
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
Crukley, Scollie, & Parsa, 2011
- Difficulty in noise can cause psychosocial, emotional and academic deficits

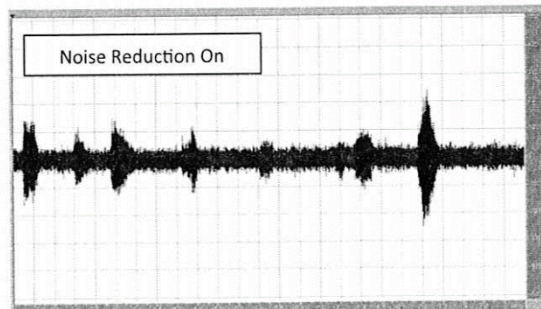
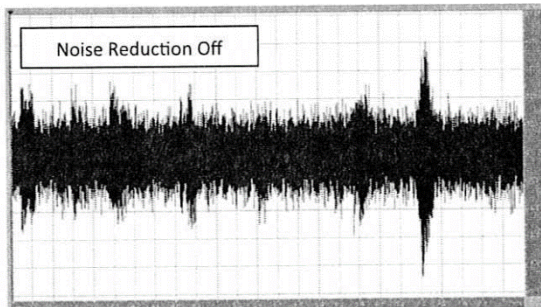
How do we help?



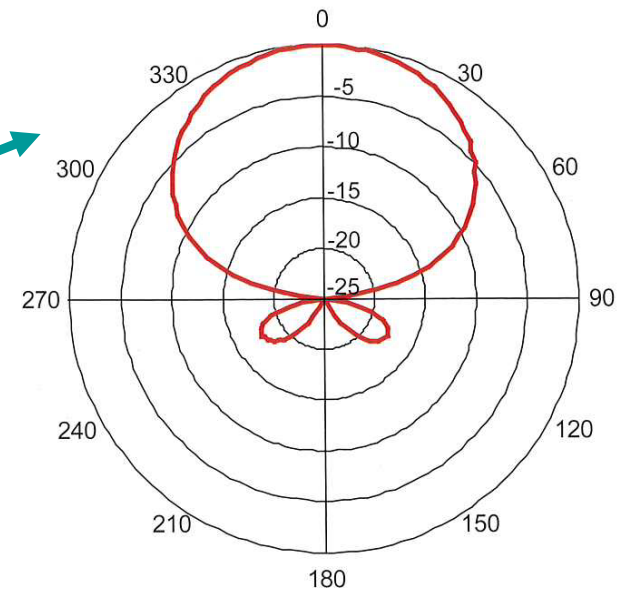
Remote Microphone



Noise Reduction



Adaptive Directional



Fact or Fiction?



MORE THAN MEETS THE EYE

An occasional feature that digs deeper into things you've been wondering about

Paper or Plastic?

We hear the question almost every time we go grocery shopping. Some shoppers answer automatically: plastic — convinced that they are making a better choice for the environment. Others ask for paper, believing the very same thing. The reality is that both paper and plastic bags gobble up natural resources and cause significant pollution. When you weigh all 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
– Review of Published Research
 - Noise Reduction Processing
 - Directional Microphones

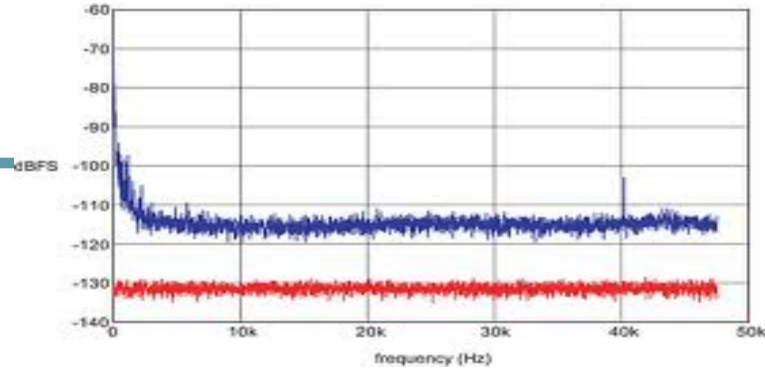
- New research on adaptive noise management tech

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



- Sound management technologies with

- C

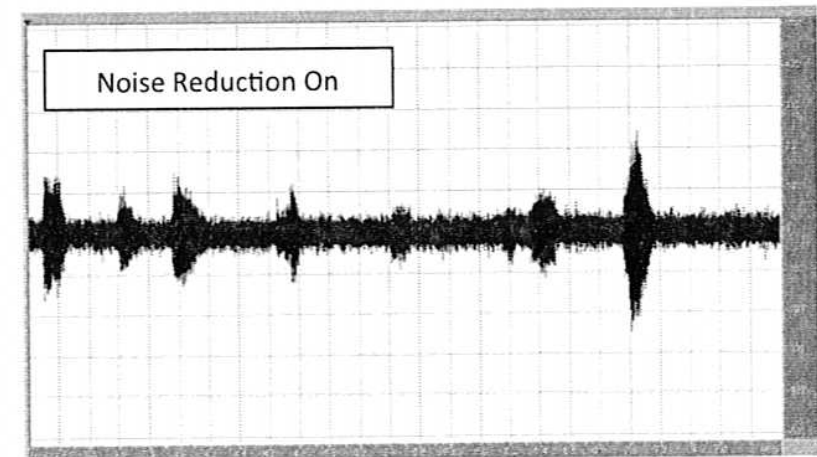
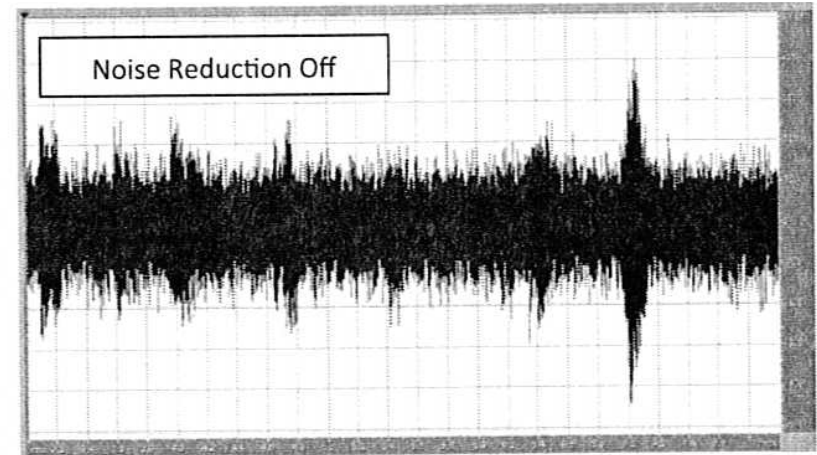


NOISE REDUCTION IN CONTEMPORARY HEARING AIDS



Noise Reduction

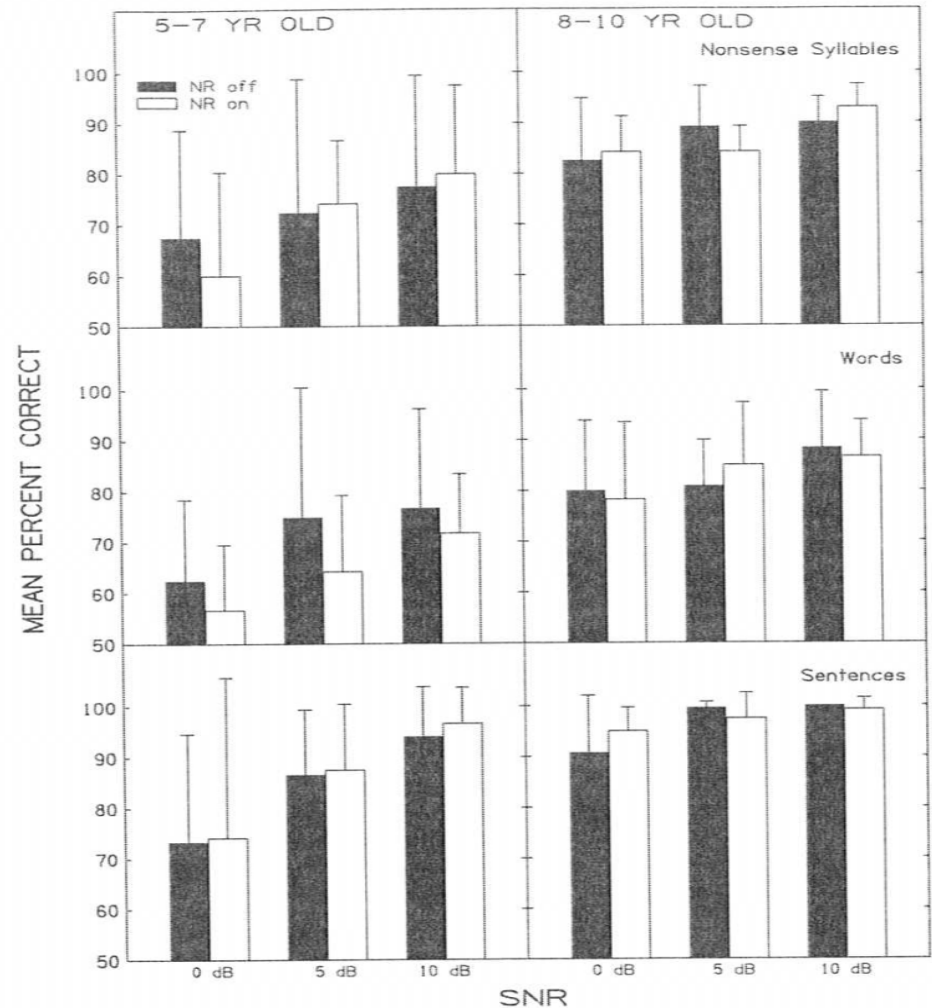
- Classifies the input as either speech or noise
- Reduces gain in channels in which the input to the aid is primarily noise (i.e., unfavorable SNR)
- Wide variety in implementation of NR across manufacturers
- **Studies with adults**
 - no change in speech recognition
 - Improvement in noise tolerance,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



