
Evaluation of Classroom Audio Distribution and Personal FM Systems

Jace Wolfe

The Hearts for Hearing Team

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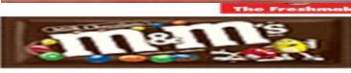
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Oklahoma!

- 48th out of 50 states in teacher
- 50th recent visit to the dentist
- 48th in physi
- 50th in



111

How Many Educational Audiologists in Oklahoma?



The Problems

- The world is a noisy place.
- Classrooms are noisy places.
- Children have trouble hearing in noise.
- Children with hearing loss really have trouble hearing in noise.

A Noisy World!

- Living Room:
 - 42 dB A (with A.C. = 52 dBA)
- Classroom Function:
 - 68 dBA
- School Auditorium:
 - 79 dBA
- School Cafeteria:
 - 82 dBA
- OKC Thunder Basketball Arena:
 - 100 dBA



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

The Problems

- The world is a noisy place.
- **Classrooms are noisy places.**
- Children have trouble hearing in noise.
- Children with hearing loss really have trouble hearing in noise.

Classrooms are Noisy Places

- Choi & McPherson (2005) reported avg. noise levels of 61 dBA in classrooms
- Massie & Dillon (2006) reported occupied classroom noise levels ranging from 64 to 72 dBA
- Typical Classrooms:
 - Sanders (1965) reports average SNRs from 47 classrooms
 - 17 Kindergarten: -1 dB
 - 12 Elementary: +5
 - 12 High school: +5



The Problems

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Hearing in Noise

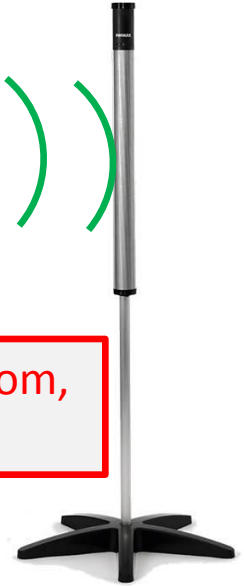
- 78.6% of users of new hearing aids are satisfied overall (Kochkin (2010), The Hearing Journal).
- 91% report continued difficulty in noise (Kochkin (2010), The Hearing Journal).
- 66% continue to report substantial difficulty in noise (Kochkin, 2010)
- Numerous studies have shown children experience greater difficulty in noise than adults.
 - Difficulty increases for younger children
 - Difficulty increases as hearing loss increases



The Solutions

- Acoustic Modifications
- Classroom Audio Distribution Systems (CADS)
- Personal FM Systems
- CADS + Personal FM

Classroom Audio Distribution Systems



Goals: Create a uniform distribution of the sound of interest across the classroom, and provide a modest improvement in the signal-to-noise ratio.



May utilize:
FM
Infrared
Digital RF

Classroom Audio Distribution Systems

- Research studies evaluating the impact of CADS on classroom SNR and speech recognition in noise have shown mixed results.
 - SNR improves by 2 to 15 dB (Leung & McPherson, 2006; Massie & Dillon, 2006)
 - Some studies show improved speech recognition while others do not (Anderson & Goldstein, 2004; Anderson et al, 2005; Schafer & Kleineck, 2009)
 - Speech recognition improvement associated with classroom acoustics (Wilson et al, 2011)
- Improvements in educational performance and behavior
 - Standardized test scores, literacy, etc.
 - Behavior problems, attention, etc.
 - Improvement with teacher fatigue, vocal strain, absences

Personal FM Systems



Primary Goals: Enhance or optimize the signal-to-noise ratio, and overcome effects of distance and reverberation.

Personal FM

- Personal FM systems are widely recognized as the most effective method to improve speech recognition in acoustically hostile environments.
 - Anderson & Goldstein (2004) found improved speech recognition in noise with personal FM but not with CADS.
 - Anderson et al. (2005) found improved speech recognition in noise with both CADS and personal FM, but personal FM provided better performance.
 - Schafer and Kleinek (2009) meta-analysis found improved speech recognition in noise for CI recipients using personal FM but not CADS.
- There is a paucity of research examining combined use of CAD + personal FM vs. personal FM alone.

Additional Consideration

- Research has shown that personal FM with adaptive (Dynamic) capability provide better speech recognition in noise than fixed-gain personal FM (Thibodeau, 2010; Wolfe et al, 2009).
- There are no published studies examining adaptive CADS vs. fixed-gain CADS.

Study Objectives

- Evaluate benefits of classroom audio distribution (CAD) systems for children with hearing loss as well as for children and adults with normal hearing.
- Compare performance in quiet and in noise obtained with an adaptive single-loudspeaker CAD vs. a fixed-gain, CAD utilizing 4 loudspeakers strategically placed in the classroom
- Compare performance in quiet and in noise obtained with:
 - Adaptive CAD alone vs. Adaptive CAD + Personal FM
 - Fixed-gain, multi-loudspeaker CAD alone vs. Fixed-gain, multi-loudspeaker CAD + Personal FM
 - Personal FM alone

Subject Inclusion Criteria

- Children with Hearing Loss
 - 5 to 13 years old
 - Mild to severe SNHL
 - Four-frequency pure tone average between 35-75 dB HL
 - Full-time hearing aid users
 - At least 60% correct on age-appropriate monosyllabic word recognition test
 - English as primary language
 - Spoken language aptitude within one year of chronological age



Subject Inclusion Criteria

- Normal Hearing Children
 - 5 to 13 years old
 - Normal Hearing
 - Air-conduction thresholds better than 20 dB HL
 - English as primary language
 - No reported history of language, processing, or attention disorders
- Normal Hearing Adults
 - 18 to 50 years old
 - Normal Hearing
 - No history of significant otologic disorders
 - English as primary language

