Reaching for the Stars: Optimizing Children's Performance with FM

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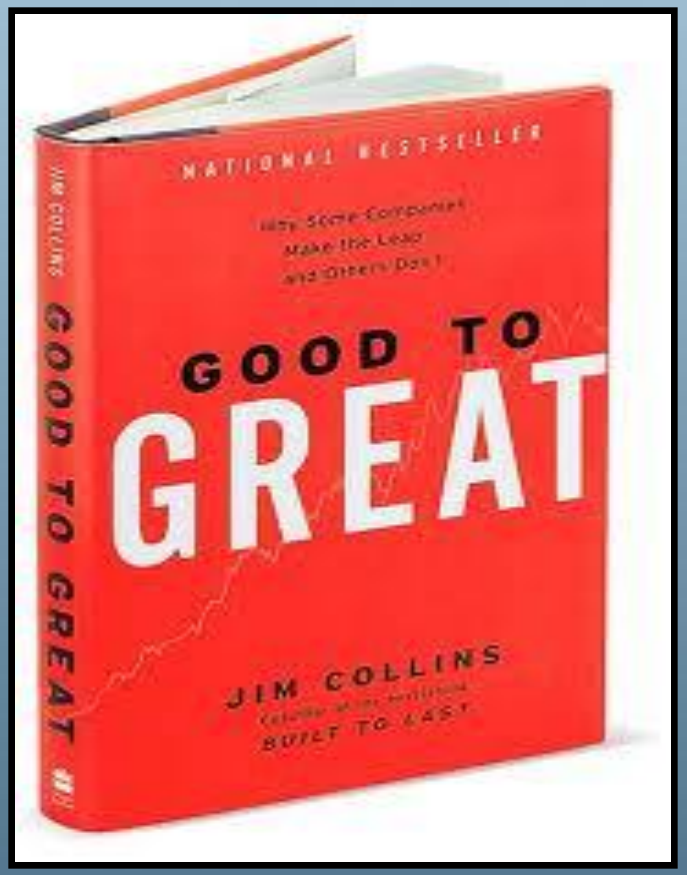
From Good to Great!



All too often, good is the enemy of great. – Jim Collins

The Oklahoma Experience

- 48th out of 50 states in teacher p
- 50th recent visit to the dentist
- 48th in physi
- 50th i le per day

Road Map

- Why FM?
- What is Dynamic FM?
- Research with Dynamic FM and hearing aids
- Verification of Dynamic FM
- Research with Dynamic FM and Cochlear Implants

The Problem

- Most hearing aid wearers are satisfied with speech recognition in quiet (Kochkin (2010), The Hearing Journal).
  - 78.6% of users of new hearing aids are satisfied overall.
- Many continue to report difficulty understanding speech in noise (Kochkin (2010), The Hearing Journal).
  - 91% report continued difficulty in noise
  - 66% continue to report substantial difficulty in noise
- Noise reduction generally improves comfort but not speech understanding in noise (Bentler, 2005).
- Directional microphones may be limited in the signal-to-noise ratio (SNR) improvement provided in the real world.
- **Children need a +15 dB speech-to-noise ratio!**

Signal-to-Noise Ratio

- Typical Classrooms:
  - Sanders (1965) reports average SNRs from 47 classrooms
    - 17 Kindergarten: -1 dB
    - 12 Elementary: +5
    - 12 High school: +5

A Noisy World!

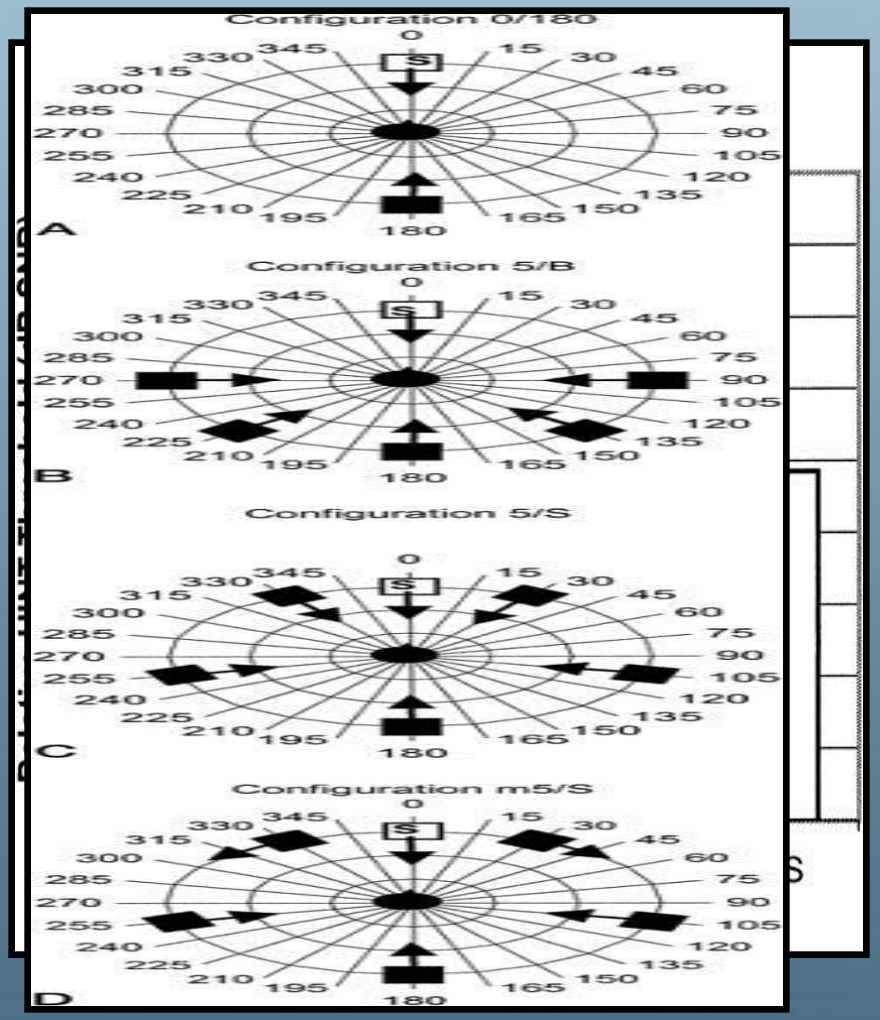
- Living Room:
  - 42 dB A (with A.C. = 52 dBA)
- Chili's (Restaurant):
  - 71 dBA
- School Function:
  - 79 dBA
- Tango!
  - 94 dBA
- OKC Thunder Basketball:
  - 100 dBA

The SNR in these environments is typically -2 to +5 dB

Hearing in Noise

Hearing Loss	SNR Loss
30 dB HL	4 dB
40 dB HL	5 dB
50 dB HL	6 dB
60 dB HL	7 dB
70 dB HL	9 dB
80 dB HL	12 dB
90 dB HL	18 dB

Killion, 2007

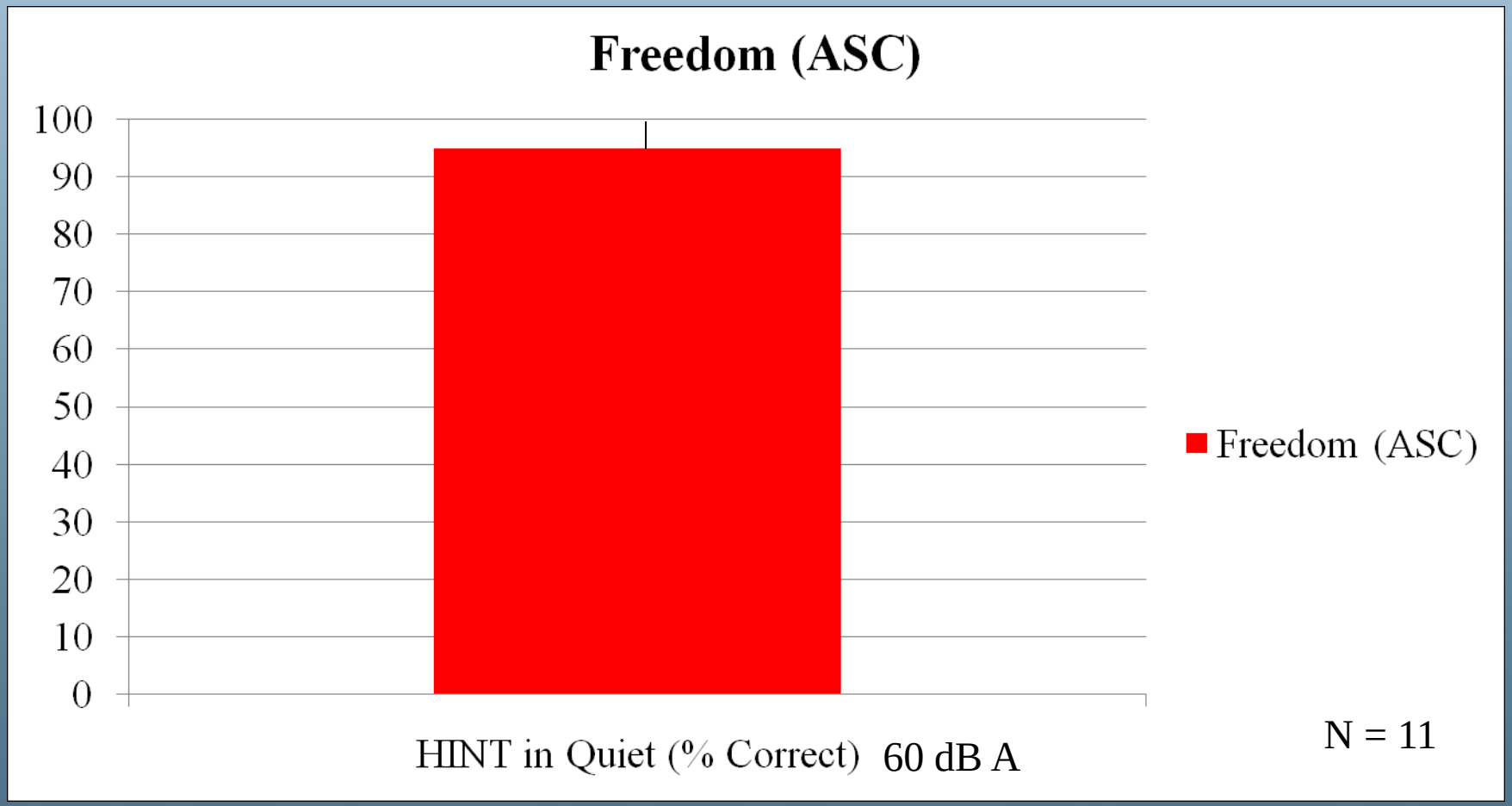


Ricketts (2000), Ear and Hearing

The Listening Brain

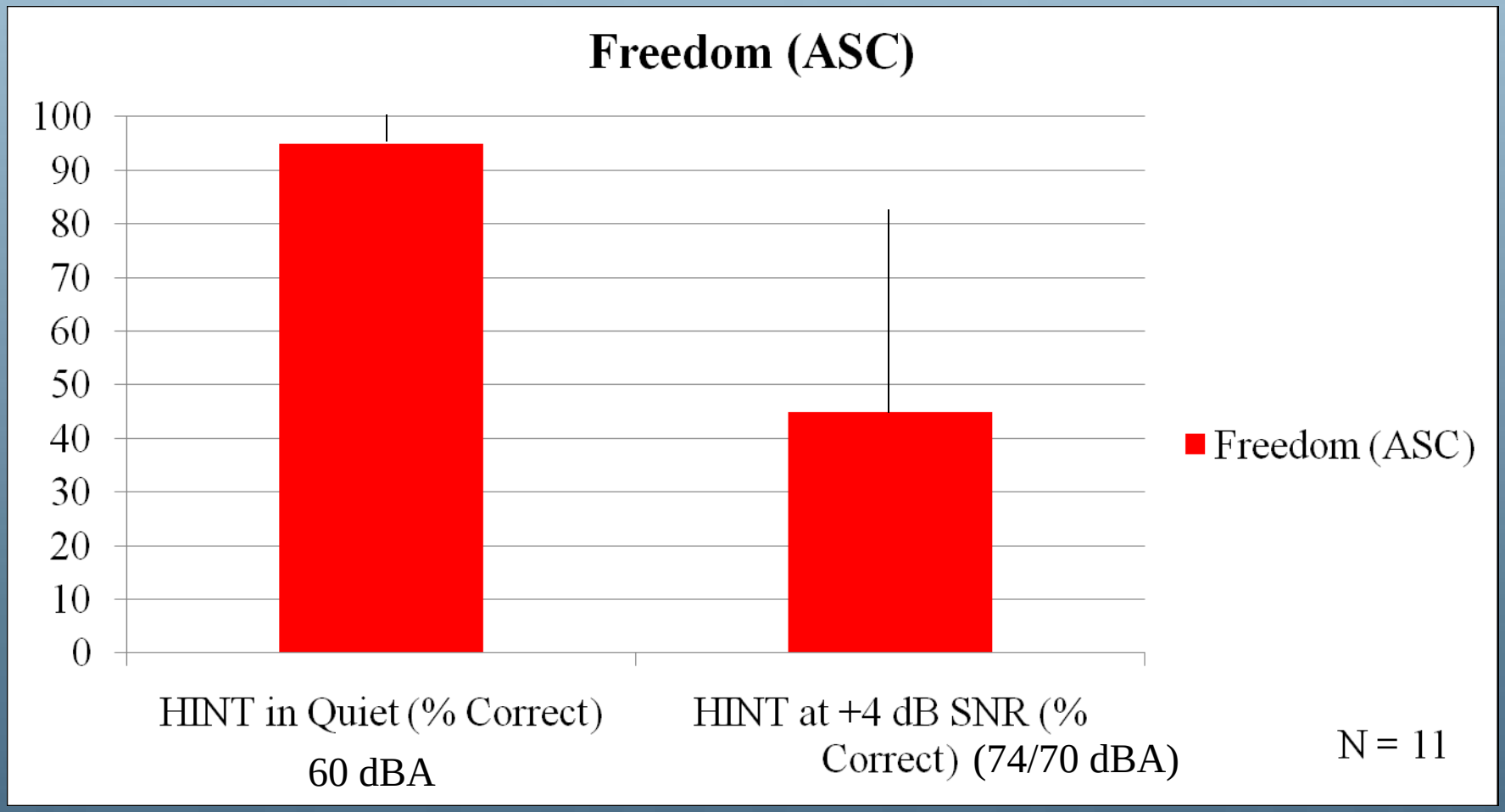
- Childhood hearing loss is a neurodevelopmental emergency!
  - Without early access to consistent, intelligible speech, the auditory centers of the brain will not develop and form intrahemispheric connections.
- How much exposure is necessary?
  - Risley and Hart: 46 million words by 4 years of age
  - Dehaene: 20,000 hours of listening required for reading development.
- The areas of the brain used for listening serve as the foundation for literacy development.
  - Phonemic awareness is the infrastructure of reading.

