If you are viewing this course as a recorded course after the live webinar, you can use the scroll bar at the bottom of the player window to pause and navigate the course.

This handout is for reference only. It may not include content identical to the PowerPoint. Any links included in the handout are current at the time of the live webinar, but are subject to change and may not be current at a later date.
Vanderbilt Audiology Journal Club: Recent Hearing Aid Innovations and Technology

Erin M. Picou, AuD, PhD
March 15, 2018

Disclosures

- Employed by Vanderbilt University Medical Center
- Editorial roles
  - *Ear and Hearing*
  - *American Journal of Audiology*
- Received research funding
  - Sivantos
  - Oticon
  - Phonak / Sonova
  - Resound
  - Starkey
  - NIH NIDCD
  - ASHA
Learner Outcomes

1) List new key journal articles on the topic of hearing aid technology
2) Describe the purpose, methods and results of new key journal articles on hearing aid technology
3) Explain some clinical takeaway points from new key journal articles on hearing aid technology

What today’s focus could have been...

- Examination of studies that address evolving role of audiologists in hearing aid provision
  - Some PSAPs offer comparable speech recognition benefits to traditional hearing aid for soft speech in noise
    - Reed et al (2017) Personal sound amplification products vs a conventional hearing aid for speech understanding in noise, JAMA , 318, 89-90
  - Patients with mild hearing loss wore their hearing aids as often as patients with moderate loss
  - Deviations from prescriptive targets negatively affect speech recognition hearing aid benefits in children
What today’s focus could have been…

- Audiologist services can affect outcomes
  - Service provision via internet / tele-audiology can be effective
    - For follow-up appointments with children and families (Muñoz et al [2017] Paediatric hearing aid management: A demonstration project for using virtual visits to enhance parent support. Int J Audiol, 56, 77-84)
    - For aural rehabilitation and communication skills training with adults (Malmberg et al [2017] Evaluating the short-term and long-term effects of an internet-based aural rehabilitation programme for hearing aid users in general clinical practice: a randomised controlled trial. BMJ open, 7, e013047)

Today’s Focus

- Hearing aid technology and innovation
  - Noise reduction and directionality on listening effort
  - Visually-guided directionality on speech recognition
  - Individual differences in bilateral directionality benefit for speech recognition
  - Brief Bonus: How clinicians fit and fine-tune processing schemes
Today’s Agenda

- What they asked
- A little background
- Why it matters
- What they did
- What they found
- What is this important
- Does it matter clinically

Impact of noise and noise reduction on processing effort: A pupillometry study

Dorthea Wendt
Renskje K. Hietkamp
Thomas Lunner

2017, Ear and Hearing, 38, 690 - 700
What they asked…

- Can noise reduction schemes (digital noise reduction and directional microphones) reduce processing effort during speech recognition?

A little background…

- Speech understanding is important
- People with hearing loss have difficulty understanding speech, especially in noise
  - Reduced speech recognition
  - Increased cognitive demands
  - Slower speech processing
- Noise reduction algorithms aim to make listening in noise easier
  - Digital noise reduction
  - Directional microphones
- So…. Do they help?
A little background…

- Many studies use unfavorable SNRs (-10 to 0 dB)
- Some schemes work best at positive SNRs
- Positive SNRs might show ceiling effects for speech perception measures
- …but, scoring high on a speech perception test doesn’t mean the person isn’t struggling

A little background …

- Researchers and clinicians are interested in “listening effort” or “processing effort”
  - Cognitive resources deployed when processing speech
  - Affected by environment (SNR, audibility, type of noise)
  - Affected by listener (age, hearing loss, cognitive abilities)
- Measured in a variety of ways
  - Subjective ratings
  - Reaction-time based paradigms (e.g., dual tasks)
  - Memory measures
  - Physiology measures (e.g., pupillometry)
A little background ....

- Pupillometry as a measure of processing effort
  - Give an indication of "real time" processing effort
  - Related to locus coeruleus function
  - Pupil dilates with increasing demands until processing resources are depleted
  - Processing or listening effort indicated by
    - Pupil diameter
    - Duration on speech processing

A little background...