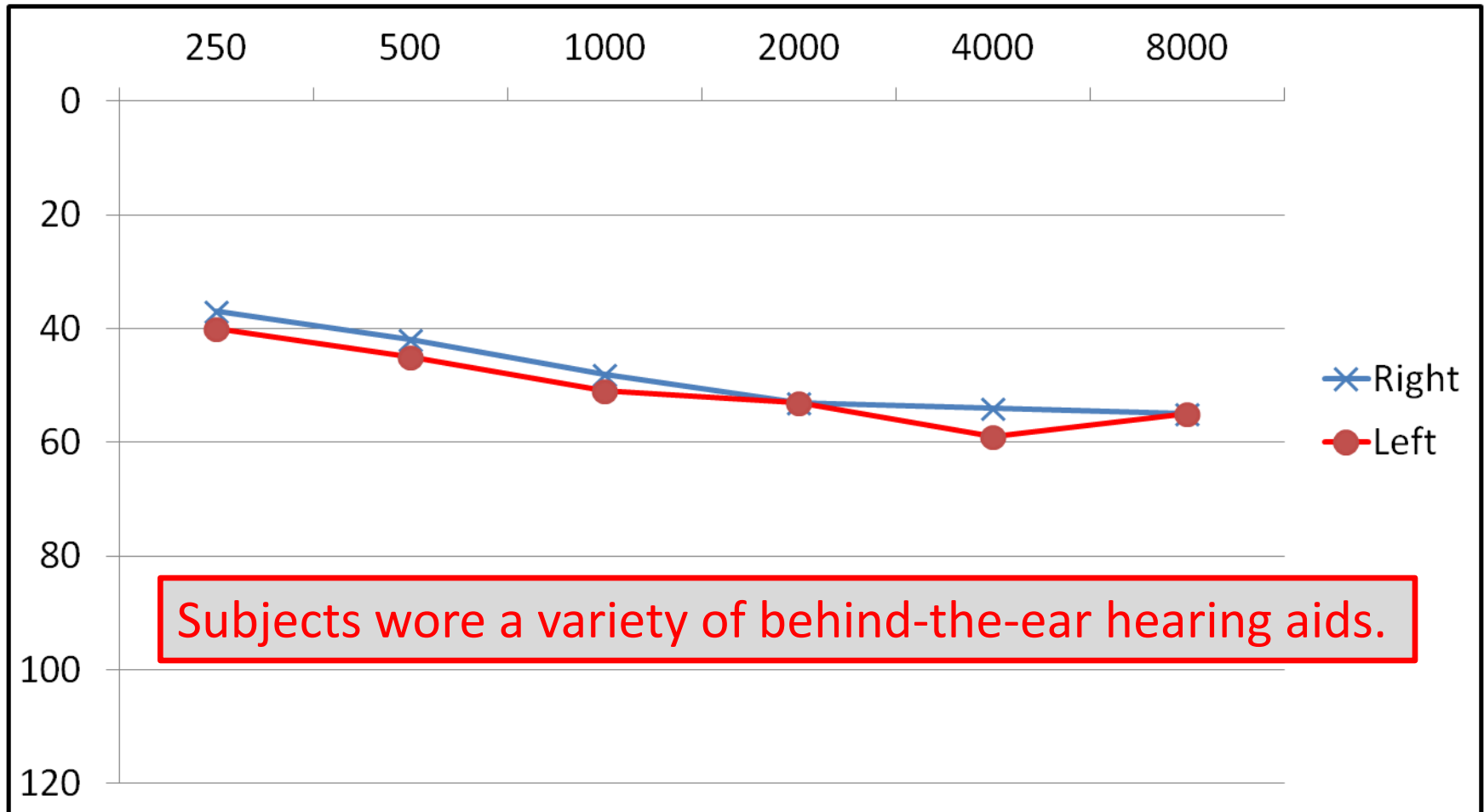


Subjects

- 15 Children with Hearing Loss
 - 6-13 years old
 - Mean Age: 9.5 years old
 - 4FPTA Range: 35 to 68.75
- 15 Children with Normal Hearing
 - 5-12 years old
 - Mean Age: 8 years old
- 10 Adults with Normal Hearing
 - 18-48 years old
 - Mean Age: 34 years old



Mean Hearing Loss



Audio Enhancement Elite II Classroom Audio Distribution System

Tear Drop Infrared Mic



Audio Enhancement Elite II 30 Watt Receiver/Amplifier



Infrared Dome Sensor



Four WS09 Wall-mounted loudspeakers



Audio Enhancement Elite II Classroom Audio Distribution System

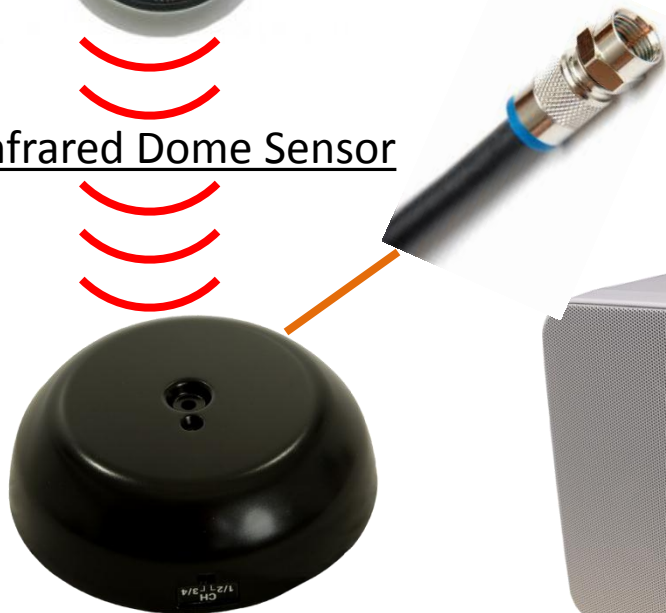
Tear Drop Infrared Mic



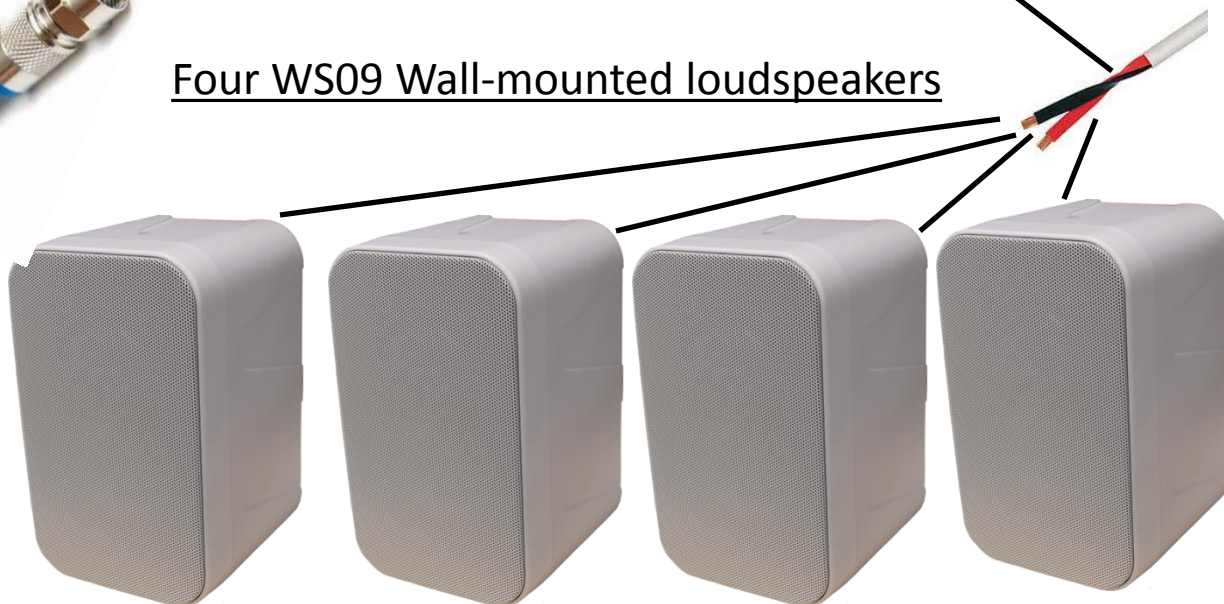
Audio Enhancement Elite II 30 Watt Receiver/Amplifier