CI Performance in Quiet



Wolfe et al. (2009)

CI Performance in Noise



Wolfe et al. (2009)

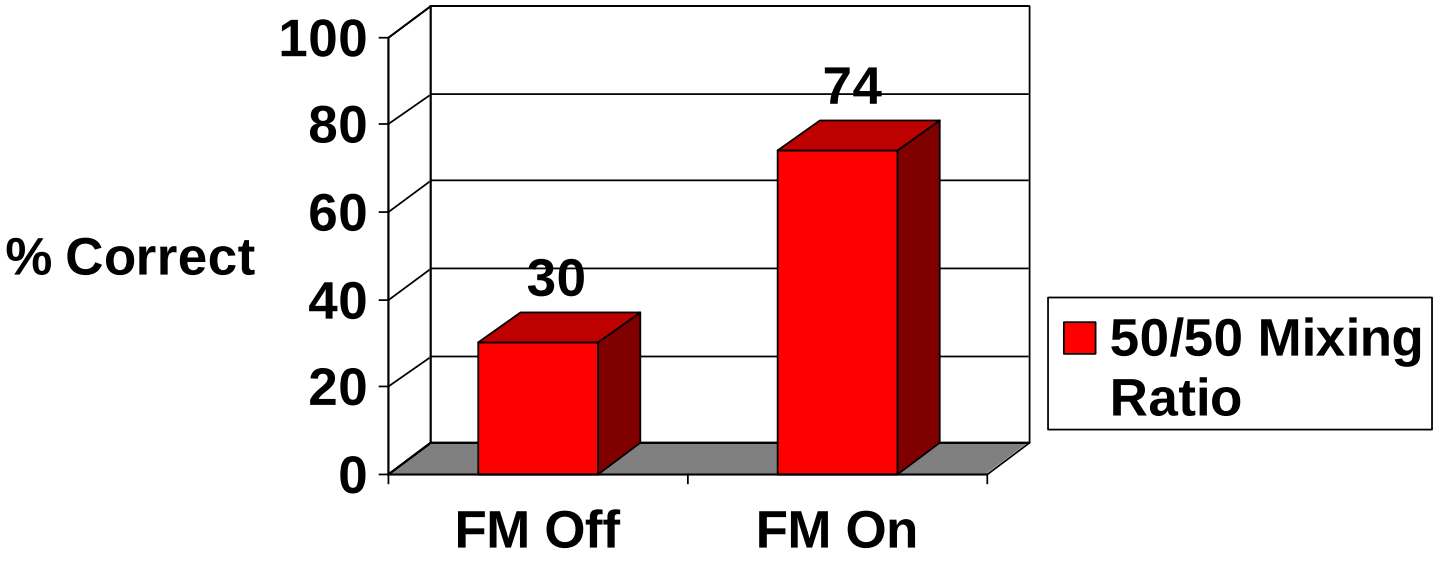
What about FM?

- FM can provide up to a 15-20 dB improvement in the SNR and provide better speech recognition in noise compared to any other technology (Boothroyd, 2004; Hawkins, 1984; Lewis et al., 2004).

- FM should be considered for **ALL** children with hearing loss and for adults experiencing difficulty in noise.

Improvement with FM for CI Users

FM improves performance in noise by over 40 % points!



N=12

Wolfe & Schafer, 2008

FM for All Children!

- But how do we optimize benefit and measure performance?

FM Advantage

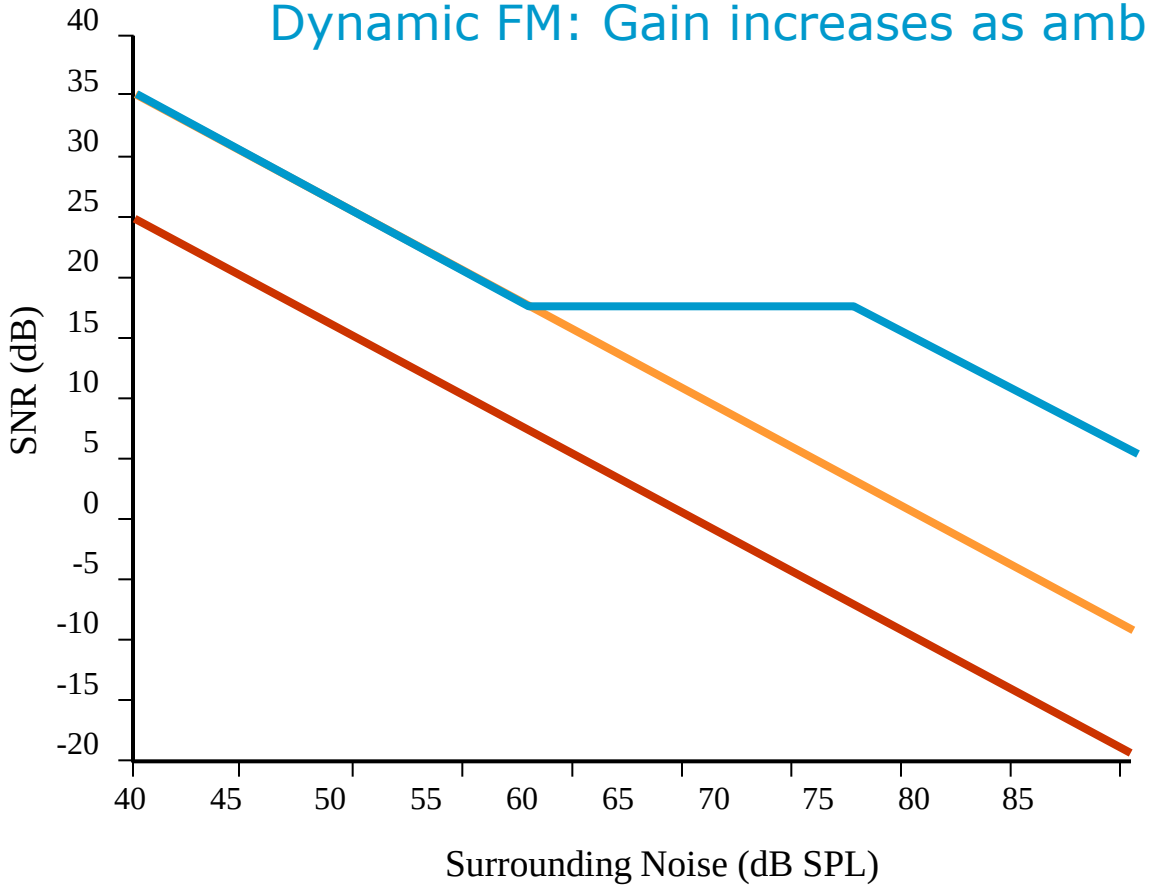
- Refers to the difference in level between the FM signal and the signal from the hearing aid mic.
- With conventional FM, we must strike a compromise: ASHA +10 dB FM Advantage
- (Lewis & Eiten, 2002): Examined preferred FM gain for a variety of listening conditions
  - Quiet: Low FM gain is preferred.
  - Noisy places (Restaurant): High gains preferred (+24 dB)

What about Dynamic FM?

No FM

Traditional FM: Gain is fixed

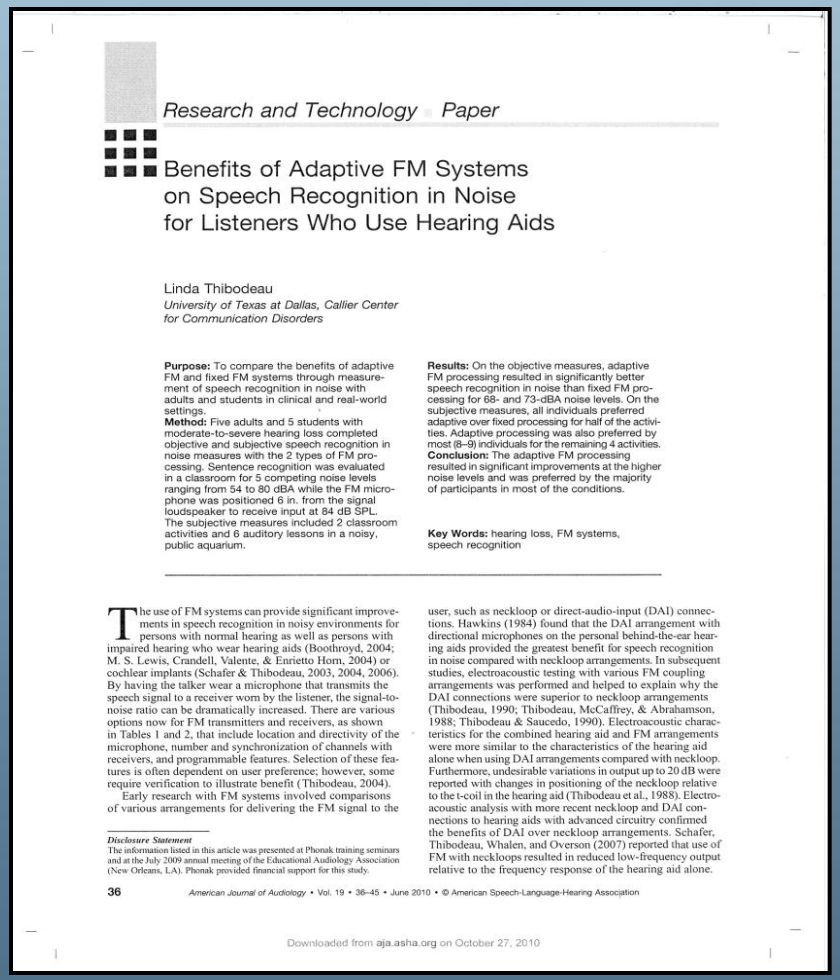
Dynamic FM: Gain increases as ambient noise increases



Distance from Speaker = 2 meters

Speech at 2 meters = 65 dB SPL

Research with Dynamic FM



Research and Technology Paper

Benefits of Adaptive FM Systems on Speech Recognition in Noise for Listeners Who Use Hearing Aids

Linda Thibodeau
University of Texas at Dallas, Callier Center for Communication Disorders

Purpose: To compare the benefits of adaptive FM and fixed FM systems through measurement of speech recognition in noise with adults and students in clinical and real-world settings.
Method: Five adults and 5 students with moderate-to-severe hearing loss completed objective and subjective speech recognition in noise measures with the 2 types of FM processing. Sentence recognition was evaluated in a classroom for 5 competing noise levels ranging from 54 to 80 dBA while the FM microphone was positioned 6 in. from the signal loudspeaker to receive input at 84 dB SPL. The subjective measures included 2 classroom activities and 6 auditory lessons in a noisy, public aquarium.
Results: On the objective measures, adaptive FM processing resulted in significantly better speech recognition in noise than fixed FM processing for 68- and 73-dBA noise levels. On the subjective measures, all individuals preferred adaptive over fixed processing for half of the activities. Adaptive processing was also preferred by most (8–9) individuals for the remaining 4 activities.
Conclusion: The adaptive FM processing resulted in significant improvements at the higher noise levels and was preferred by the majority of participants in most of the conditions.

Key Words: hearing loss, FM systems, speech recognition

The use of FM systems can provide significant improvements in speech recognition in noisy environments for persons with normal hearing as well as persons with impaired hearing who wear hearing aids (Boothroyd, 2004; M. S. Lewis, Crandell, Valente, & Enrietto Horn, 2004) or cochlear implants (Schafer & Thibodeau, 2003, 2004, 2006). By having the talker wear a microphone that transmits the speech signal to a receiver worn by the listener, the signal-to-noise ratio can be dramatically increased. There are various options now for FM transmitters and receivers, as shown in Tables 1 and 2, that include location and directivity of the microphone, number and synchronization of channels with receivers, and programmable features. Selection of these features is often dependent on user preference; however, some require verification to illustrate benefit (Thibodeau, 2004).

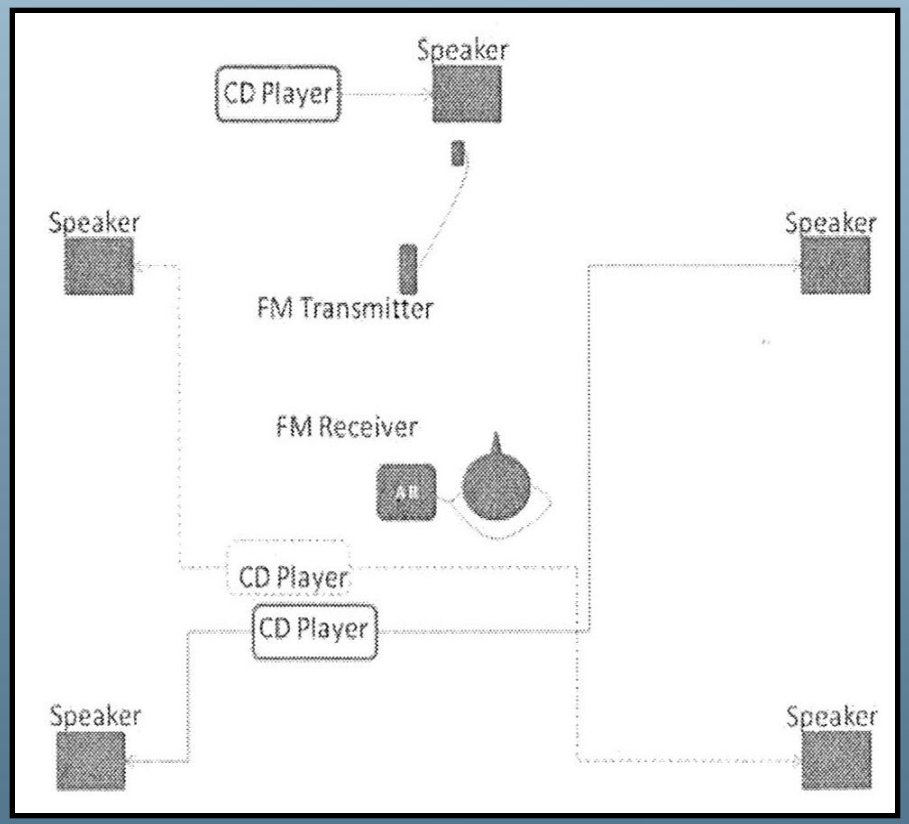
Early research with FM systems involved comparisons of various arrangements for delivering the FM signal to the user, such as neckloop or direct-audio-input (DAI) connections. Hawkins (1984) found that the DAI arrangement with directional microphones on the personal behind-the-ear hearing aids provided the greatest benefit for speech recognition in noise compared with neckloop arrangements. In subsequent studies, electroacoustic testing with various FM coupling arrangements was performed and helped to explain why the DAI connections were superior to neckloop arrangements (Thibodeau, 1990; Thibodeau, McCaffrey, & Abrahamson, 1988; Thibodeau & Saucedo, 1990). Electroacoustic characteristics for the combined hearing aid and FM arrangements were more similar to the characteristics of the hearing aid alone when using DAI arrangements compared with neckloop. Furthermore, undesirable variations in output up to 20 dB were reported with changes in positioning of the neckloop relative to the t-coil in the hearing aid (Thibodeau et al., 1988). Electroacoustic analysis with more recent neckloop and DAI connections to hearing aids with advanced circuitry confirmed the benefits of DAI over neckloop arrangements. Schafer, Thibodeau, Whalen, and Overson (2007) reported that use of FM with neckloops resulted in reduced low-frequency output relative to the frequency response of the hearing aid alone.