Stelmachowicz et al., (2010) Ear and Hearing

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)



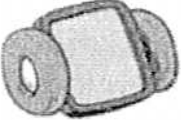










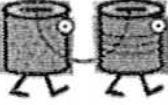



Stelmachowicz et al., (2010) Ear and Hearing

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

Pittman (2011b) J Speech Language Hearing Research

TOYS	FLOWERS	ALIENS
		
		
		
		
		

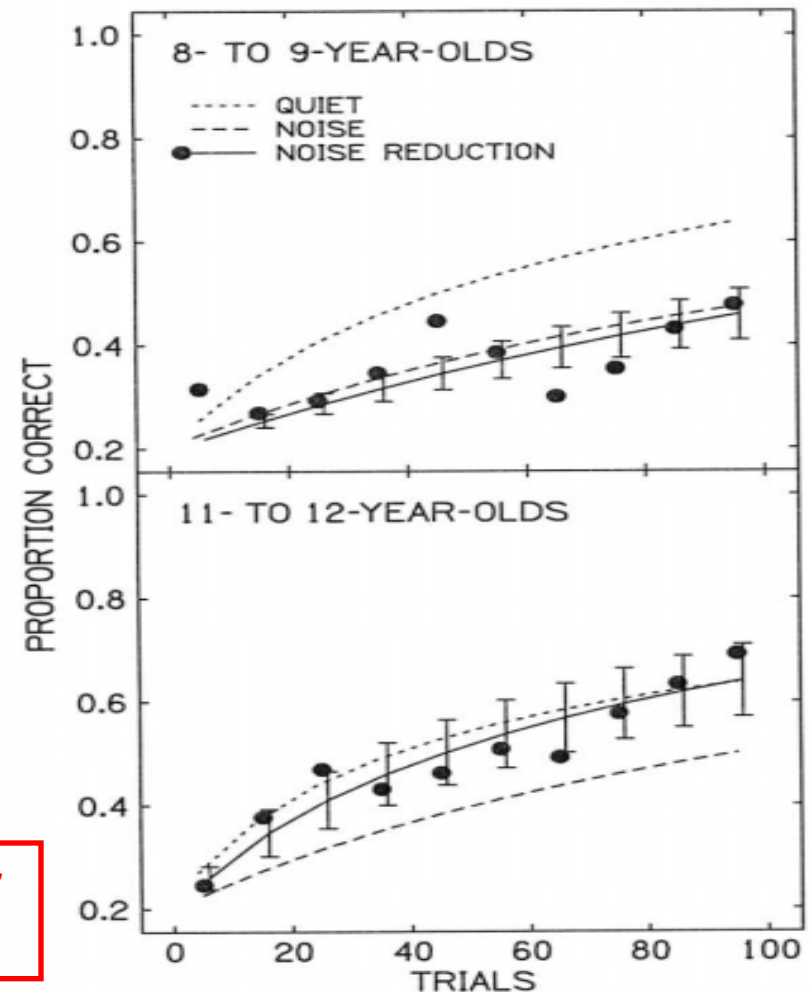
- 41 children with NH
- 26 children with mild to moderately severe HL
- 8-9 years old and 11-12 years old
- Evaluated ability to learn “nonsense” words associated with a picture
- With and without NR (-7 dB)

Pittman (2011) J Speech Language Hearing Research

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

J Am Acad Audiol 27:237–251 (2016)

Fitting Noise Management Signal Processing
Applying the American Academy of Audiology
Pediatric Amplification Guideline:
Verification Protocols

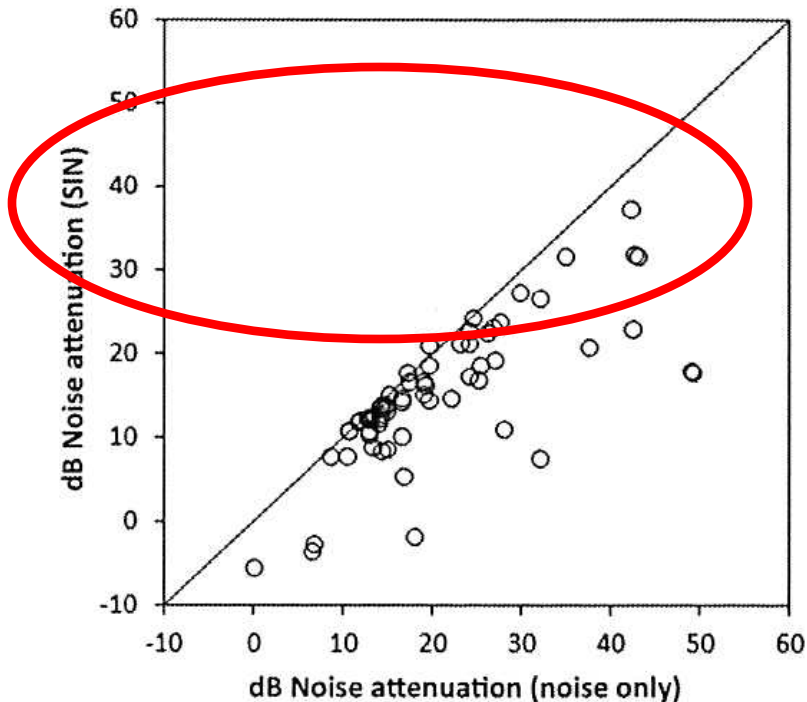
DOI: 10.3766/jaaa.15060

Susan Scollie*
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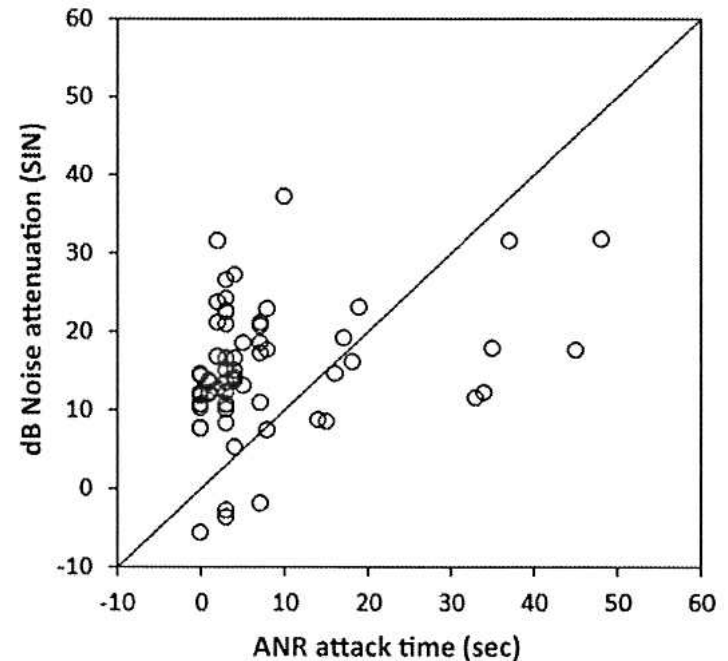
- Measured NR with clinical systems (e.g., Verifit) and research system for seven different hearing aids in order to describe variation in behavior of NR in modern hearing aids and with verification of NR by modern hearing aid analyzers

Scollie et al., 2016

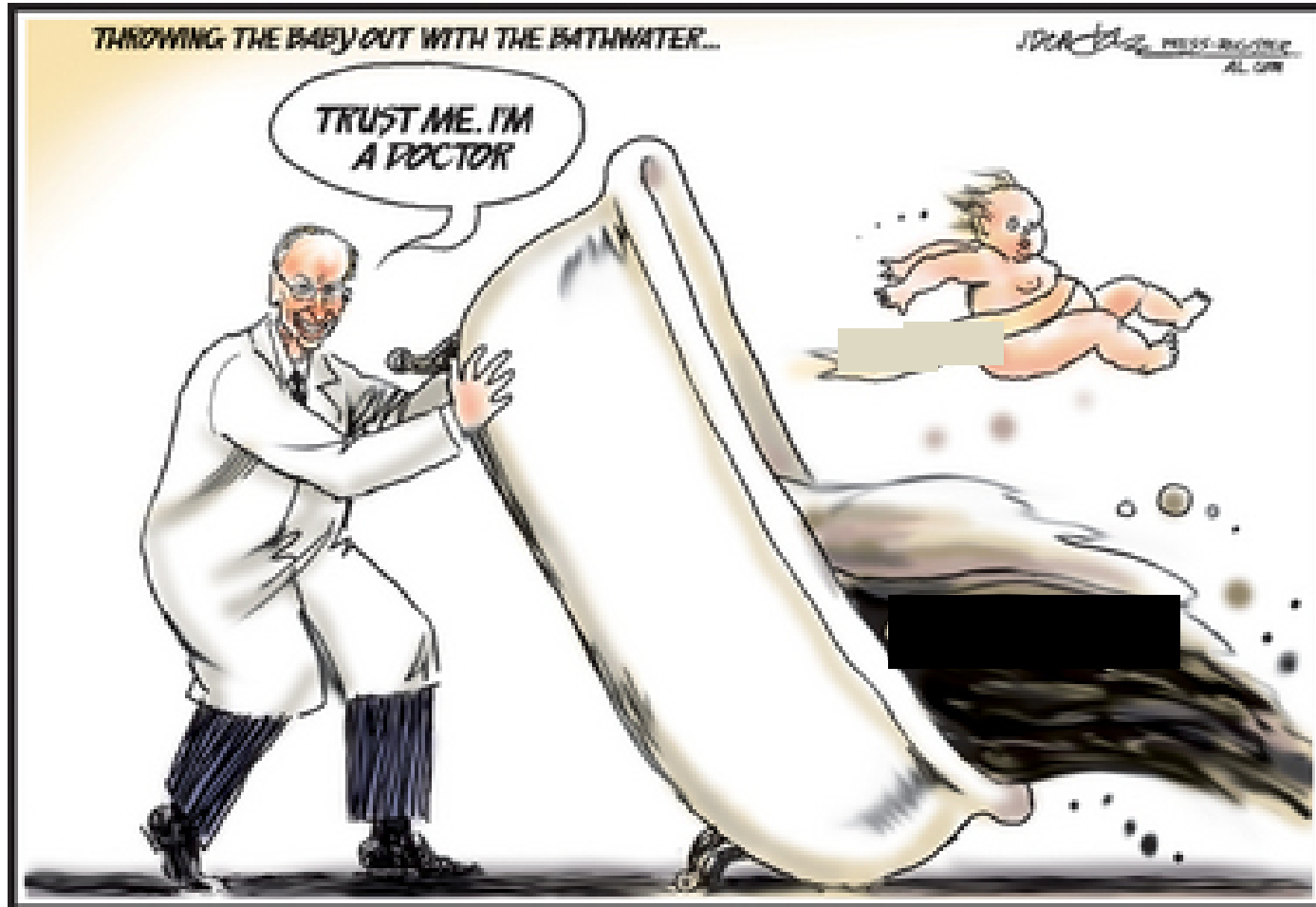
Considerable variability in NR as a function of hearing aid and as a function of test signal



