HEARTS for HEARING

Hear Well or Hearsay? The Effectiveness of Modern Technologies for Improving Hearing Performance in Noise

Jace Wolfe, PhD

December 8, 2015

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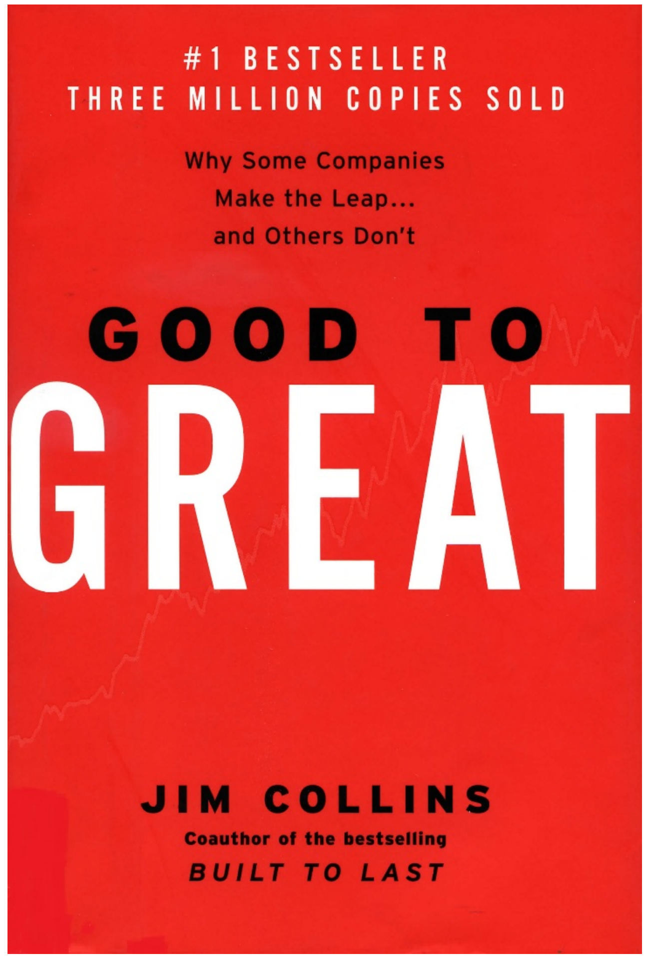
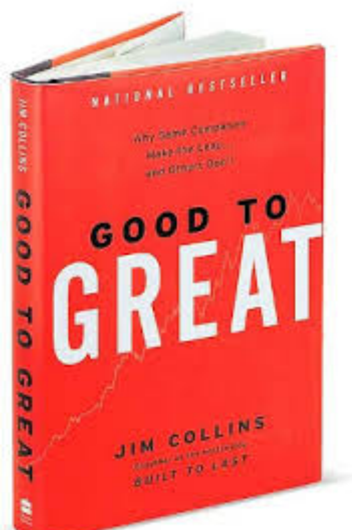
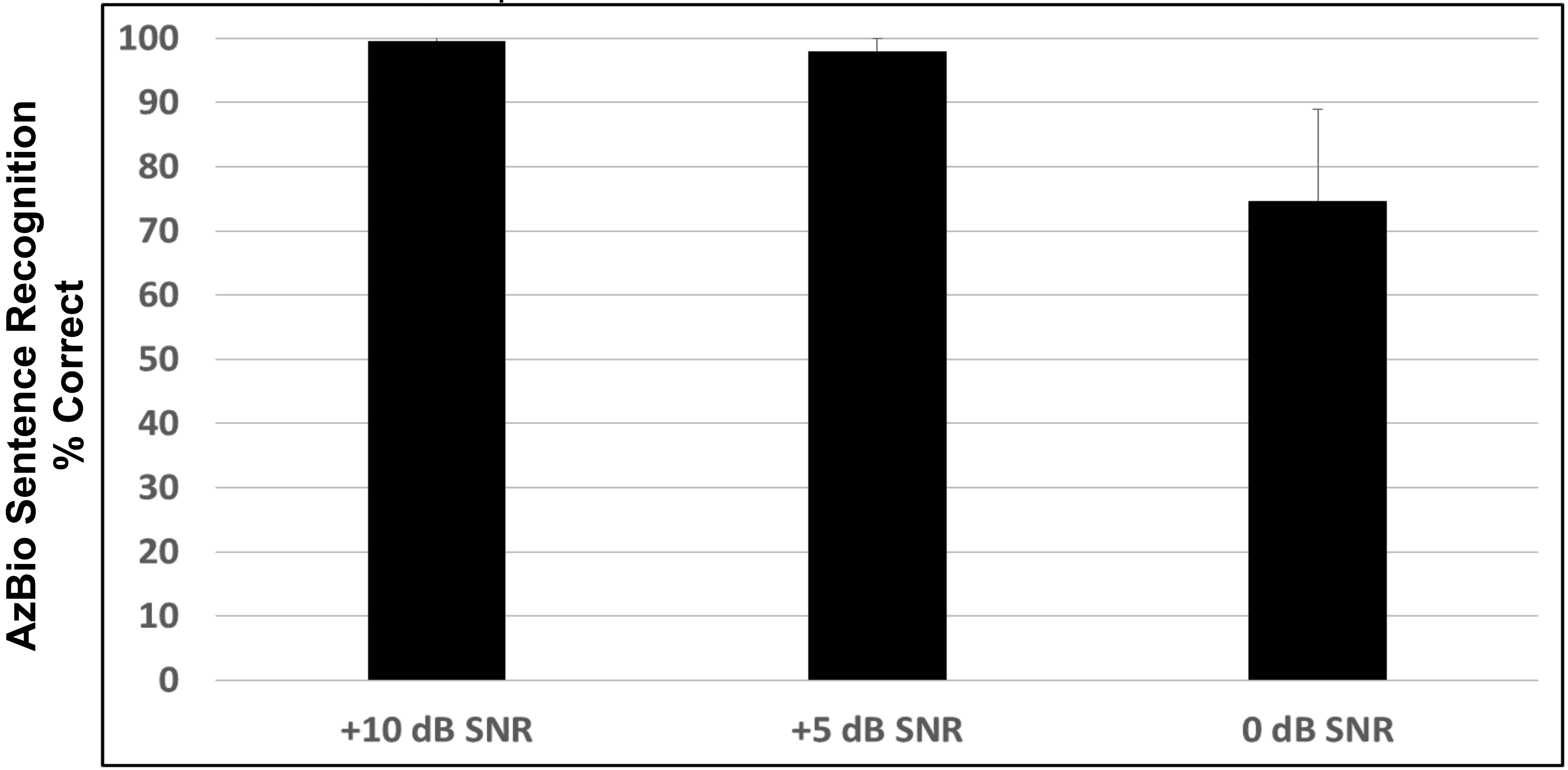




Good is the enemy of great.

What is great?

Wolfe et al., 2015, Unpublished Data



n = 10 Young Adult Normal Hearing Listeners

Not so great…

J Am Acad Audiol 23:501–509 (2012)

List Equivalency of the AzBio Sentence Test in Noise for Listeners with Normal-Hearing Sensitivity or Cochlear Implants

DOI: 10.3766/jaaa.23.7.2

Erin C. Schafer*
Jody Pogue*
Tyler Milrany*

Abstract

Background: Speech recognition abilities of adults and children using cochlear implants (CIs) are significantly degraded in the presence of background noise, making this an important area of study and assessment by CI manufacturers, researchers, and audiologists. However, at this time there are a limited number of fixed-intensity sentence recognition tests available that also have multiple, equally intelligible lists in noise. One measure of speech recognition, the AzBio Sentence Test, provides 10-talker babble on the commercially available compact disc; however, there is no published evidence to support equivalency of the 15-sentence lists in noise for listeners with normal hearing (NH) or CIs. Furthermore, there is limited or no published data on the reliability, validity, and normative data for this test in noise for listeners with CIs or NH.

Purpose: The primary goals of this study were to examine the equivalency of the AzBio Sentence Test lists at two signal-to-noise ratios (SNRs) in participants with NH and at one SNR for participants with CIs. Analyses were also conducted to establish the reliability, validity, and preliminary normative data for the AzBio Sentence Test for listeners with NH and CIs.

Research Design: A cross-sectional, repeated measures design was used to assess speech recognition in noise for participants with NH or CIs.

Study Sample: The sample included 14 adults with NH and 12 adults or adolescents with Cochlear Freedom CI sound processors. Participants were recruited from the University of North Texas clinic population or from local CI centers.

Data Collection and Analysis: Speech recognition was assessed using the 15 lists of the AzBio Sentence Test and the 10-talker babble. With the intensity of the sentences fixed at 73 dB SPL, listeners with NH were tested at 0 and −3 dB SNRs, and participants with CIs were tested at a +10 dB SNR. Repeated measures analysis of variance (ANOVA) was used to analyze the data.

Results: The primary analyses revealed significant differences in performance across the 15 lists on the AzBio Sentence Test for listeners with NH and CIs. However, a follow-up analysis revealed no significant differences in performance across 10 of the 15 lists. Using the 10, equally-intelligible lists, a comparison of speech recognition performance across the two groups suggested similar performance between NH participants at a −3 dB SNR and the CI users at a +10 SNR. Several additional analyses were conducted to support the reliability and validity of the 10 equally intelligible AzBio sentence lists in noise, and preliminary normative data were provided.

Conclusions: Ten lists of the commercial version of the AzBio Sentence Test may be used as a reliable and valid measure of speech recognition in noise in listeners with NH or CIs. The equivalent lists may be used for a variety of purposes including audiological evaluations, determination of CI candidacy, hearing aid and CI programming considerations, research, and recommendations for hearing assistive technology. In addition, the preliminary normative data provided in this study establishes a starting point for the creation of comprehensive normative data for the AzBio Sentence Test.

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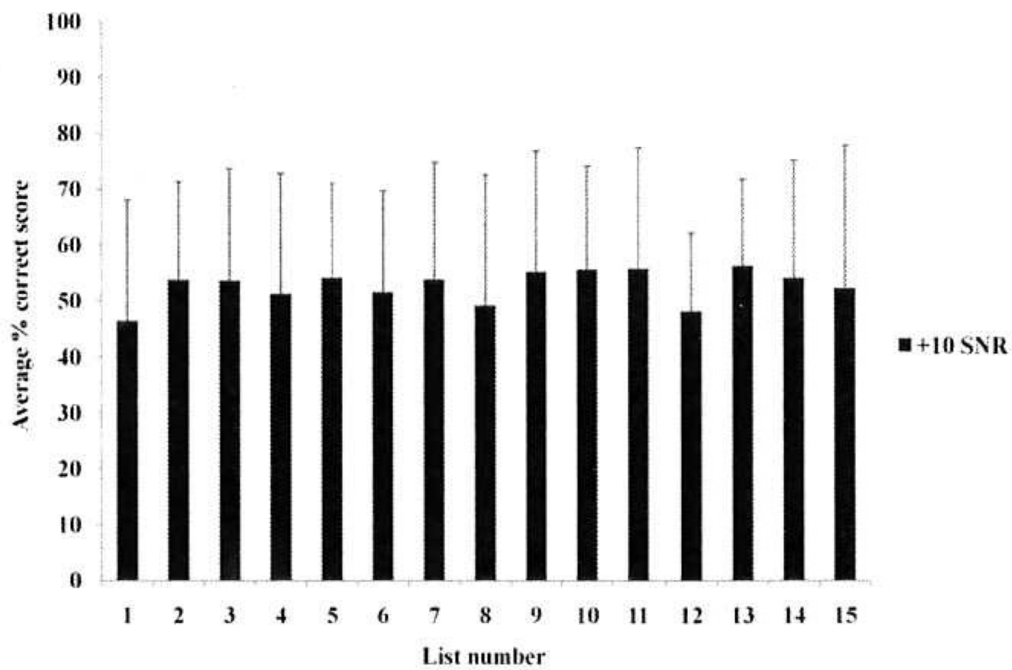
Preliminary data from this study was presented in a research poster at AudiologyNOW! 2011, Chicago, IL.