Disclosure Statement
The information listed in this article was presented at Phonak training seminars and at the July 2009 annual meeting of the Educational Audiology Association (New Orleans, LA). Phonak provided financial support for this study.

- Measured speech recognition and perceptual benefit for 5 adults and 5 children with moderate to severe SNHL.
- Dynamic FM vs. Traditional, fixed gain FM.

Thibodeau (2010), American Journal of Audiology

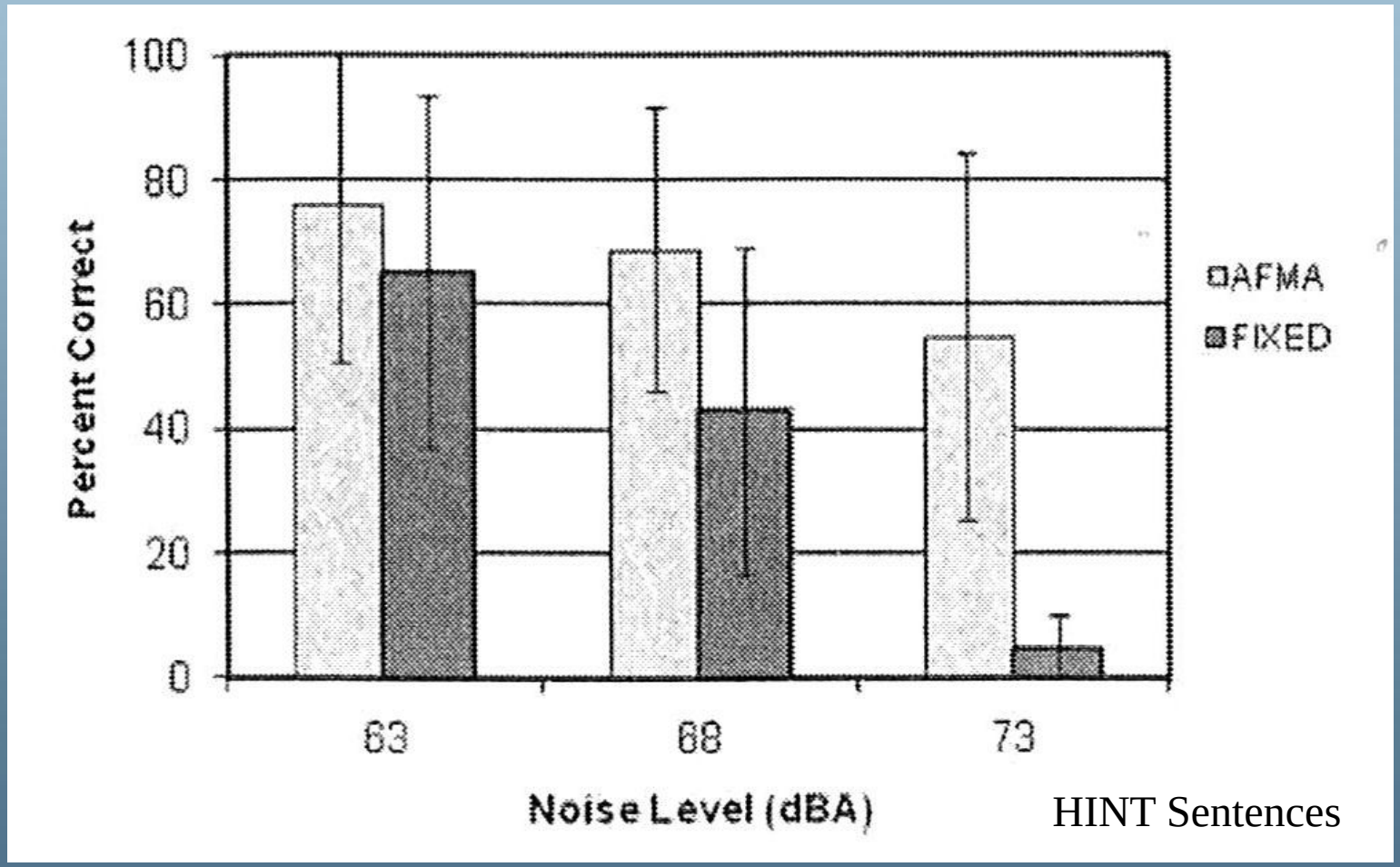
Thibodeau -- Dynamic FM



- Speech Recognition in Noise
  - HINT & SPIN Sentences
    - 84 dB SPL @ FM Mic
    - Front Loudspeaker
  - Classroom Noise
    - 54, 63, 68, 73, 80 dB SPL
    - Four Loudspeakers
- Subjective Assessment
  - Classroom Activities
  - Aquarium "Fieldtrip"
  - Participants were blinded

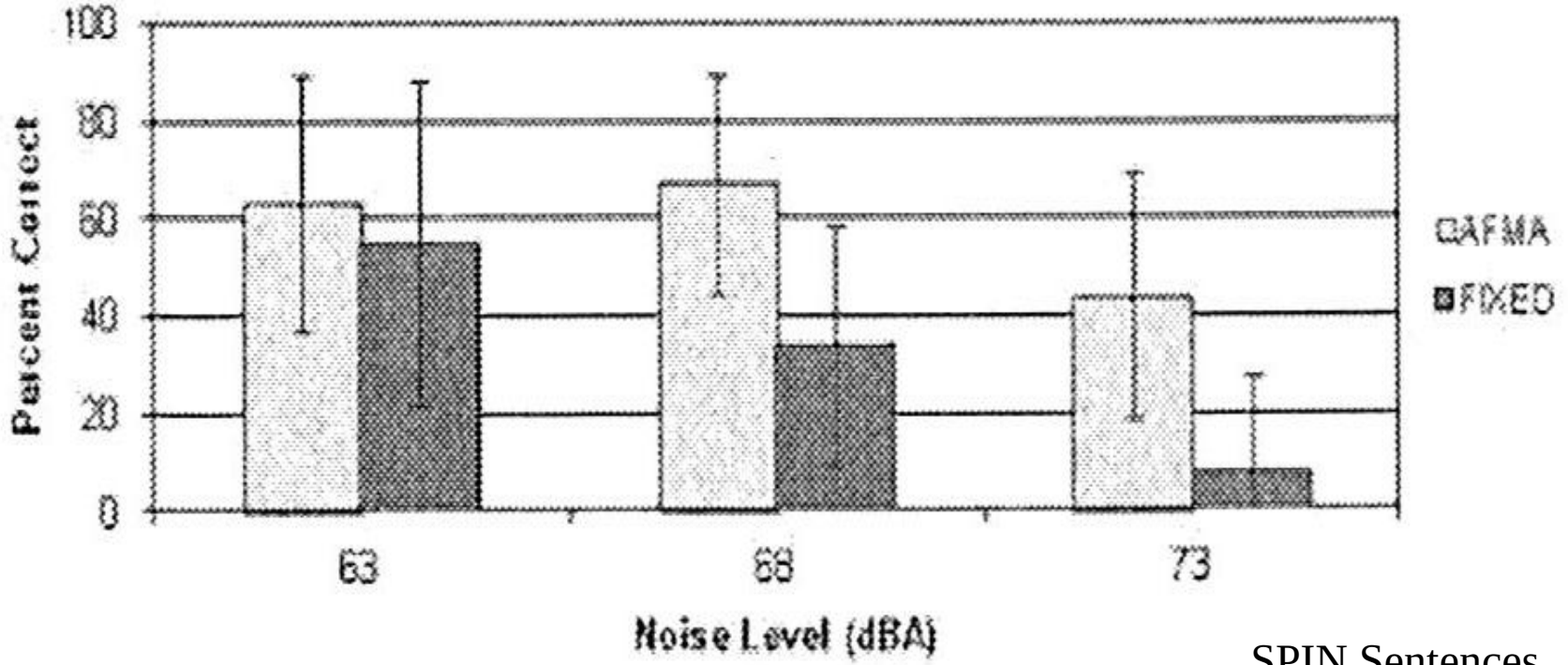
Thibodeau (2010), American Journal of Audiology

Thibodeau -- Dynamic FM



Thibodeau (2010), American Journal of Audiology

Thibodeau -- Dynamic FM



SPIN Sentences

Thibodeau (2010), American Journal of Audiology

Thibodeau -- Dynamic FM

No.	Activity	Location	Task		% selecting AFMA	% selecting fixed
1	Origami	Classroom	Participants were seated in classroom chairs with folding desktops. One research assistant wore the transmitter and gave instructions to fold paper to make a flower while classroom noise was played in surrounding speakers at 65 dBA.		100	0
2	Catch phrase game	Classroom	Participants were seated in chairs in a large circle. The transmitter microphone was passed around as each participant gave clues regarding a word or phrase for others to guess while the same noise used in No. 1 was presented.		100	0
3	Tour guide stations	Aquarium	A trained tour guide wore the transmitter and provided information regarding 6 aquarium exhibits while the ambient noise levels ranged from 70 to 95 dBA. The participants stood around the guide.	Stations		
				40-foot waterfall	90	10
				Sloth in rainforest	100	0
				Reptile exhibit	100	0
				Manatee feeding	80	20
				Aquatic tunnel	80	20
				Coral and seahorses	90	10

Note. AFMA = adaptive FM advantage.

Thibodeau (2010), American Journal of Audiology

FM: How to Verify

- AAA Clinical Practice Guideline:

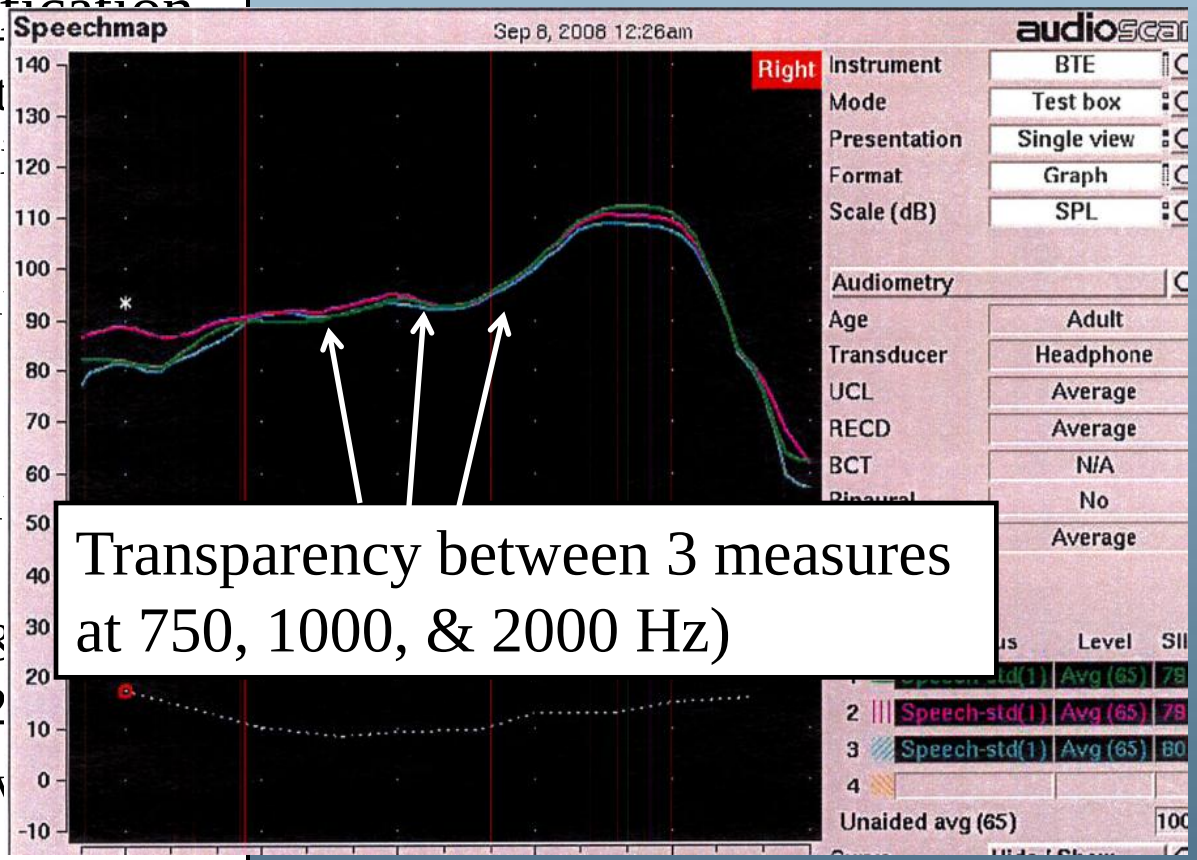
  Remote Microphone Hearing Assistance Technologies for Children and Youth Birth-21 Years (2007)

  www.audiology.org

http://www.audiology.org/resources/documentlibrary/Pages/HearingAssistanceTechnologies.aspx

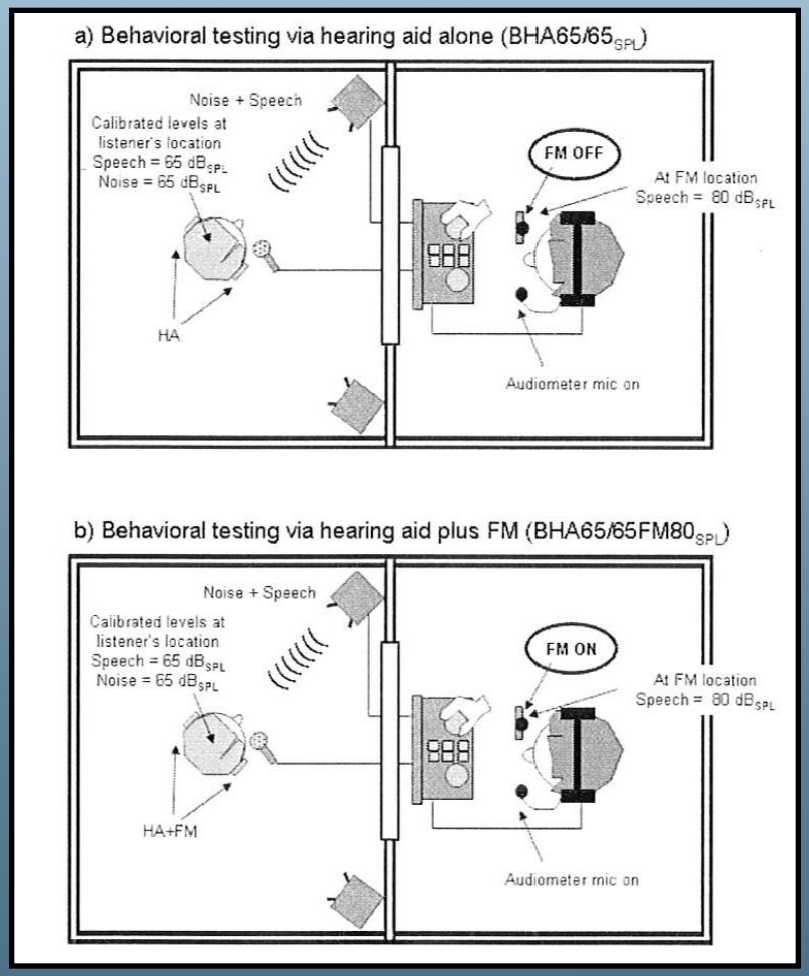
FM Verification

- Electroacoustic Verification
- Ensure optimal aided out
  65 dB SPL speech-like s
  HA mic without FM
- Measure aided output wi
  attached and 65 dB SPL
  like input to HA mic
- Measure aided output wi
  SPL speech-like input to
- Difference between 2nd &
  measures should be +/- 2
- Adjust FM gain to achiev
  transparency.



