More Than Just the Teacher: Evaluation of Noise Management Technologies Designed to Optimize Hearing Performance Across All Environments

Jace Wolfe
Just Preaching to the Choir!

-- Children with hearing loss often struggle to understand speech in noise.

-- Children are routinely exposed to moderate to high levels of noise.

-- Difficulty in noise can cause psychosocial, emotional and academic deficits.
How do we help?

Remote Microphone

Noise Reduction

Adaptive Directional
Fact or Fiction?

MORE THAN MEETS THE EYE

Paper or Plastic?

When we think of the environment, we often think about the value of paper or plastic for packaging. However, the amount of plastic produced each year is far greater than the amount of paper. The reality is that both paper and plastic have their place in the environment. When you weigh the costs to the environment, you might just choose to reuse.
Adaptive Noise Management Technology
Is it good for kids?

Basing decisions upon evidence…
Road Map

Intelligibility is queen!

Audibility is king!

• Hearing Aid Technologies to Improve Communication
  – Review of Published Research
  • Noise Reduction Processing
  • Directional Microphones
• New research on adaptive noise management technologies designed for children

Comfort, sound quality, fatigue, & cognitive load are also royalty!

• Should we use adaptive noise management technologies with children?
• Clinical considerations…
NOISE REDUCTION IN CONTEMPORARY HEARING AIDS
Noise Reduction

- Classifies the input as either speech or noise
- Reduces gain in channels in which the input to the aid is primarily noise (i.e., unfavorable SNR)
- Wide variety in implementation of NR across manufacturers
- Studies with adults
  - no change in speech recognition
  - Improvement in noise tolerance, listening ease, comfort, and cognitive load (Bentler, 2005)
  - Kochkin (2009) found great value associated with noise reduction
Overall, NR use resulted in no change in speech recognition in noise

- 16 children with mild to moderately severe HL
  - 8: 5-7 years old
  - 8: 8-10 years old

- Evaluated speech recognition in noise with and without NR (-6 dB)
Overall, NR use resulted in no change in speech recognition in noise.

Other studies examining auditory performance for school-aged children have also shown no degradation in speech recognition in noise with the use of NR.

-- Auriemmo et al. (2009), J American Acad Audiology
-- Pittman (2011a), J Speech Language Hearing Research
-- Pittman & Hiipakka (2013), J American Acad Audiology
-- Gustafson et al. (2014), Ear and Hearing
• 41 children with NH

• 26 children with mild to moderately severe HL

• 8-9 years old and 11-12 years old

• Evaluated ability to learn “nonsense” words associated with a picture

• With and without NR (-7 dB)
NR may improve novel word learning as well as tolerance of noise

- Older children outperformed younger children
- Older children performed better with NR

Gustafson et al. (2014) also found shorter verbal response time with use of NR
Scollie et al., 2016

• Measured NR with clinical systems (e.g., Verifit) and research system for seven different hearing aids in order to describe variation in behavior of NR in modern hearing aids and with verification of NR by modern hearing aid analyzers.
Considerable variability in NR as a function of hearing aid and as a function of test signal

Considerable variability in magnitude and speed of NR

Noise reduction magnitude ranges from 0 to 37 dB
THROWING THE BABY OUT WITH THE BATHWATER...

TRUST ME. I'M A DOCTOR
Noise Reduction for Children

• Inspired by
  – McCreery (2011) – AudiologyOnline.com
Gain Reduction – Noise Only
“High-End Hearing Aids” – Moderate HL

$\ p < .05$ – Main Effect of Manufacturer

Wolfe, unpublished
Gain Reduction – Speech + Noise
“High-End Hearing Aids” – Moderate HL

$p < .05$ – Main Effect of Manufacturer

Wolfe, unpublished
NR magnitude varied by type of signal and by hearing aid analyzer
Does NR “work” for children?”

Take-home Point!

- Yes!

- At the very least, **when implemented correctly**, it seems to result in no degradation in speech recognition

- It may improve listening ease, comfort, cognitive load, fatigue, & novel word learning
Should we use NR with our youngest children?

**Take-home Point!**

- Yes

- But we should attempt to verify that gain will not be reduced when audible speech is present

- We need standardized measures (and signals) to verify the effect of NR for noise-only conditions and for speech-in-noise conditions
Directional Technology for Children

• Experts are divided as to whether directional technology should be used with young children

• Historically, guidelines have varied in recommendation for use/non-use of directional technology in children
  – American Academy of Audiology Pediatric Amplification Guideline (2013)
  – Australian National Protocol for Paediatric Amplification (King, 2010)
    – Harvey Dillon’s Hearing Aids textbook (Dillon, 2012)
...infants and young children should routinely be fit with advanced directional microphones.
• What about the evidence?
• There’s basically no evidence directly supporting the benefits of directional use with infants and young children!
Ricketts & Galster (2007) American J of Audiology