Infrared Dome Sensor

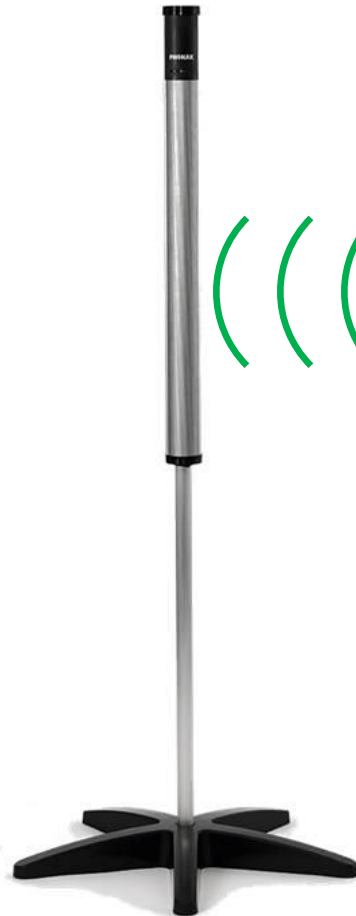


Four WS09 Wall-mounted loudspeakers



Phonak DigiMaster 5000 Classroom Audio Distribution System

Phonak DigiMaster 5000



Phonak inspiro transmitter

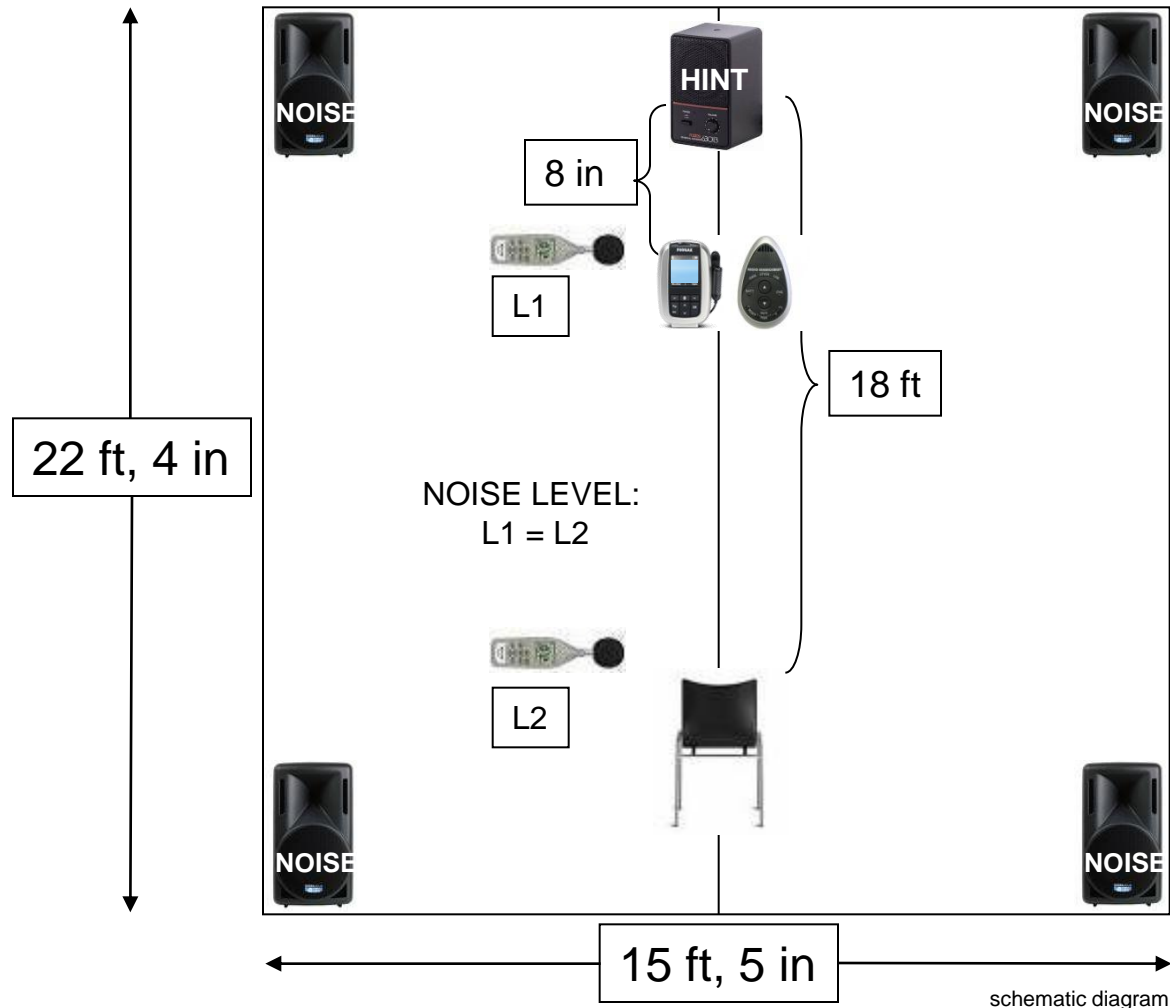


Phonak DigiMaster 5000

Classroom Audio Distribution System

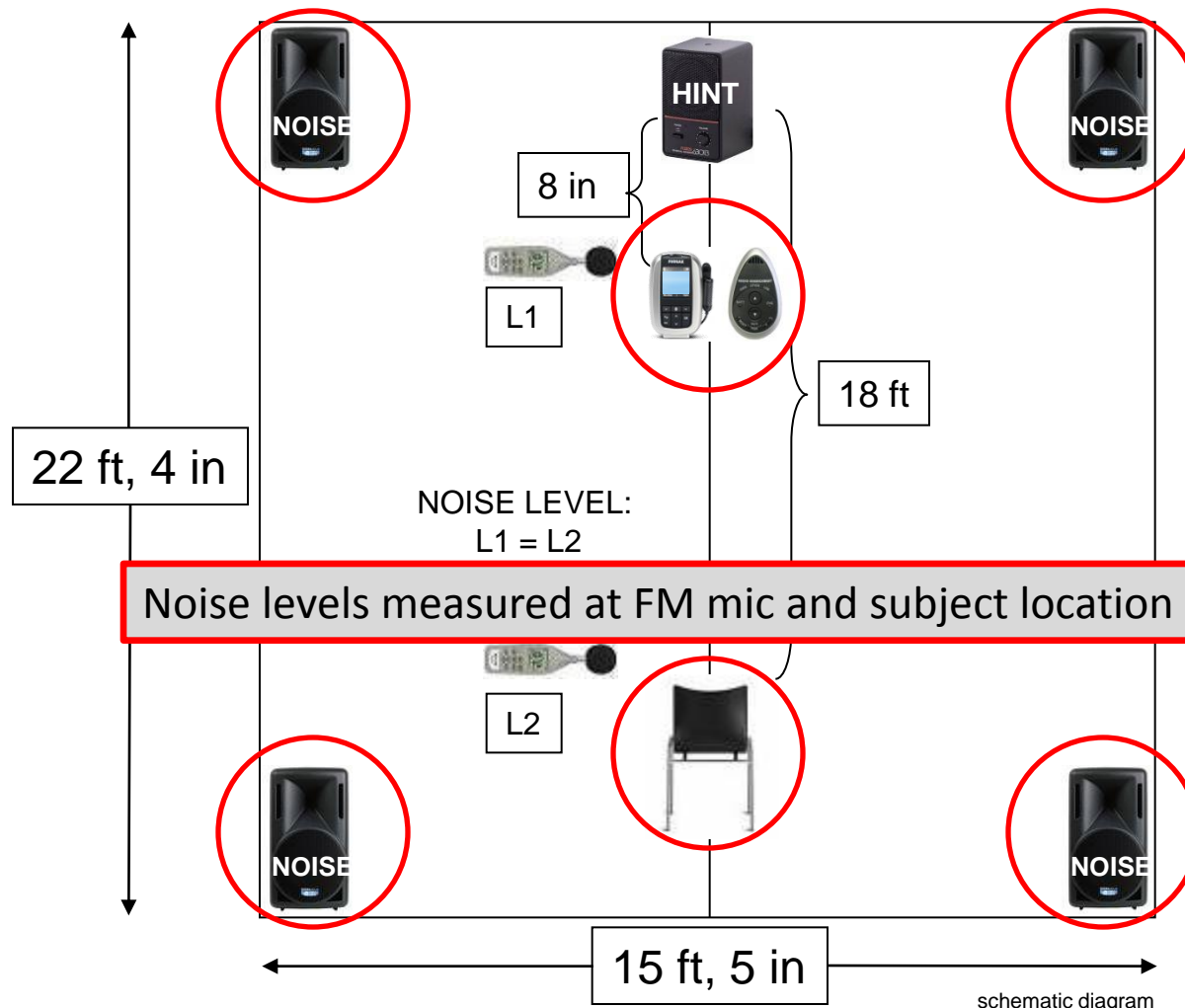
- Utilizes digitally modulated (DM) radio frequency transmission
- Features adaptive (Dynamic) changes in loudspeaker gain dependent upon classroom noise levels.
- Features an array of 12 loudspeakers
 - Emits sound in horizontal plane, with minimal vertical spread → Reduce reverberation
 - Distributes sound across classroom
 - Loudspeakers positioned at head level
- Acoustic feedback cancellation