Listeners with Cochlear Implants

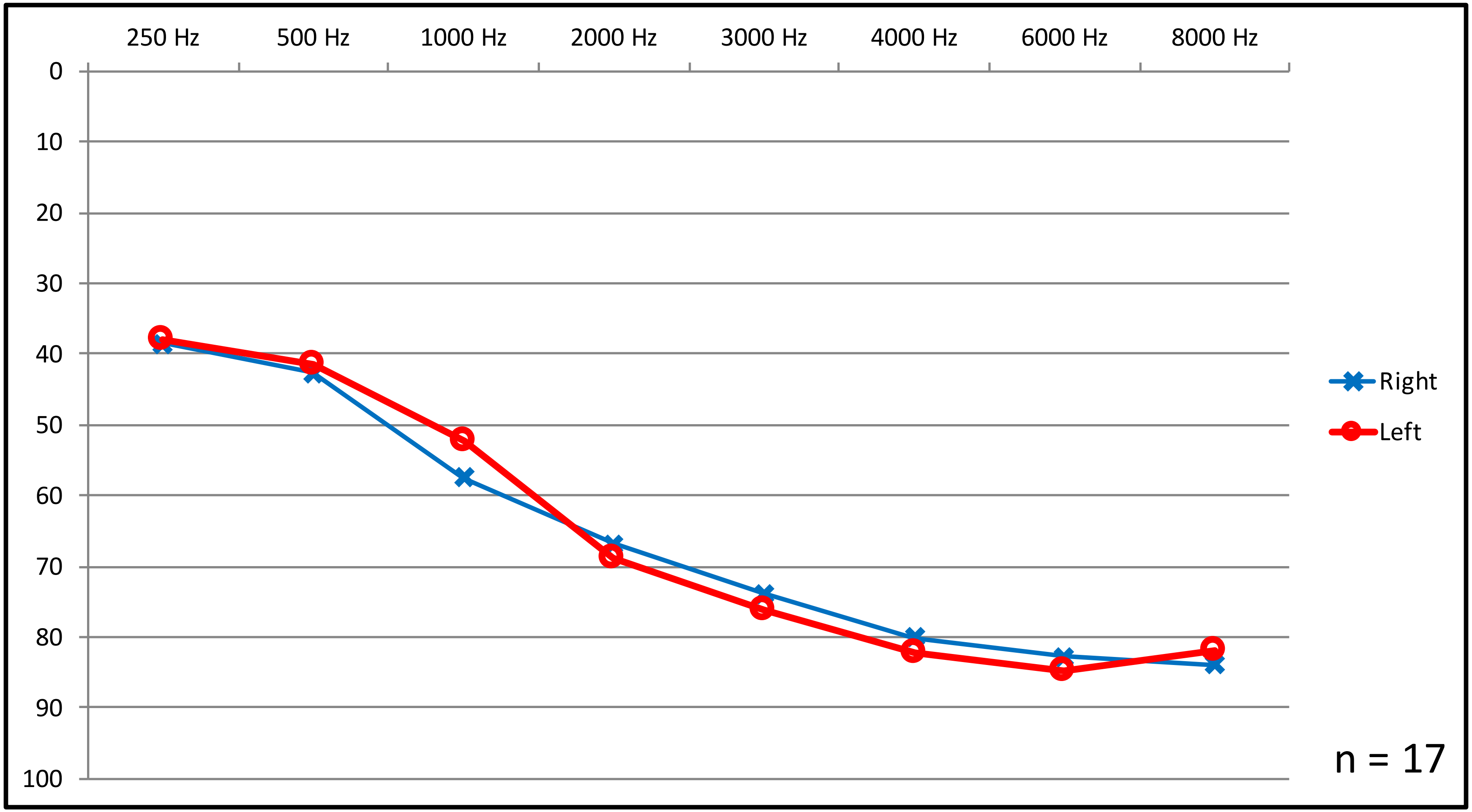
AzBio Sentences



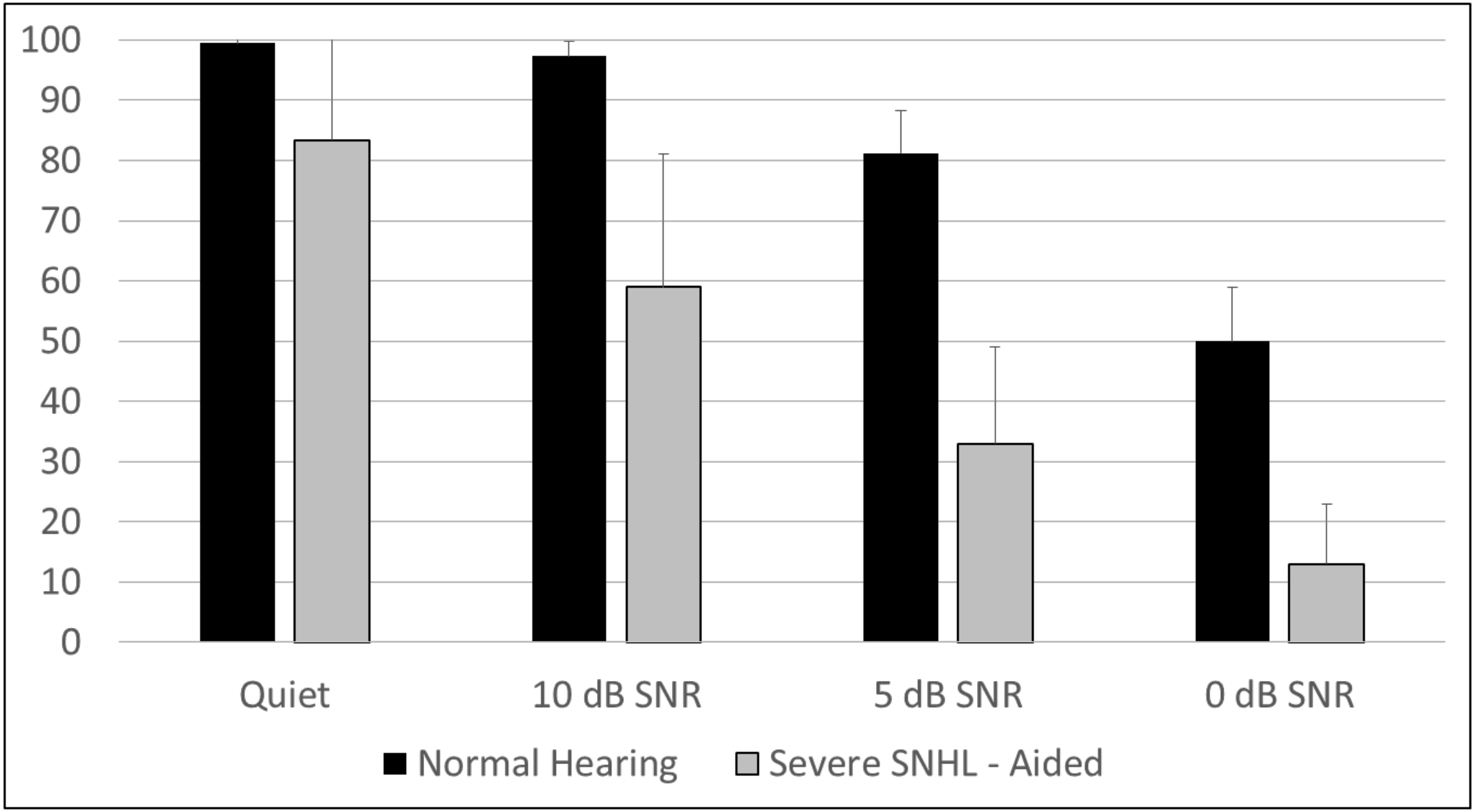
n = 12

Schafer et al., 2012

Hearing Aid Wearers



AzBio Sentence Recognition



From Good to Great…

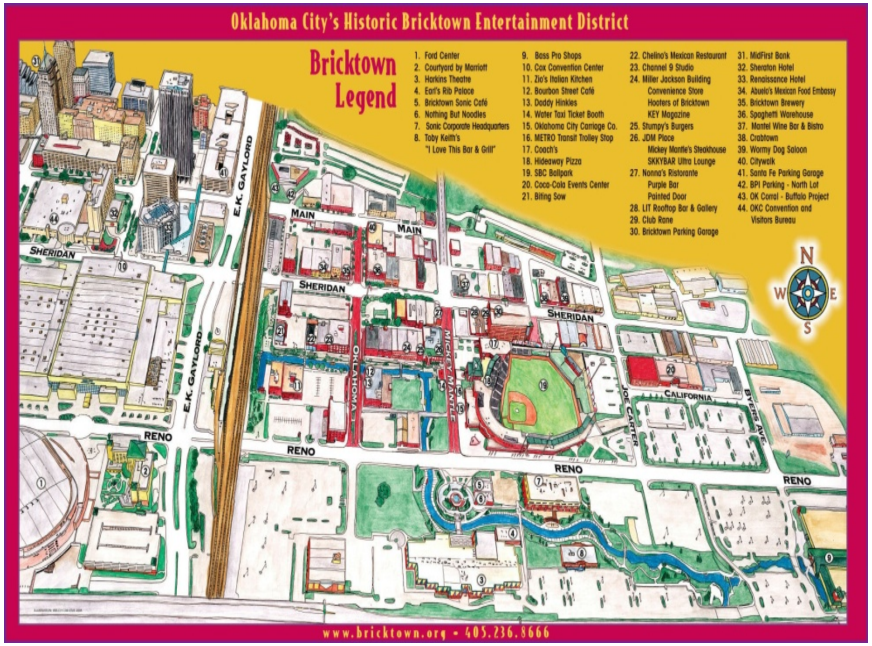
- Hearing aid wearers with severe hearing loss score about 30% correct on sentence recognition testing at a 5 dB SNR
- Approximately 37.5 million Americans have hearing loss impacting communication (NIDCD)
- Approximately 1.2 million persons with severe to profound hearing loss in the USA (American Academy of Audiology)
- Approximately 26 million persons with severe to profound hearing loss worldwide
- Approximately 120,000 Americans have cochlear implants (NIDCD)

HEARTS for HEARING

Make the World Great Again!

Road Map

- Points of Discussion
  - Identifying Contemporary Technologies That Facilitate Great Outcomes
  - Results of Studies Evaluating Contemporary Technology
  - Clinical Tips



A Noisy World!

HEARTS for HEARING

The SNR in these environments is typically -5 to +5 dB

- Living Room:
  - 37 dB A (with A.C. = 52 dBA)
- Classroom:
  - 63 dBA
- Dr.'s Waiting Room (4:00 pm):
  - 76 dBA
- Public Transportation:
  - 79 dBA
- Chili's Restaurant:
  - 81 dBA
- OKC Thunder Basketball:
  - 100 dBA

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Crukley et al., 2011

An Exploration of Non-Quiet Listening at School

Jeffery Crukley, Ph.D.
Susan Scollie, Ph.D.
Vijay Parsa, Ph.D.
University of Western Ontario
London Ontario Canada

The first goal of this study was to describe acoustic properties across an entire day in each of three educational environments: daycare (pre-kindergarten), an elementary school (kindergarten to grade 8), and a high school (grades 9 through 12). Instructional and non-instructional listening situations were included in this description. Second, we classified the various listening situations experienced by the cohorts at each school. Three sites participated in this study. At each site, empty room measurements were obtained, including noise floor and reverberation levels, across the various rooms frequently occupied by the participating cohorts of children. Next, the first author followed the cohorts throughout their regular school routines, recording sound level data with a dosimeter and documenting observations of the types of listening situations encountered by the children. Noise floor, reverberation, and sound levels were compared to classroom standards and large scale classroom studies. The cohorts in this study encountered highly variable acoustic environments throughout the day, for signal levels, noise sources, and reverberation properties. These results have implications for digital signal processing and hearing instrument fitting approaches for school-age children. Furthermore, the results of this exploratory study may impact on future research on classroom acoustics.

Introduction

The purpose of the current study was to gather detailed information about the school-day listening environments of three cohorts of children in mainstream educational environments. This study served as a precursor to a larger study investigating hearing instrument fitting strategies for children in non-quiet listening environments and situations. Modern hearing instruments typically offer some combination of frequency-gain adjustment, directional microphones, and digital noise reduction (DNR) with the goal of providing better speech recognition and listening comfort/tolerance in noise. While research has demonstrated that directional microphones can improve children's speech recognition in noise performance (Auriemmo et al., 2009; Gravel, Fausel, Liskow, & Chobot, 1999; Kuk, Kollofski, Brown, Melum, & Rosenthal, 1999), the use of DNR with children has not demonstrated any measureable improvement (Pittman, 2011; Stelmachowicz et al., 2010). These results are consistent with similar findings in adult listeners, and have led to mixed recommendations regarding the use of directional microphones and DNR in pediatric hearing instrument fittings. Some guidelines do not recommend using these features (AAA, 2003), whereas others consider them viable options (Bagatto, Scollie, Hyde, & Seewald, 2010; CASLPO, 2002; Foley, Cameron, & Hostler, 2009) or recommend directional microphones universally (King, 2010).

As part of an overall project investigating strategies to improve children's hearing instrument fittings for non-quiet listening, the current study explored the daily listening experiences of children over an entire school day. This exploration included situations beyond the classroom situation of listening to a teacher. This may be an informative first step in determining optimal signal processing for children in non-quiet environments.

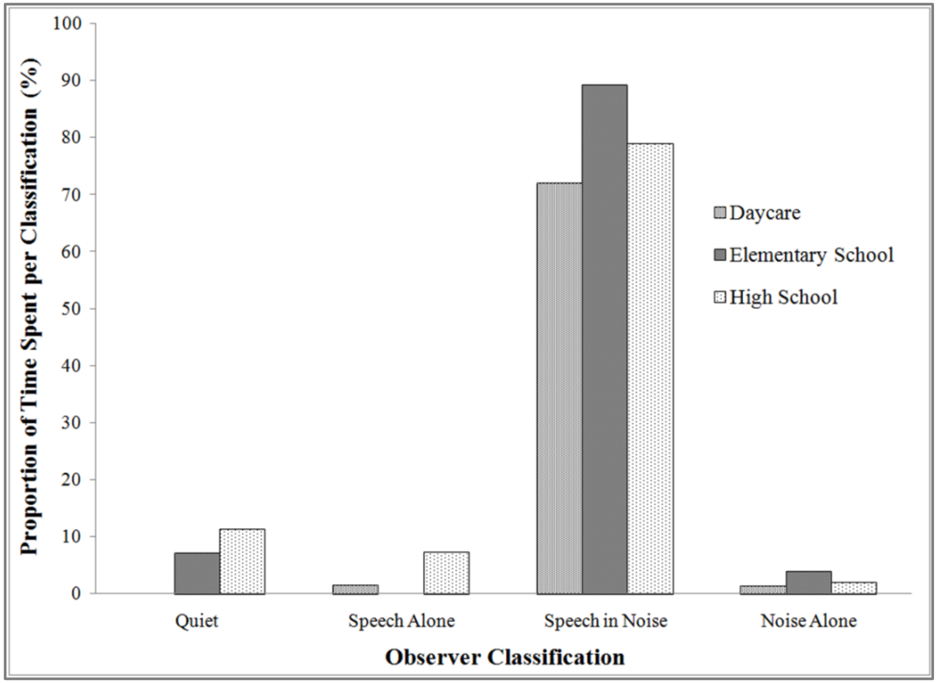
Studies of adults who wear hearing instruments have applied the concept of auditory ecology (Gatehouse, Elberling, & Naylor, 1999; Gatehouse, Naylor, & Elberling, 2003, 2006a, b), a concept in which the sound levels across a real-life, real-time sample from an individual hearing instrument wearer are used to inform hearing instrument signal processing choices. This study used an auditory ecology measurement approach in a small number of classroom cohorts. We measured reverberation time (RT) and noise floor levels across the many school environments. Additionally, we measured sound levels across an entire day, rather than a large scale sampling of sound levels during only targeted (typically classroom) listening situations. This ecological approach allowed the description of both instructional and non-instructional parts of the day, which may serve to improve hearing instrument fitting practices for children attending school. For example, listening to a friend while playing outside is an important listening situation, and one that is not well described in the classroom acoustics literature. This paper presents data across all listening environments and situations encountered by three cohorts of children.

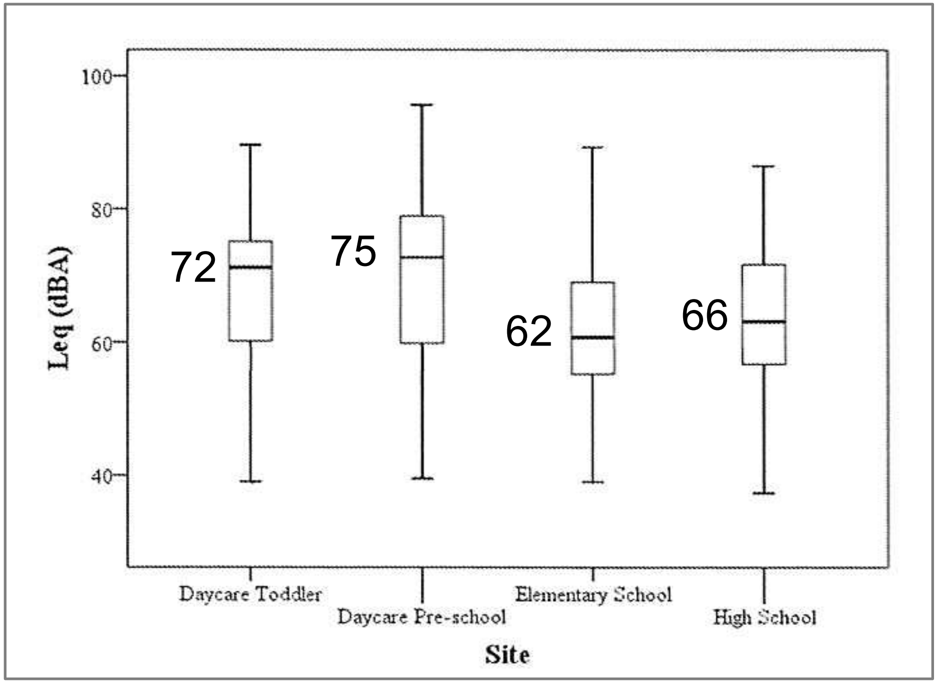
Auditory Ecology: Children in Non-Quiet Environments

Auditory ecology has been defined as the range of acoustical environments that a person experiences, the auditory demands of those environments, and the importance of those demands to an individual's daily life (Gatehouse, et al., 1999; Gatehouse, et al., 2003, 2006a, b). A hearing instrument's ability to support multi-environment listening is a significant predictor of hearing instrument

Journal of Educational Audiology

Crukley et al., 2011





A Noisy World

Perspective

Average Speech Levels and Spectra in Various Speaking/Listening Conditions: A Summary of the Pearson, Bennett, & Fidell (1977) Report

Wayne O. Olsen
Mayo Clinic, Rochester, MN

In 1977, Pearsons, Bennett, and Fidell completed a report for the U.S. Environmental Protection Agency describing their measurements of speech levels in a variety of settings. Their report, entitled *Speech Levels in Various Noise Environments,* Report No. EPA-600/1-77-025, was prepared for the Office of Health and Ecological Effects, Office of Research and Development, U.S. Environmental Protection Agency in Washington DC.

Pearsons, Bennett, and Fidell collected a unique yet large sample of data on background levels and the levels of conversational speech in schools, homes, hospitals, department stores, trains, and airplanes. Their data, therefore, provide vital information regarding speech levels and signal-to-noise (S/N) ratios encountered in "everyday" listening situations.

In addition, they measured speech levels and speech spectra of females, males, and children uttering a standard phrase at various vocal efforts in an anechoic chamber, thereby documenting differences in speech spectra related to gender, age, and vocal effort. The intent of this paper is to summarize their report and provide its important information to a larger segment of the professional community. Their measurements in everyday listening environments and in the anechoic chamber are treated separately in this summary.

Everyday Listening Situations

Method

Pearsons et al. (1977) completed measurements of speech levels of teachers in 20 classrooms, and for a "listener" in conversations with residents inside and outside 25 homes in urban and suburban areas, with patients and nurses in 23 locations in four hospitals, with personnel in seven large department stores, with 11 passengers on the Bay Area Transport trains in San Francisco, and with 12 passengers in four commercial jet aircraft and one commercial propeller-type airplane.

In the classroom setting, the teachers' speech was recorded at a lavaliere microphone worn by each teacher and with microphones at a distance of 2 m (near the front of the classroom) and a distance of 7 m (at the back of the classroom). Measurements from the lavaliere microphone were mathematically adjusted (i.e., normalized) to levels equivalent to those that would have been observed at a distance of 1 m.

For measurements in the home settings, hospitals, department stores, trains, and airplanes, recordings were made for the listener, who wore a microphone near the ear in an eyeglass frame. Several segments of continuous conversation at least 10 s in length by the "talker," that is, without responses by the "listener," were recorded. The distance between the talker and the listener generally was 1 m—a distance voluntarily selected in the home environment as a "usual" communication distance. In the train and airplane settings, the distance between the talker and listener was approximately 0.5 m. Also, recordings were completed for the background noise levels when there was no conversation between the participants.