Directional amplification reduced performance when signal arrived from behind

- Evaluated speech recognition in 26 school-age children with mild to moderate HL
- Simulated classroom environment
- Directional vs. Omnidirectional
- Signal from front and signal from behind
Directional mode was judged to be optimal
- 30% of a traditional classroom setting
- 40% of special classrooms (e.g., music, art)
- 83% of lunch situations

No research examining children’s experiences with adaptive noise management technology

Adaptive directional technology is probably appropriate for school-age children with hearing loss
• New Study of Automatic Noise Management Technology Designed for Children

Inspired by research of Manuela Feilner that resulted in automatic scene classifier designed for children
Automatic Noise Management Technology for Children

• 15 Children
  – Moderate to severe hearing loss
    • Pure Tone Average (Better Ear): 53.9 dB HL
  – Ages 9-14 y.o. (mean = 12 y.o.)

• Compared performance across 3 conditions:
  – Default pediatric program (Real Ear Sound)
  – Automatic, adaptive noise management (AutoSense)
  – Manual noise management (e.g., Speech in Noise)
Mean Audiogram

![Mean Audiogram Graph](image)

- **Frequency (Hz)**
  - 250
  - 500
  - 1000
  - 2000
  - 3000
  - 4000
  - 6000
  - 8000

- **Threshold (dB HL)**
  - 0
  - 10
  - 20
  - 30
  - 40
  - 50
  - 60
  - 70
  - 80

- **Legend**
  - Right Ear
  - Left Ear
Automatic Noise Management Technology for Children

• Phonak Audeo V90 hearing aids fitted to DSL v5.0 target

• Children wore hearing aids for 2-4 weeks with default pediatric program & automatic program

• Phase 1
  – Speech recognition in noise across three technology conditions

• Phase 2
  – 4-week real-world trial with journaling to capture technology preference in everyday use

• Phase 3
  – Speech Intelligibility Rating Index (Cox & McDaniel, 1989)
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- **AzBio Sentences** (Spahr et al., 2012) & **Classroom Noise** (Schafer & Thibodeau), 2006

- **Four Acoustic Situations** (Pearsons et al., 1977)
  - **Speech in Noise**
    - Speech: 60 dBA/Noise: 55 dBA
  - **Speech in Loud Noise**
    - Speech: 72 dBA/Noise: 70 dBA
  - **Car**
    - Speech: 55 dBA/Noise: 50 dBA
  - **Quiet**
    - Speech: 60 dBA

- **Three Hearing Aid Programs**
  - RES vs. Manual vs. AutoSense
  - Double blinded – Counter-balanced
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- Journal (2-4 Weeks)
  - 2 Programs
    - Adaptive Noise Management
    - Real Ear Sound & Minimal DNR

- Indicate Program Preference (at least twice per condition)
  - Cafeteria
  - Classroom
  - Restaurant
  - Car

Date: ____________________
Location: Cafeteria

Which program sounds best?

1. Which program is more comfortable?
   [A, B, A, B, AB, B, A, B, A, B, A]

2. Which program helps understand speech better?
   [A, B, A, B, AB, B, A, B, A, B, A]

3. Which program makes the noise go away the most?
   [A, B, A, B, AB, B, A, B, A, B, A]

Comments: ___________________________________________________________

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
Automatic Noise Management Technology for Children

- Speech Intelligibility Rating Index (Cox & McDaniel, 1989)
  - Speech in Noise
    - Speech from 0°
    - Speech from 180° /Front Facing
    - Speech from 180° /Face Toward Preferred Direction
  - Speech in Loud Noise
    - Speech from 0°
    - Speech from 180° /Front Facing
    - Speech from 180° /Face Toward Preferred Direction

![Speech Intelligibility Rating Test Diagram]
3 Hearing Aid Programs:
1. **Calm**: minimal noise reduction; microphone mode set to **Real Ear Sound (RES)**, which mimics natural directionality of the ear

2. **AutoSense OS**: contains an environmental classifier to select the noise management technologies that would optimize hearing performance (e.g., in noisy situations, adaptive directional mode active, and gain attenuation provided by noise reduction (NR) processing).

3. **Manual directional program**: Condition-specific that was manually selected by the clinician.
   - **Speech in Quiet**: NR set to weak setting, microphone set to RES
   - **Speech in Noise**: NR set to weak, microphone set to UltraZoom (adaptive beamformer)
   - **Speech in Loud Noise**: NR set to moderate, microphone set to StereoZoom, (binaural beamforming)
Dual-Mic Directional

- Most all modern hearing aids and CI sound processors use single-ear, dual-mic directional systems.
- These are known as 1st-order directional systems.
Higher-order Directional Systems

- The output of more than two mics may be combined to form higher-order directional systems.
- $3 \text{ mics} = 2^{\text{nd}} \text{ Order}; \; 4 \text{ mics} = 3^{\text{rd}} \text{ order}; \; \text{and so on…}
- Higher order directional systems possess greater noise attenuation.
Binaural Beamformer