- Hearing aids can reduce listening effort; effort may be comparable with well-fit hearing aid to listeners with normal hearing
  - Desjardins & Doherty (2014) *Ear Hear.*, 35, 600 - 610

- Noise reduction and directional microphones can further reduce effort
  - Directionality – Picou et al (2017) *JSHLR*, 60, 199 - 211
  - Directionality – Desjardins (2016) *JAAA*, 27, 29 - 41
A little background…

- These benefits have been related to individual listeners’ cognitive abilities
  - Working memory related to speech recognition performance and processing effort
    - Rönnberg et al. (2013) Front Syst Neurosci, 7, 31
  - Working memory capacity might be related to benefit from digital noise reduction
    - Ng et al (2015) Ear Hear, 36, 82 - 91

Why it matters…

- We want to make listening easier for our patients
- Evidence of feature benefits in realistic listening environments
  - Few natural situations have negative SNRs
  - Most SNRs are between 2 and 14 dB (63% of situations)
  - Most common situation is 68: 60.5 for 7.5 dB SNR
What they did...

- **Participants**
  - 24 listeners with mild to moderately-severe hearing loss
  - Average age of 59 years (range 35 to 80)
  - Experienced bilateral hearing aid users (average of 1 year of experience)

- **Reading span task**
  - Participant listens to and comprehend a sentence
  - Half sentences were semantically incorrect
    - The train sang a song
  - Participant reported on semantical correctness (yes / no)
  - After a set of sentences (3, 4, 5, or 6), a participant recalled the initial or final word

What they did...

- **Pupillometry**
  - Measured response of pupil
  - 5 loudspeakers presented 4 talker babble
  - Loudspeaker in front presented Danish HINT sentences
What they did...

- Conducted 2 experiments:
  - Experiment 1
    - Evaluated effect of noise reduction and directional microphones when speech recognition 50% and 95%
    - Evaluated effect of individual differences in cognitive ability on processing effort and hearing aid processing
  - Experiment 2
    - Examined the effect of noise reduction and directional microphones using commercially available hearing aids
      - HA 1 – multi-microphone noise estimate and beamformer with a post-filter resulting in fast-acting noise reduction
      - HA 2 – single-channel noise estimate, first-order directionality effect and slow-acting noise reduction

What they did (Experiment 1)...

- Speech intelligibility levels individualized for each participant
  - L50 – approximately 50% speech recognition
  - L95 – approximately 95% speech recognition

- Hearing aid settings
  - NoNR – curvilinear amplification based on patient’s hearing thresholds
  - NR – processed first with directionality (rear cardioid directivity) and then with 2 channel noise reduction
What they found (Exp 1)…

What they found (Exp 2)…
What they found...

- In the NR conditions (both L50 and L95), significant relationship between working memory capacity and pupil dilation
  - Those with higher working memory had smaller pupils and thus less processing effort
  - Relationship was significant, but weak ($r = -0.3$ to -0.4)
  - Relationship did not hold in the NoNR conditions

Why is this important...

- Further evidence supporting
  - Dissociation between listening effort and speech recognition
  - Pupillometry conceptually related to task difficulty
  - Benefits of noise reduction (combined digital noise reduction and directionality) for speech recognition and also processing effort

- Realistic SNRs
  - Average L50 was 1.3 dB
  - Average L95 was 7.1 dB
Does it matter clinically…

- Testing at ecologically valid SNRs supports clinical utility, so it is likely the benefits translate to “real world” listening experiences
- Lingering questions remain
  - Would benefits be experienced in actual environments?
  - Would patients notice the benefits?
  - Can we expect the relationships with working memory capacity to affect individualization of technologies?
  - Are we convinced the benefits are related to cognition and not only arousal?

Neurodynamic evaluation of hearing aid features using EEG correlates of listening effort

Corinna Bernarding
Daniel J. Strauss
Ronny Hannemann
Harald Seidler
Farah I. Corona-Strauss

2017, Cognitive Neurodynamics, 11, 203 - 215
What they asked…

- Can electroencephalography be used as an indication of listening effort?
- Can a combination of directional microphones and digital noise reduction reduce listening effort?

A little background…

- Limitations of existing methodologies
  - Subjective ratings – influenced by bias
  - Response time measures – requires cooperation and other assumptions about motivation / strategy
  - Pupillometry – influenced by arousal or stress
  - Auditory evoked responses – stimuli must be short duration and are prone to exogenous effects (noise levels, hearing aid settings)
A little background…

- Electroencephalography (EEG)
  - Ongoing oscillatory activity
  - Higher phase synchronization occurs due to increased attentional modulation in the theta band and reflects higher cognitive effort
    - Low effort conditions, phase uniformly distributed
    - High effort conditions, phase clustered or entrained

Why it matters…

- Clinically our patients report difficulties understanding speech in noise
  - Speech intelligibility
  - Listening effort
  - Fatigue
- Hearing aids and special features can reduce listening effort, but the existing methodologies have conceptual limitations
What they did...