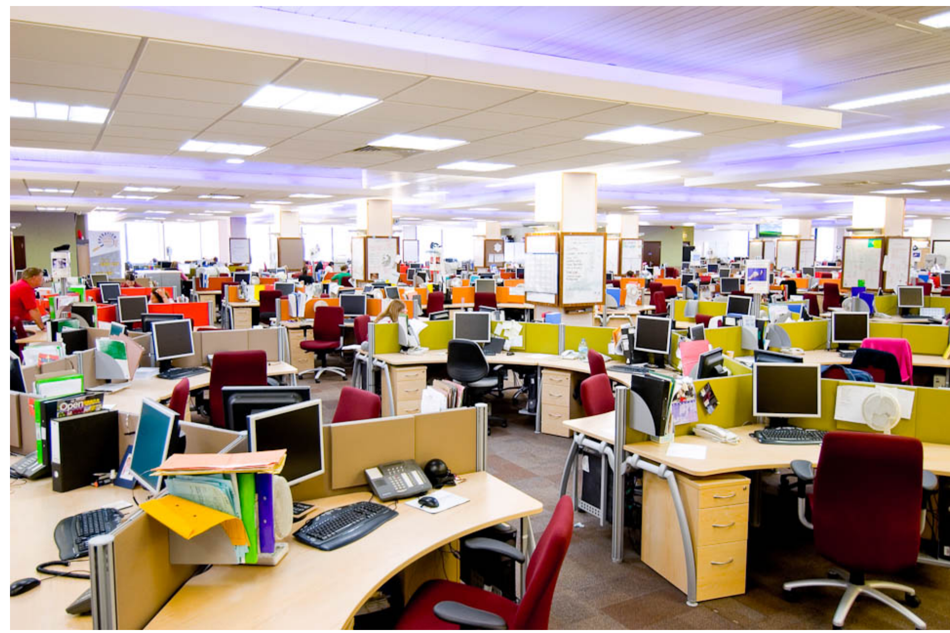
Recordings were analyzed with a real-time one-third octave analysis system. Levels of the speech and background noise were given in A-weighted sound pressure levels. The integration time on the analyzer was equivalent to "fast" on sound-level meters.

Results

The means and standard deviations for the background noise and teachers' speech levels while lecturing are provided in Table 1. Mean background levels in the two schools were 48 and 51 dBA; mean speech levels near the front of the classroom (2 m) were 62 and 66 dBA, for schools 1 and 2, respectively, maintaining a S/N ratio on the order of +15 dB. The speech level near the back of the classroom (7 m) was approximately 5 dB weaker. The authors also reported that, normalized at a distance of 1 m,

Pearsons et al., 1977

Office Environment



Typical Signal Noise Ratio: +5 dB

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A Noisy World

Public Transportation

Typical Signal Noise Ratio: 0 to -5 dB
Noise Levels: 75-90 dBA

Restaurants & Bars

Typical Signal Noise Ratio: -5 to +5 dB
Noise Levels: 70-100 dBA

For persons with severe to profound hearing loss, we can strive for greatness!

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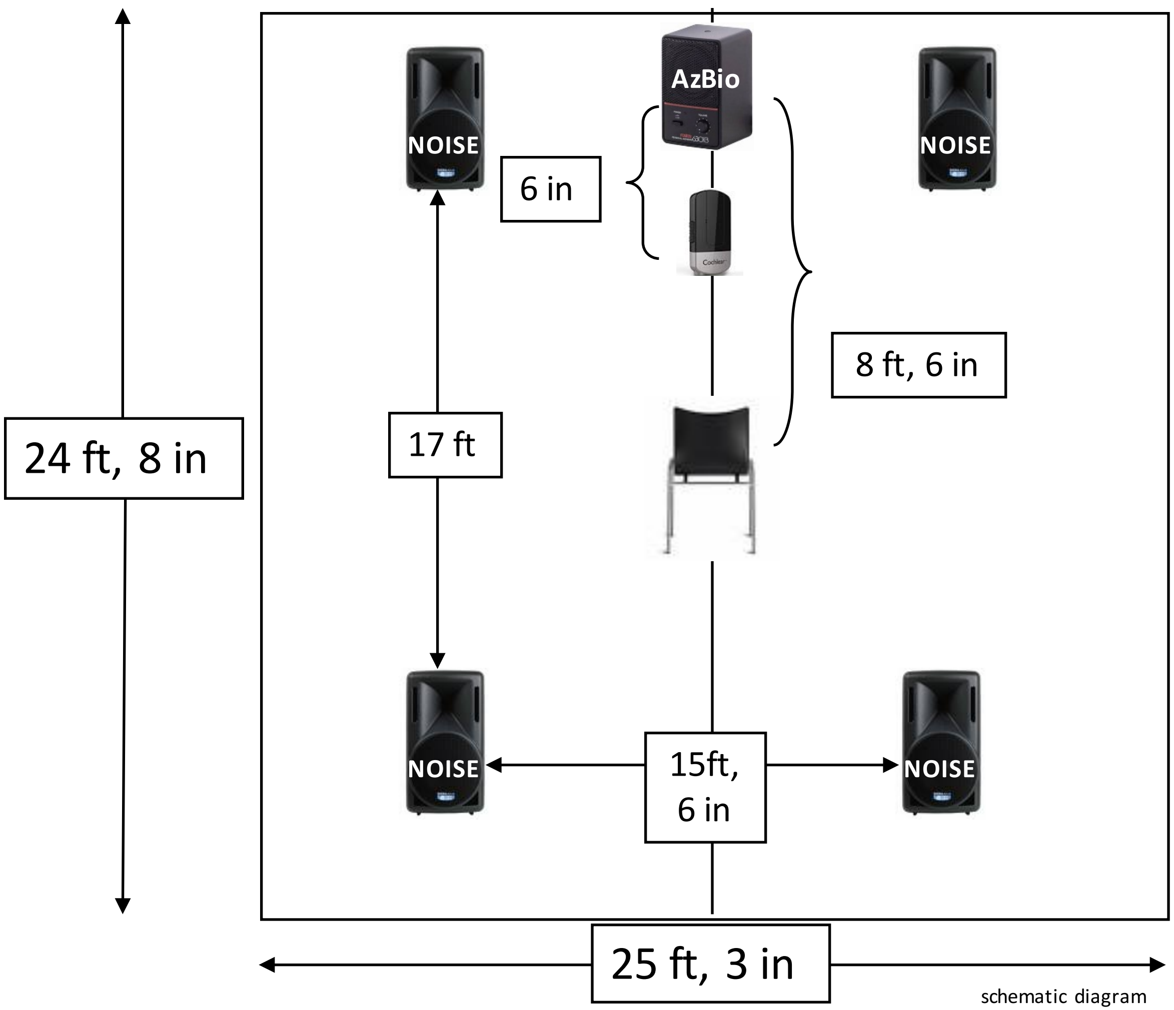
Just Preaching to the Choir!

Research Setup



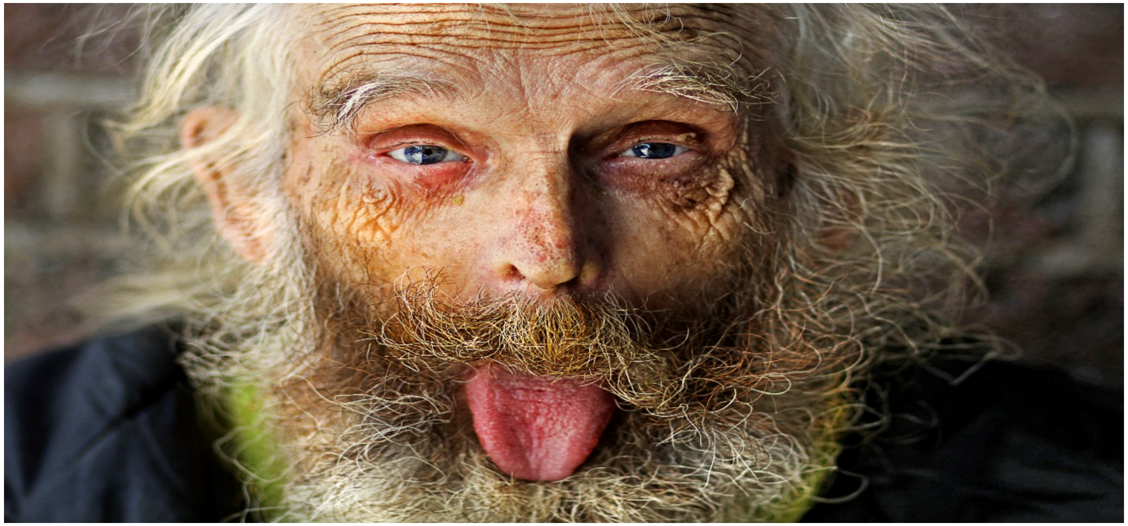
Research Setup

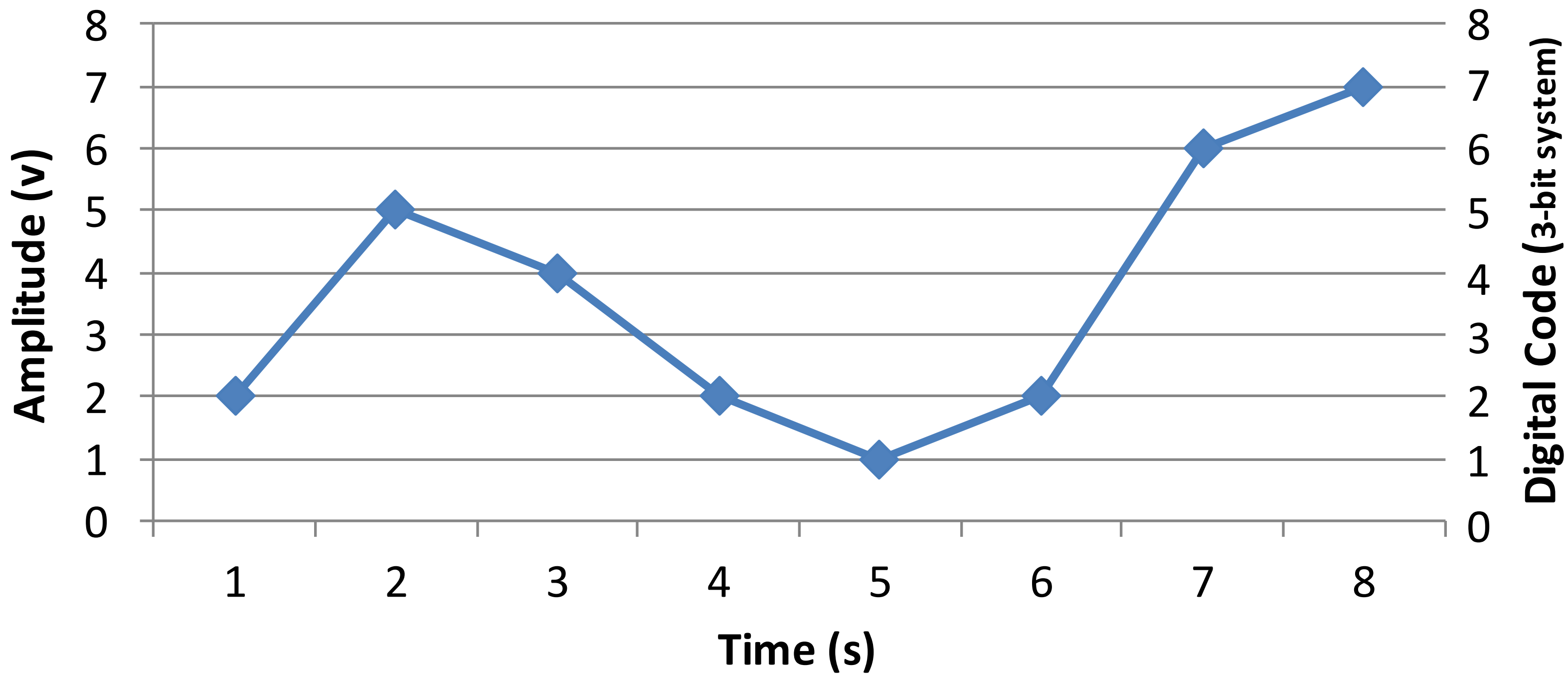
Ambient Noise Level: 44 dBA

Reverberation: .6 sec

Not your father's FM…

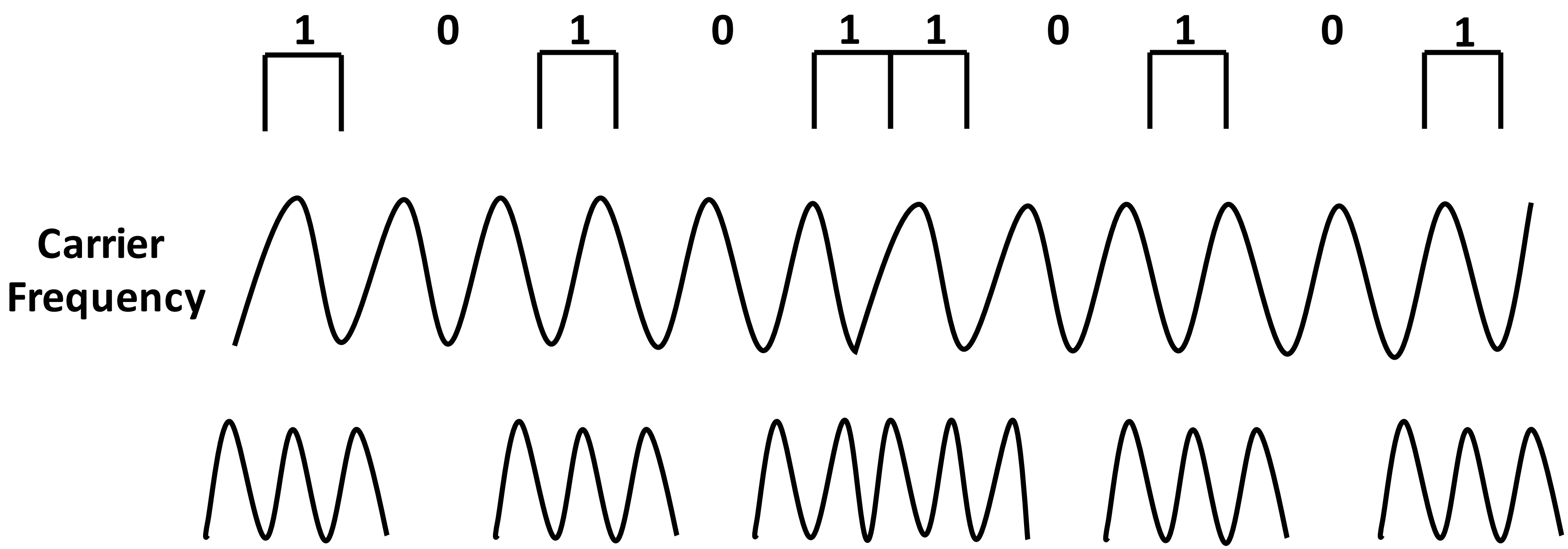


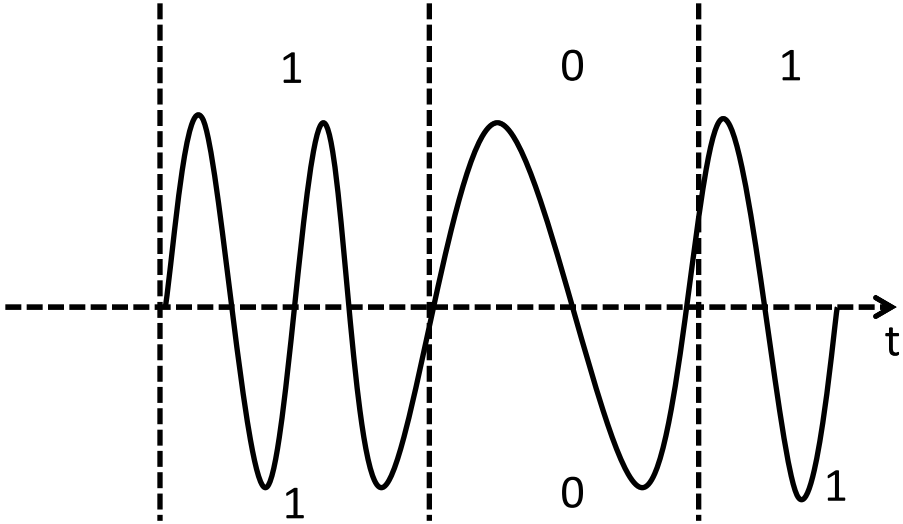


Time	Digital Code	Fours	Twos	Ones
1	2	0	1	0
2	5	1	0	1
3	4	1	0	0
4	2	0	1	0
5	1	0	0	1
6	2	0	1	0
7	6	1	1	0
8	7	1	1	1

Digital Radio Frequency Transmission
Amplitude Shift Keying

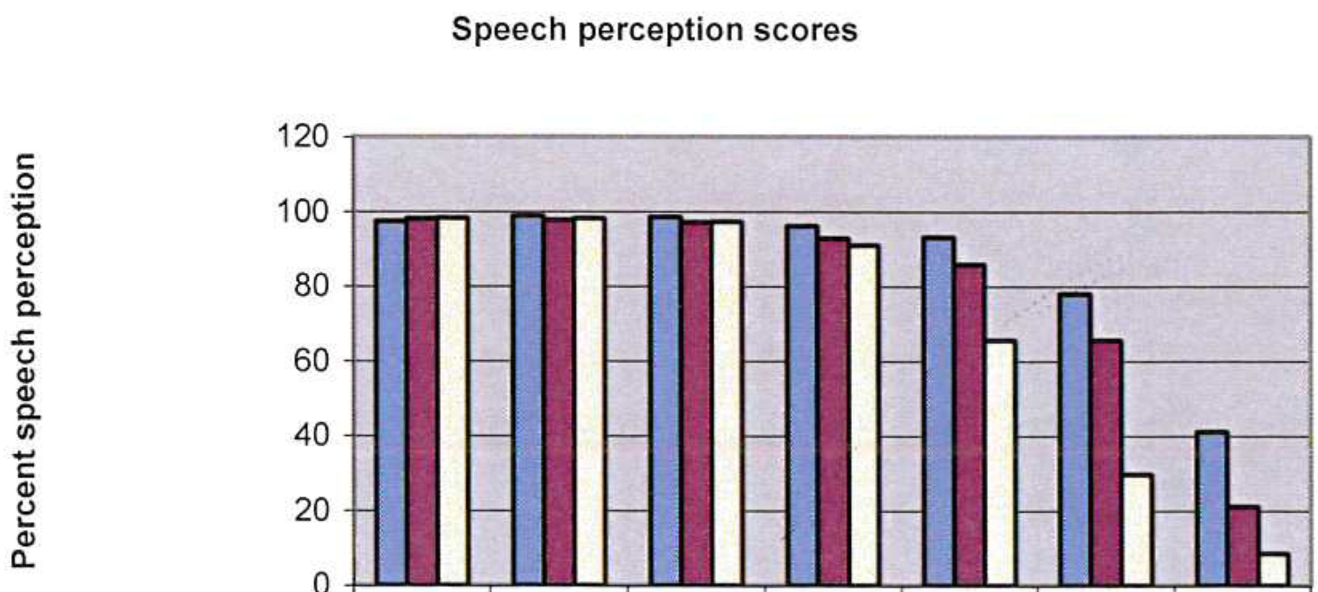


Digital Radio Frequency Transmission
Gaussian Frequency Shift Keying



- Is digital better?

