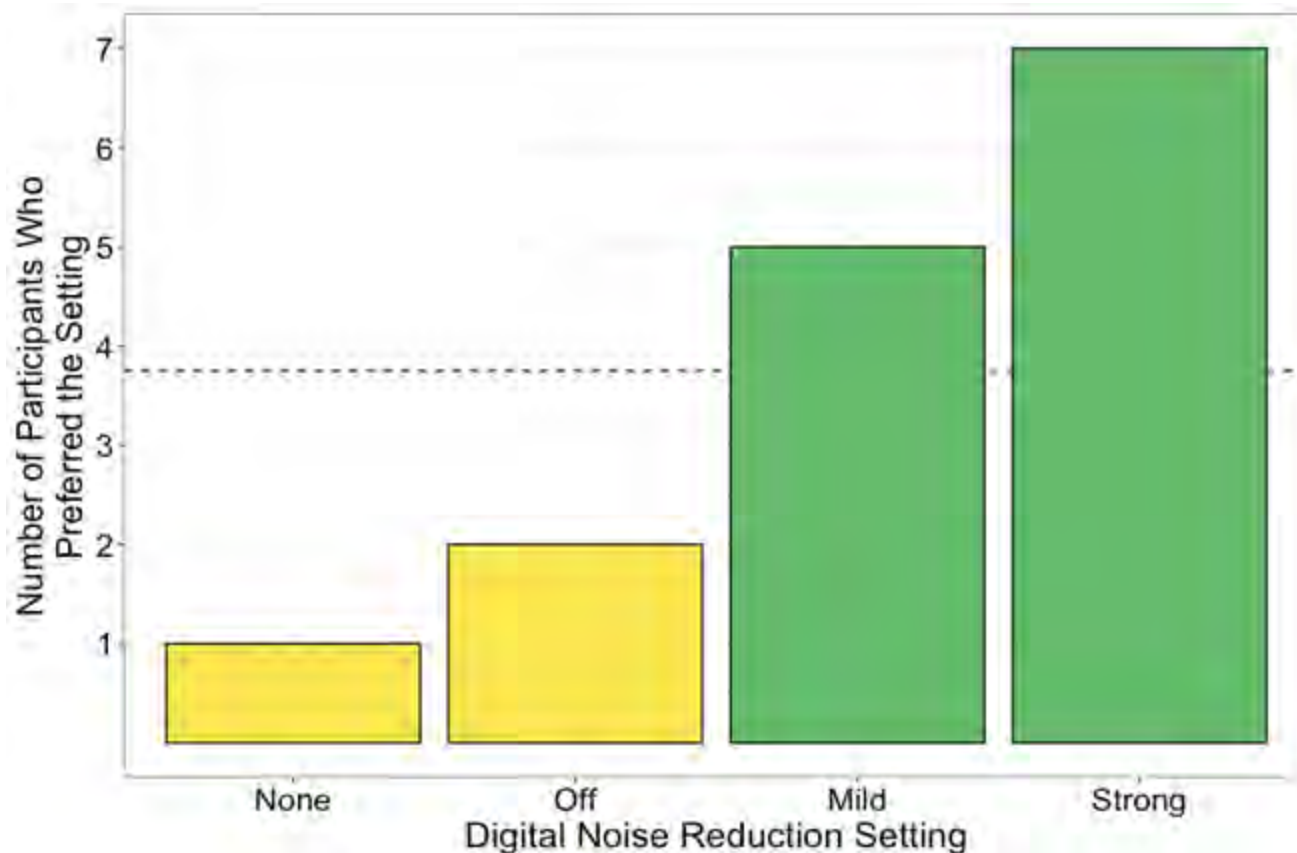
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5

Most Teenagers Preferred to Have Advanced Digital Noise Reduction Activated



Advanced Noise Reduction and Sentence Recognition in Noise

- Advanced noise reduction does not negatively affect speech recognition performance in noise
- Adaptive task (HINT-C)
- Sentence recognition thresholds
- Vary across settings by 0.01 dB

Digital Noise Reduction Setting	Mean	Standard Deviation	Range
Off	1.01	0.05	0.92 – 1.13
Mild	1.02	0.05	0.95 – 1.14
Strong	1.02	0.06	0.94 – 1.17

Summary of Evidence for Advanced Digital Noise Reduction

- No effect on sentence recognition performance in noise
- Most teenagers preferred to have it activated
 - 80% preferred to have it active
 - Not able to predict based on audiometric information who would not prefer to have advanced digital noise reduction activated
- Robust benefits for subjective ratings of preference

Hunter*

- Could expect activating advanced features might support school-based listening
- Reducing listening effort and fatigue

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Noise Cleaning Algorithms

Control



Hunter*

- Can we give him control of advanced features?