Considerable variability in magnitude and speed of NR



Noise reduction magnitude ranges from 0 to 37 dB

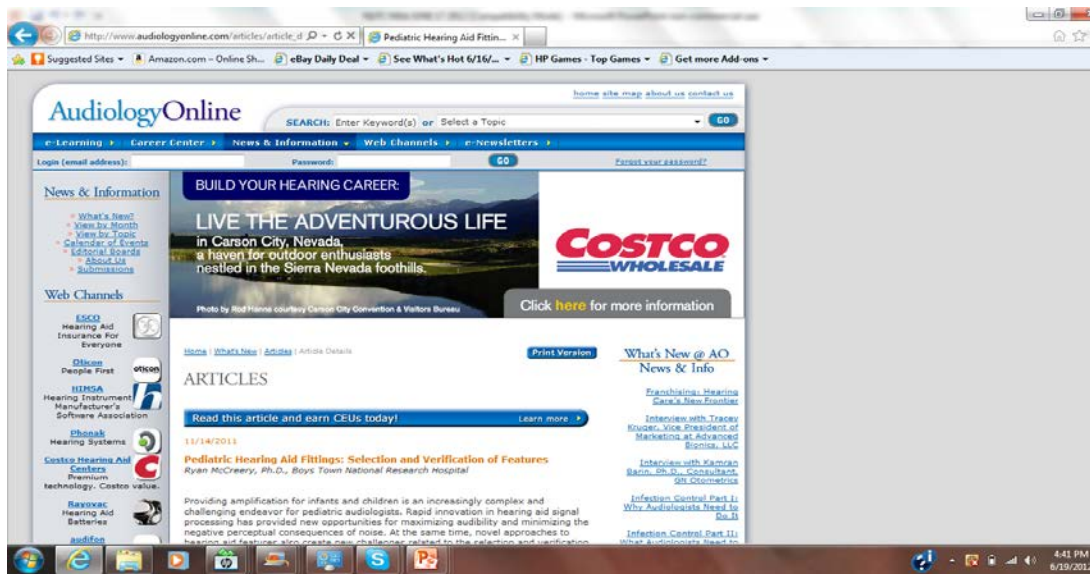


Noise Reduction for Children

- Inspired by
 - Stelmachowicz et al (2010)