Dynamic FM & Digital RF



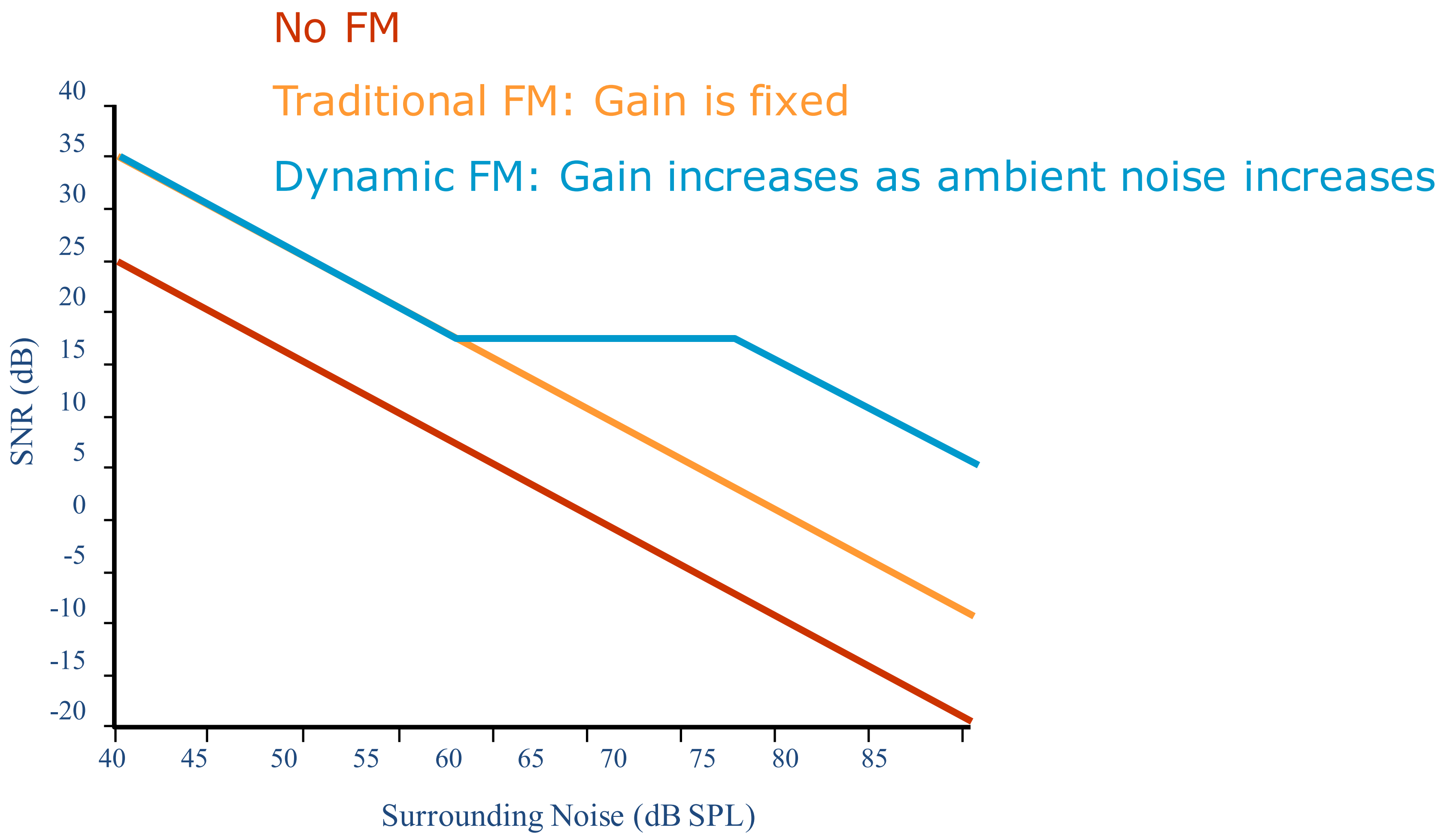
	quiet	55	60	65	70	75	80
Phonak MLxi	97,4	98,95	98,5	96,1	93,1	77,95	41,2
Phonak MyLink+	98,05	97,7	97,05	92,8	85,9	65,55	21,15
Comfort Audio	98,25	98,05	97,35	90,9	65,55	29,65	8,6

Noise level

Aslund et al., 2011

N = 20

Adaptive RF



No FM
Traditional FM: Gain is fixed
Dynamic FM: Gain increases as ambient noise increases
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
SNR (dB)
40
45
50
55
60
65
70
75
80
85
Surrounding Noise (dB SPL)

What's possible with digital?

- Audio signals are sampled, digitized and packaged in very short (160 μs) digital bursts of codes (packets) and broadcast several times, each at different channels between 2.4000 and 2.4835 GHz
  - The 2.4 GHz ISM (Industry, Science and Medical) band is globally license free
- Frequency hopping between channels, in combination with repeated broadcast, avoids interference issues
- The frequency hopping is adaptive, both receivers and transmitters are searching continuously to find free channels and to avoid occupied channels
- End-to-end audio delay is well below 25 ms – 7500 Hz BW
- **Digital control of adaptive (Dynamic) gain changes**

- Does an adaptive digital wireless system offer benefit for CI users?

Roger Technology

Does it work for cochlear implant users?

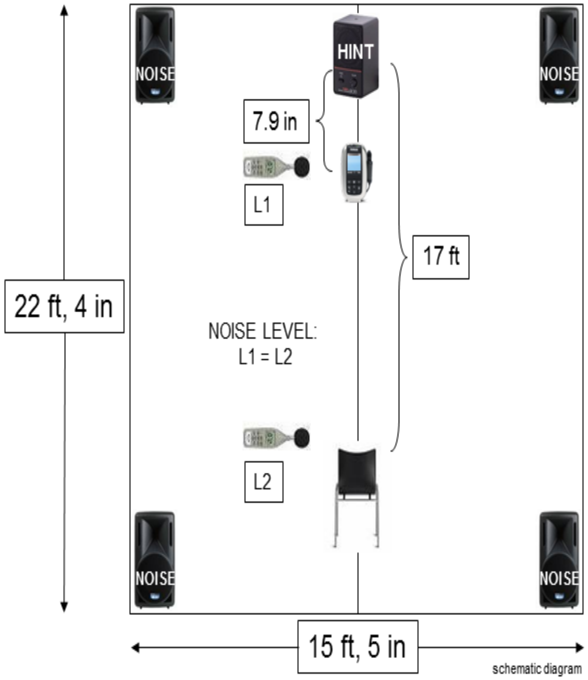
What about hearing aid users?

Study Objectives

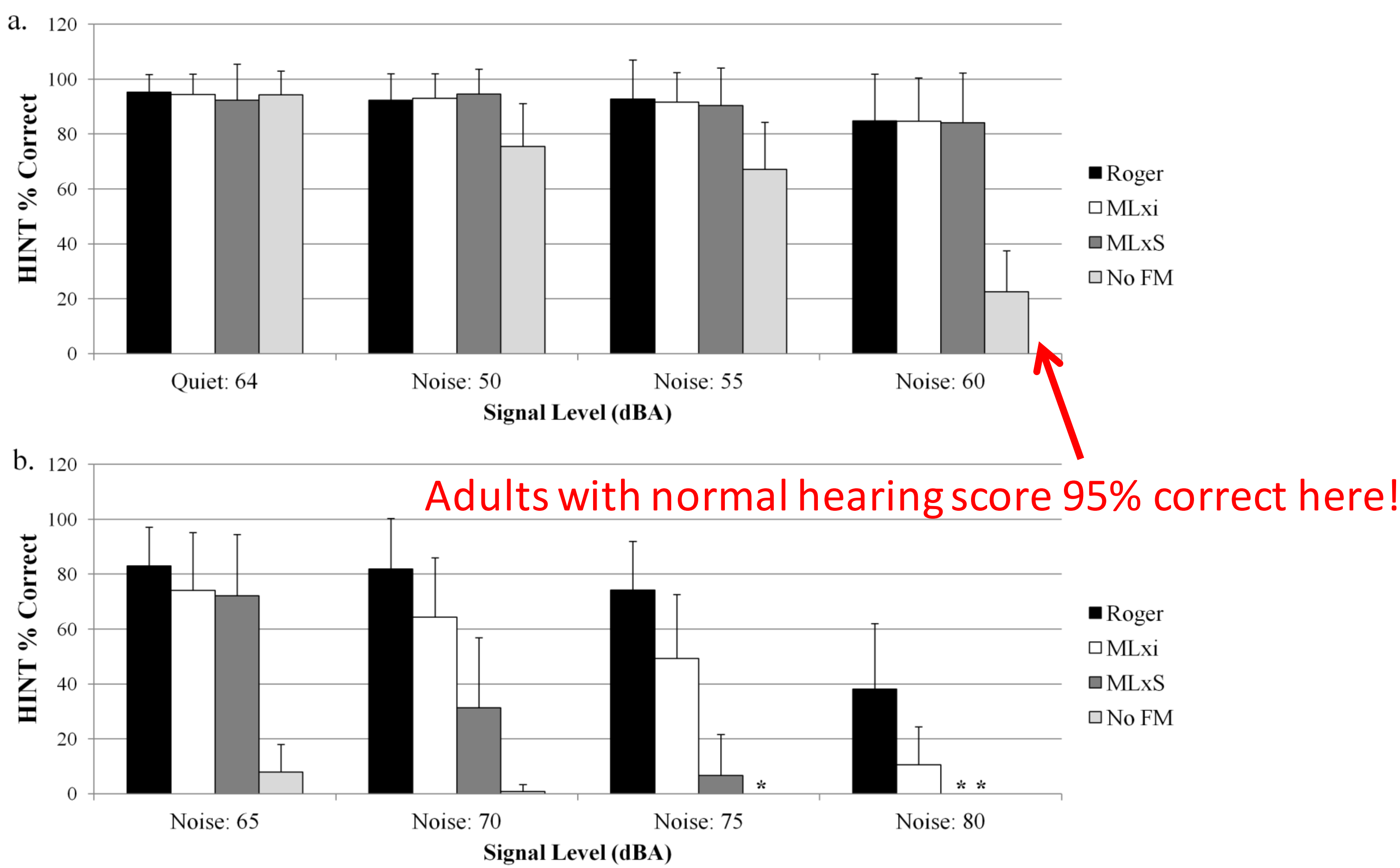
- Evaluate speech recognition in quiet and in noise with speech (HINT) at 85 dBA at transmitter and classroom noise at 50, 55, 60, 65, 70, 75, 80 dBA

- Evaluated 3 RF remote microphone systems:
  - Fixed-gain FM – MLxS
  - Adaptive FM – MLxi
  - Digital RF – Roger

- Ensure consistency of signal and a lack of interference.

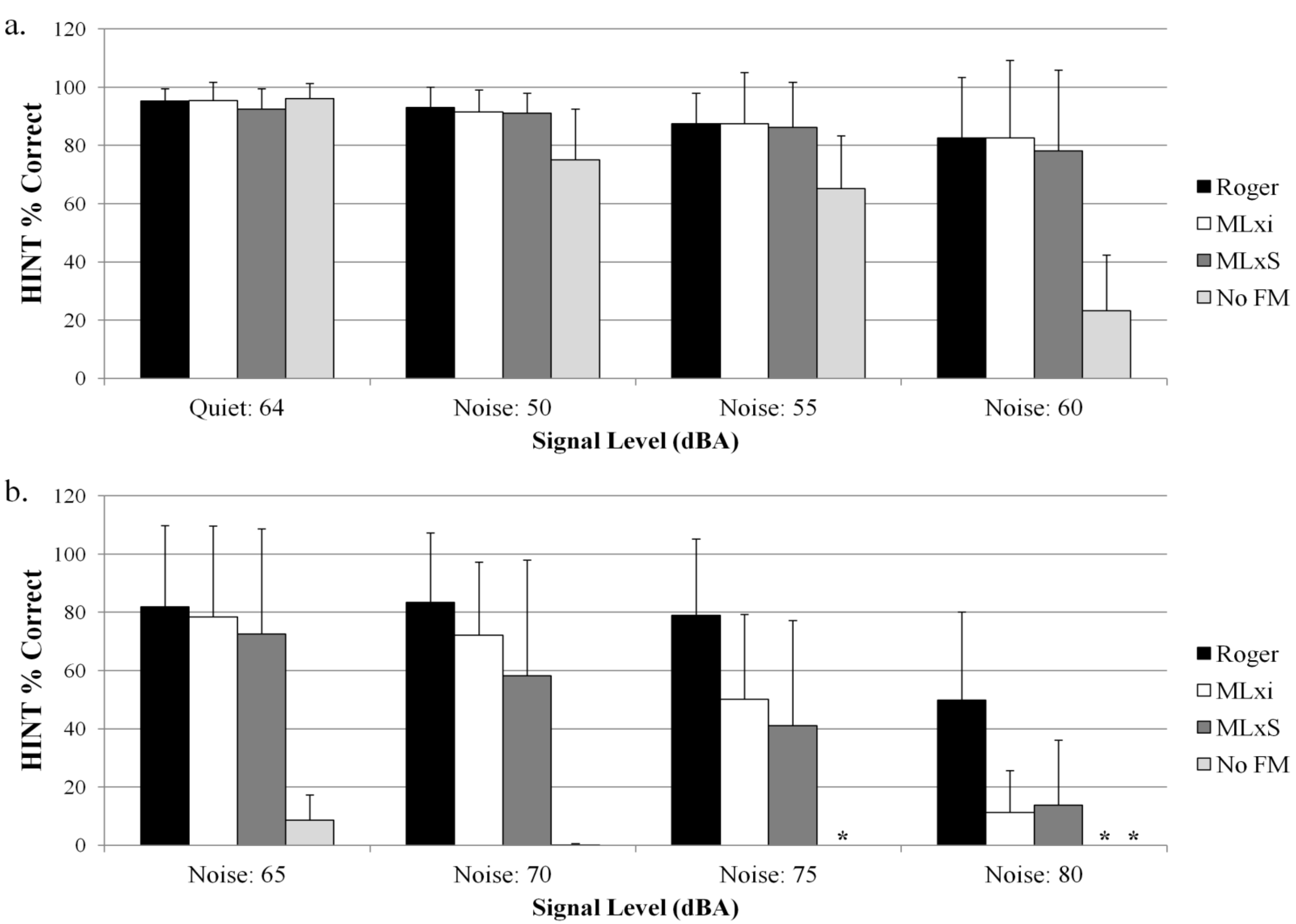


Results
Advanced Bionics Recipients (n = 16)