- **Participants:**
  - 14 participants (average age 65.64 years)
  - Experienced hearing aid users
  - Mild-to-moderate bilateral hearing loss

- **Hearing aid fitting**
  - Commercial BTE device with occluding domes
  - Individually fitted based on proprietary algorithm
  - 4 hearing aid settings
    - DSEstr – directional microphone and strong Wiener filter NR
    - DSEmed – directional microphone and medium Wiener filter NR
    - DSEoff – directional microphone and off Wiener filter NR
    - ODM – omnidirectional microphone and off Wiener filter NR

What they did...

- **Condition 1 (speech recognition)**
  - Oldenburg Sentence Test (subject-verb-number-adjective-object / Peter buys three red cups); 65 dB

- **Condition 2 (story comprehension)**
  - Stories from German comprehension test; 65 dB

- **Presentation levels**
  - Speech – 65 dB
  - Noise
    - ISTS – 60 dB
    - Cafeteria – 67 dB
What they did...

- Speech recognition (condition 1) or story comprehension (condition 2) in each of the 4 hearing aid settings
- Subjective ratings of perceived listening effort
  - “No effort” to “Extreme effort” (7 point scale)
- Subjective ratings of speech intelligibility
  - “Excellent” to “Insufficient” (7 point scale)

What they found...

Bernarding et al (2017)
Cogn Neurodyn. 11, 203 – 215
https://creativecommons.org/licenses/by/4.0/
What they found...

On the relationship between EEG and subjective reports of listening effort

- EEG highly correlated with perceived effort in all HA settings ($r = 0.8$ and $0.94$ for conditions I and II, respectively)
- Omnidirectional microphone resulted in highest perceived effort and highest measured effort

Bernarding et al (2017)
Cogn Neurodyn, 11, 203 – 215
https://creativecommons.org/licenses/by/4.0/
Why is this important…

- Supports use of EEG and neural phase entrainment as an indication of listening effort
  - Instantaneous phase of EEG in the theta band correlated with cognitive effort
  - Phase is more clustered in demanding conditions
- Further evidence that directionality can improve
  - Speech intelligibility
  - Listening effort (physiologic)
  - Listening effort (subjective report)

Does it matter clinically…

- Converging lines of evidence suggest noise reduction and directional microphones improve listening effort – could be beneficial for patients
- Lingering questions remain
  - Are there individual factors that might affect benefits or candidacy?
  - Are these changes enough to matter to patients?
  - Evidence of reduced effort in natural situations?
The benefit of a visually guided beamformer in a dynamic speech task

Virginia Best
Elin Roverud
Timothy Streeter
Christine R. Mason
Gerald Kidd, Jr.

2017, Trends in Hearing, 21

What they asked…

- Can a visually guided hearing aid improve speech intelligibility in a dynamic, “real world” communication setting?
A little background…

- Directional microphones are mostly standard in hearing aids and provide benefits to patients
- Difficulty understanding speech remains a common clinical complaint
- Advanced directional microphones combine signals from multiple microphones
  - Bigger microphone array (higher order microphone)
  - Across a pair of hearing aids (bilateral beamformer)

A little background…

- Visually guided beamformer (c.f., Kidd et al [2013] J Acous Soc Am, 133, EL202 – EL207)
  - Microphone array with 16 microphones mounted on a headband
  - Eye tracker mounted on the head uses eye gaze to steer beamformer
  - Directivity index of approximately 9 dB
  - Improves speech recognition by 6 – 9 dB
A little background…

- Advanced beamformers have downsides
  - Output is a single channel
  - Loss of binaural information
  - Performance can be worse where location-based segregation is important
- Cue preservation balances downsides
  - Re-introduction of binaural cues with modeled head-related transfer functions
  - Beamforming only at some frequencies (e.g., highs)

A little background…

- Cue preserving, visually guided hearing aid helps when speech is in the front and competing talkers are on either side (Kidd et al [2015] Trends Hearing, 19, 1–15).
- Many typical situations do not involve a talker in front and the talker might change moment to moment
- Microphones need to be “steered”
  - Head movement
  - Eye movement
Why it matters…

- Traditional directional microphones have been available for several decades, but speech in noise difficulties persist
- Advanced microphones improve the SNR, but have drawbacks
- Steering and cue preservation would limit the drawbacks

What they did…

- Participants: 14 young adults
  - 7 with normal hearing (21 to 24 years)
  - 7 with bilateral mild to severe SNHL (19 to 41 years)
- Hearing aid conditions:
  - BEAM: simulated visually guided hearing aid
  - KEMAR: recorded in acoustic manikin (unaided)
  - BEAMAR: low frequency KEMAR; high frequency BEAM
- Test environment:
  - Participant seated in test booth
  - Head fixed
  - Eye tracker measured position and updated microphone output in real time
What they did…