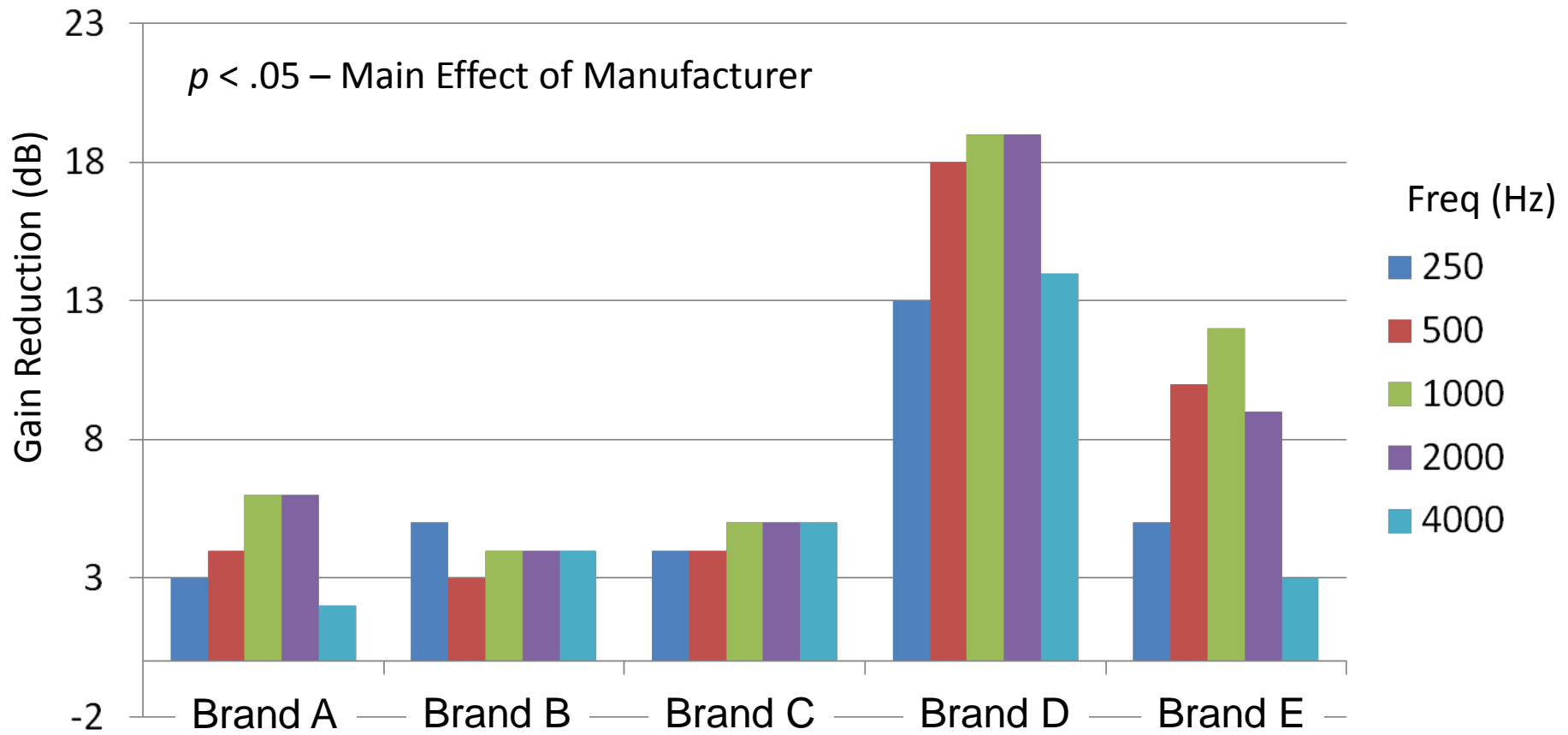
- McCreery (2011) – AudiologyOnline.com



Gain Reduction – Noise Only



“High-End Hearing Aids” – Moderate HL

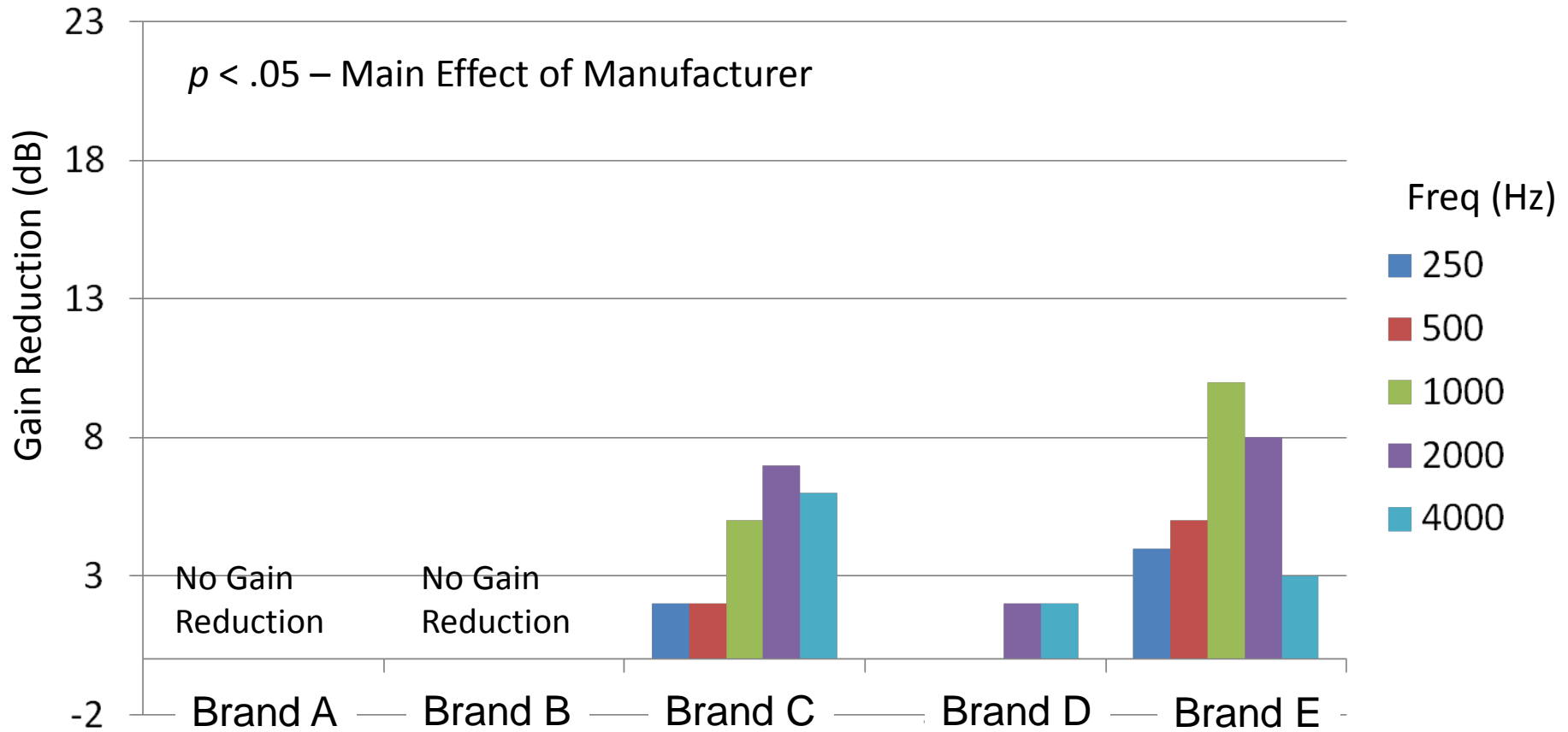


Pediatric Default NR Setting

Gain Reduction – Speech + Noise

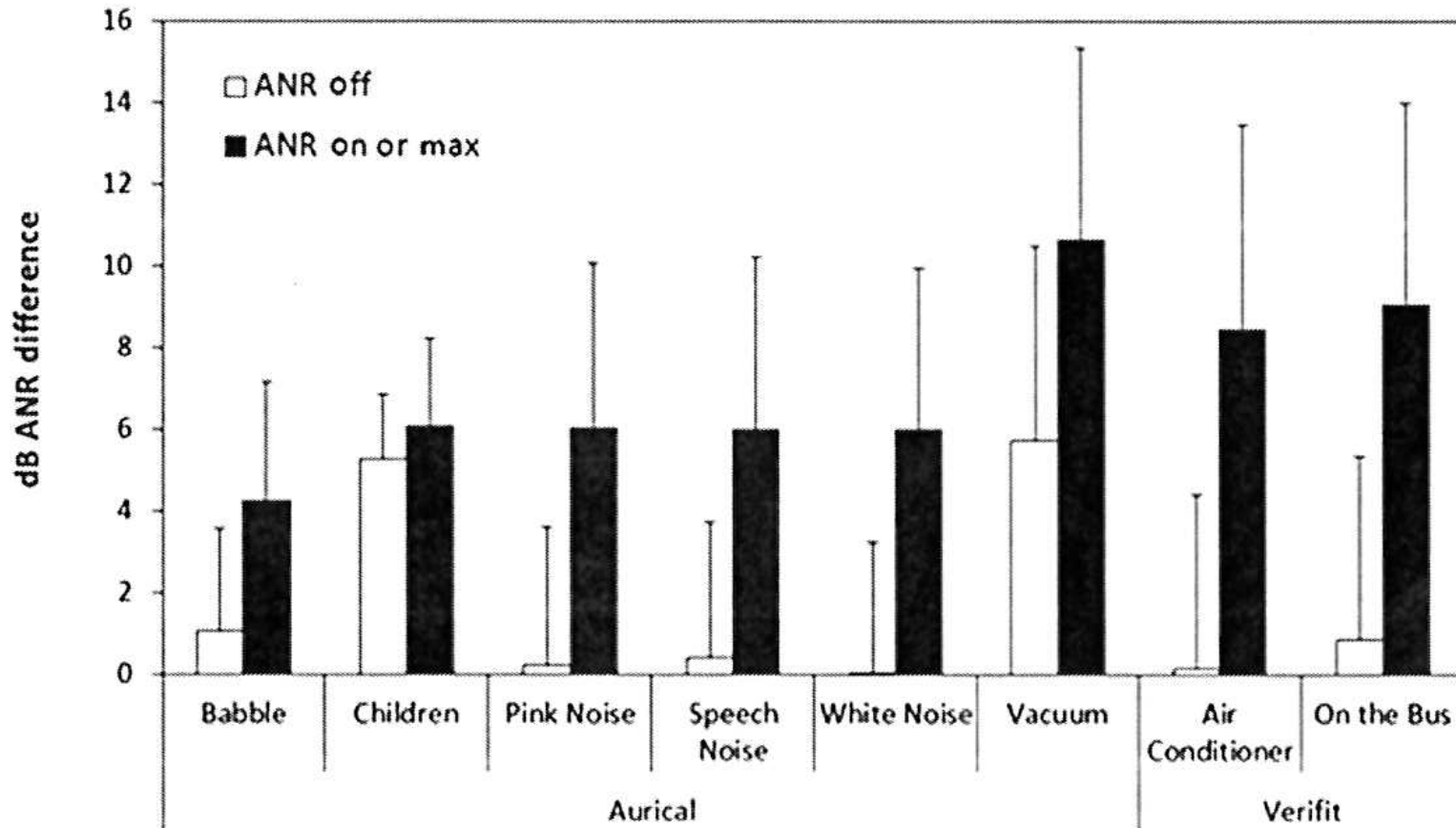


“High-End Hearing Aids” – Moderate HL



Pediatric Default NR Setting

Scollie et al., 2016



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
 - Ontario Infant Hearing Program Amplification Protocol (2014)
 - American Academy of Audiology Pediatric Amplification Guideline (2013)
 - Australian National Protocol for Paediatric Amplification (King, 2010)
 - Harvey Dillon's Hearing Aids textbook (Dillon, 2012)

16.4.4 Signal processing features

Each of the features in this section has been covered in detail in Chapters 7 and 8. The following discusses the applicability of these features to infants and young children.

Directional microphones

Switchable directional microphones are probably as useful for older children as they are for adults. Hearing aids permanently in directional mode are as unacceptable for infants and young children as they are for adults.

of directional microphones just as much as it limits their advantages. That is, just as directional microphones typically improve SNR by only around 2 to 3 dB when the wearer is looking in the general direction of the talker, they also decrease SNR by only around 2 to 3 dB when the wearer is looking away from the talker. Greater benefits, and presumably disadvantages, are observable if children are tested at close distances in artificial low-reverberation environments, such as test booths.⁶⁴⁵

Measurement of the looking behavior of children

...infants and young children should routinely be fit with advanced directional microphones.

...he realizes that it takes only a head-turn by the infant to switch the hearing aid to the other mode to be optimal.

...ver using directional microphones that at first seem like an appropriately simple solution, this solution means that the only hearing aids that significantly improve hearing in noisy places would be unavailable to the children who most need it - young children. As outlined in Section 16.4.1, young children need hearing aids if speech is to be intelligible to them. Infants and young children will have difficulty understanding speech when it is masked by noise, so it is worth finding a way to obtain the benefit of directional microphones when possible.

...signal caused by directional microphones has a low-distortion effect, similar to just a gain effect. Thus, the magnitude of the benefit (in decibels of SNR) change in the environment on benefit should be greater for infants and young children than that for older children or adults, as reviewed in Section 16.4.1. As directly observed in children,⁶⁴⁵ young children, who are still learning to listen, need the SNR more than anyone else.

...understand that current directional microphones are not all that directional, particularly in reverberation limits the disadvantages

...directional microphones, directional microphones on average improved SNR by 2.4 dB when the children looked in the general direction of the talker and decreased SNR by 1.6 dB when they looked away. The overall "net benefit" that a directional microphone could provide can then be calculated by weighting its effect on SNR by the proportion of time it has this effect. The resulting net benefit averaged across listening situations was a 0.02 dB decrease in SNR - a change so small to be of no consequence. Furthermore, the effect of the directional microphone was assessed in the absence of any compression, which as outlined in Section 7.3.3, partly reverses the decrease in signal level caused by a directional microphone when a wanted talker is to the rear or sides.

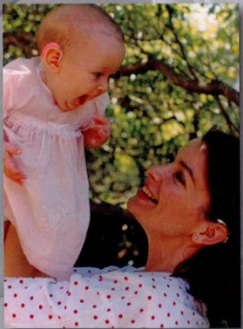
This nil result suggests that infants and young children should routinely be fit with advanced directional microphones, and they should receive considerable benefit from them, for the following reasons:

- The experimental results were obtained on normal-hearing children, and children with hearing loss wearing omni-directional microphones. It is likely (but by no means proven) that children wearing directional microphones will notice that looking at the talker improves the clarity of the signal and will adapt their behavior to look at the talker more often than children wearing omni-directional microphones. A study of 4 to 17-year old children in the classroom indicated that

Hearing Aids

Harvey Dillon

Second Edition

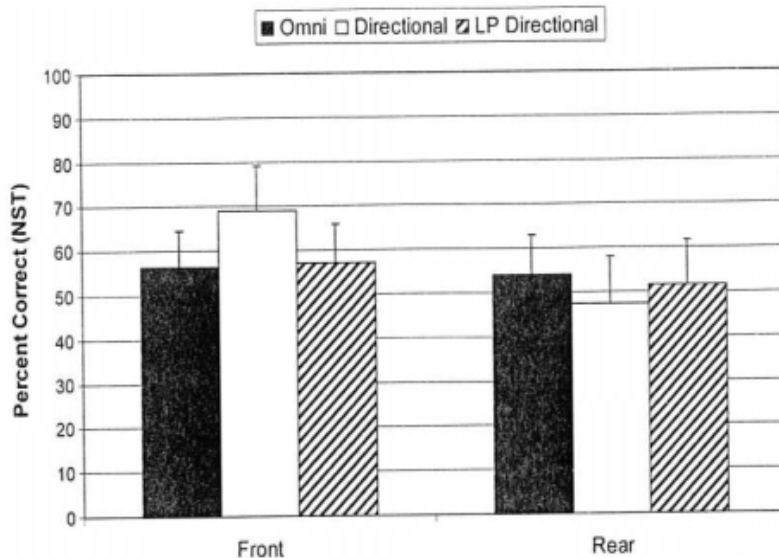


- What about the evidence?