Classroom Setup



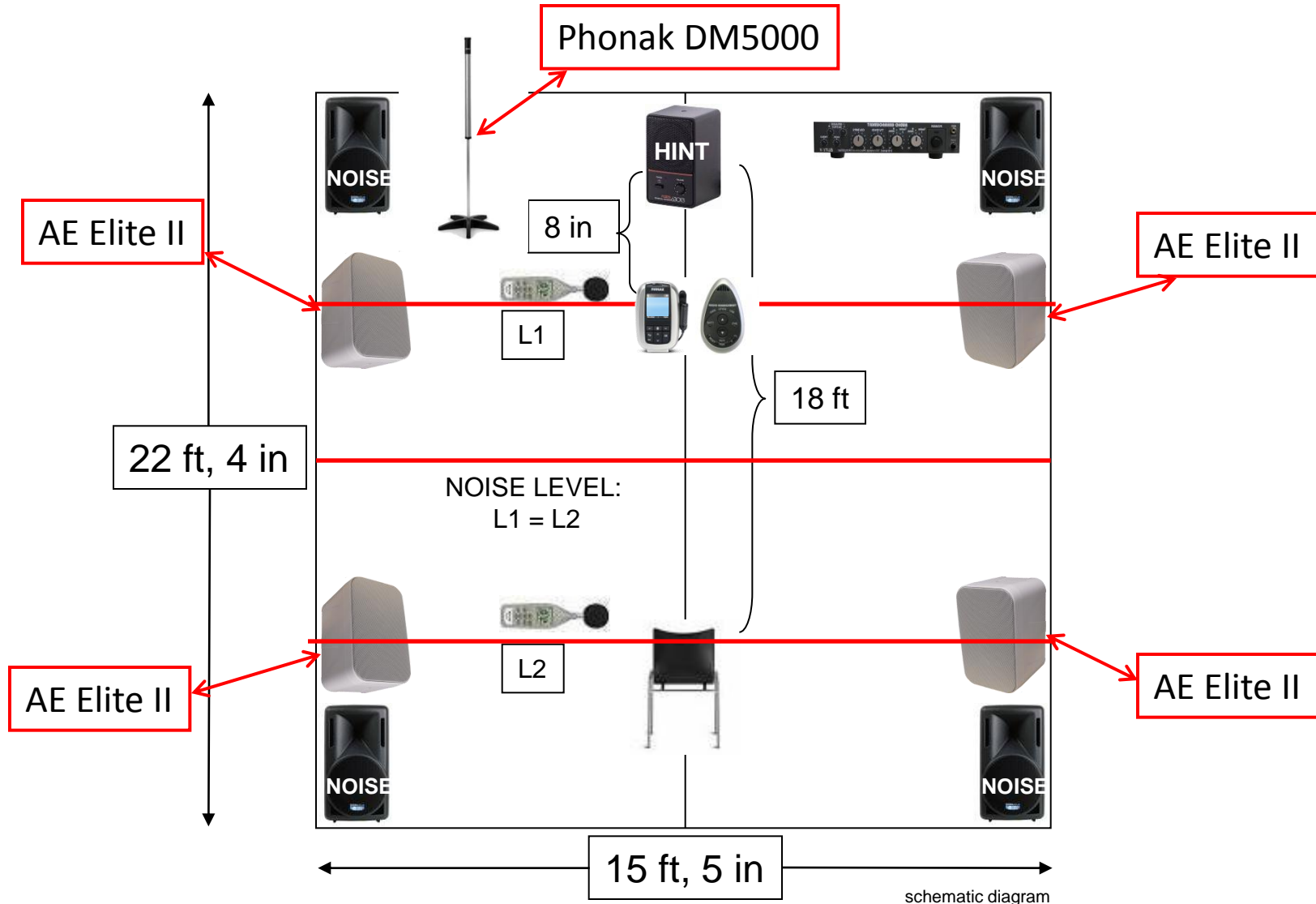
Background Noise

Classroom noise was presented from the four loudspeakers in the corners of the room.

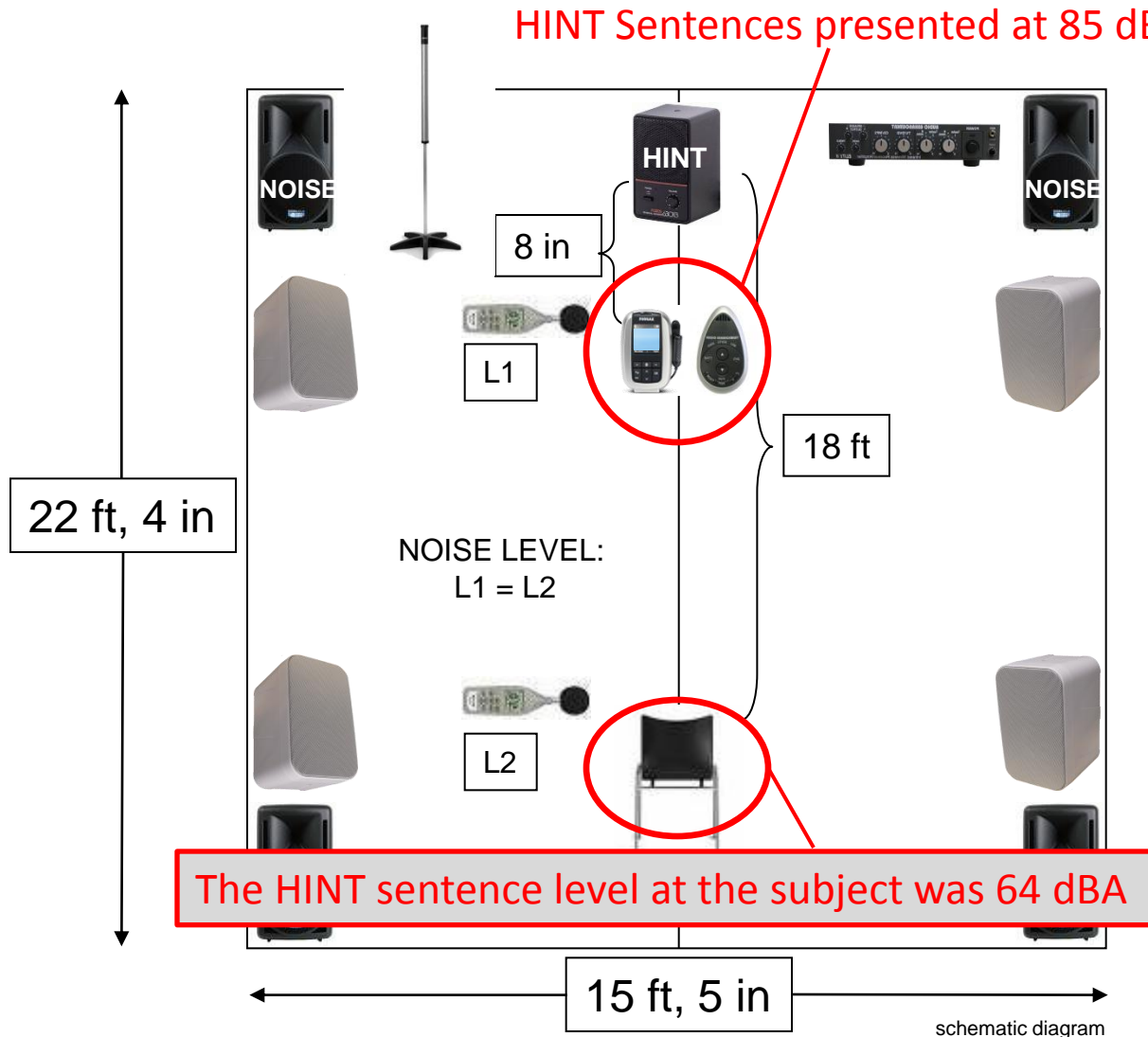


Tested in:
 Quiet & Noise at
 50 dBA
 55 dBA
 60 dBA
 65 dBA
 70 dBA
 75 dBA

Classroom Setup

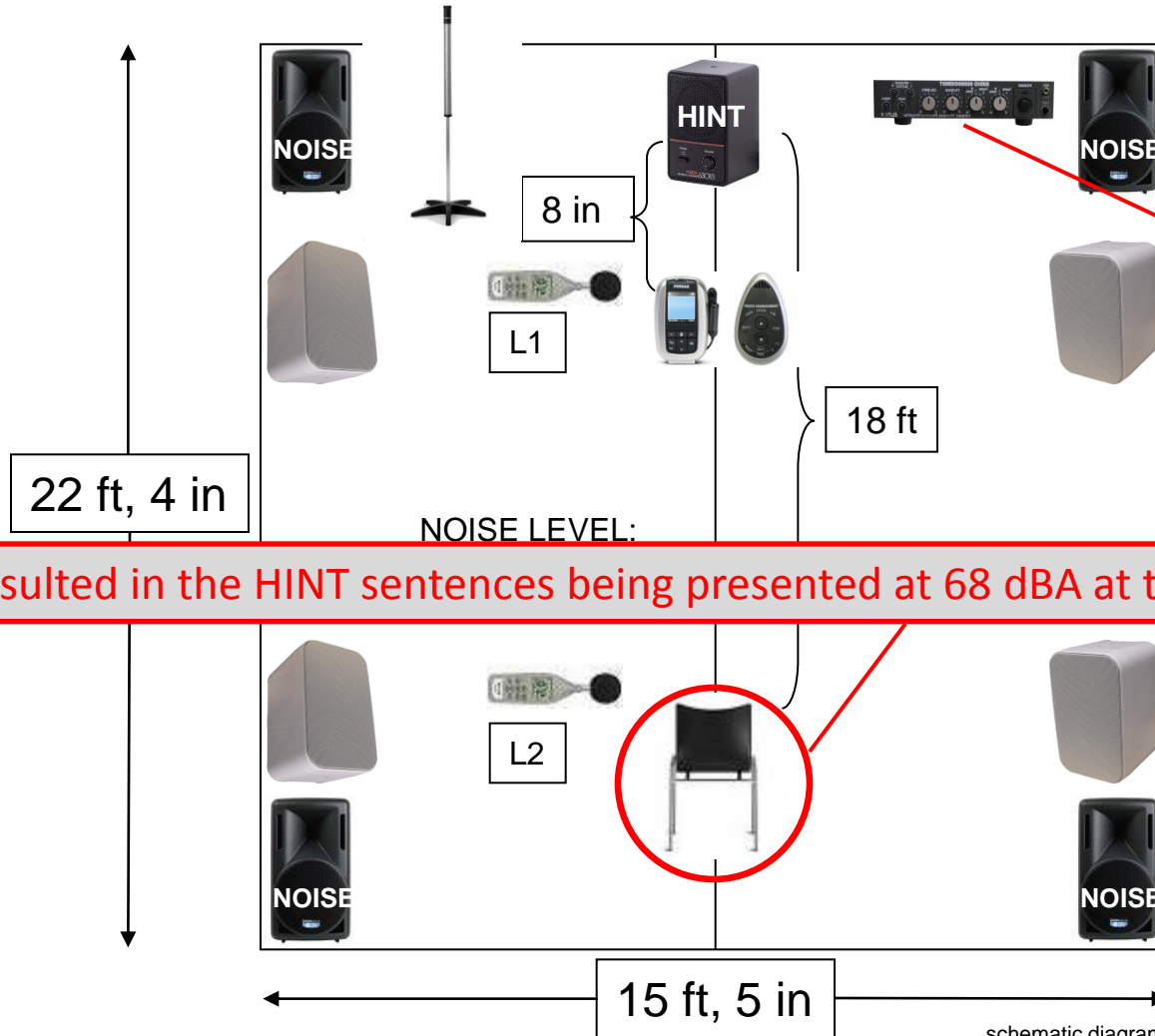


Classroom Setup



Classroom Setup

The output of the Phonak DigiMaster 5000 was set to the manufacturer's default setting.