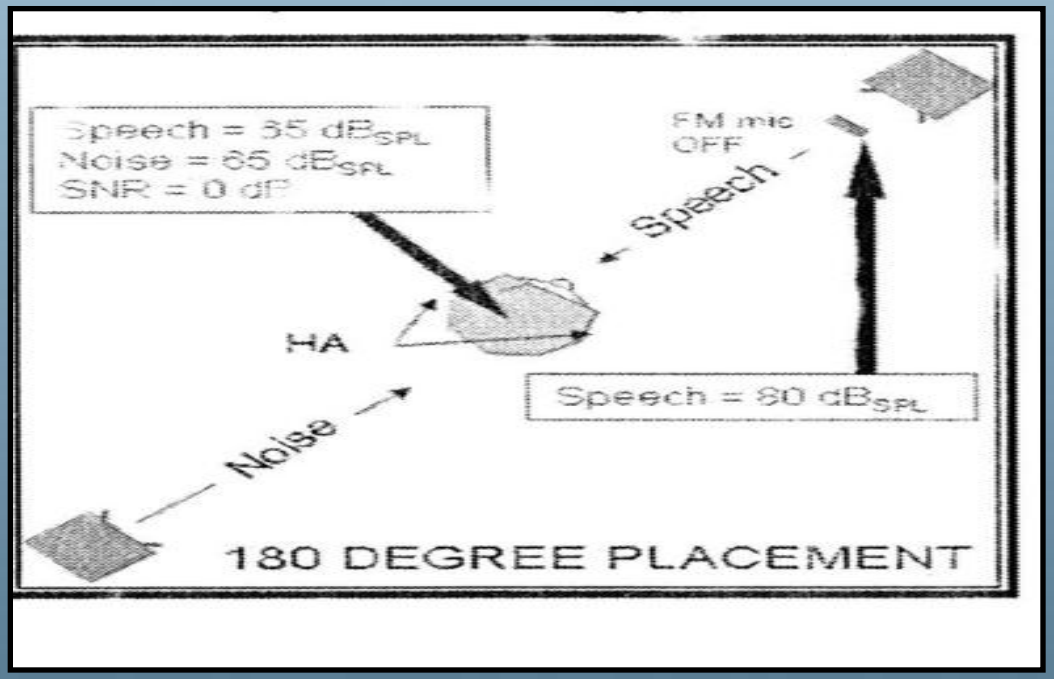
Transparency between 3 measures at 750, 1000, & 2000 Hz)

Validation: Speech Recognition



- AAA recommends testing in noise (50 dBHL/50 dBHL: 0 dB SNR) and in quiet.
- Can be conducted via MLV with tester wearing FM mic

AAA Clinical Practice Guidelines: Remote Microphone: Hearing Assistance Technologies for Children Birth to 21 Years



Recorded presentation with FM mic positioned 15-20 cm from the loudspeaker used to present speech.

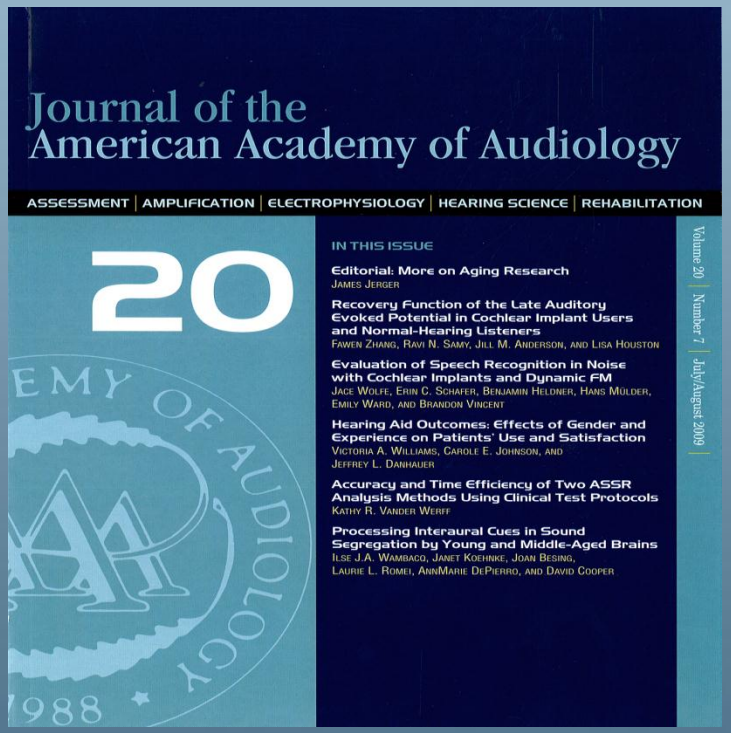
Noise from 180 degrees.

Speech = 50 dB HL

Noise = 50 dB HL

- What about Dynamic FM for Cochlear Implants?

Evaluation of Dynamic FM with Cochlear Implants



J Am Acad Audiol 20:409–421 (2009)

Evaluation of Speech Recognition in Noise with Cochlear Implants and Dynamic FM

DOI: 10.3766/jaaa.20.7.3

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Brandon Vincent§

Abstract

Background: Use of personal frequency-modulated (FM) systems significantly improves speech recognition in noise for users of cochlear implants (CIs). Previous studies have shown that the most appropriate gain setting on the FM receiver may vary based on the listening situation and the manufacturer of the CI system. Unlike traditional FM systems with fixed-gain settings, Dynamic FM automatically varies the gain of the FM receiver with changes in the ambient noise level. There are no published reports describing the benefits of Dynamic FM use for CI recipients or how Dynamic FM performance varies as a function of CI manufacturer.

Purpose: To evaluate speech recognition of Advanced Bionics Corporation or Cochlear Corporation CI recipients using Dynamic FM vs. a traditional FM system and to examine the effects of Autosensitivity on the FM performance of Cochlear Corporation recipients.

Research Design: A two-group repeated-measures design. Participants were assigned to a group according to their type of CI.

Study Sample: Twenty-five subjects, ranging in age from 8 to 82 years, met the inclusion criteria for one or more of the experiments. Thirteen subjects used Advanced Bionics Corporation, and 12 used Cochlear Corporation implants.

Intervention: Speech recognition was assessed while subjects used traditional, fixed-gain FM systems and Dynamic FM systems.

Data Collection and Analysis: In Experiments 1 and 2, speech recognition was evaluated with a traditional, fixed-gain FM system and a Dynamic FM system using the Hearing in Noise Test sentences in quiet and in classroom noise. A repeated-measures analysis of variance (ANOVA) was used to evaluate effects of CI manufacturer (Advanced Bionics and Cochlear Corporation), type of FM system (traditional and dynamic), noise level, and use of Autosensitivity for users of Cochlear Corporation implants. Experiment 3 determined the effects of Autosensitivity on speech recognition of Cochlear Corporation implant recipients when listening through the speech processor microphone with the FM system muted. A repeated-measures ANOVA was used to examine the effects of signal-to-noise ratio and Autosensitivity.

Results: In Experiment 1, use of Dynamic FM resulted in better speech recognition in noise for Advanced Bionics recipients relative to traditional FM at noise levels of 65, 70, and 75 dB SPL. Advanced Bionics recipients obtained better speech recognition in noise with FM use when compared to Cochlear Corporation recipients. When Autosensitivity was enabled in Experiment 2, the performance of Cochlear Corporation recipients was equivalent to that of Advanced Bionics recipients, and Dynamic FM was significantly better than traditional FM. Results of Experiment 3 indicate that use of

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The Phonak Hearing Aid Company provided financial support for this study.

Wolfe et al. (2009)

Subjects

- 30 subjects
  - 8-82 years old
- Used Advanced Bionics Corporation or Nucleus cochlear implants
- Evaluated performance with various speech processors (39 total)
  - 8 Harmony
  - 4 Auria
  - 2 CII
  - 3 PSP
  - 2 Platinum BTE
  - 1 S-Series
  - 12 Freedom
  - 3 Esprit 3G
  - 2 Sprint
  - 1 Spectra

Reporting on…..

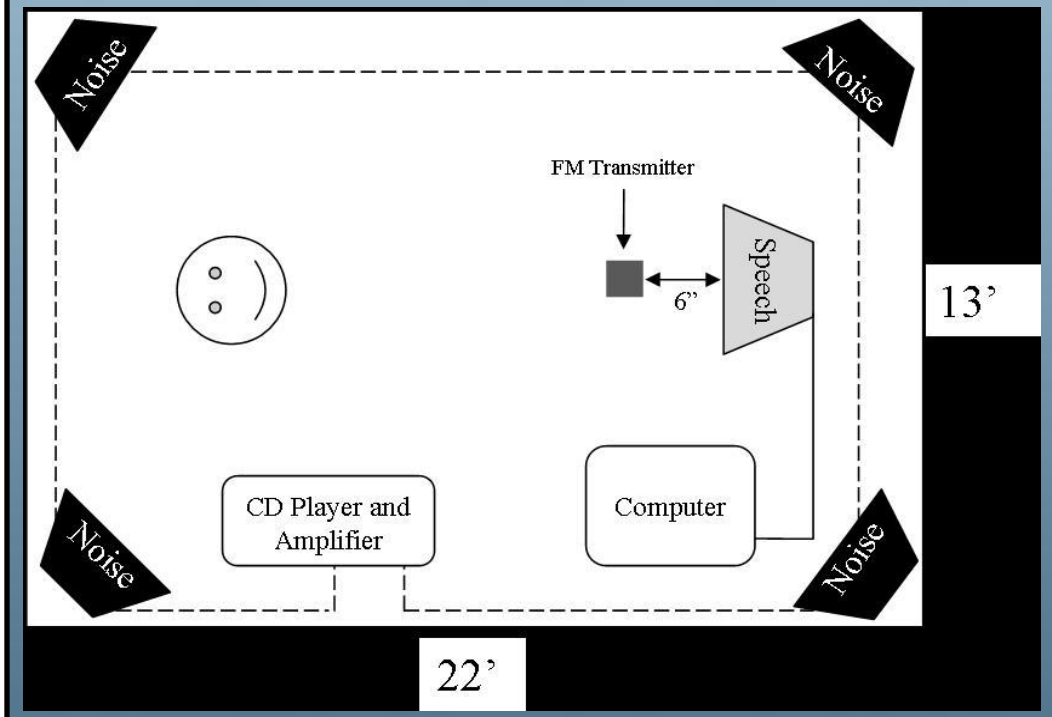
- 13 Advanced Bionics users
  - Various speech processors
- 11 Nucleus users
  - Freedom speech processors

- These users reflect general trends observed for persons with Advanced Bionics and Nucleus cochlear implants.

Wolfe et al. (2009)

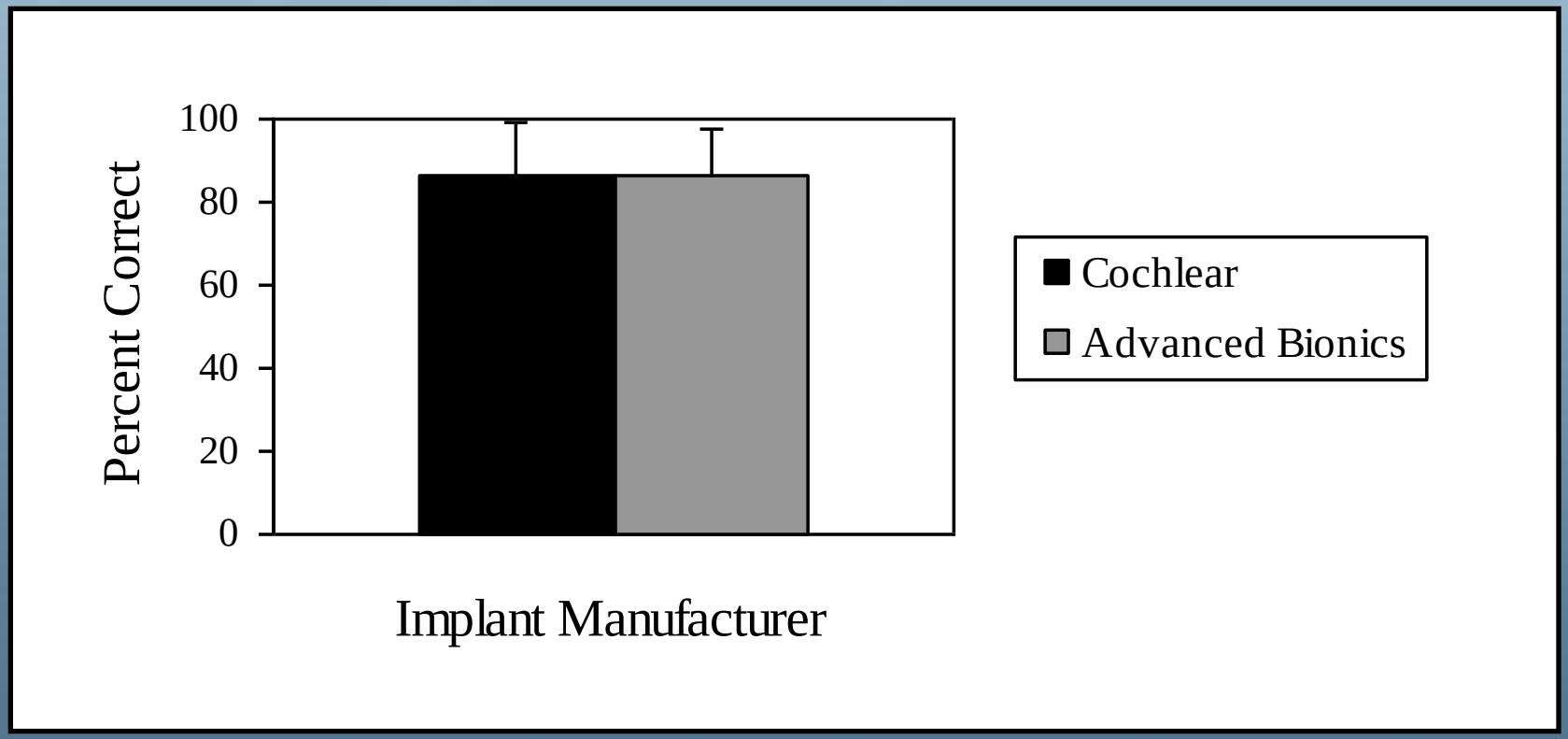
Equipment

- Ambient noise level: 46 dB SPL.
- HINT sentences presented at 85 dB SPL to the input of the FM microphone directly in front of subject (2 lists/condition).
- The FM microphone was suspended 6 inches from the single-cone of the loudspeaker used to present the stimuli.
- Performance measured in quiet & in classroom noise (Schafer & Thibodeau, 2004) at:
  - 55 dB(A) SPL
  - 65 dB(A) SPL
  - 70 dB(A) SPL
  - 75 dB(A) SPL
- Noise presented from 4 loudspeakers.
- Measured with MLxS (traditional) and Mlxi (Dynamic).