-
- 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

Todd Ricketts at Sound Foundations

- 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



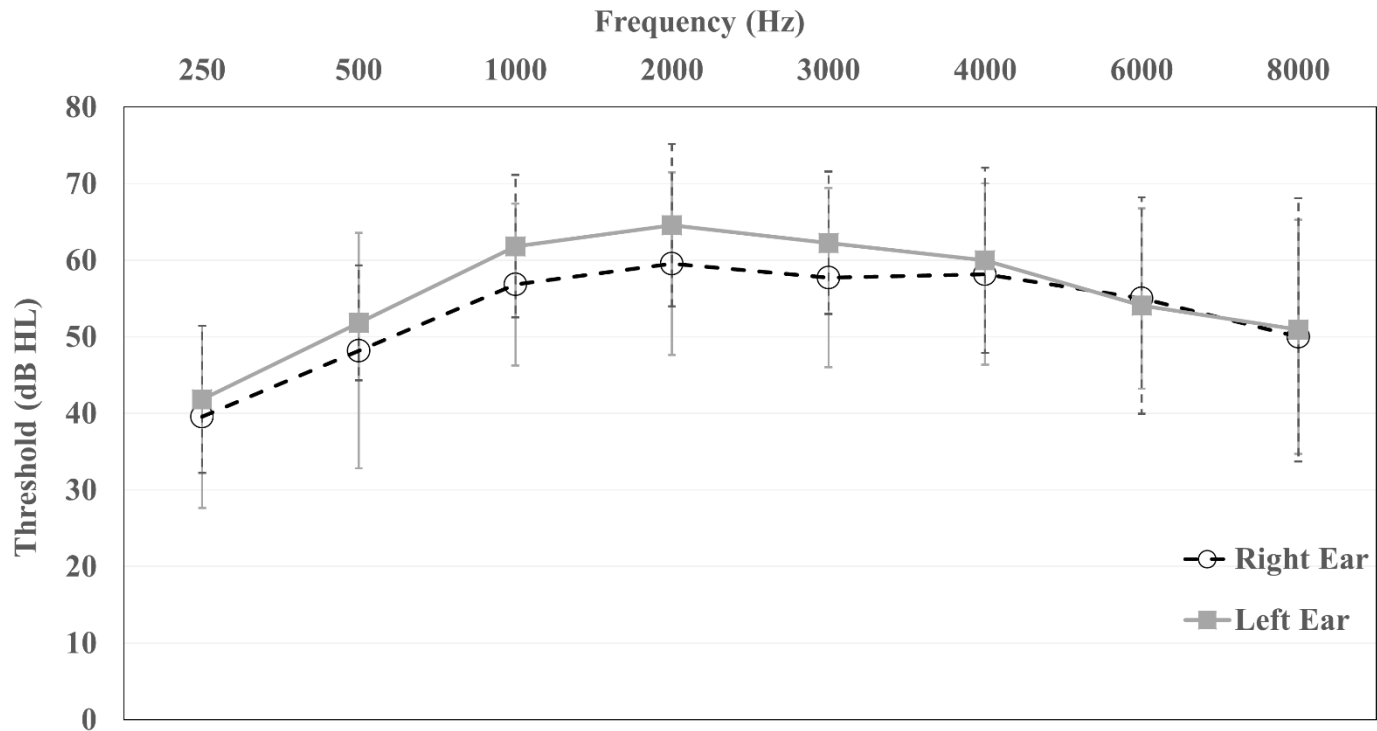
-
- **New Study of Automatic Noise Management Technology Designed for Children**

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

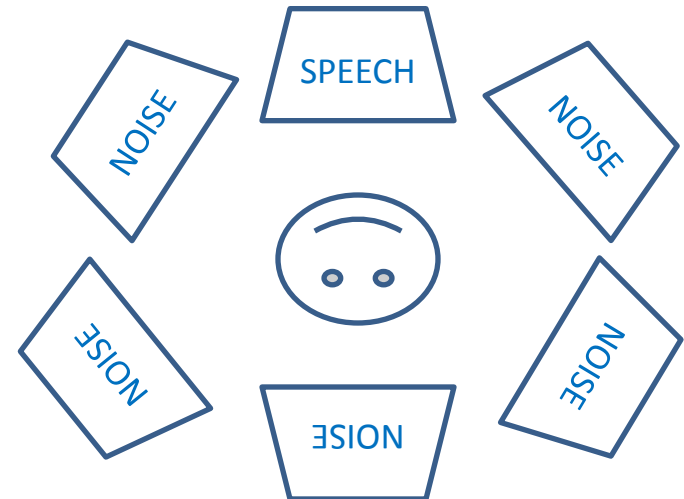


Automatic Noise Management Technology for Children

- 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)

Automatic Noise Management Technology for Children

- **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



Automatic Noise Management Technology for Children



- 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?

A_B A_B AB B_A B_A

1- Which program is more comfortable?

A_B A_B AB B_A B_A

2- Which program helps understand speech better?

A_B A_B AB B_A B_A

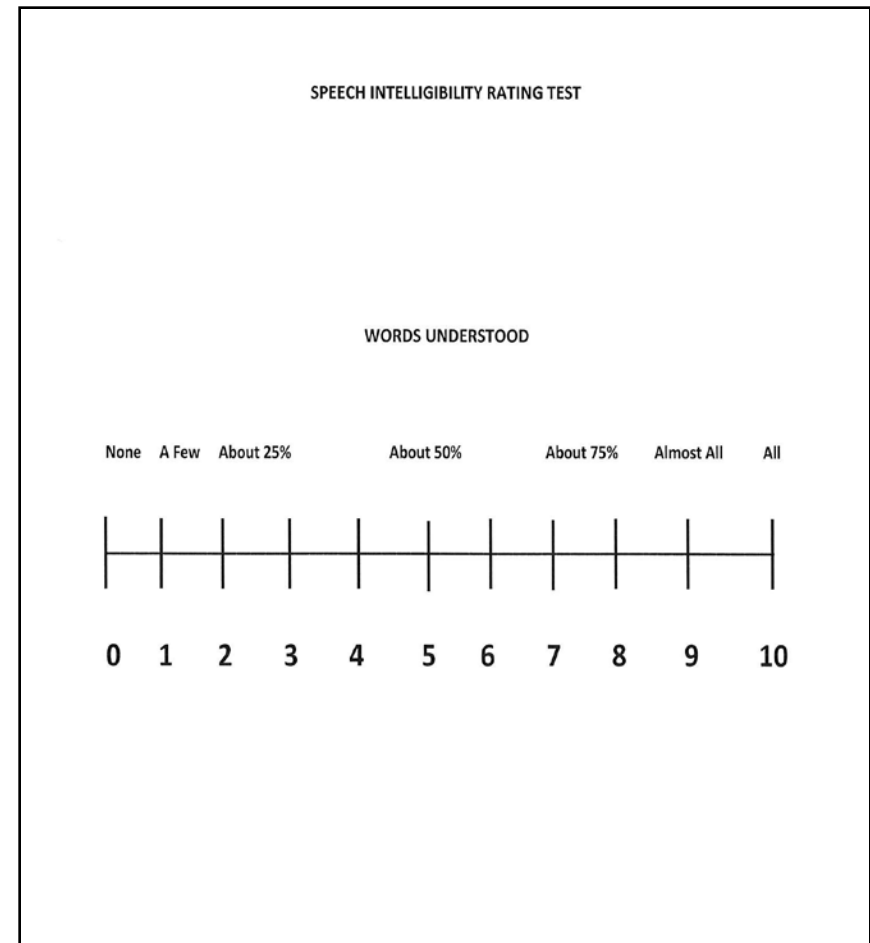
3- Which program makes the noise go away the most?

A_B A_B AB 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



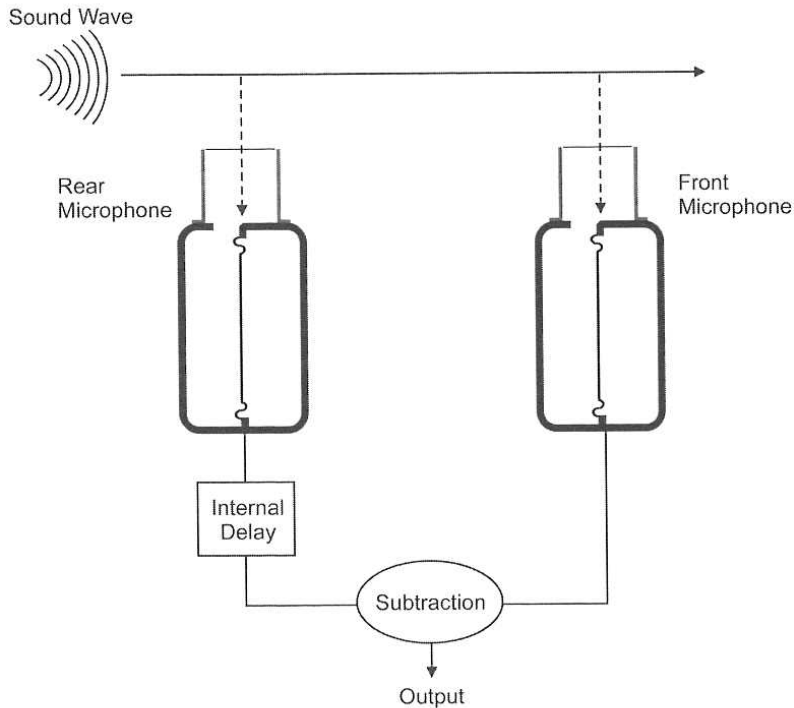
Automatic Noise Management Technology for Children



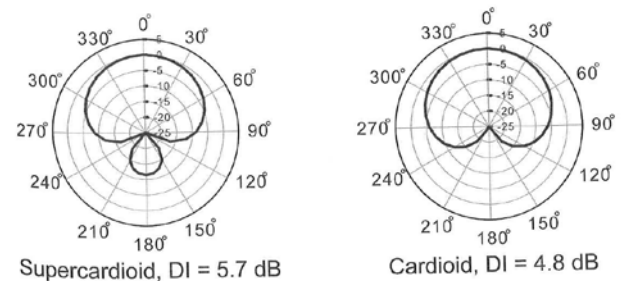
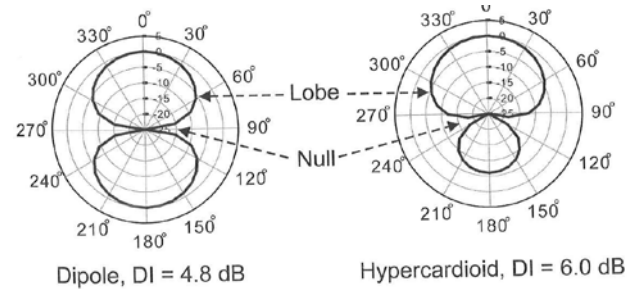
- **3 Hearing Aid Programs:**