The gain of the Elite II was set to provide an equivalent level in quiet at the subject location.

This resulted in the HINT sentences being presented at 68 dBA at the subject location.

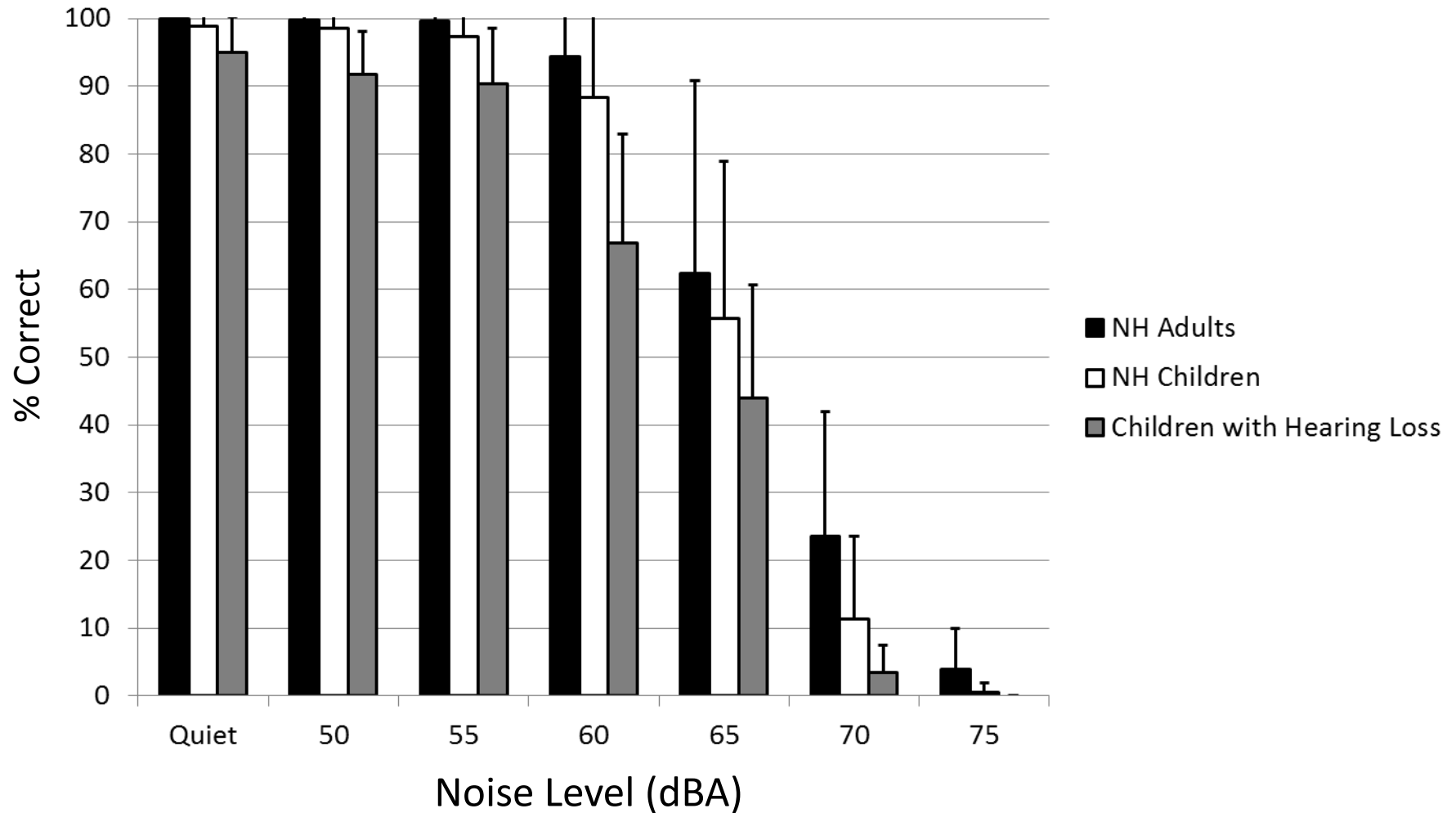
Test Conditions

- No FM
- Phonak DM5000 alone
- Audio Enhancement Elite II alone
- Phonak DM5000 + Personal FM
 - Inspiro to DM5000 and Personal FM
- Audio Enhancement Elite II + Personal FM
 - Inspiro connected to audio output port of Elite II
- Personal FM alone
 - Inspiro to personal FM



Results

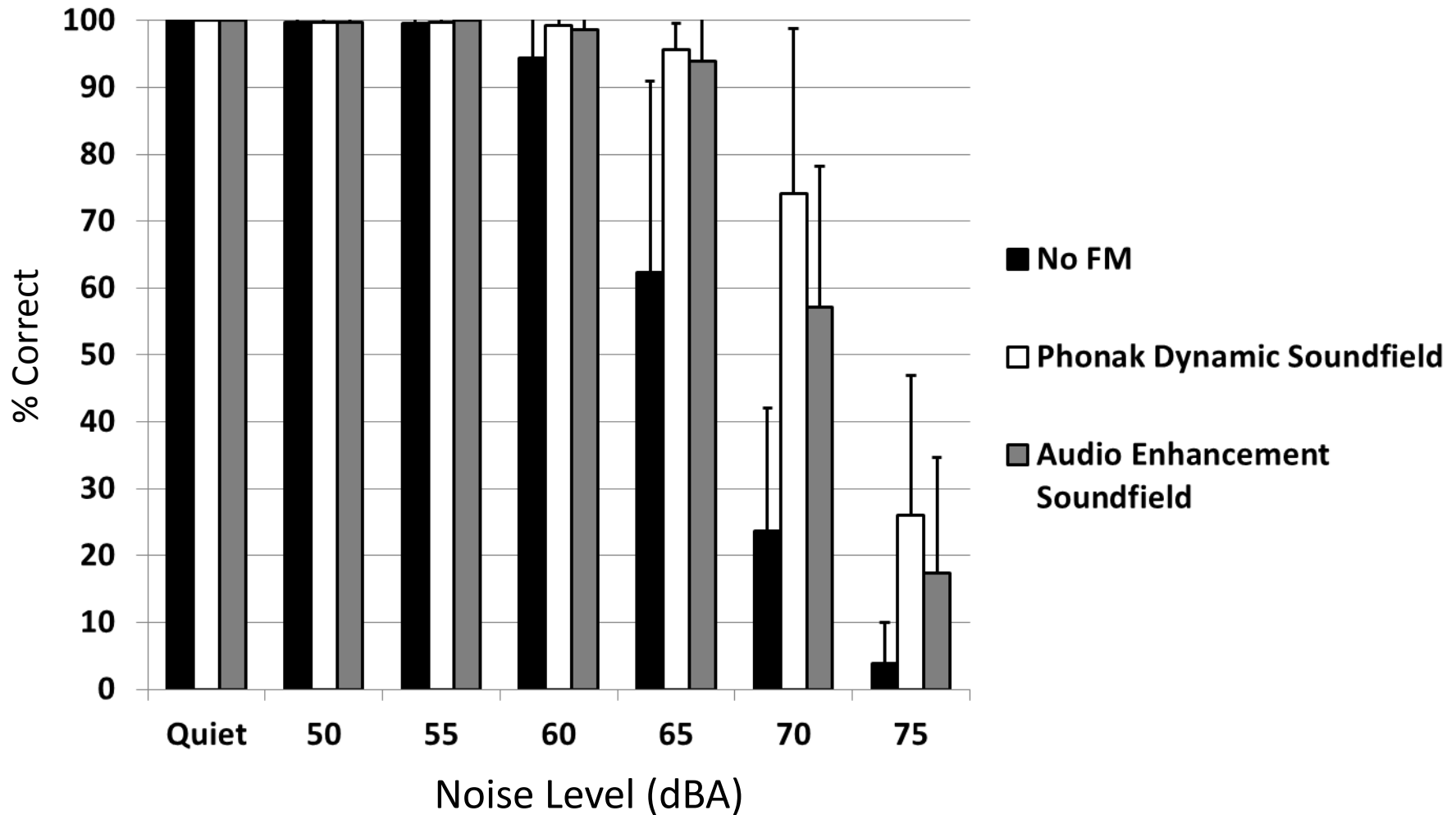
Speech Recognition without FM



Results

- Adults understand speech in noise better than children.
- Children with normal hearing understand speech in noise better than children with hearing loss.
- The difference between groups becomes greater at higher noise levels.
- All groups experience more trouble in noise (60, 65, 70, & 75 dB A).
 - Performance became progressively poorer from 60 to 75 dB A.