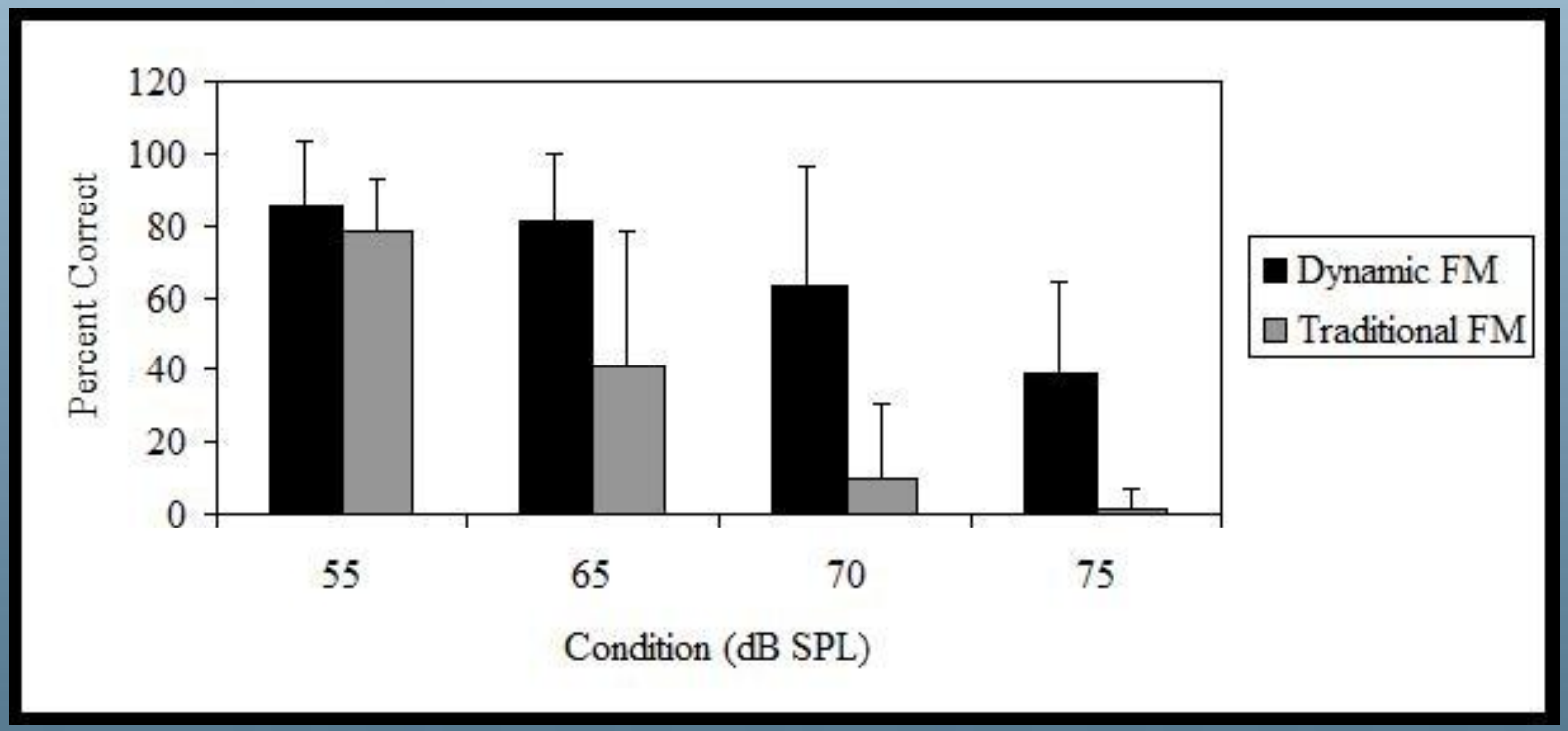
Wolfe et al. (2009)

Speech Recognition in Quiet Results



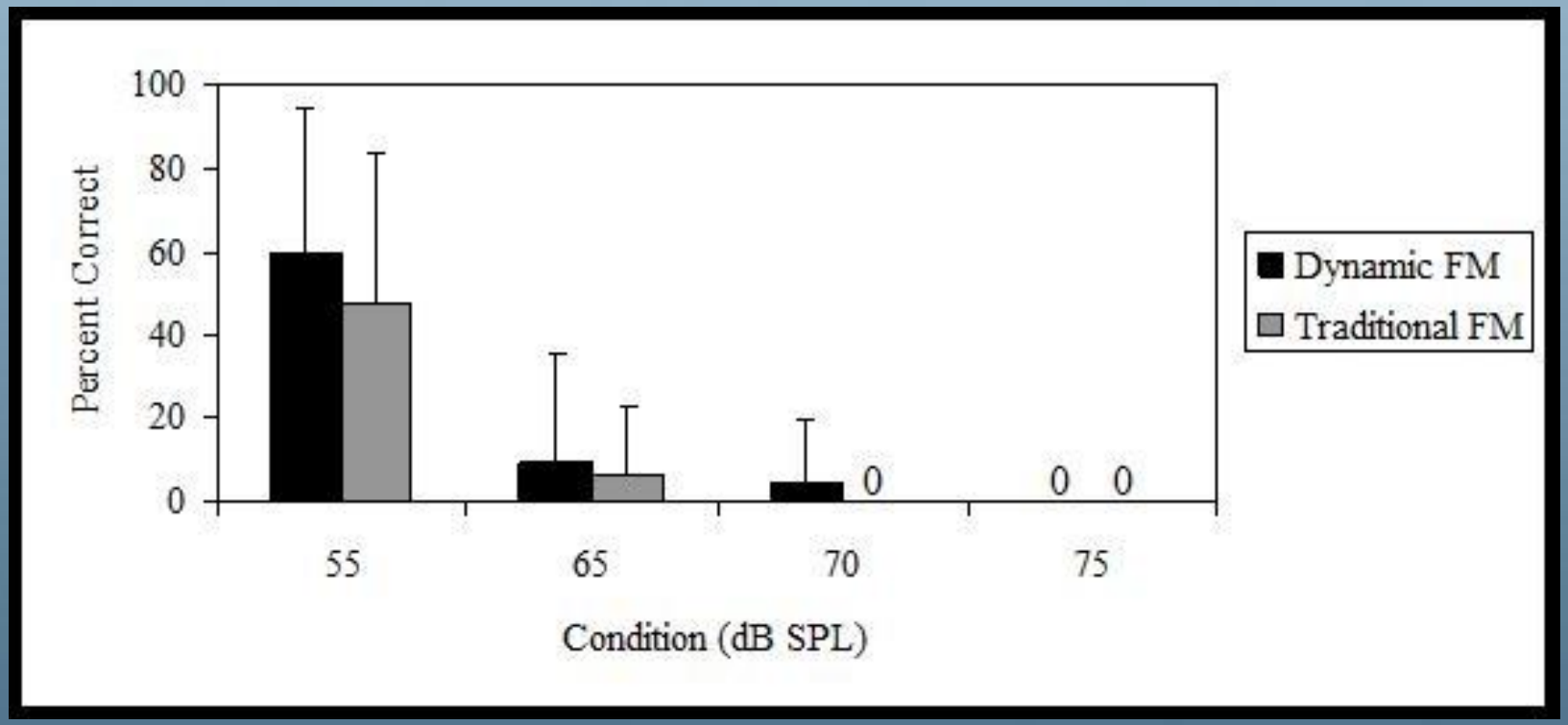
Wolfe et al. (2009)

Speech Recognition in Noise Results – Advanced Bionics



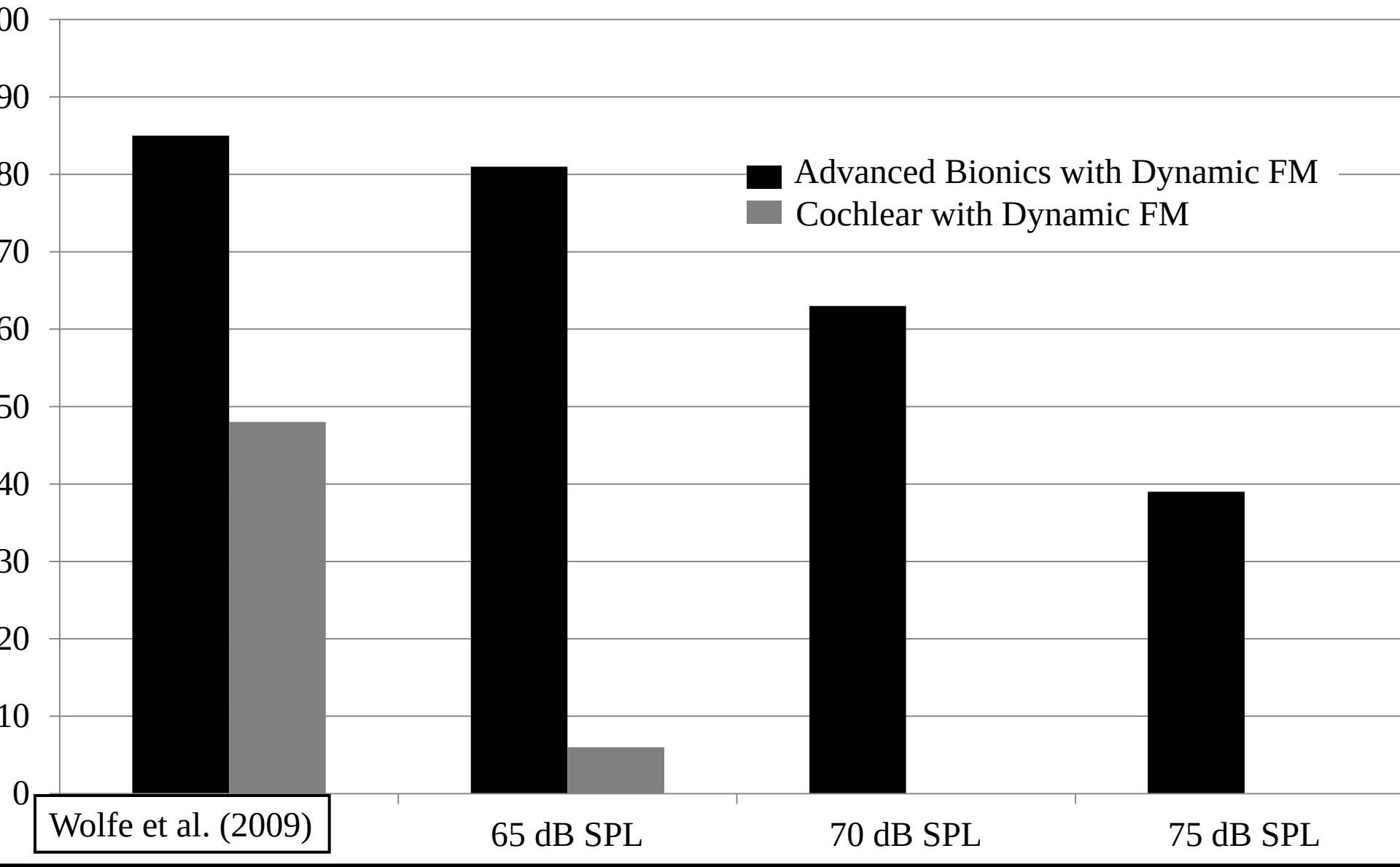
Wolfe et al. (2009)

Speech Recognition in Noise Results – Cochlear Corporation



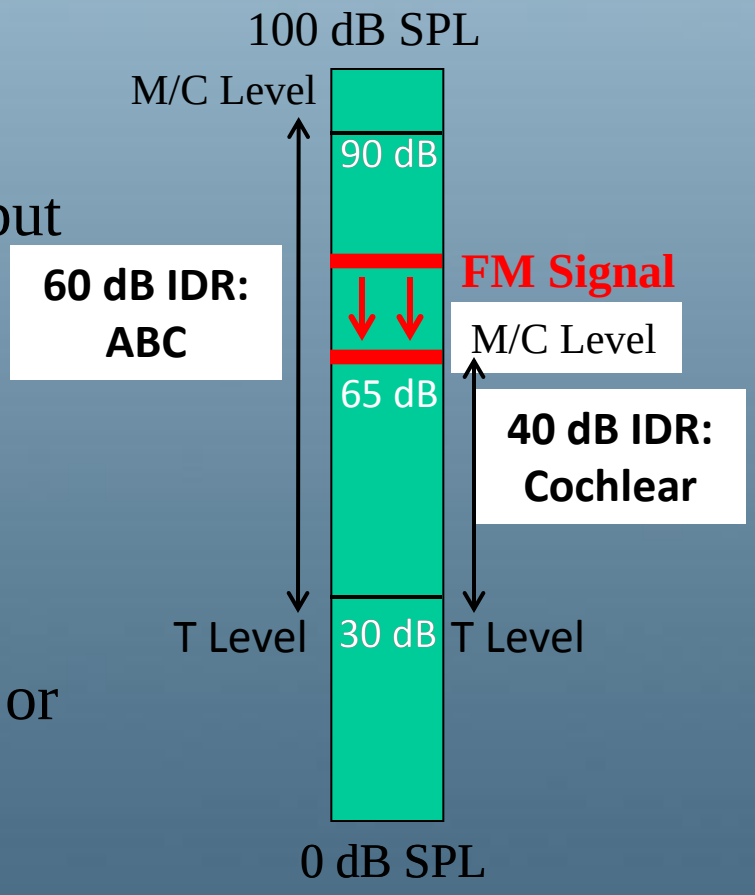
Wolfe et al. (2009)