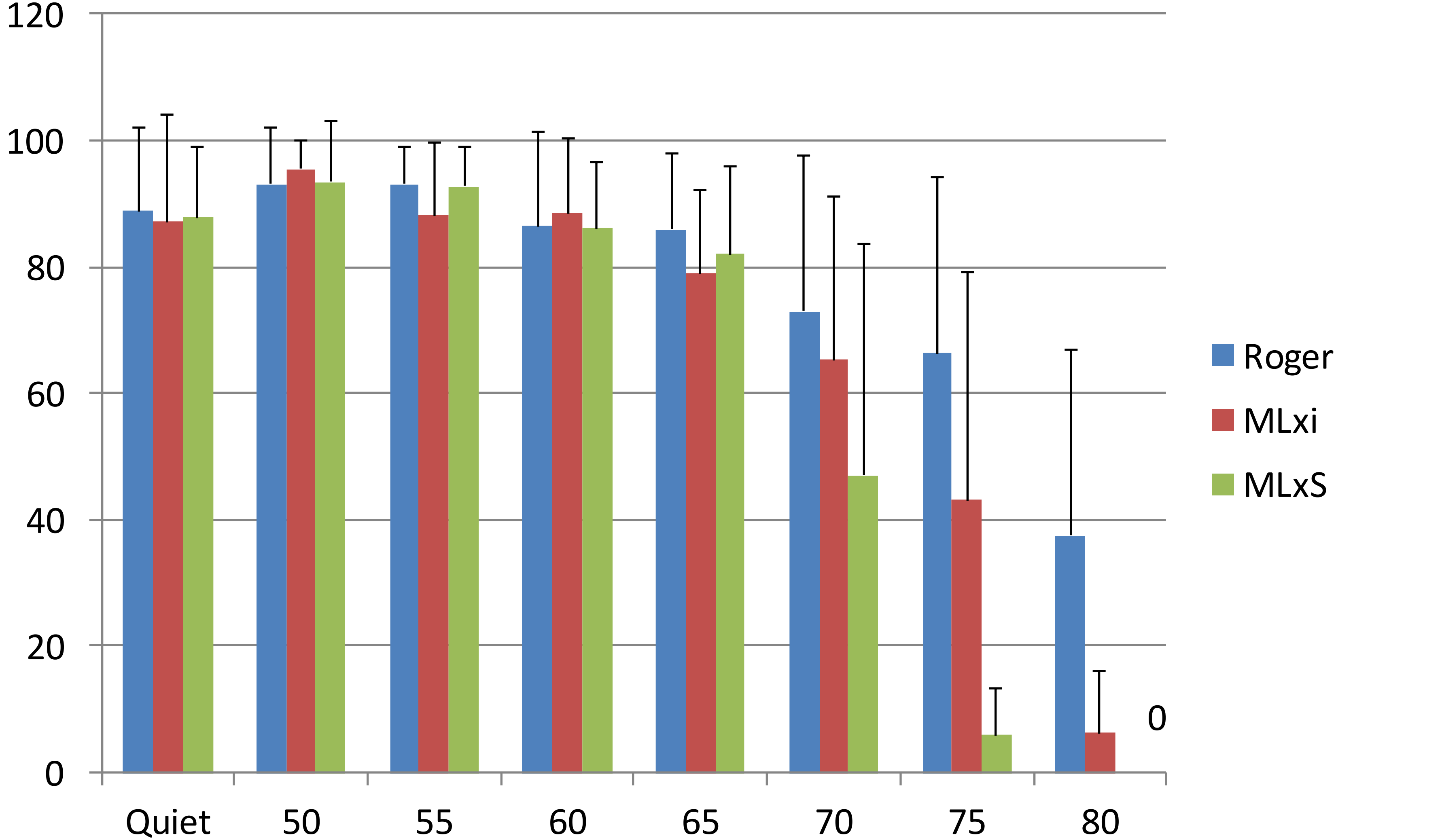
Wolfe et al., 2013, JAAA

Results
Cochlear Recipients (n = 21)



Wolfe et al., 2013, JAAA

MED-EL and Roger



N = 7

Wolfe et al., (2013), Hearing Journal

What about hearing aids?

Speech Recognition Benefits of Digital Adaptive Broadband Wireless Transmission Technology

Linda M. Thibodeau

AAA, 2013

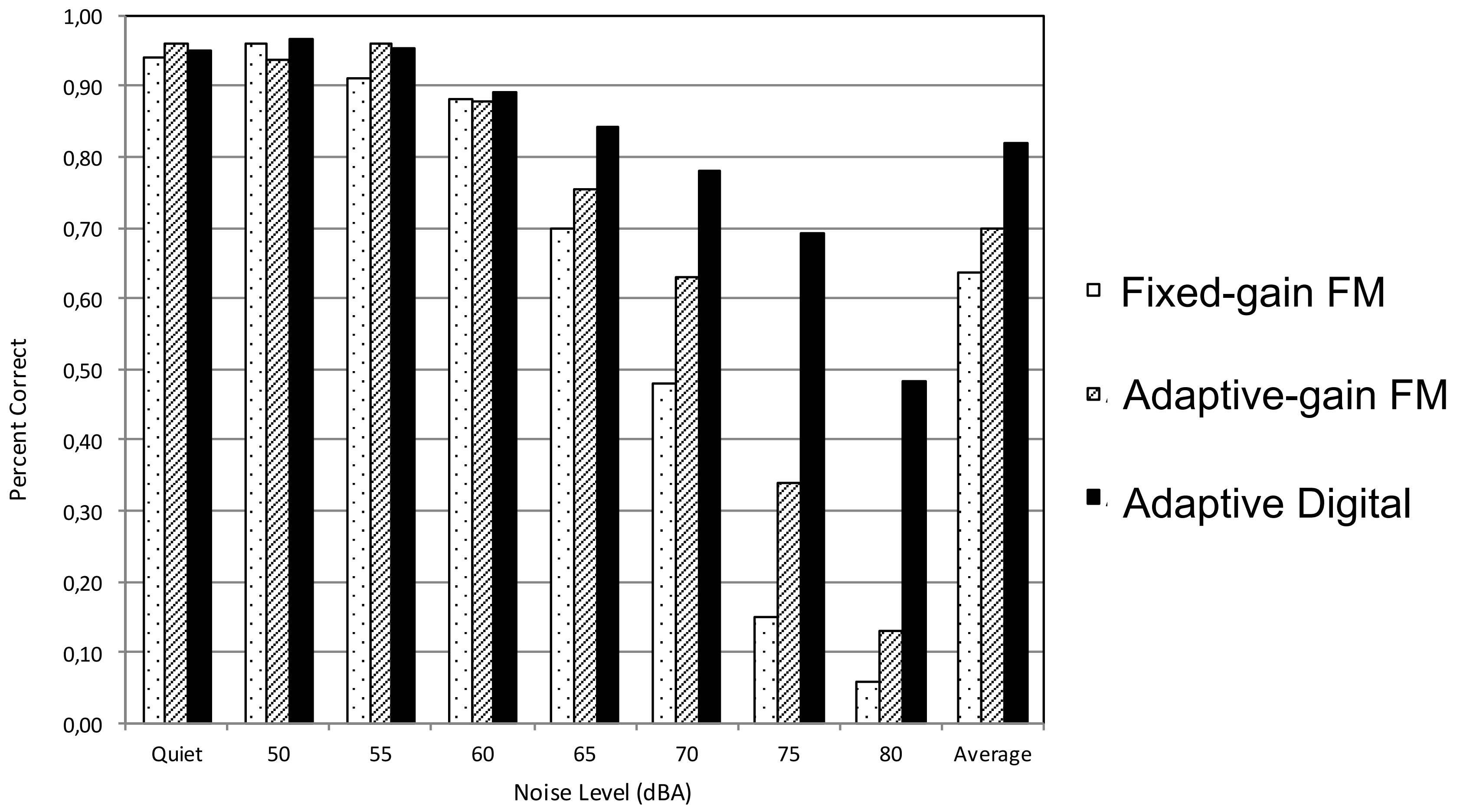
Annaheim, CA

Research outline

- Dr. Linda Thibodeau
- University of Texas at Dallas
- Speech in noise testing
- 11 listeners using their own BTE's
- Ages 15 to 78
- Traditional FM vs Dynamic FM vs Roger
- Randomized, blinded
- Different noise levels

Courtesy of Dr. Thibodeau, 2014

HINT Results (N=10)



Courtesy of Dr. Thibodeau, 2014

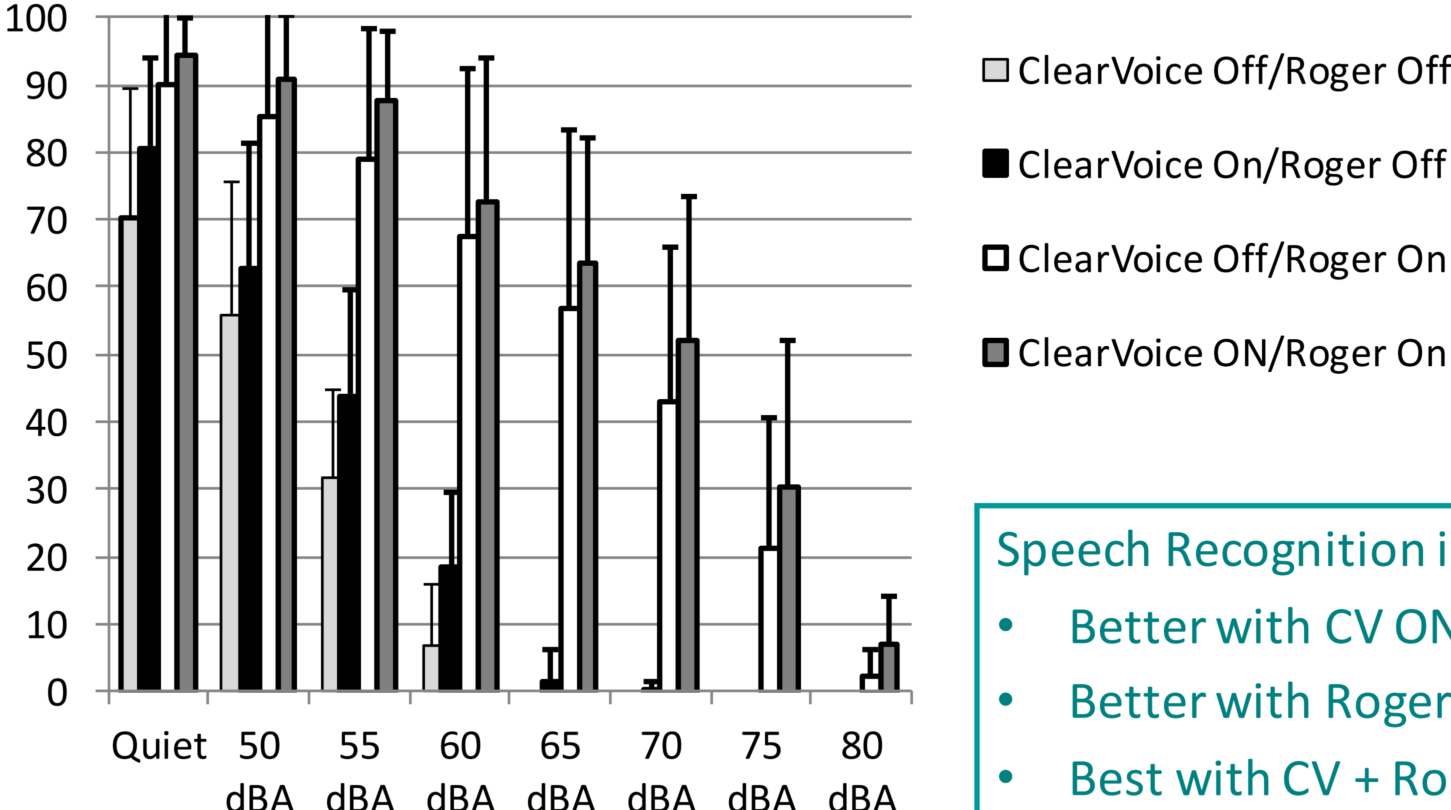
Be a Lionel Richie audiologist

- Can it get any better?

ClearVoice

- Within each analysis channel:
  - Gain is reduced if input is steady state → **noise is attenuated**
  - **Modulated inputs are transmitted**, e.g. speech and music
- Overall signal-to-noise ratio (SNR) is improved
- Hearing in quiet remains same

Advanced Bionics ClearVoice Processing



Speech Recognition is

- Better with CV ON than OFF
- Better with Roger ON than OFF
- Best with CV + Roger

Benefit also seen in "Quiet"

Wolfe et al., 2015, JAAA

(RMANOVA)

- How do digital wireless accessory remote microphone devices compare to digital adaptive remote microphone systems?