• The output of the dual-mic directional system of each ear may be combined to form a four-mic beamformer

• 3rd-Order System

• This type of system allows for greater focus toward front axis and more attenuation of sounds from sides and behind
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- **3 Hearing Aid Programs:**
  1. **Calm:** minimal noise reduction; microphone mode set to Real Ear Sound (RES), which mimics natural directionality of the ear
  2. **AutoSense OS:** contains an environmental classifier to select the noise management technologies that would optimize hearing performance (e.g., in noisy situations, adaptive directional mode active, and gain attenuation provided by noise reduction (NR) processing).
  3. **Manual directional program:** Condition-specific that was manually selected by the clinician.
     - Speech in Quiet: NR set to weak setting, microphone set to RES
     - Speech in Noise: NR set to weak, microphone set to UltraZoom (adaptive beamformer) – *1st-order Dual Mic*
     - Speech in Loud Noise: NR set to moderate, microphone set to StereoZoom, (binaural beamforming) – *3rd-order Binaural Beamformer*
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Wolfe et al., in press, JAAA

* p < .001
Automatic Noise Management Technology for Children

Wolfe et al, in press, JAAA

**Design – Test Session 2:**
- Examined effects of directional technology when the talker is behind the listener (speech at 0 vs. 180° azimuth)
- Speech intelligibility ratings & journals

**Session 2 Results:**
- Speech at 0 better than speech at 180
- AutoSense better than RES for in the speech at 0 condition
- RES better than AutoSense in 180 conditions
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- Speech Intelligibility Ratings:

  ![Speech Intelligibility Ratings Diagram]

  WORDS UNDERSTOOD

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Wolfe et al, in press, JAAA

- **SIR Results:**
  - Similar ratings, except 2 significant differences:
    - 1. AutoSense better than RES for Noise (Speech 0°, facing front)
    - 2. Directional better than RES for Loud Noise (Speech at 0°, facing front)
**Participant Journals:**
- Completed after field trial to compare AutoSense & RES
- Ratings provided 4 situations: cafeteria, car, home, and restaurant
- Rated 2 occurrences for each situation
- $A =$ AutoSense; $B =$ RES (Counter-balanced)
- $A_B = 2$
- $A_B = 1$
- $AB = 0$
- $B_A = -1$
- $B_A = -2$

```
1- Which program sounds best?
A_B A_B AB BA BA

2- Which program is more comfortable?
A_B A_B AB BA BA

3- Which program helps understand speech better?
A_B A_B AB BA BA

4- Which program makes the noise go away the most?
A_B A_B AB BA BA
```
Most participants preferred AutoSense (positive ratings) over RES.
Most participants preferred *AutoSense* (positive ratings) over RES Automatic Noise Management Technology for Children

Wolfe et al, in press, JAAA

Not a single child preferred the pediatric default over AutoSense

Most participants preferred *AutoSense* (positive ratings) over RES
Automatic Noise Management Technology in Children: Journal Experience

Charles
11 years-old
Automatic Noise Management
Technology in Children: Journal Experience

Assigned Date: 
Program: 

Location: Cafeteria

1. Which program sounds best?

A, B, AB, BA, B, A

2. Which program is more comfortable?

A, B, AB, BA, B, A

3. Which program helps understand speech better?

A, B, AB, BA, B, A

4. Which program makes the noise go away the most?

A, B, AB, BA, B, A

Comments:
I like B better because it helps me be heard clearly.
Do adaptive directional mics “work” for children?

Take-home Point! • Yes!

• Research conclusively shows that they can improve speech recognition in noise when the signal arrives from the front

• They may degrade speech recognition for signals arriving from behind (Ching et al., 2009; Ricketts & Galster, 2007)
  – But our most recent research suggests the benefits may outweigh the detriments when designed for pediatric use

• There is no evidence supporting their efficacy for infants and young children
  – More research is needed!
Should we use adaptive directional amplification with children?

Take-home Point!

- Possibly

- Unlikely to be beneficial for infants birth through 9-12 months

- Most likely to be beneficial and well-received for school-aged children
  - Can they report on experiences?
  - Do they understand rationale behind directional use?

- More research is needed to determine whether adaptive directional microphones limit access to speech for toddlers and pre-school aged children.
Summary

• Adaptive noise management technology designed for school-age children appears to be beneficial with limited detriment
  – Children seem to prefer it
  – Future research will delineate which technologies provide most subjective benefit

• Pediatric audiologists must be aware of the operation of adaptive noise management technologies available in hearing aids selected for children
  – These technologies can behave quite differently across manufacturers

• When possible, verification of noise management technologies should be completed

• Validation should also be completed
  – Aided speech recognition assessment
  – Questionnaires (PEACH; APHAB; SSQ-C; OIHP-ABQ, etc.)
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Thank you for your attention!!!

Shoot for the moon!

www.heartsforhearing.org