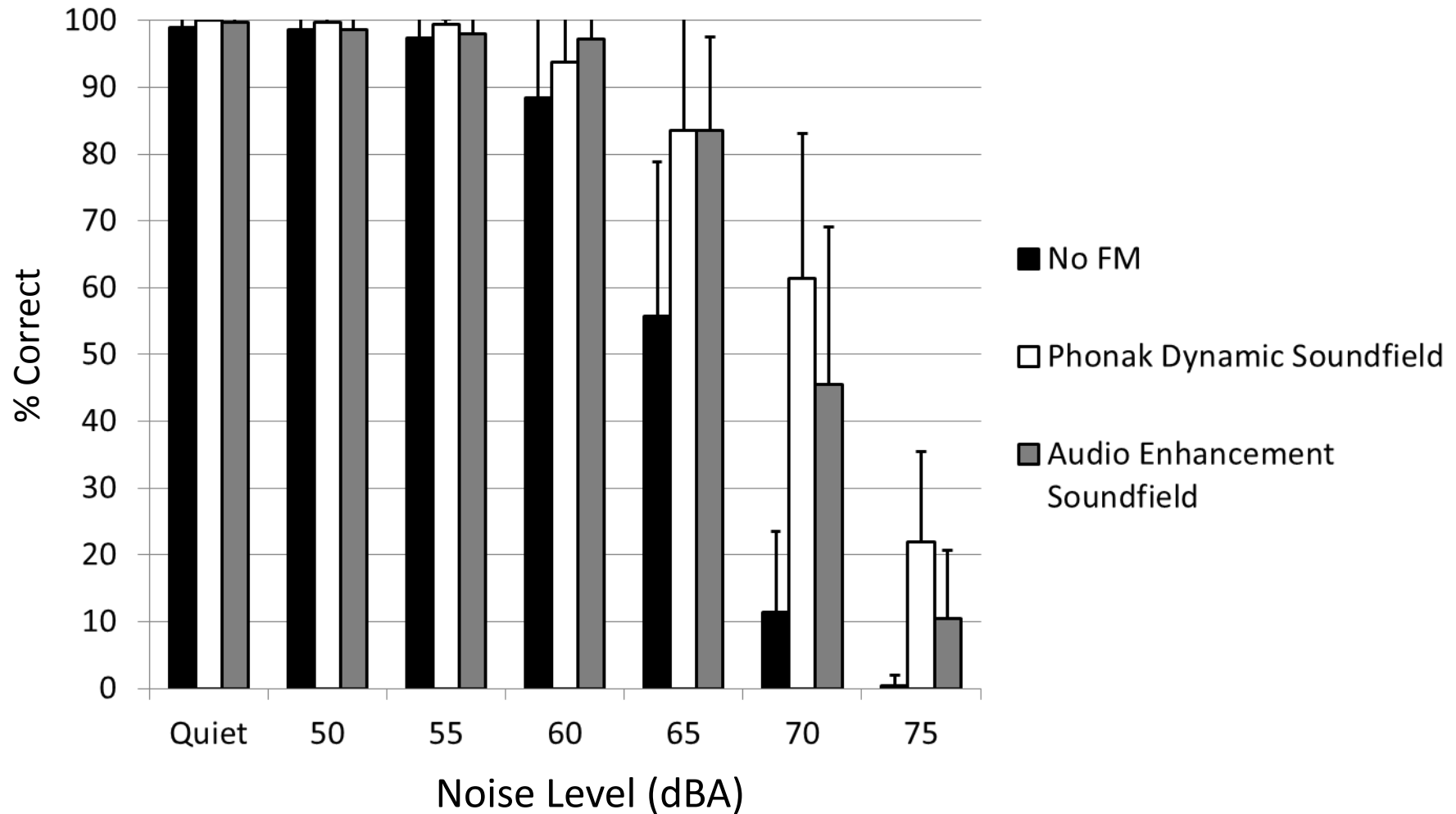
Normal Hearing Adults with CADS



Results

- CADS improve adults' speech recognition in noise at noise levels of 65, 70, and 75 dB A.
- Phonak DM5000 Dynamic CADS provided better speech recognition in noise than Audio Enhancement Elite II system at 70 and 75 dB A.

Normal Hearing Children with CADS

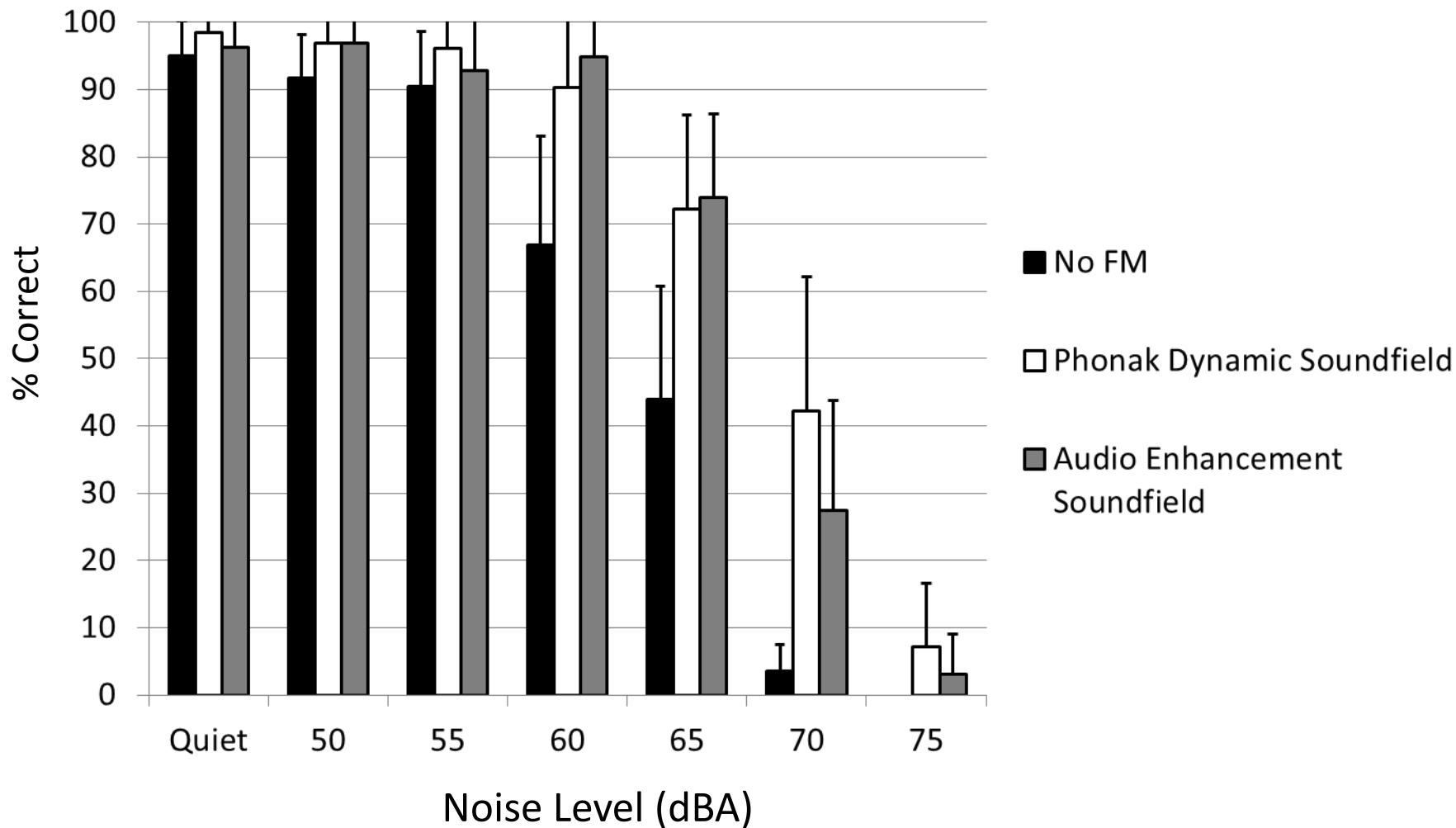


Results

- CADS improve speech recognition in noise of children with normal hearing at noise levels of 60, 65, 70, and 75 dB A.
- Phonak DM5000 Dynamic CADS provided better speech recognition in noise than Audio Enhancement Elite II system at 70 and 75 dB A.