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)

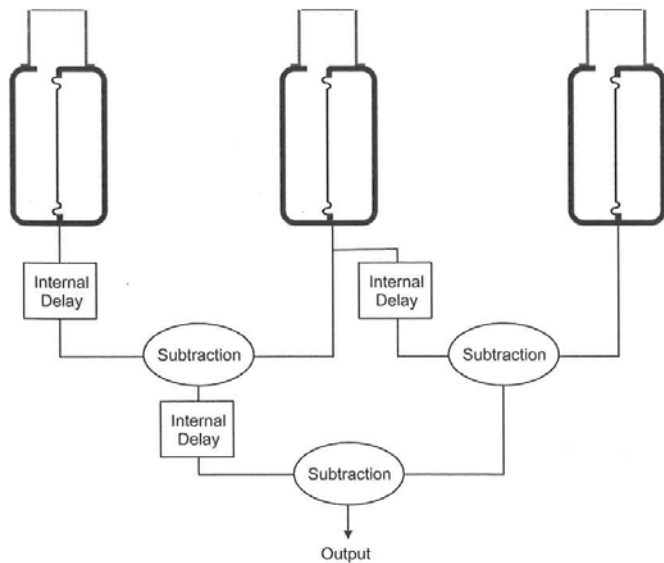
Dual-Mic Directional



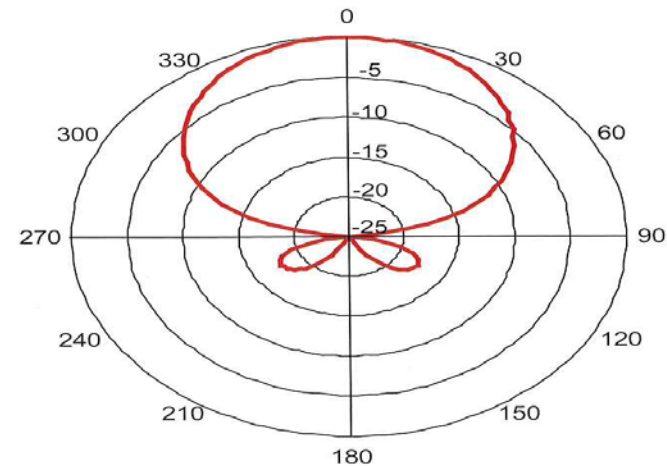
- Most all modern hearing aids and CI sound processors use single-ear, dual-mic directional systems
- These are known as 1st-order directional systems



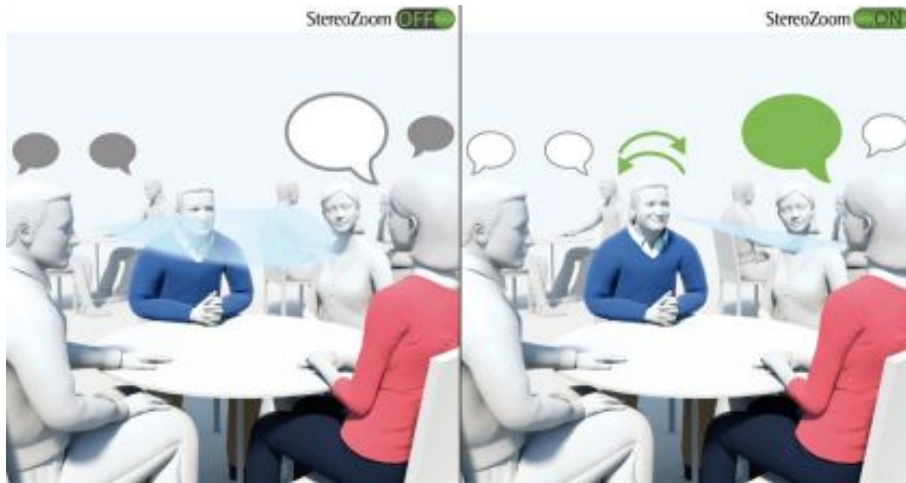
Higher-order Directional Systems



- The output of more than two mics may be combined to form higher-order directional systems
- 3 mics = 2nd Order; 4 mics = 3rd order; 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

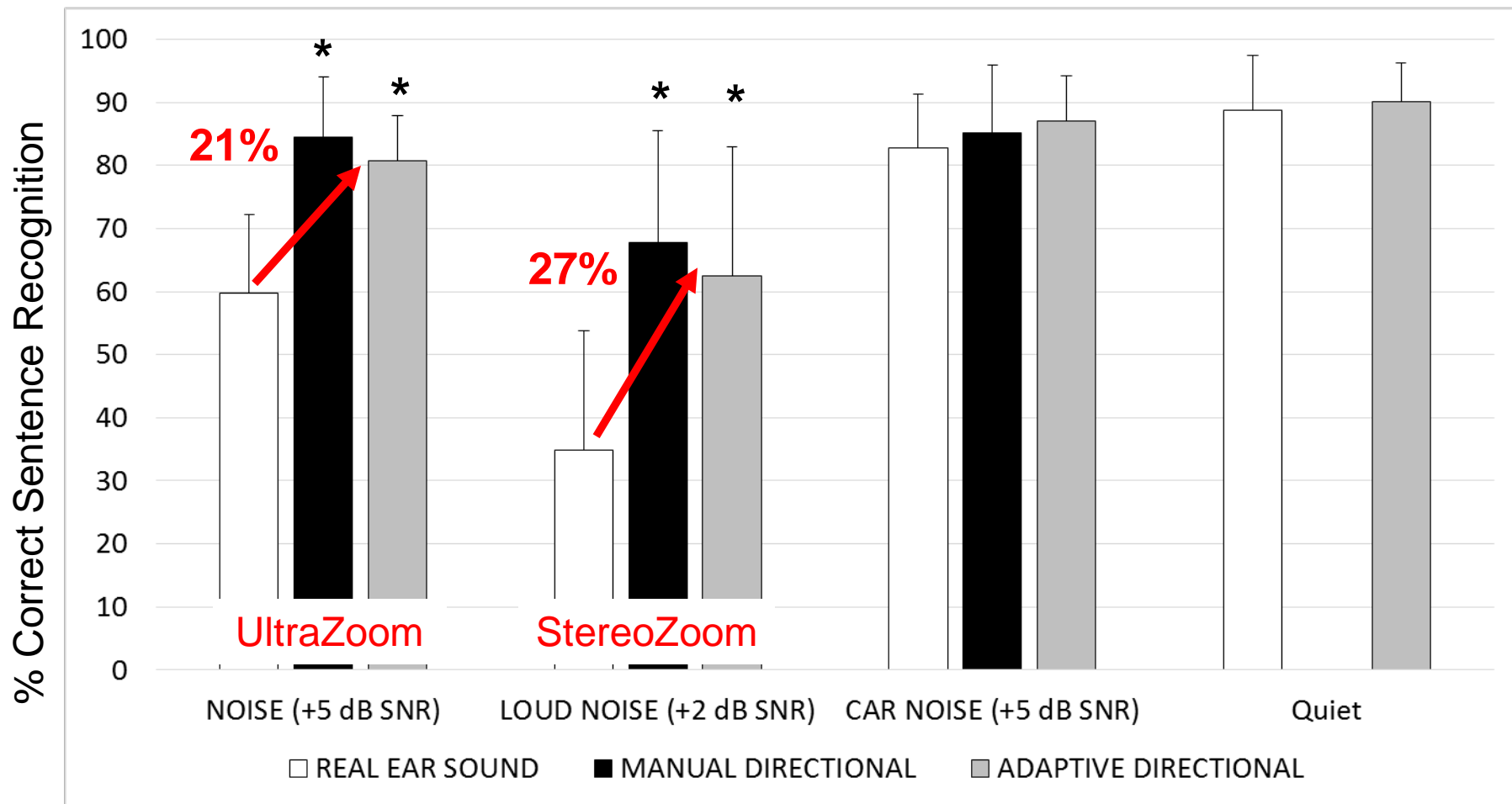
Automatic Noise Management Technology for Children



- 3 Hearing Aid Programs:

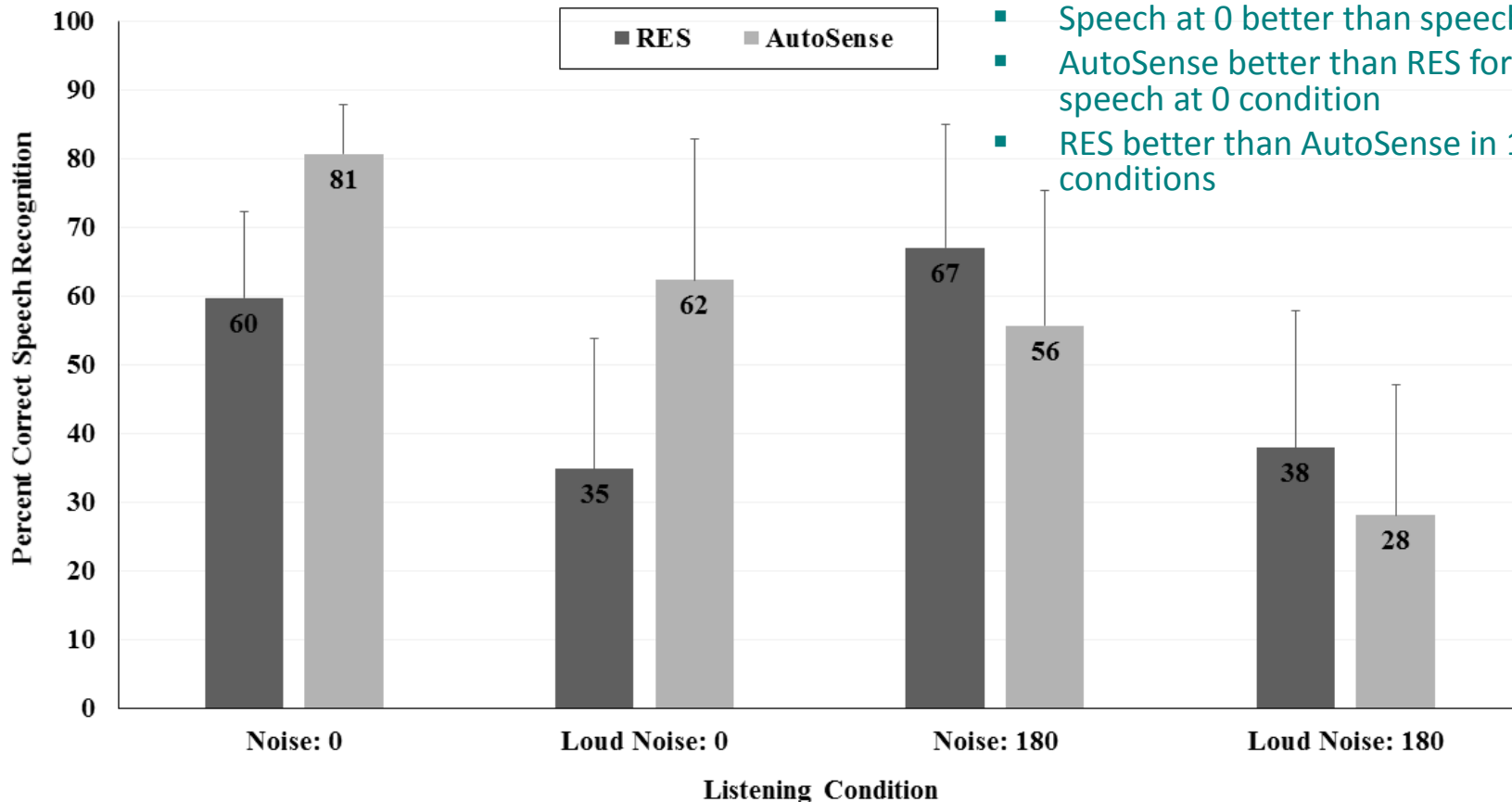
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3. Manual directional program: Condition-specific that was manually selected by the clinician.
 - Speech in Quiet: NR set to weak setting, microphone set to RES
 - Speech in Noise: NR set to weak, microphone set to UltraZoom (adaptive beamformer) – **1st-order Dual Mic**
 - Speech in Loud Noise: NR set to moderate, microphone set to StereoZoom, (binaural beamforming) – **3rd-order Binaural Beamformer**

Automatic Noise Management Technology for Children



Automatic Noise Management Technology for Children

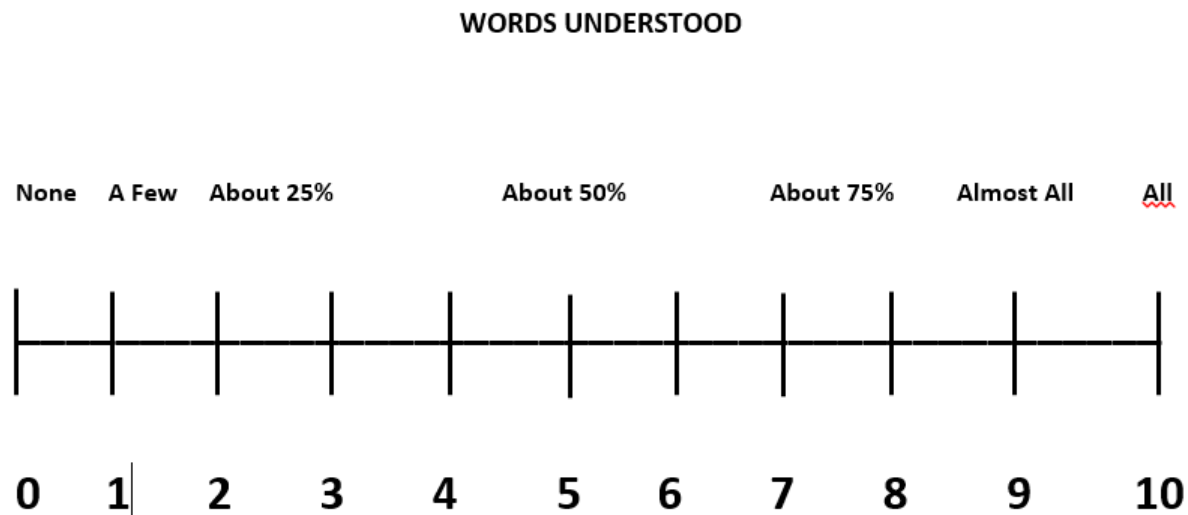
Wolfe et al, in press, JAAA



- **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

Automatic Noise Management Technology for Children

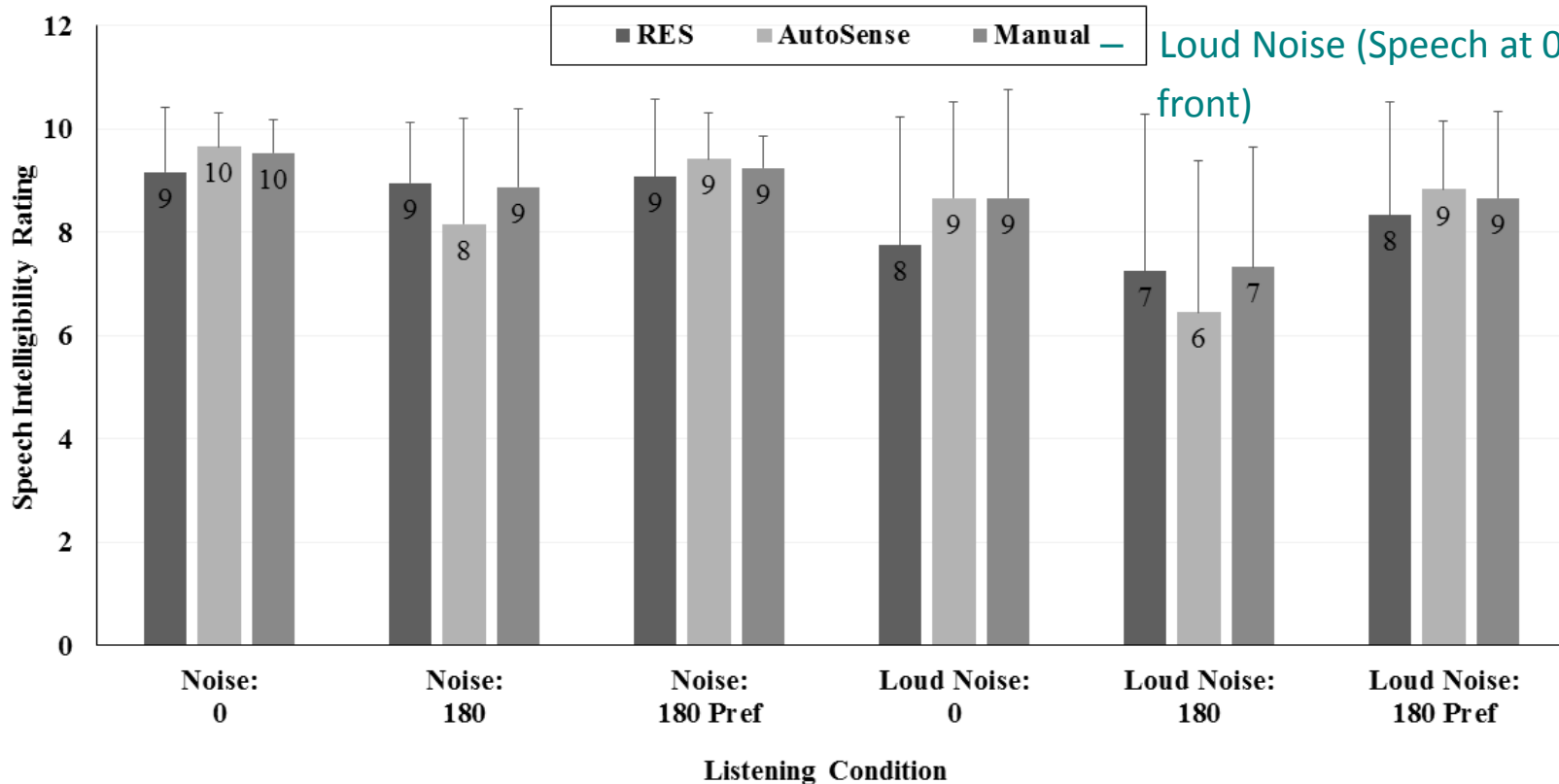
- **Speech Intelligibility Ratings:**



Automatic Noise Management Technology for Children

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)



Automatic Noise Management Technology for Children



- **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)
- $A_B = 2$
- $A_B = 1$
- $AB = 0$
- $B_A = -1$
- $B_A = -2$

Date: _____

Location: Restaurant

1- Which program sounds best?

A_B A_B AB B_A B_A

2- Which program is more comfortable?

A_B A_B AB B_A B_A

3- Which program helps understand speech better?