Technology

Phonak Bolero

Phonak Roger X

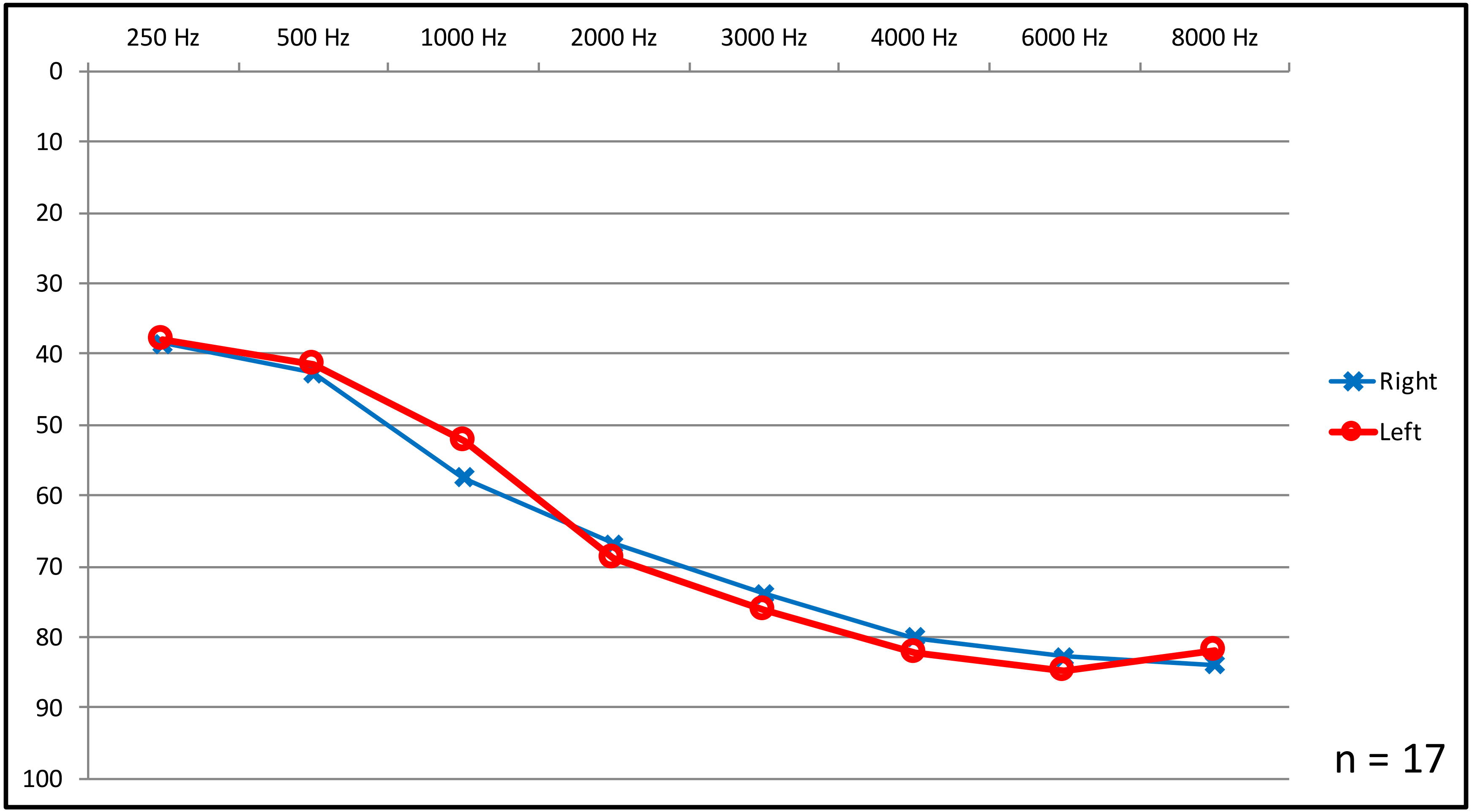
Resound Verso

Phonak Roger Pen

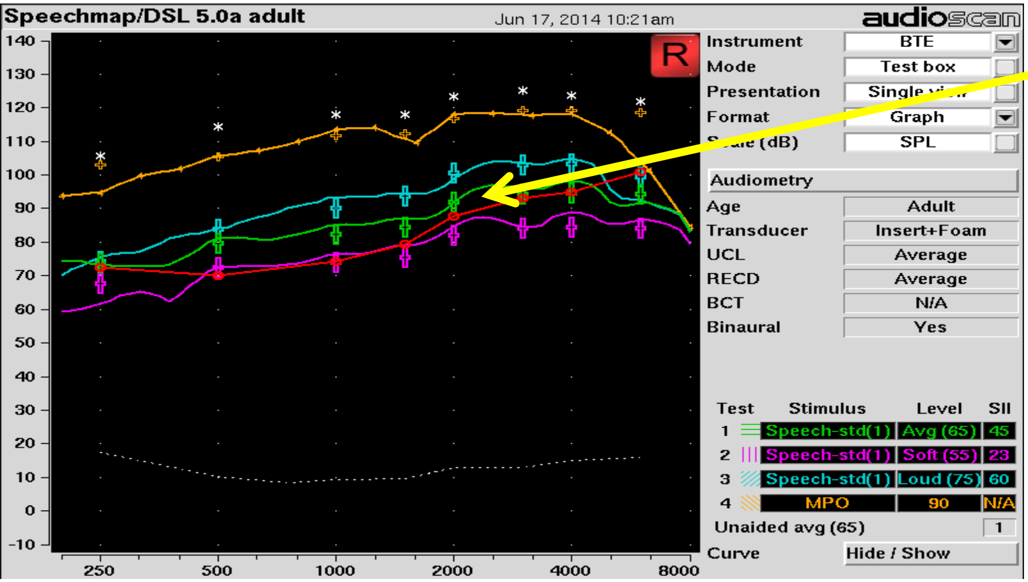
Resound Unite Mic

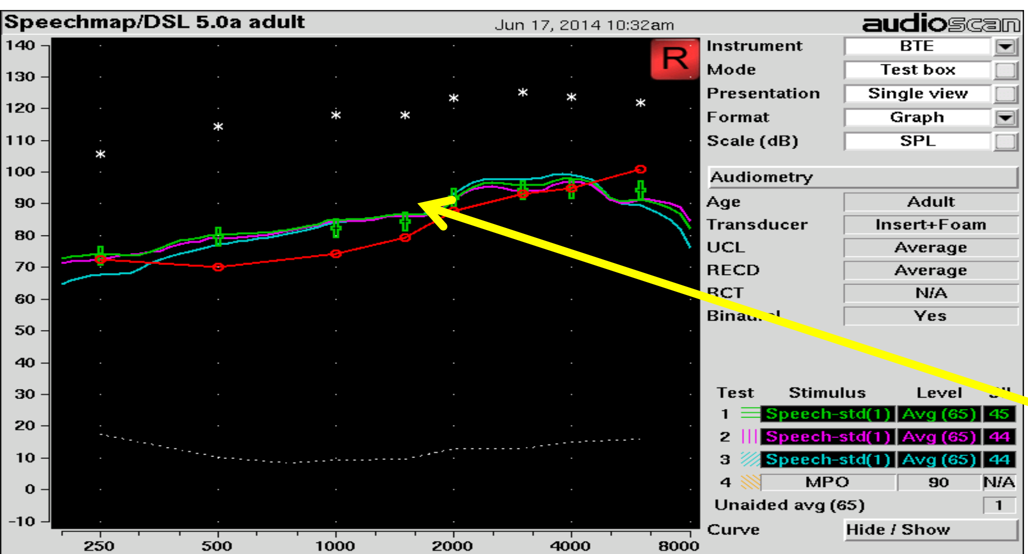
Evaluated sentence recognition both with and without wireless technology

Mean Audiogram



Programming Hearing Technology





- Fitted Resound and Phonak aids to DSL v5.0 target for adults
- SII within 2 points for the two hearing instruments
- Disabled all NR technologies and NLFC; fb cancellation enabled
- Ensured transparency for each remote mic condition

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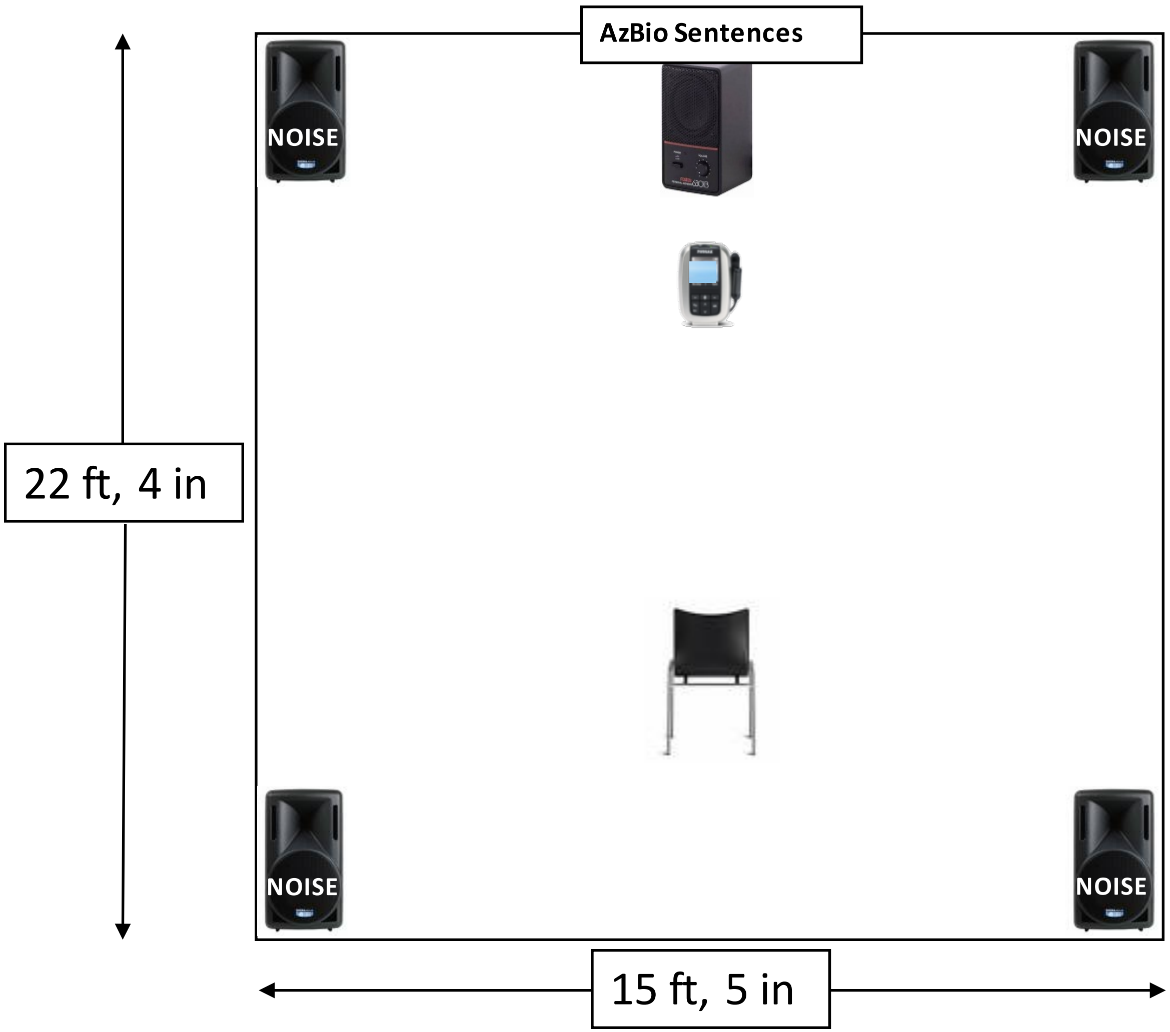
Study of Wireless Technologies



<u>Sentence Recognition</u>

Quiet & Noise at

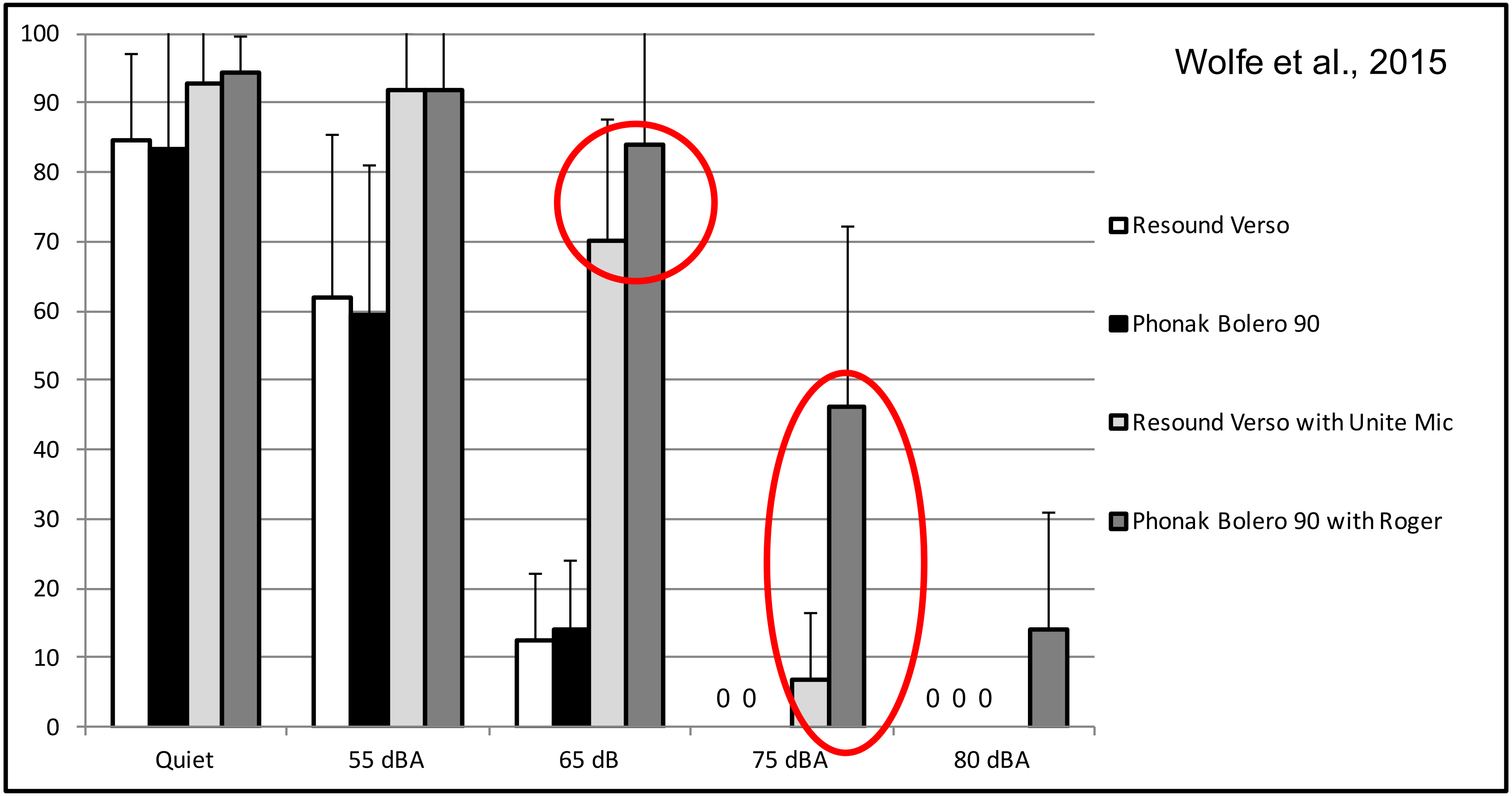
55 dBA

65 dBA

75 dBA

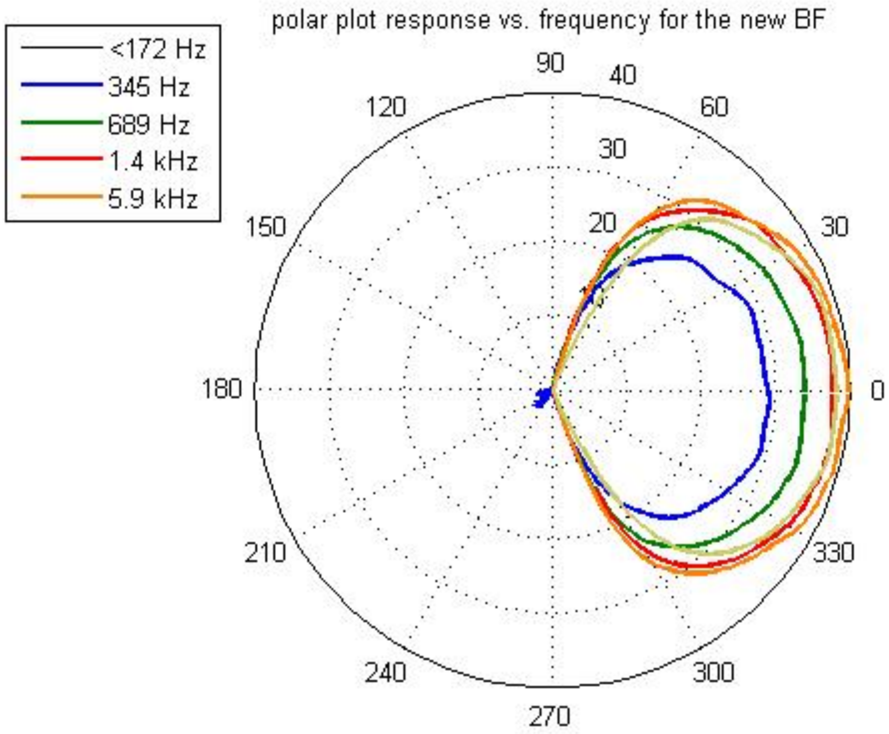
80 dBA

Dynamic Digital RF vs. Digital Audio Streaming

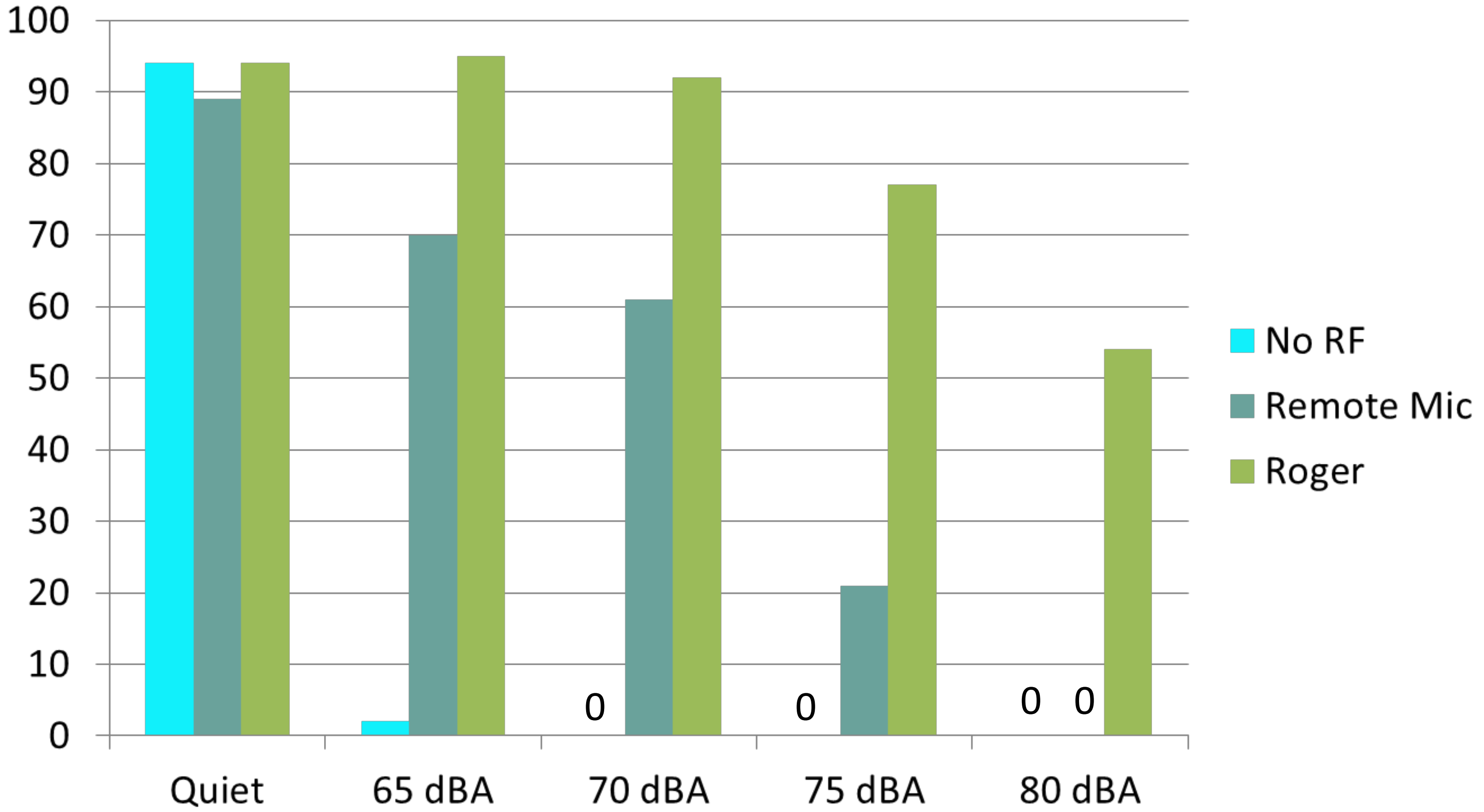


Hearing Aids Users (Moderately Severe/Severe Hearing Loss) **n = 17**

Is it all about the gain?