Children with Hearing Loss

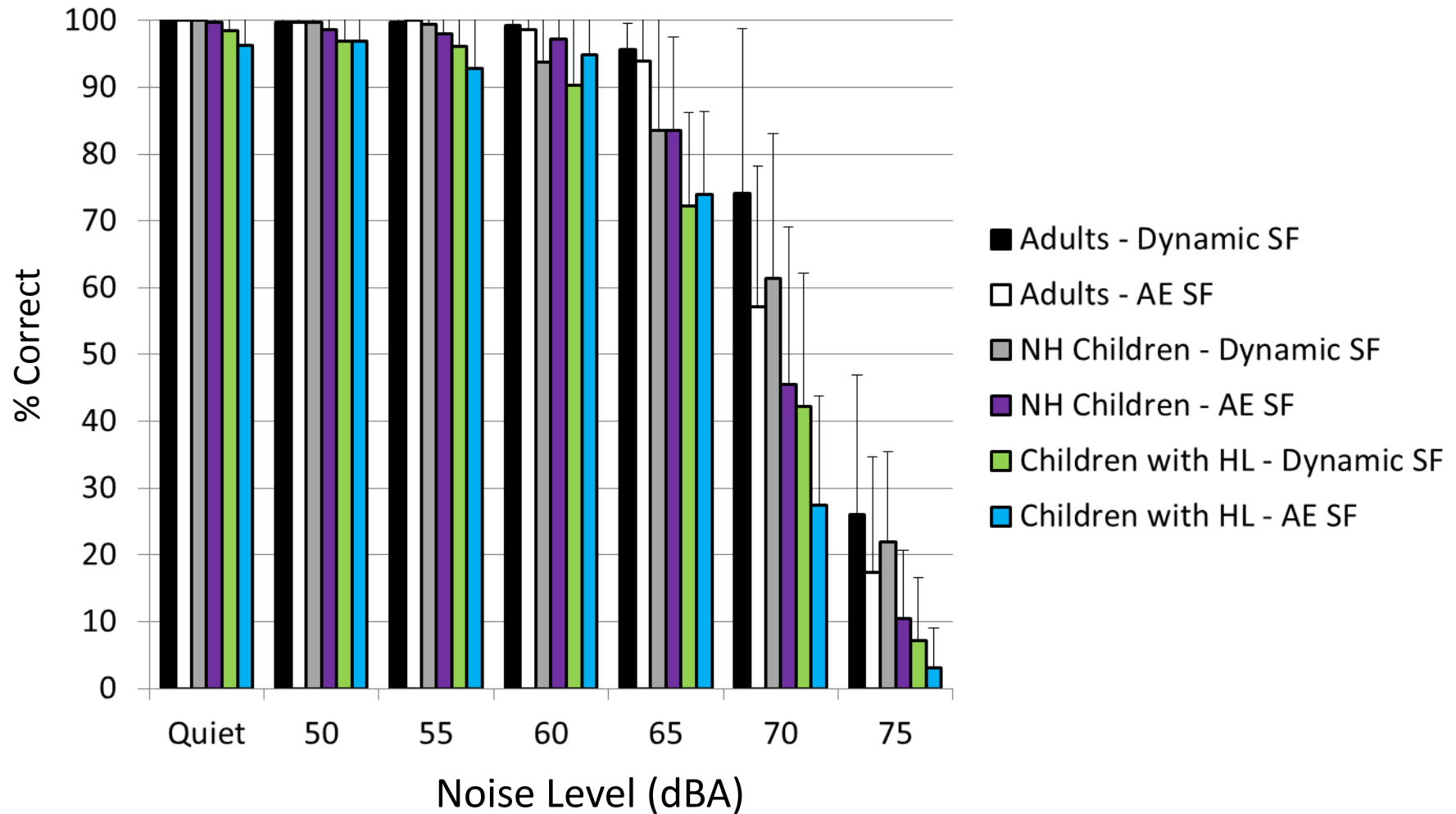
CADS Performance



Results

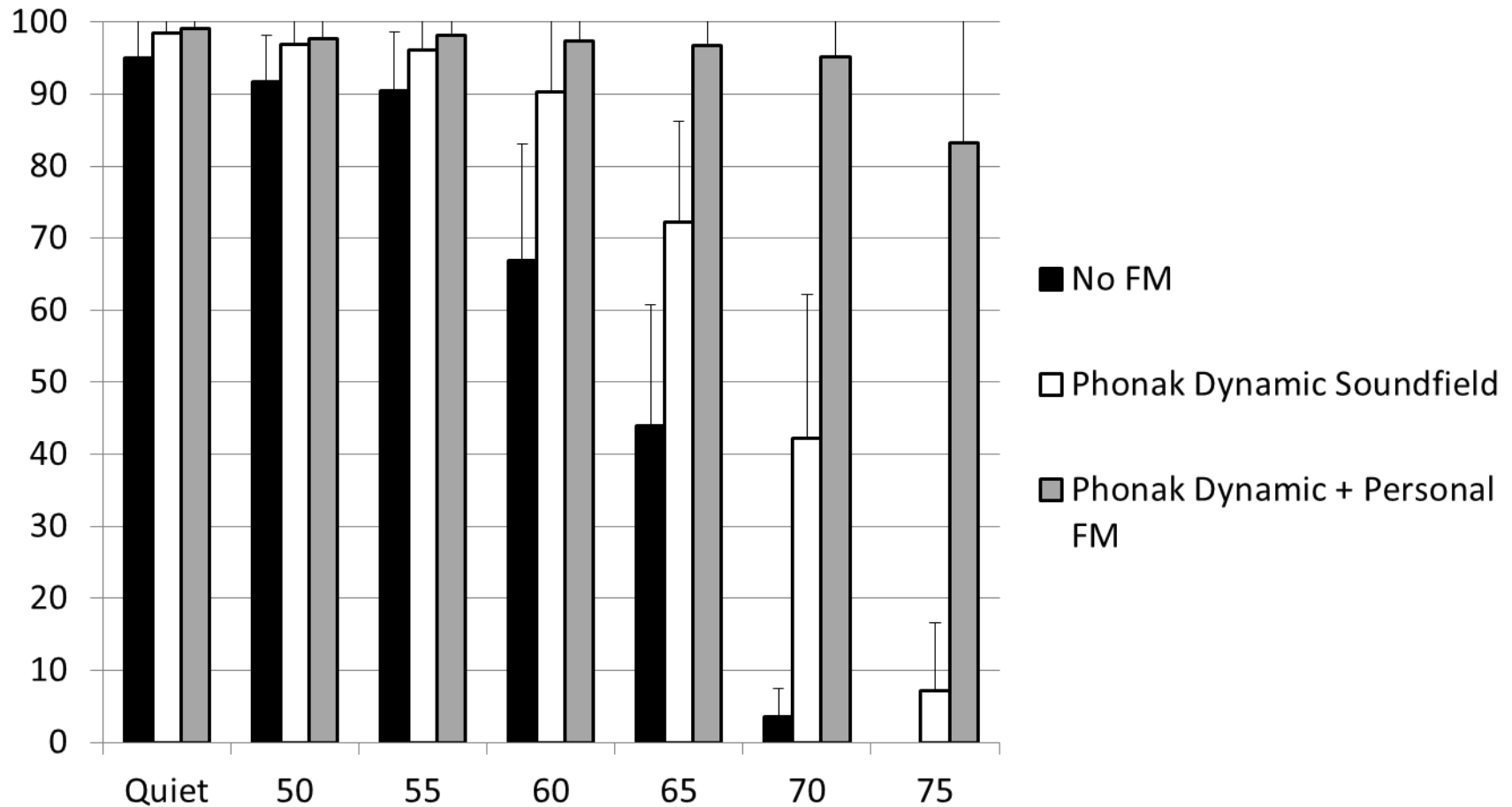
- CADS improve speech recognition in noise of children with hearing loss at noise levels of 60, 65, 70, and 75 dB A.
- Phonak DM5000 Dynamic CADS provided better speech recognition in noise than Audio Enhancement Elite II system at 70 and 75 dB A.