Advanced Bionics vs. Nucleus



Input Dynamic Range

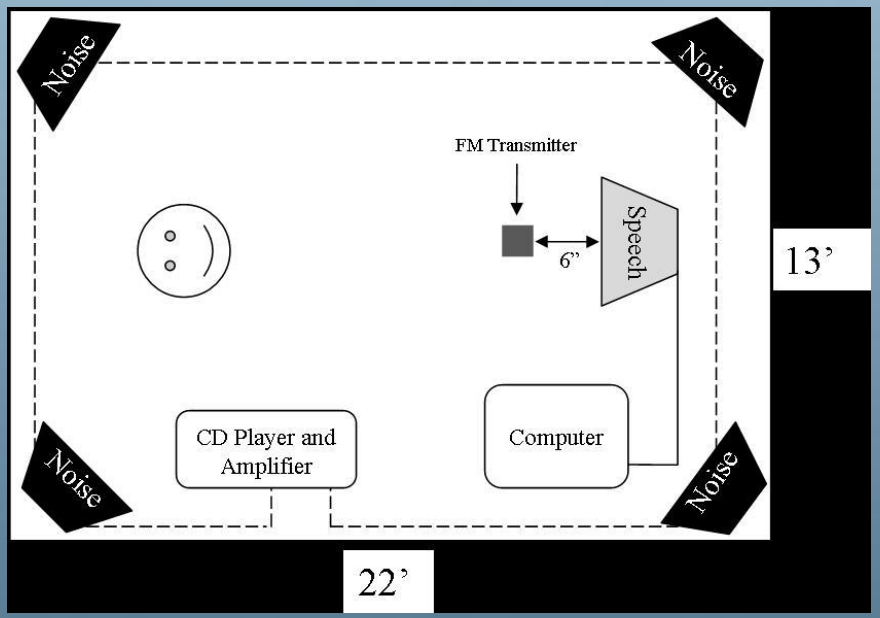
- Why would IDR affect FM benefit?
  - FM signal compressed when IDR significantly limits the input signal at 65 dB
  - Cochlear users: speech recognition scores unchanged with increased FM gain
  - ABC users: higher IDR allows for coding of the gain changes or louder inputs from the FM



Wolfe et al, Journal of the American Academy of Audiology, 2009

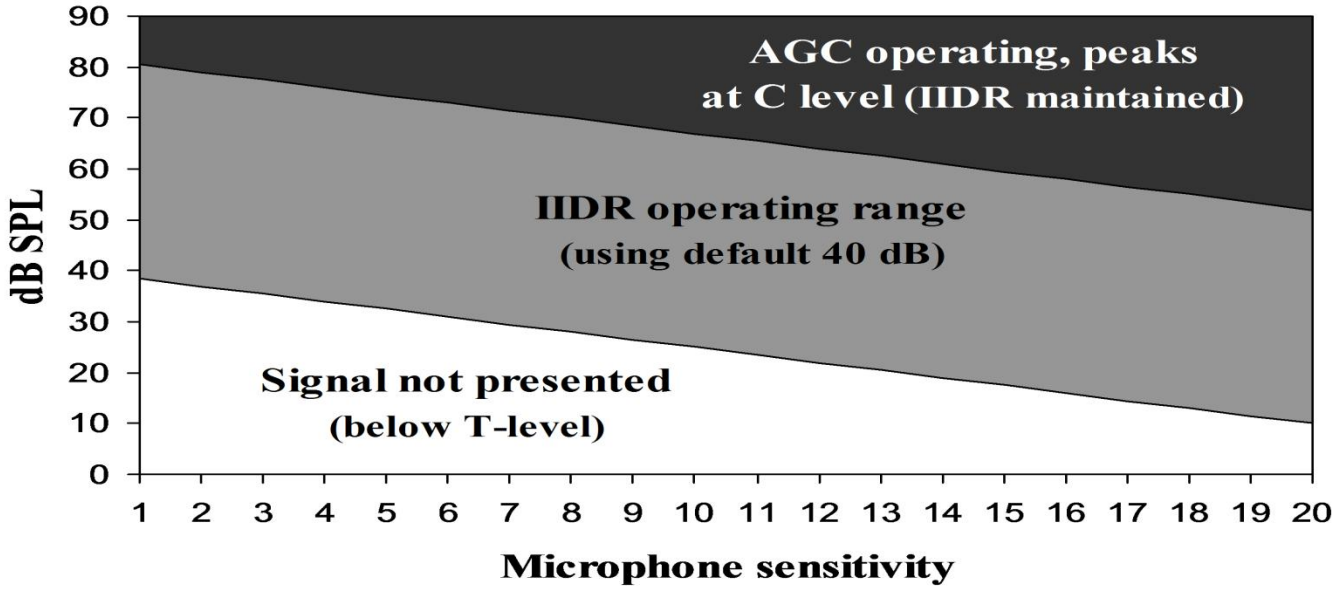
Procedure

- The same equipment and set-up was used as in the previous study mentioned.
- Speech recognition in noise was examined with dynamic FM and traditional FM at three noise levels (65, 70, and 75 dB SPL) with ASC on and off for a total of twelve listening situations.

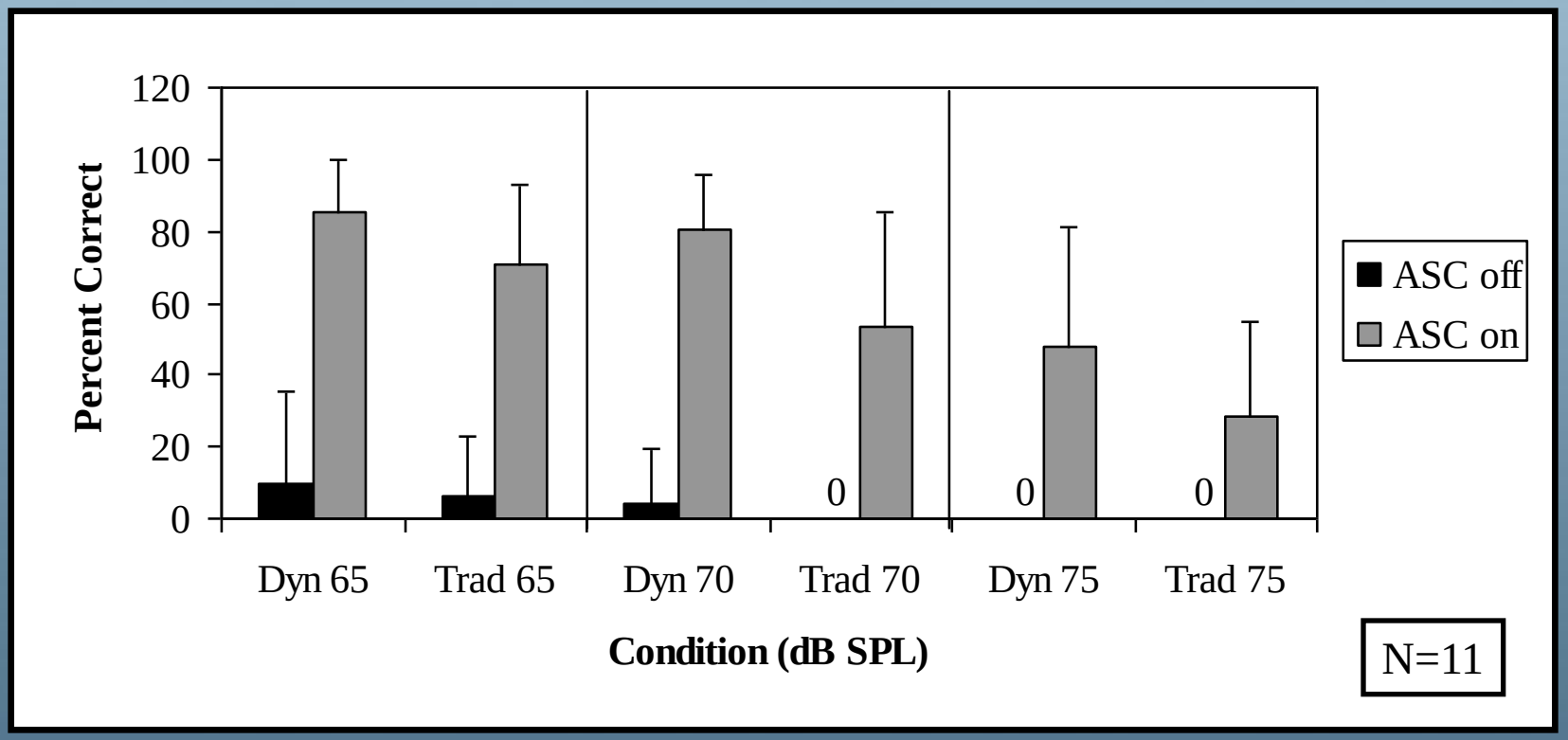


Wolfe et al. (2009)

Autosensitivity (ASC)

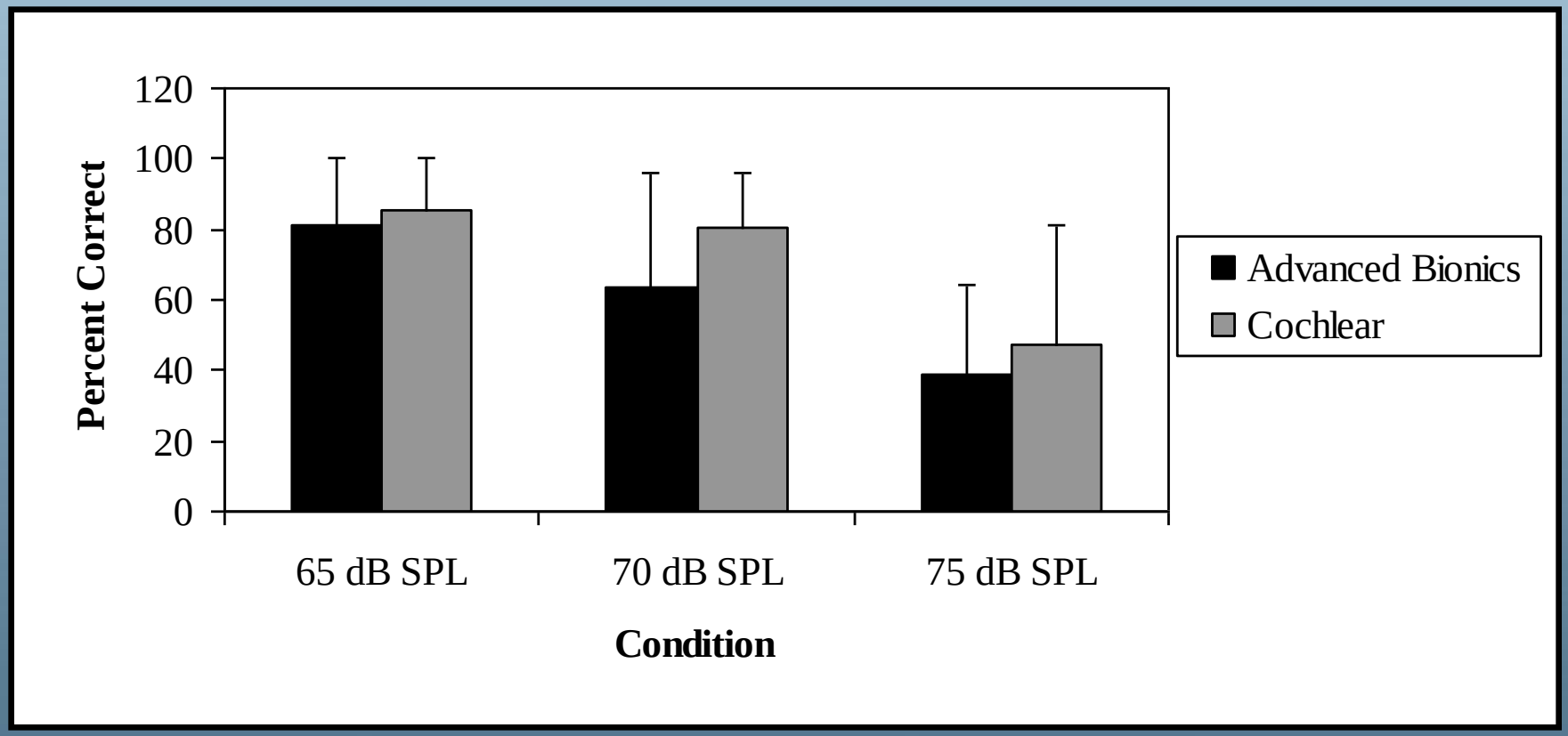


Results



Wolfe et al. (2009)

Results

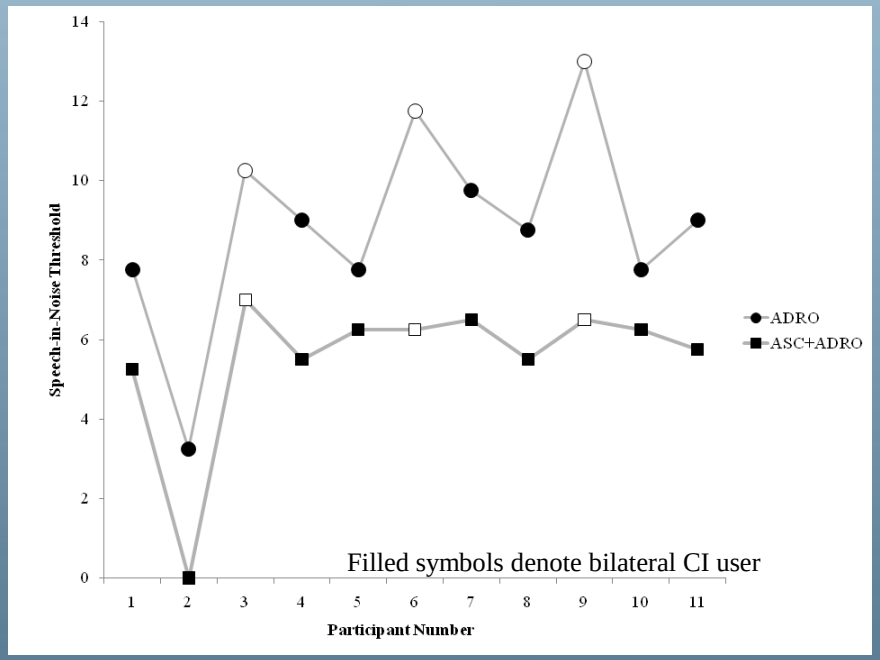


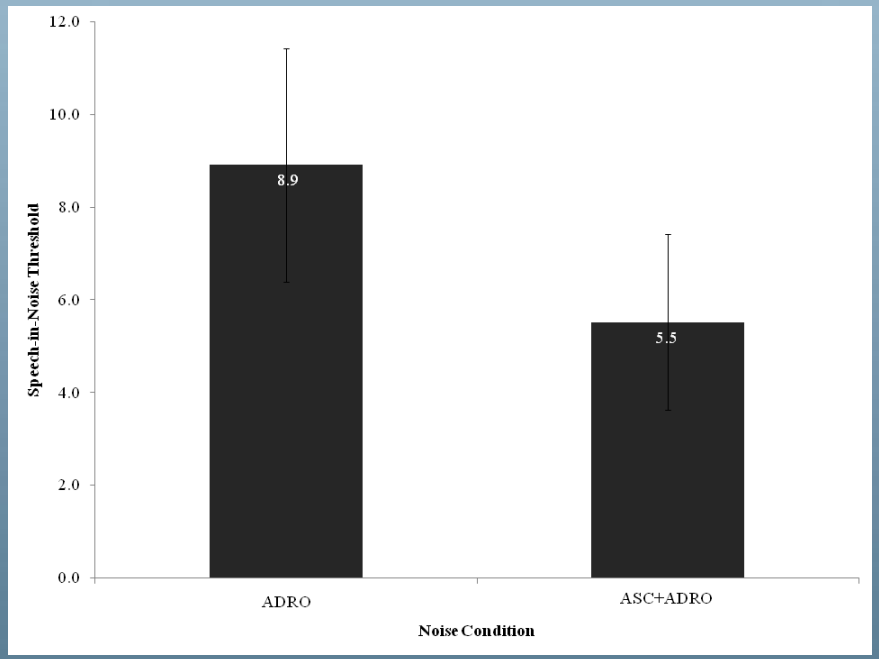
Wolfe et al. (2009)

- What about ASC for kids?