- Question and answer task
  - Question and answer spoken by 22 talkers (11 male)
  - ½ of answers were “correct”
  - Example: What day comes before Monday? Sunday.
  - Participants responded “correct” or “incorrect” with a keypad

What they did…

- Spatial conditions
  - Dynamic – locations of questions and answers moved unpredictably across target locations
  - Fixed – all questions and answers were presented from one target location throughout a run

- Stimuli
  - Target locations: -30, 0, +30
  - Masker locations: -60/-45, -15/15, 45/60
  - Target level: 55 dB SPL
  - Masker level:
    - NH: -10, -5, 0, +5
    - HI: -5, 0, +5, +1-
What they found…

![Graph showing SNR for 75% correct speech intelligibility in NH and HI conditions for Fixed and Dynamic conditions.

What they found…

![Graph showing SNR for 75% correct speech intelligibility in NH and HI conditions for Center and Sides conditions.]
What they found…

- Wide range of benefits for both microphone types
  - PTA was related to performance in general
  - PTA was not related to BEAM or BEAMAR benefit
- Eye gaze errors
  - Larger for dynamic conditions
  - Larger for answers than questions
  - Larger for stimuli presented from the side
  - Independent of microphone condition
- Larger eye gaze errors in dynamic explain less benefits, since steering is suboptimal

Why is this important…

- Cue preserving, visually-guided beamformer microphones improve speech perception for both NH and HI
  - Combined BEAMAR more beneficial than BEAM
  - Benefits likely tied to eye gaze accuracy
- Data demonstrate benefits of microphone technology on a cognitive task (question / answer) rather than a simple speech recognition task
  - No attention switching cost for moving targets (performance in static and dynamic generally comparable)
Does it matter clinically…

- Data support
  - Importance of low frequency binaural cues
  - Potential utility of technologically innovative microphone
- Lingering questions remain
  - How well do these conditions reflect natural conditions, particularly with respect to factors that influence eye gaze?
  - Will the benefits translate to a wearable device?
  - What candidacy factors need to be considered and how can we predict who will benefit from the technology?
    - Pure tone average wasn’t a “significant” predictor

Speech reception with different bilateral directional processing schemes: Influence of binaural hearing, audiometric asymmetry, and acoustic scenario

Tobias Neher
Kirsten C. Wagener
Matthias Latzel

2017, Hearing Research, 353, 36 - 48
What they asked…

- Can we identify candidacy for bilateral directional processing schemes?
  - Symmetry of hearing thresholds below 2000 Hz
  - Binaural intelligibility level difference (BILD)

A little background…

- Patients have trouble understanding speech in noise (!)
- Beamforming microphones improve the SNR by taking advantage of two or more microphone signals and are spatially-based technology
- Bilateral beamformers combine information across microphones on two hearing aids
  - Compromise between improved SNR and binaural cue preservation
A little background…

- Binaural hearing, what is it good for?
  - Binaural squelch (dichotic)
  - Binaural redundancy (diotic)
  - Improved speech in recognition ability
- For broadband speech signals,
  - Interaural timing differences useful below 1500 Hz
  - Interaural timing differences useful above 1500 Hz
- Considerable variability in
  - Binaural hearing abilities
  - Binaural speech reception benefits

A little background…

- Binaural intelligibility level difference (BILD)
  - Measure of improvement in speech in noise reception due to binaural processing
  - Difference in dB between the SNR required for 50% correct reception with binaural and monaural speech
    - Oldenburg sentences presented from in front
    - Stationary speech-shaped noise presented directly from the left or right
    - Using virtual acoustics, present the stimuli to both ears or to the ear opposite the noise
Why it matters…

- We want to improve outcomes for patients and, whenever possible, address their primary clinical complaints
- Bilateral beamformer benefits are variable
  - Fitting these on all patients would be counterproductive
  - NOT fitting them is also counterproductive

What they did…

- Participants: 39 participants, almost all HA users
  - Symmetric hearing loss below 2000 Hz
  - Asymmetric hearing loss below 2000 Hz
  - Both groups exhibited similar spread on measures of
    - Age
      - Symmetric: Mean = 74 years; Range = 63 to 80 years
      - Asymmetric: Mean = 72 years; Range = 35 to 69 years
    - Overall degree of hearing loss
    - Binaural masking level differences
      - Symmetric: Mean = 2.6 dB; Range: 0.2 to 5.2 dB
      - Asymmetric: Mean = 2.5 dB; Range: -0.4 to 4.7 dB
What they did...