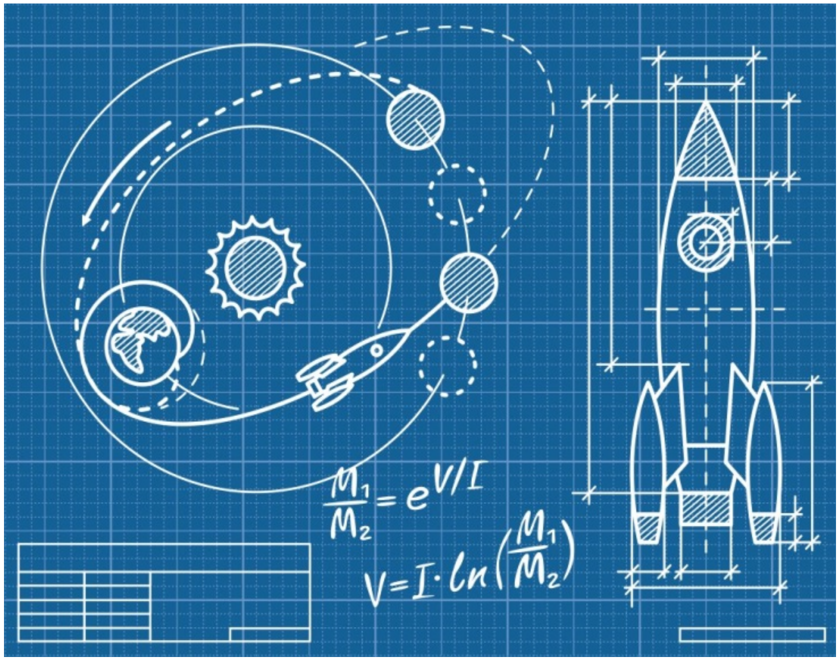


Case Study
Remote Mic Streaming vs. Roger



HEARTS for HEARING

Remote Mic Use



Remote Mic Orientation

- Take the time…
- Demonstration
  - Tell, show, touch, live, and give!
- Take the challenge
  - Speech recognition with and without
- Matching tech to needs
  - COSI
  - Budget
- Engage the family
  - Parent Persuasion
  - Give your spiel to the spouse

- Chasing Greatness with Bilateral Hearing

DuoPhone
(Advanced Bionics Naida CI Q70)

Phonak HiBAN Technology

Hearing Instrument Body Area Network:

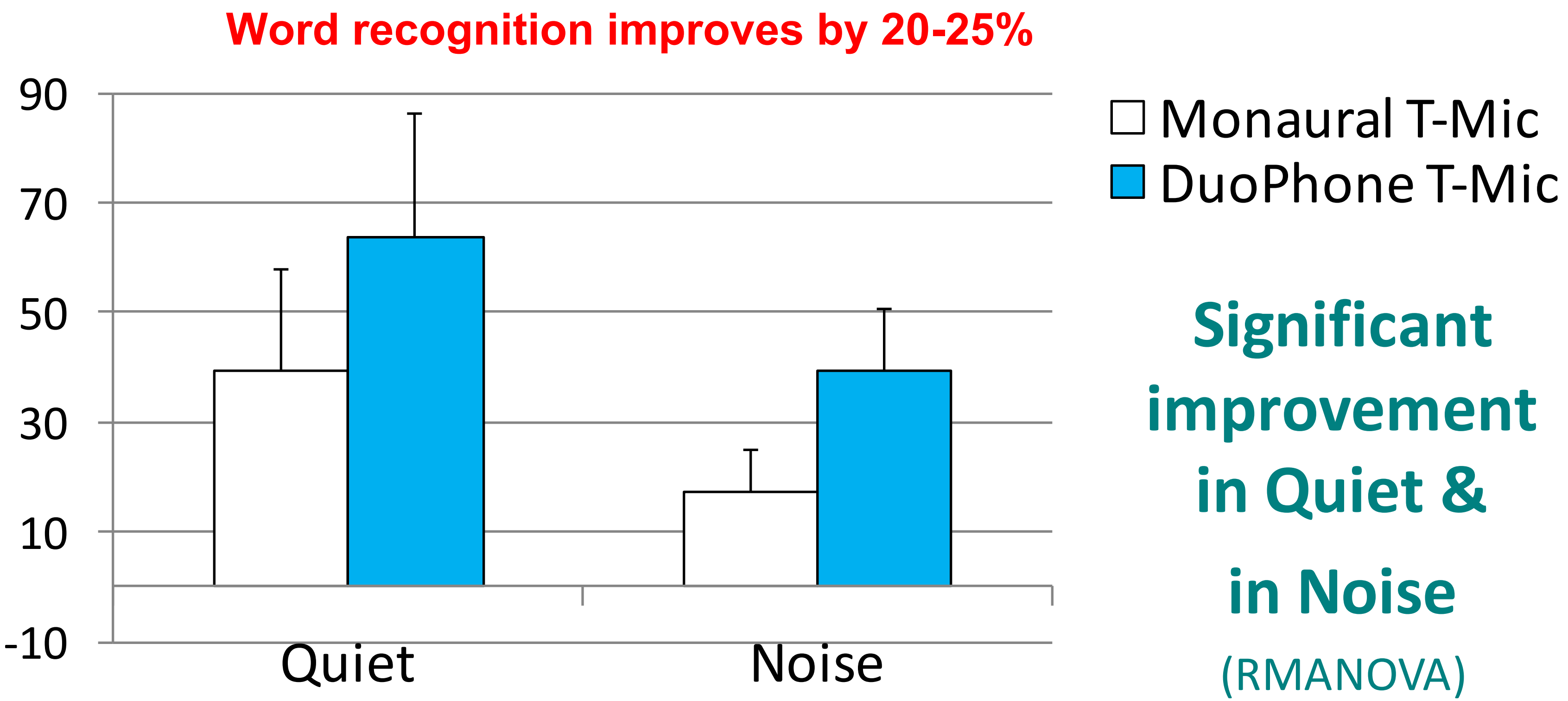
Short-range audio streaming

via digital near-field magnetic induction (10.6 MHz) and CODEC

Methods: Subjects

- 10 Adult Bilateral CI Users
  - Age
    - Range: 43-70 years old
    - Mean: 58.7 years old (SD=8.7)
  - Advanced Bionics HiRes 90K and/or CII implants
  - Duration of Hearing Loss: 15.7 years
  - Duration of Severe-Profound Hearing Loss: 7.6 years

T-Mic2 – Monaural vs. DuoPhone

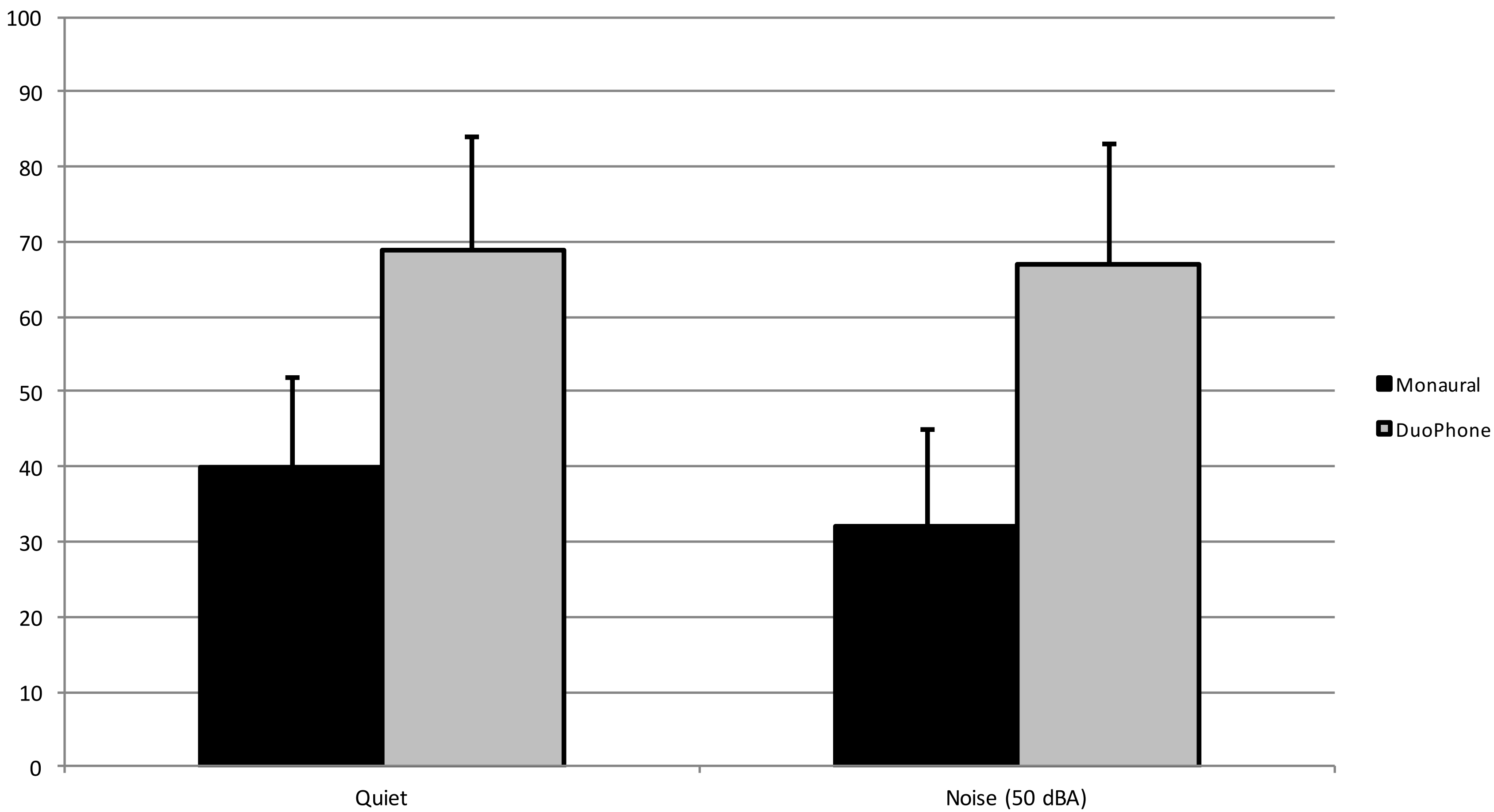


Significant improvement in Quiet & in Noise

(RMANOVA)

Wolfe et al., 2015, JAAA

Mean CNC Word Recognition Scores for Children (6-14 years-old) with Hearing Aids



Wolfe et al., 2014

Making it Great with Bimodal

Original Paper

Audiology & Neurotology

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The Benefits of Bimodal Hearing: Effect of Frequency Region and Acoustic Bandwidth

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Key Words
Bimodal hearing · Bimodal benefit · Cochlear implants · Acoustic bandwidth

Abstract
We examined the effects of acoustic bandwidth on bimodal benefit for speech recognition in adults with a cochlear implant (CI) in one ear and low-frequency acoustic hearing in the contralateral ear. The primary aims were to (1) replicate Zhang et al. [Ear Hear 2010;31:63–69] with a steeper filter roll-off to examine the low-pass bandwidth required to obtain bimodal benefit for speech recognition and expand results to include different signal-to-noise ratios (SNRs) and talker genders, (2) determine whether the bimodal benefit increased with acoustic low-pass bandwidth and (3) determine whether an equivalent bimodal benefit was obtained with acoustic signals of similar low-pass and pass band bandwidth, but different center frequencies. Speech recognition was assessed using words presented in quiet and sentences in noise (+10, +5 and 0 dB SNRs). Acoustic stimuli presented to the nonimplanted ear were filtered into the following bands: <125, 125–250, <250, 250–500, <500, 250–750, <750 Hz and wide-band (full, nonfiltered bandwidth). The primary findings were: (1) the minimum acoustic low-pass bandwidth that produced a significant bimodal benefit was <250 Hz for male talkers in quiet and for female talkers in multitalker babble, but <125 Hz for male talkers in background noise, and the observed bimodal benefit did not vary significantly with SNR; (2) the bimodal benefit increased systematically with acoustic low-pass bandwidth up to <750 Hz for a male talker in quiet and female talkers in noise and up to <500 Hz for male talkers in noise, and (3) a similar bimodal benefit was obtained with low-pass and band-pass-filtered stimuli with different center frequencies (e.g. <250 vs. 250–500 Hz), meaning multiple frequency regions contain useful cues for bimodal benefit. Clinical implications are that (1) all aidable frequencies should be amplified in individuals with bimodal hearing, and (2) verification of audibility at 125 Hz is unnecessary unless it is the only aidable frequency.

Introduction

According to Dorman and Gifford [2010], approximately 60% of modern-day adult implant recipients have potentially usable (i.e. aidable) residual hearing in the nonimplanted ear, defined as audiometric thresholds ≤80–85 dB HL at 250 Hz. Combining electric stimulation with a cochlear implant (CI) and acoustic stimulation is now commonly referred to as electric and acoustic stimulation (EAS). Combining electric hearing with acoustic hearing in the nonimplanted ear is also commonly termed

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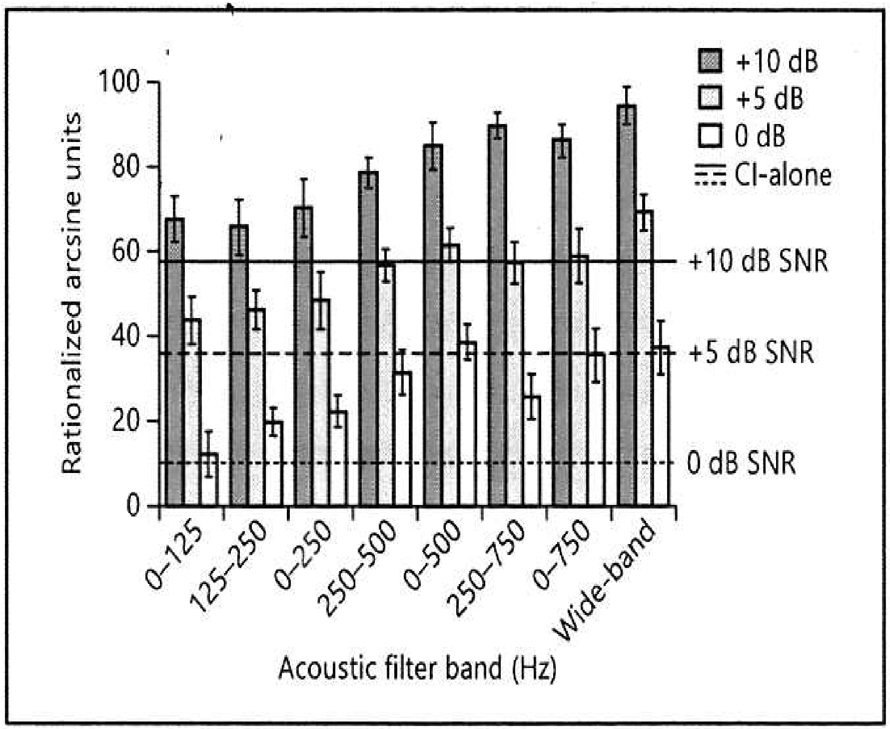
Sheffield & Gifford, 2014

And It Doesn't Take Much…

12 Bimodal Users
In a Test Booth



AzBio Sentences
Male Talker

Sheffield and Gifford, 2014

Binaural, Bimodal, or Bilateral?

- **Clinical assessment**
  - Audiometric (**but it's not just about the audiogram!**)
  - Speech recognition: Right alone, Left alone, Both ears
    - Word recognition in quiet
      - » Mean (CNC) performance with one CI is 60-65% correct
        - Bimodal/bilateral performance exceeds 60-65%
    - Sentence recognition in quiet **and in noise**
      - » Typical AzBio score with one CI is 50-60% correct at +10 dB SNR
        - Bimodal/bilateral performance exceeds 50-60%
  - Localization & music???
- Subjective impression of benefit from amplification
  - Speech recognition -- APHAB
  - Localization -- SSQ
  - Music – Informal assessment
- Patient's lifestyle, preferences, desires, etc.