How about ASC for kids?

- 11 Children: Ages 4 to 12 years old
- Nucleus Freedom and Nucleus 5 Users



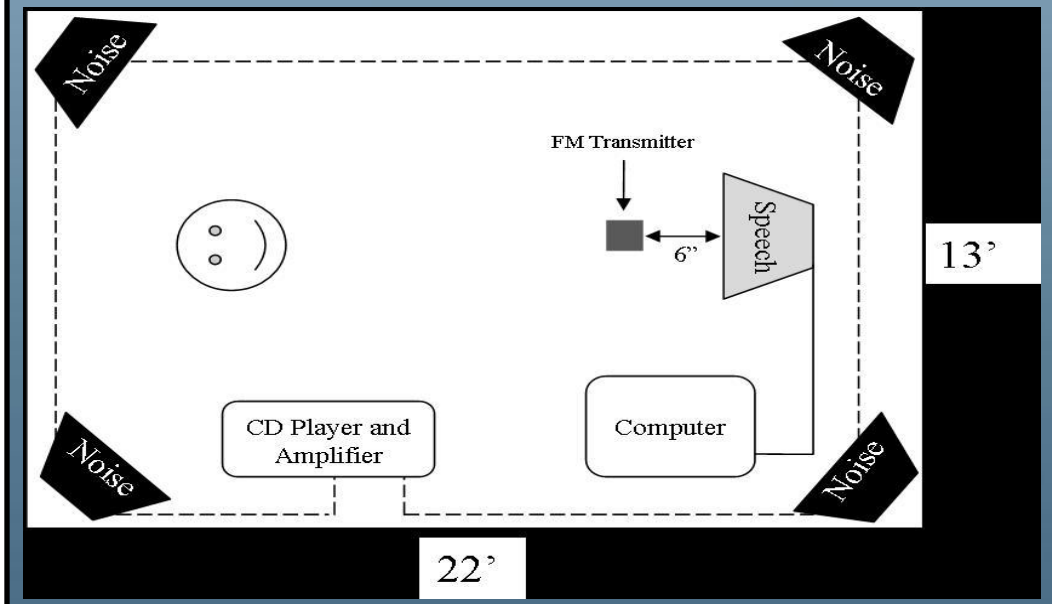


Mean Word Recognition in Quiet (PBK-50): 93% Correct

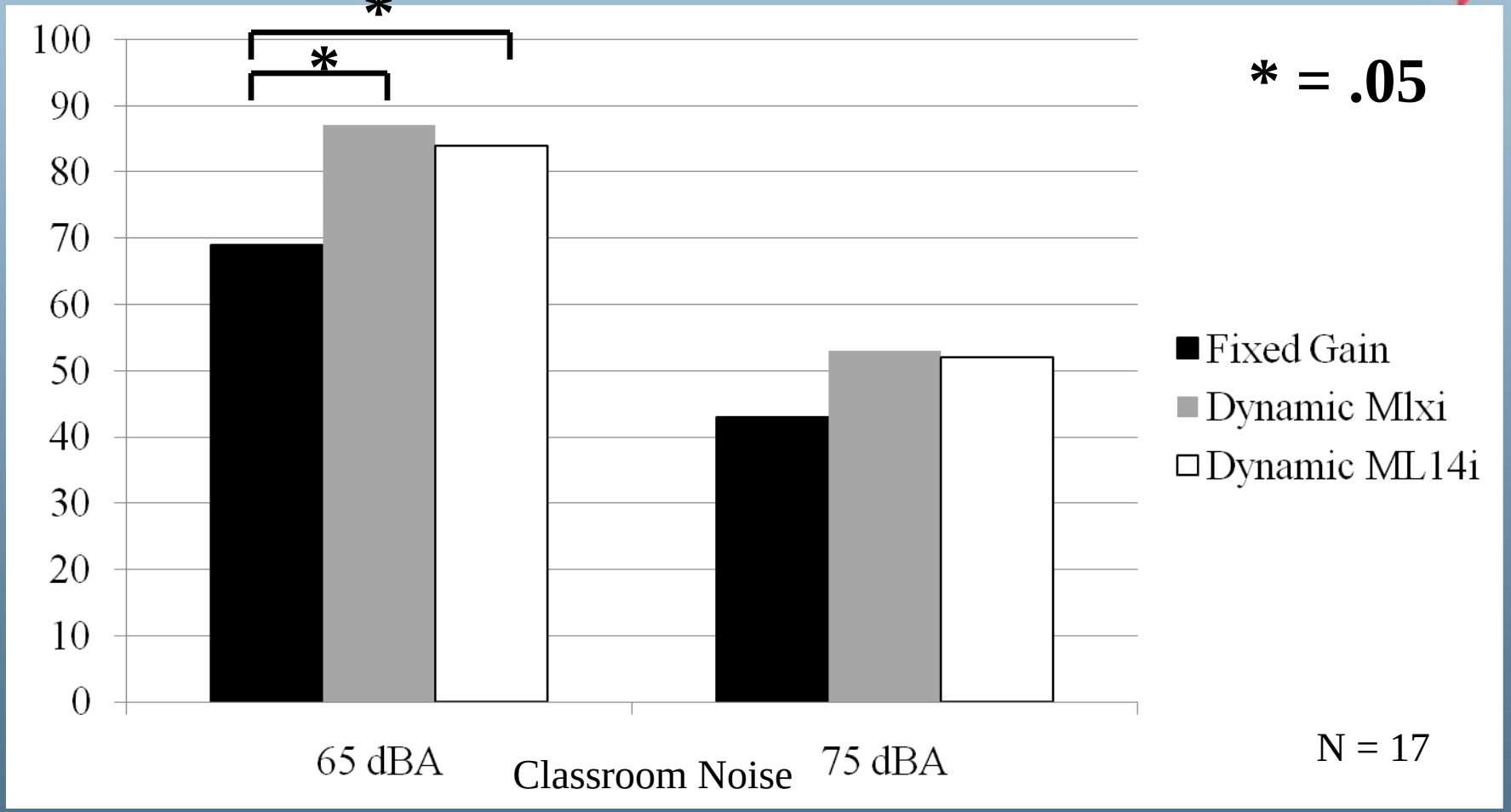
Wolfe et al. (2011)

Dynamic FM and the Nucleus 5

- Ambient noise level: 45 dBA
- HINT sentences presented at 85 dBA to the input of the FM microphone directly in front of subject (2 lists/condition).
- The FM microphone suspended 6 inches in front of loudspeaker used to present the stimuli.
- Performance measured in quiet & in classroom noise (Schafer & Thibodeau, 2004) at:
  - 55 dB(A) SPL
  - 65 dB(A) SPL
  - 70 dB(A) SPL
  - 75 dB(A) SPL
- Noise presented from 4 loudspeakers.
- Nucleus 5
- Measured with Dynamic FM and fixed-gain FM.



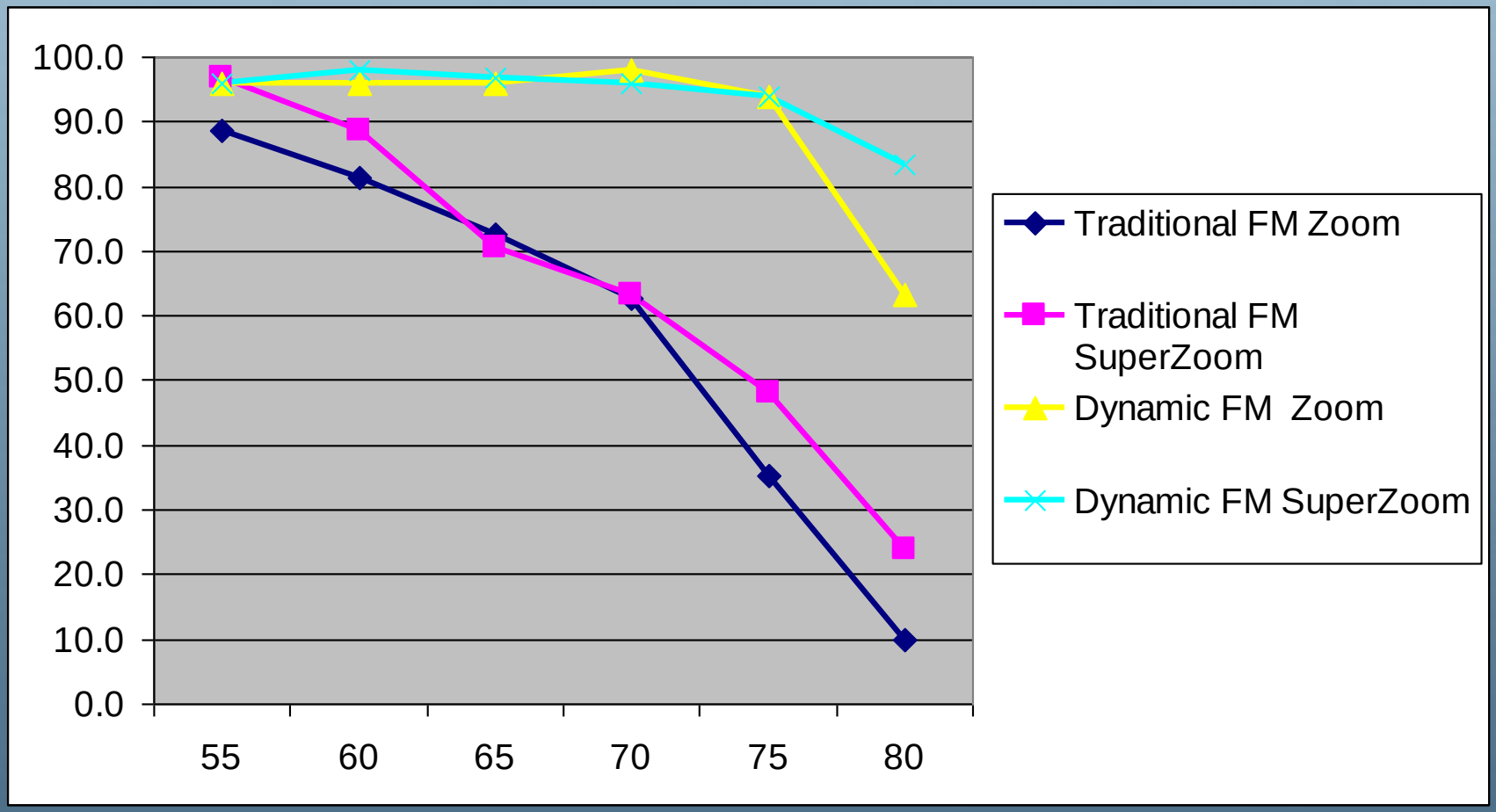
Dynamic FM/N5 Results



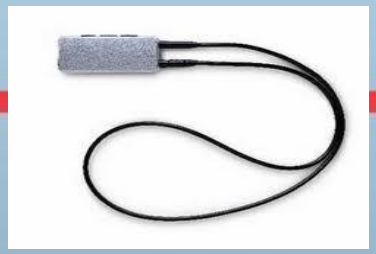
Dynamic FM and Cochlear Implants from MED-EL Felix Goldbeck, Switzerland

- 3 adult MED-EL Opus 2 users
- Speech recognition in noise: OLSA test (German)
- Similar set up as Thibodeau and Wolfe
- Speech recognition in various noise level for Dynamic FM and traditional FM for various transmitter microphone modes
- Noise levels: 55, 60, 65, 70, 75 and 80 dB(A)
- Transmitters: SmartLink (traditional FM) and SmartLink+ (Dynamic FM)
- Microphone modes tested: Zoom (fixed cardioid) and SuperZoom (adaptive multiband beamformer)