- Presented stimuli using virtual acoustics
  - Convolved sentences with head-related impulse responses
  - Speech: Oldenburg sentence test
  - Maskers (65 dB):
    - Male talker uttering Oldenburg sentences (110 Hz F0)
    - Modified International Speech Test Signal (ISTS) modified to have a 110 Hz F0
    - Cafeteria noise (diffuse)

What they did...

- Hearing aid (simulation of linked BTE devices with no venting)
  - Master Hearing Aid research platform
  - Directional processing
  - Linear amplification (NAL-RP)
  - Headphone equalization
What they did...

- Hearing aid microphone conditions
  - Pinna (2 unilateral BTE devices with modest directivity above 1000 Hz; binaural cues available across full range)
  - Beamfull (combined information across hearing aids and output diotic signals; no binaural cues available SNR improvement maximized; 4.4 dB directivity improvement)
  - Beam > 800 Hz (pinna < 800 Hz; beamfull > 800 Hz; preserved low frequency binaural cues; improved mid and high frequency SNR; 2.1 dB directivity improvement)
  - Beam < 2000 Hz (pinna > 2000 Hz; beamfull < 2000 Hz; improved low and mid frequency SNR; preserved high frequency binaural cues; 2.1 dB directivity improvement)
  - Beambetter (beamfull, but signal presented to ear with better speech in noise performance; 4.4 dB directivity improvement)

What they found...

[Bar chart showing SNR for 50% correct across different conditions: Single talker +/- 60°, Speech noise +/- 60°, Diffuse cafeteria noise]
What they found…

- Maskers +/- 60 degrees
  - Listeners with large BILDs (> 2 – 3 dB) benefited more from low-frequency binaural cues (pinna; beam >800 Hz) than from greater directionality (beamfull; beambetter)
  - Listeners with small BILDS benefited more from greater directionality (beamfull; beambetter) than from low-frequency binaural cues (pinna; beam >800 Hz).
- In diffuse noise, maximal SNR improvements provided the most benefits, regardless of BILD
Why is this important…

- Individualization of technologies based on patient characteristics can improve outcomes
- Suggests that people with poor binaural hearing are not good candidates for beamforming technology if they will be in situations with spatial maskers
- Everyone can benefit from beamforming in diffuse, cafeteria noise

Does it matter clinically…

- Need replications and larger samples – big data and meta-analyses
- Lingering questions remain
  - Are the results repeatable and do they hold for a large population of clinical patients?
  - Will the relationships hold with clinically appropriate venting, where vent-transmitted sound is not directional?
  - Do the results translate to natural listening scenarios?
  - Will clinicians use these recommendations to fit or fine tune directionality?
Survey of Current Practice in the Fitting and Fine-Tuning of Common Signal-Processing Features in Hearing Aids for Adults

Melinda C. Anderson
Kathryn H. Arehart
Pamela E. Souza


Research Question and Methods

- How do audiologists make clinical decisions about fitting signal-processing features for adults?
- Surveyed clinical audiologists with diverse experiences
What they found...

- Initial hearing aid fitting
  - Frequency-specific gain
    - 51% use prescriptive fitting method
    - 35% use manufacturers’ first fit
  - WDRC time constants; 80% use first fit
  - Noise suppression; 58% use first fit
  - Feedback management; 69% use first fit
  - Directional microphones; 66% use first fit

- Frequency lowering
  - Manufacturers’ first fit (40%)
  - Own expertise (36%)
  - Disabled feature (17%)

What they found...

- Fine tuning
Summary and Conclusions

- Audiologists fit and fine-tune using best practices recommendations and first fits (Anderson, Arehart & Souza, 2018)
  - Long-term goals for us all to research individualization and to implement the findings into clinic
  - Most audiologists not currently using individualized loudness, ANL, or cognitive measures to fine-tune
- For bilateral beamformers, one area of individualization is binaural hearing (Neher, Wagener & Latzel, 2017)
  - For some situations, poor binaural hearing candidacy consideration
  - For diffuse cafeteria noise, everyone benefits
- Visually guided hearing aids in the laboratory can be beneficial, especially in combination with natural low frequency binaural cues (Best et al 2017)

Summary and Conclusions

- Noise reduction technologies reduce listening effort
  - Pupillometry: research and commercial hearing aids reduce pupil dilation using a combination of directional microphones and digital noise reduction
  - Electroencephalography: directional microphones reduce neural phase synchronization
Thank You!

Questions?