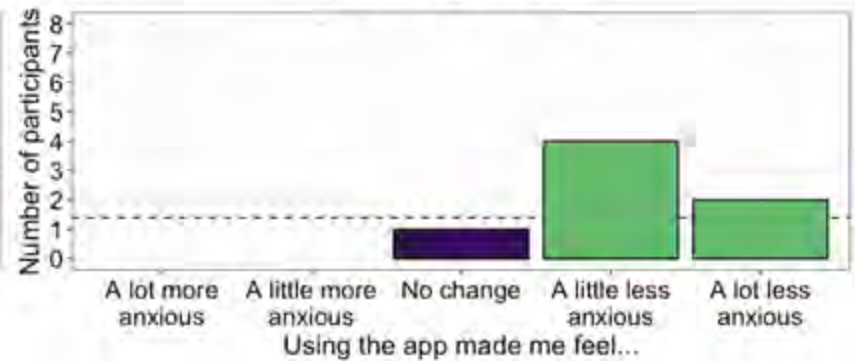
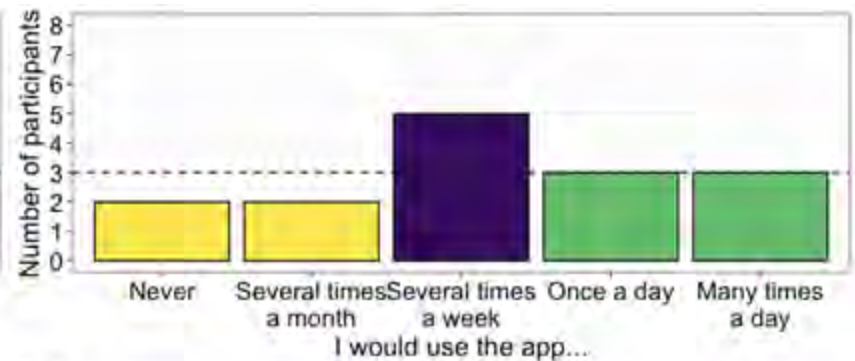
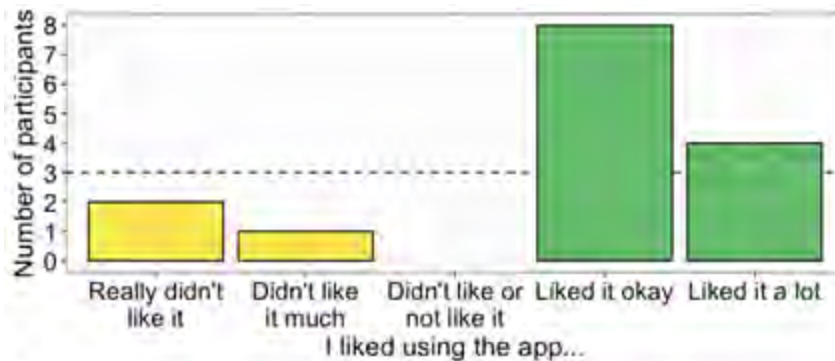
Control Options for Noise Reduction

- Program button / remote control
 - - Teenagers are unlikely to use it (Ricketts et al., 2017)
- Tap control
 - - For streaming / phone / voice assistant
- Smartphone application
 - - Requires access to smartphone (generally and specifically at school)
 - - Concern for too much adjustment

Testing Smartphone Application

- Same participants as the Tap control and laboratory tests with advanced digital noise reduction
- Trained on smartphone application and participated in a field trial
 - Their smartphone
 - Borrowed laboratory smartphone

Teenager Reports of App Use at Home



Summary of Noise Reduction Controls

- Tap control works for controlling streaming and phone calls
- Smartphone applications
 - Can be useful for changing strength of advanced digital noise reduction
 - Teenagers are internally consistent with the controls and preference
 - Most likely to use it 'several times a week' – not as frequently as their noise needs change

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Learning Outcomes

- Summarize unique listening needs of adolescents
 - *Diverse, rapidly changing*
 - *In schools, far away talkers are most challenging*
- Describe the benefits and limitations of tap control for adolescents
 - *Works well for phone calls and streaming*
 - *Easy to train teenagers to use it*
- Summarize the benefits and limitations of noise reduction for adolescents
 - *Improved subjecting ratings of preference, no speech rec downsides*
 - *Like using the app, but would only use it several times a week*

Thank you!

erin.picou@vumc.org

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