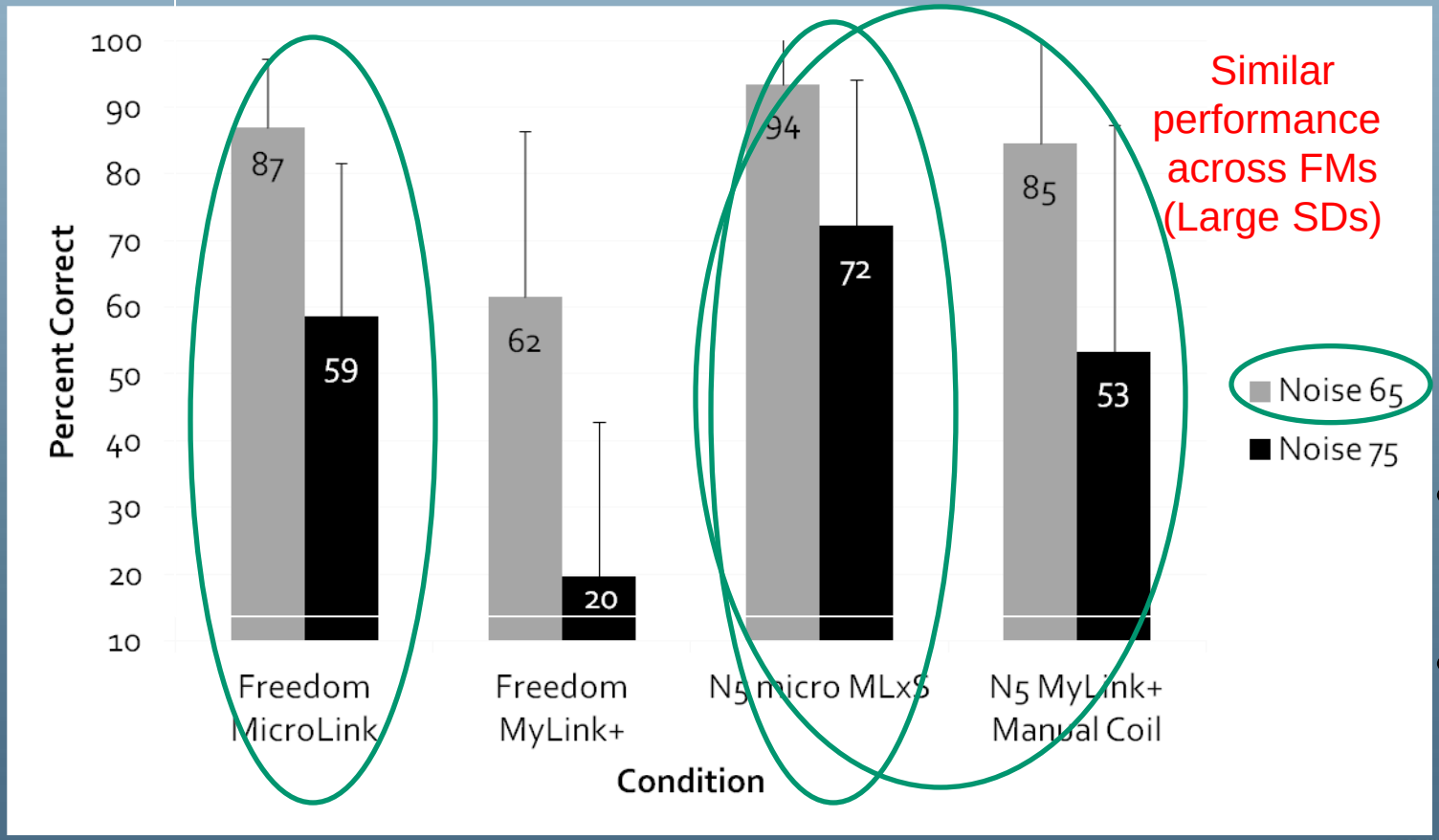
Speech recognition in noise for traditional FM and Dynamic FM for Zoom and SuperZoom



Are neckloop receivers helpful to those with CIs?



- 14 Freedom users upgrading to Nucleus 5



Significantly Better:

- At 65 dB SPL
- Nucleus 5
- Direct Connection

Multi-center/Wolfe, submitted

Dynamic FM for normal hearing listeners with simulated loss
Linda Thibodeau et al, USA

- Ongoing study by Linda Thibodeau, PhD, University of Texas at Dallas, USA, and the Callier Centre for Communication Disorders, Dallas

- Both tested with persons with temporary unilateral hearing loss, as a result of a yellow foam earplug

Equipment

iSense

inspiro

Pillow Pack

EduLink

Output of iSense set to match EduLink with VC full on in 2 cc coupler

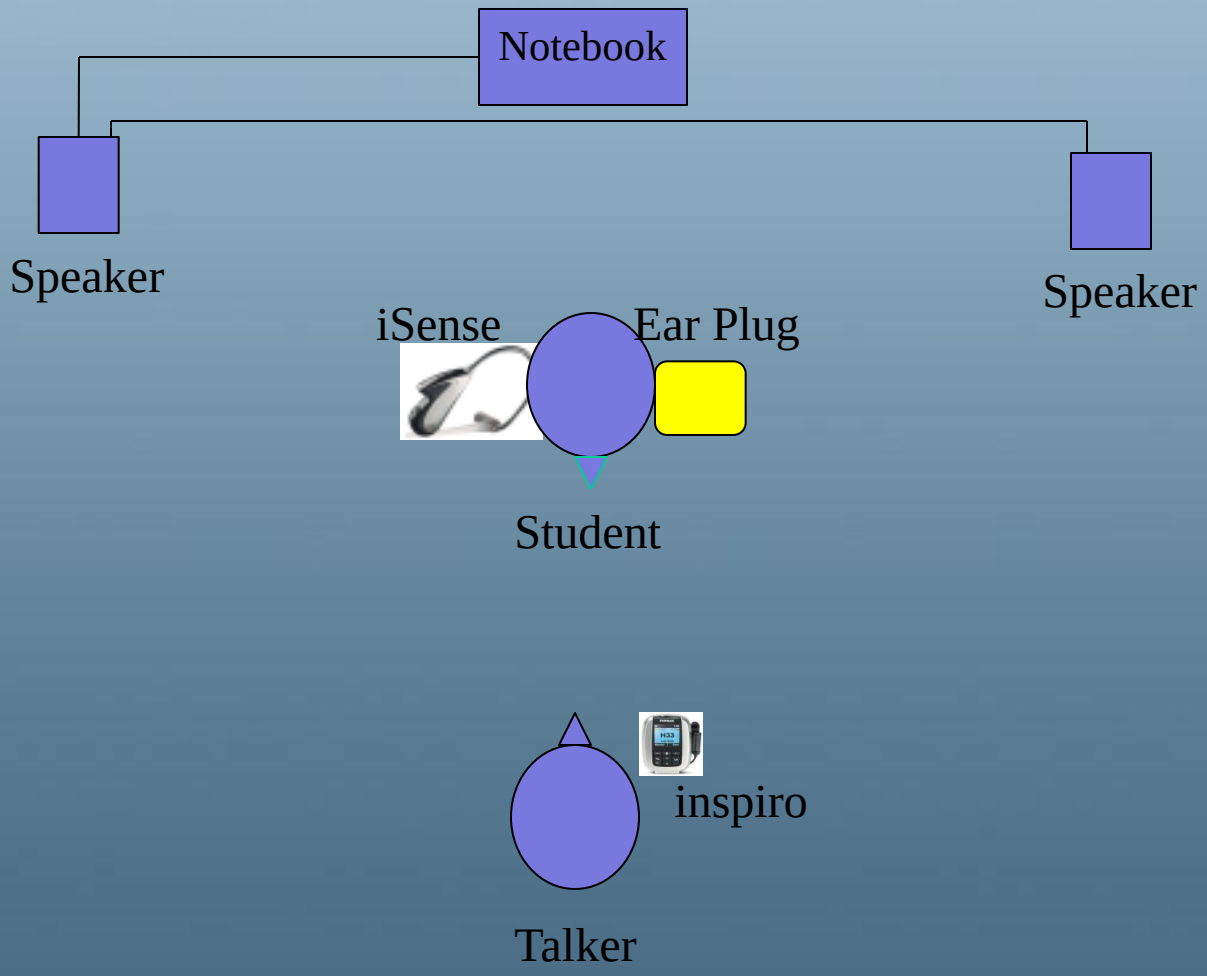
Subjects and equipment

- Eight normal-hearing students, ages 6-11
- No known learning difficulties
- Performing at grade level
- Equipment: inspiro, EduLink, iSense, yellow foam plug

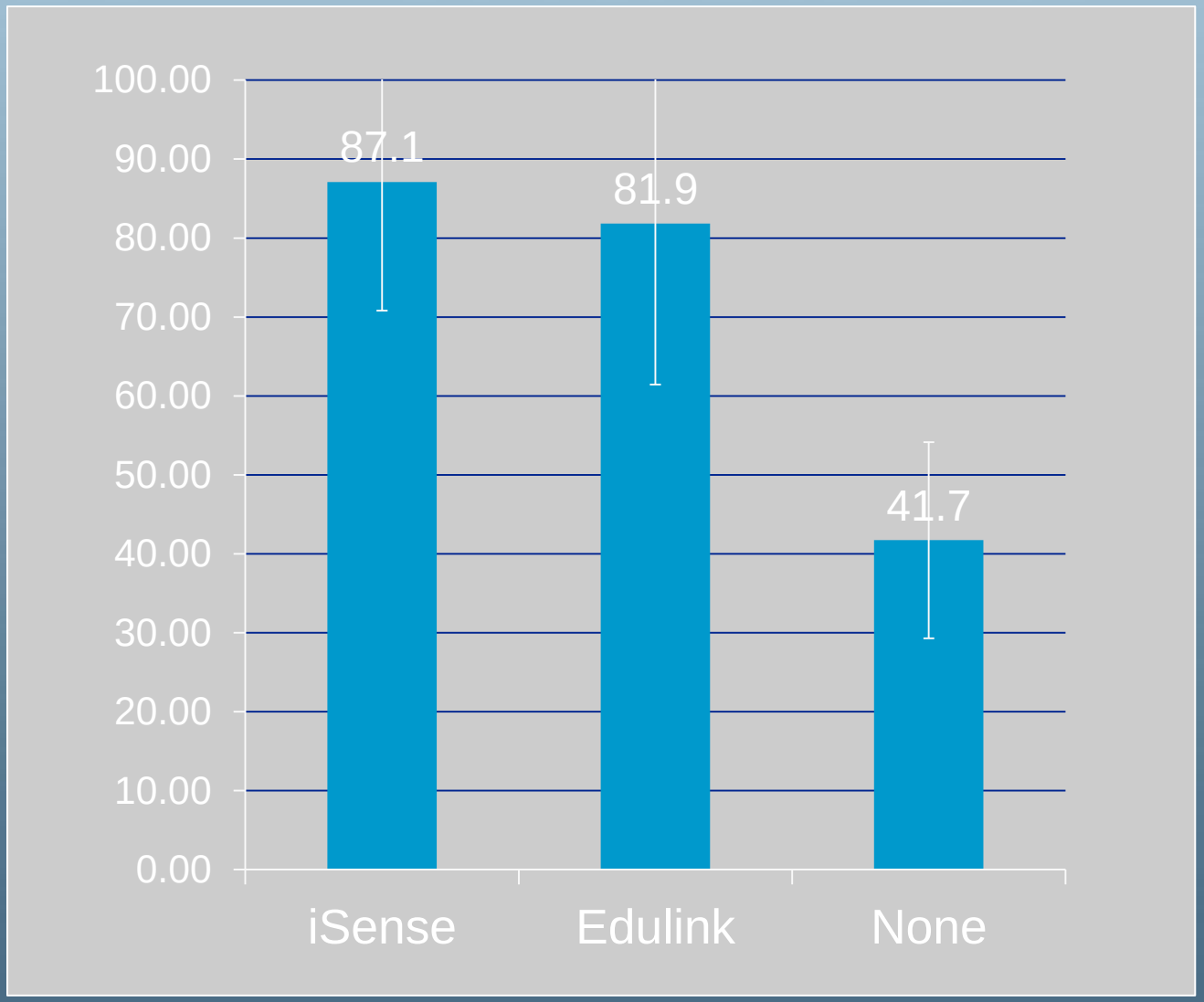
Procedure

- Testing in a quiet room in clinic
- Recorded classroom noise presented at 75 dB(A)
- Monitored live voice presentation of 20 BKB Sentences for each condition (counterbalanced)
  - No device
  - EduLink
  - iSense
- Open set responses - repeated sentence
- Incentives - $10 and pizza!

Test Arrangement



Speech Recognition in Noise with EduLink vs. iSense



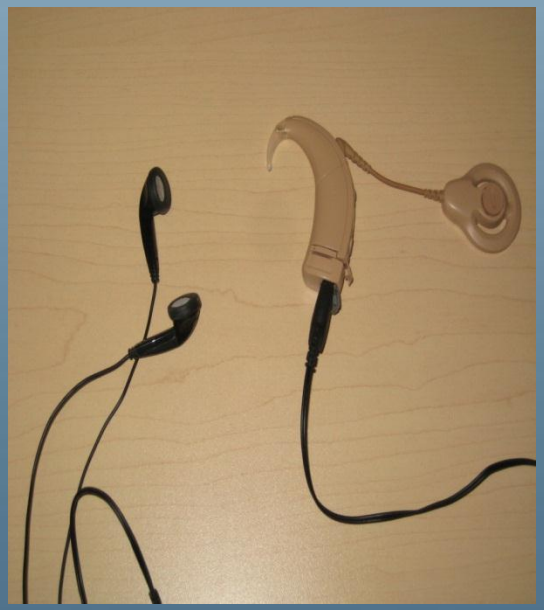
Performance with iSense significantly better than with EduLink ($p<.05$)
Both devices significantly better than no device ($p<.05$)

Listening Checks

KEY TO LISTENING CHECKS:

Must give input to both microphones separately

- Have the child repeat or act out what you say:



1. Ling – ah, oo, ee, sh, ss, mm
2. Numbers – one, two, three
3. Count syllables – ba, ba, ba
4. Long or short – baaaaa, ba ba ba
5. Simple commands – Hide your face
6. Speech awareness with play – rings, blocks, etc

Orientation

- The audiologist should orient the child, the child's family, and the "manager" about appropriate FM use.
  - Connecting FM to sound processor
  - Battery use and life (e.g., charging battery)
  - How to care for and maintain FM system
  - Where does it live when not in use? ("safe box")
  - Carrying Case (e.g., pencil box)
  - Social/emotional

- Arrange plan for troubleshooting
  - Troubleshooting 101
  - Who you gonna call?

Identify a "Manager"

- A school employee who will ultimately be responsible for the child's FM system
  - SLP
  - School Nurse
  - Classroom teacher
- Conducts daily informal assessment with and without FM
  - Simple quizzes
  - Ling 6 Sound Test
  - Listening check (if possible)
  - Ensures reliable procedure for activating FM program
    - Telecoil for Neckloop
- Dialogues with audiologist when problems arise.

Summary

- FM should be considered for all children with hearing loss.
- Dynamic FM provides ideal performance in difficult listening situations for hearing aid and cochlear implant users.
- Conduct contemporary verification to ensure benefit and optimal performance.
- Ensure appropriate use in the real world.

Acknowledgments

- Erin Schafer, Ph.D., Univ. North Texas
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  - Jaime Hampton, Emily Ward, Brandon Vincent, & Maranatha Sims, Angie Mucci, Sarah Price, Mila Morais, Emily Mills

Shoot for the stars!

- **Utilize contemporary technology to its fullest extent!**

- **Thank you for your attention!**