- Anything else to strive for greatness?

Hearts for Hearing Experience with Adaptive NLFC

Adaptive NLFC

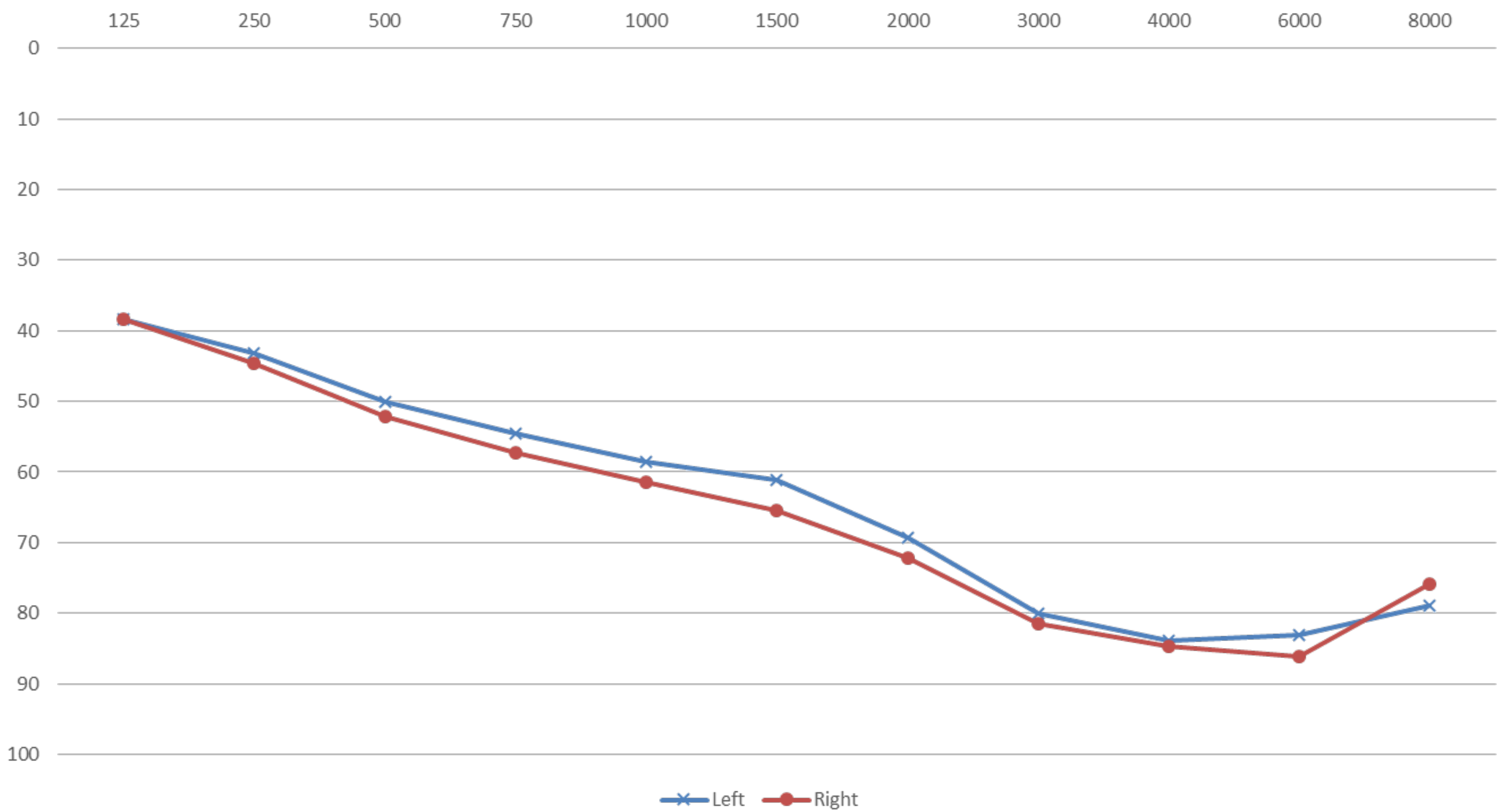
- Only compresses signal when high-frequency acoustic energy is much greater in level than low-frequency acoustic energy

- This adaptive nature allows for stronger compression settings to restore audibility for high-frequency sounds

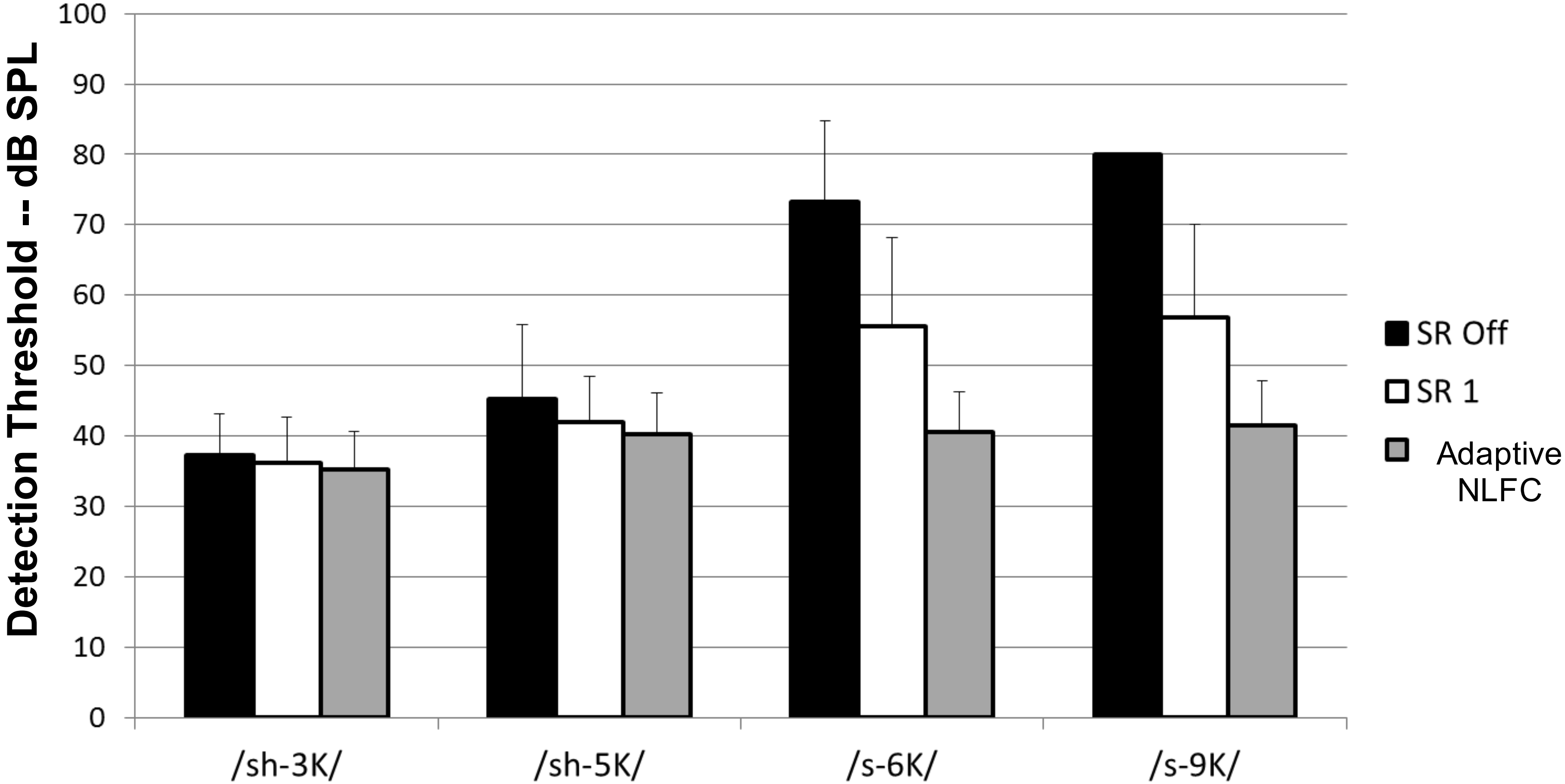
- Tested prototype version – May be available in commercial product in the future

- Adaptive NLFC with 10 Adults with Severe to Profound High-Frequency Hearing Loss

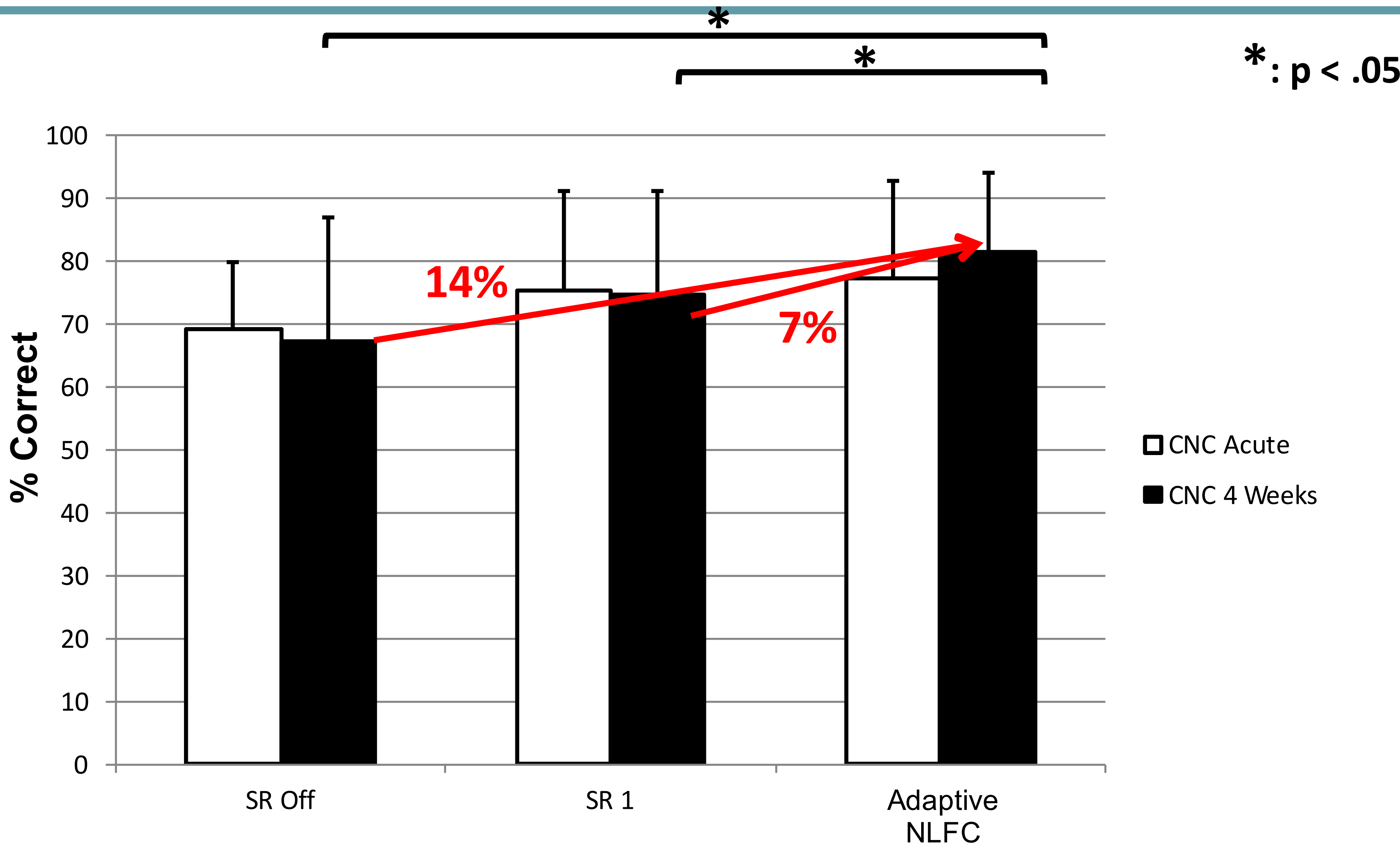
Mean Audiogram



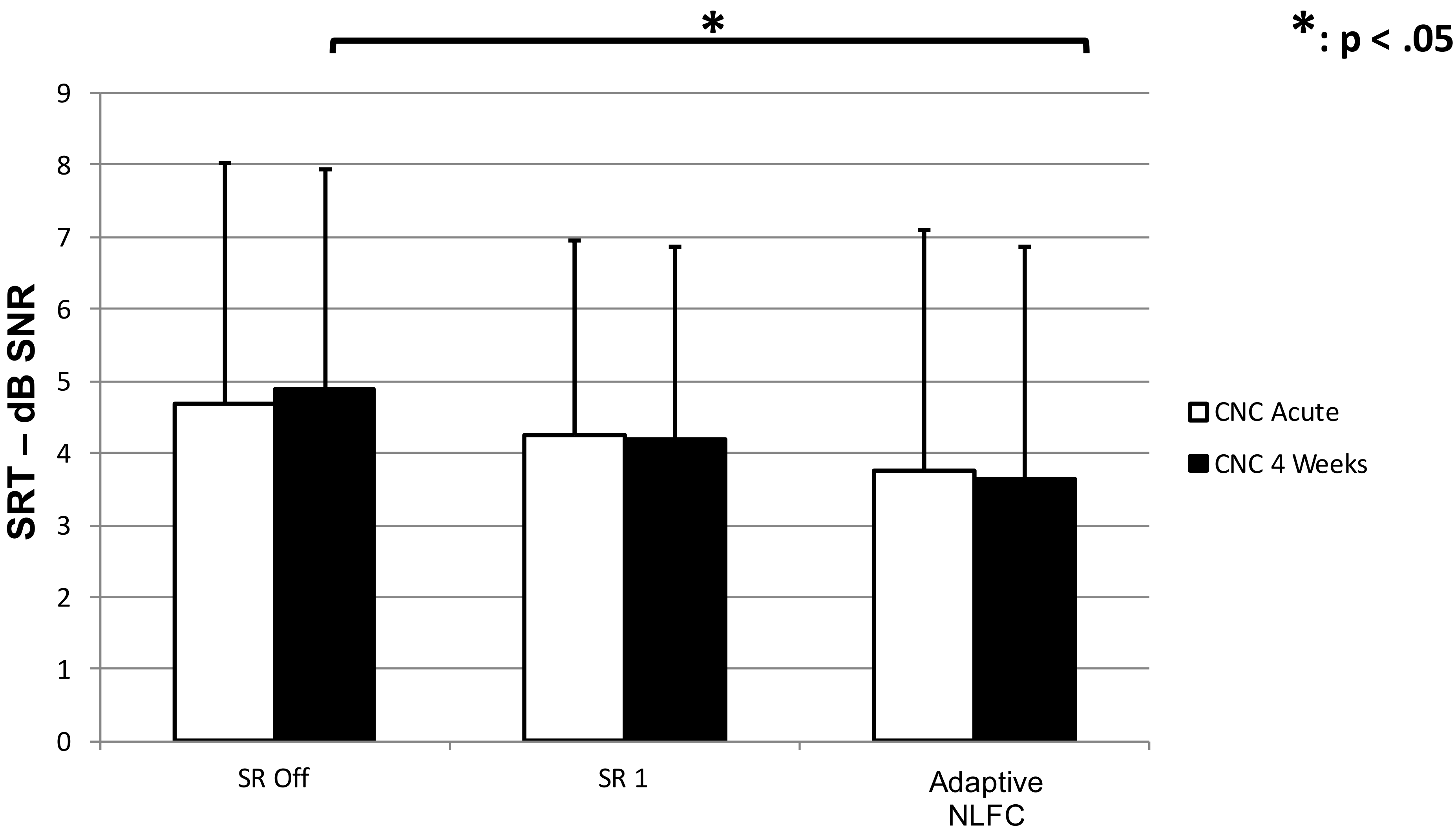
Phoneme Perception Test -- Detection



CNC Word Recognition



BKB-SIN (dB SNR – 50%)



Take Home Points

- Adults with severe to profound hearing loss need remote microphone technology with adaptive gain changes and beamforming to hear well in noise

- Try to make everyone a two-eared listener!
  - Binaural vs. Bimodal vs. Bilateral
  - Test in quiet (with words and sentences) and in noise to identify best solution for an individual
  - Evaluate an individual's unique needs to determine ideal solutions

- Changes in hearing technology, such as adaptive non-linear frequency compression, may improve performance, and it is our job as clinicians to stay abreast of these changes and to implement them effectively with our patients.

Shoot for the Moon!

- THANK YOU FOR YOUR ATTENTION