A_B A_B AB B_A B_A

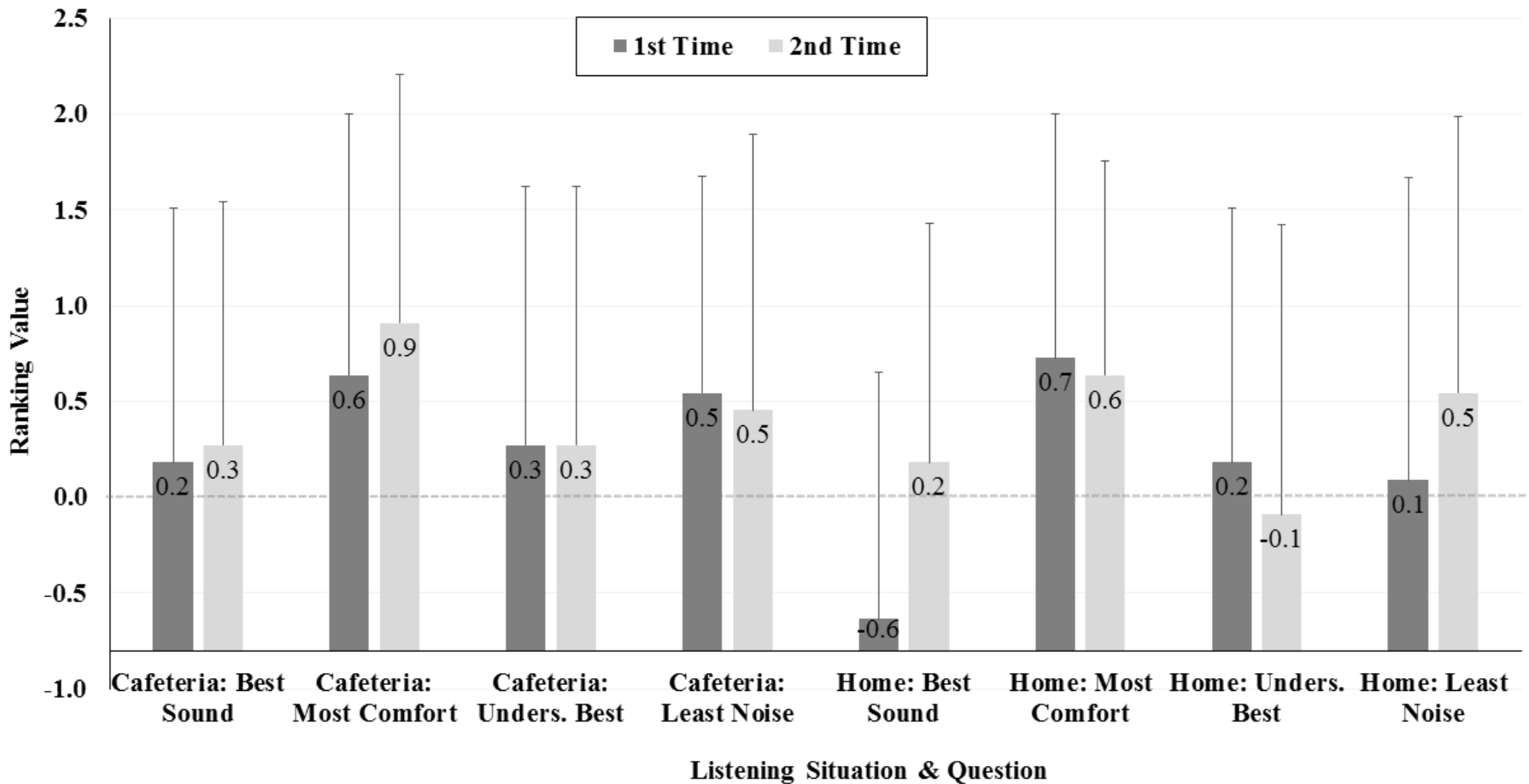
4- Which program makes the noise go away the most?

A_B A_B AB B_A B_A

Automatic Noise Management Technology for Children



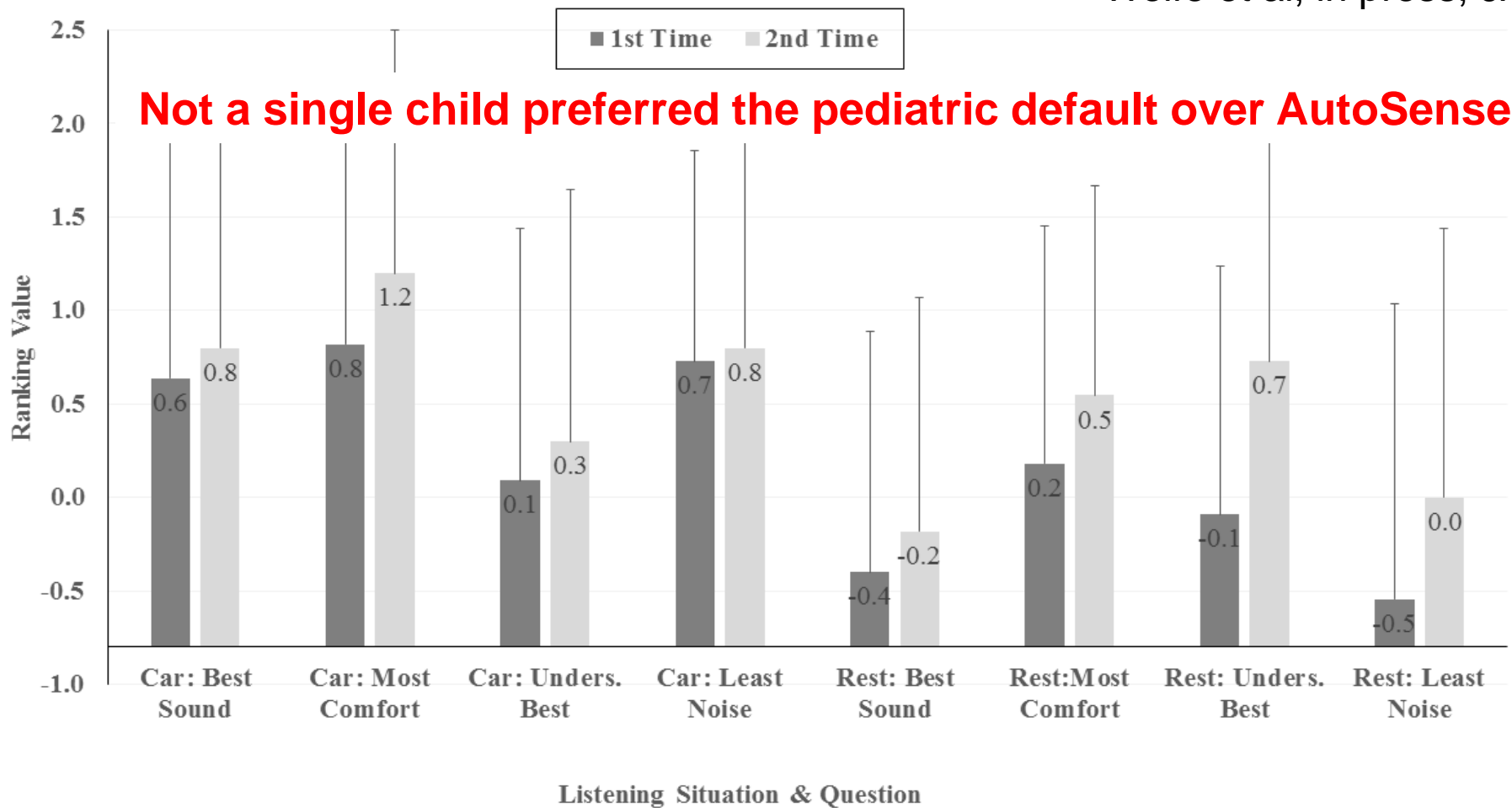
Wolfe et al, in press, JAAA



Most participants preferred AutoSense (positive ratings) over RES

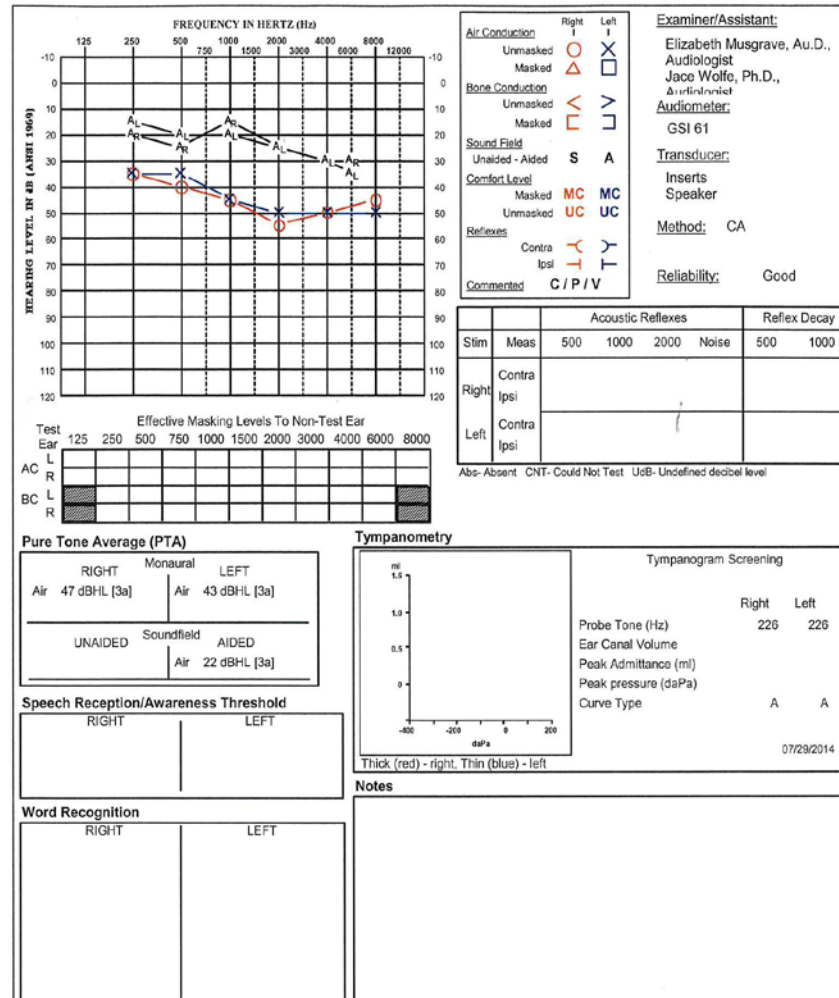
Automatic Noise Management Technology for Children

Wolfe et al, in press, JAAA



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 A_B AB B_A B_A

2- Which program is more comfortable?

A_B A_B AB B_A B_A

3- Which program helps understand speech better?

A_B A_B AB B_A B_A

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

A_B A_B AB B_A B_A

Comments: I like A better because
it is quieter. I like B better because it is clearer.
These hearing aids are really aiding me in life.
Thank you!

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
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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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- Erin Schafer, Ph.D., Audiologist
- Christine Jones, Lori Rakita, Manuela Feliner, & Michael Boretzki



Thank you for your attention!!!



Shoot for the moon!

www.heartsforhearing.org