CADS Performance Across Groups



- What about personal FM?

CADS vs. CADS + Personal FM

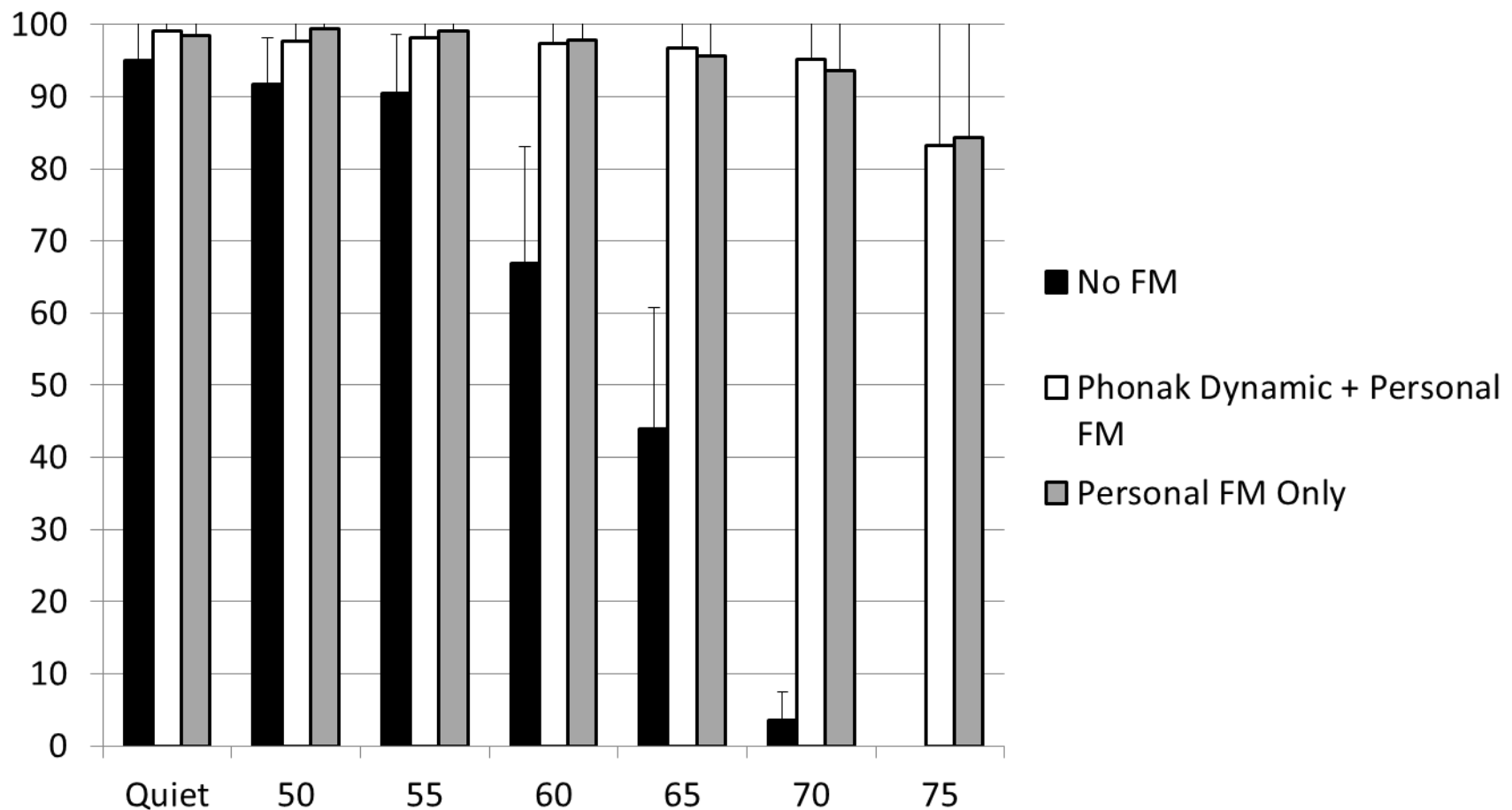


Results

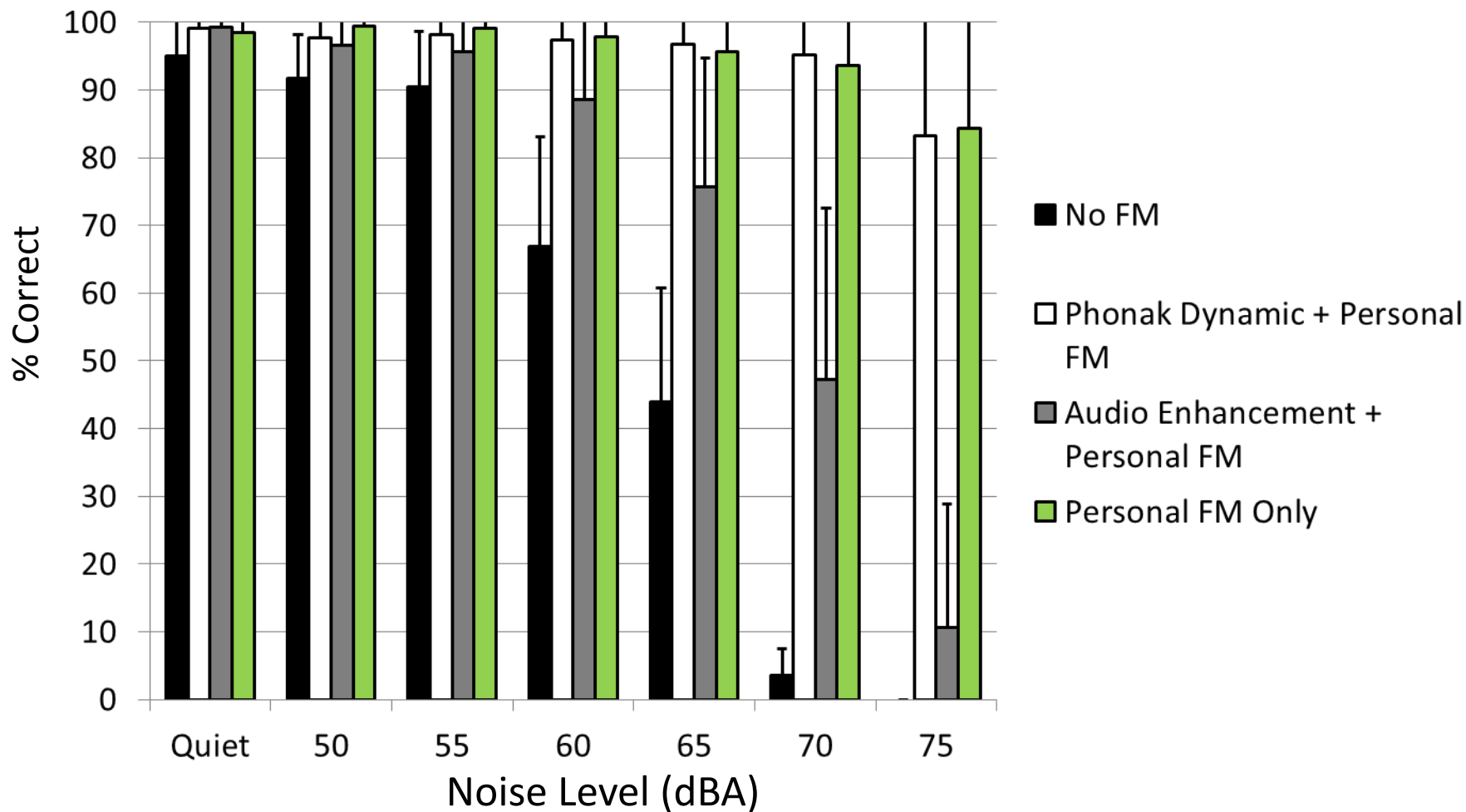
- Personal FM better than no FM at all noise levels.
- Personal FM better than CADS at 60, 65, 70, and 75 dB A.

Phonak CADS + Personal FM vs. Personal FM alone

No difference in performance between CADS + personal FM vs. personal FM alone



Children with Hearing Loss CADS + FM vs. Personal FM

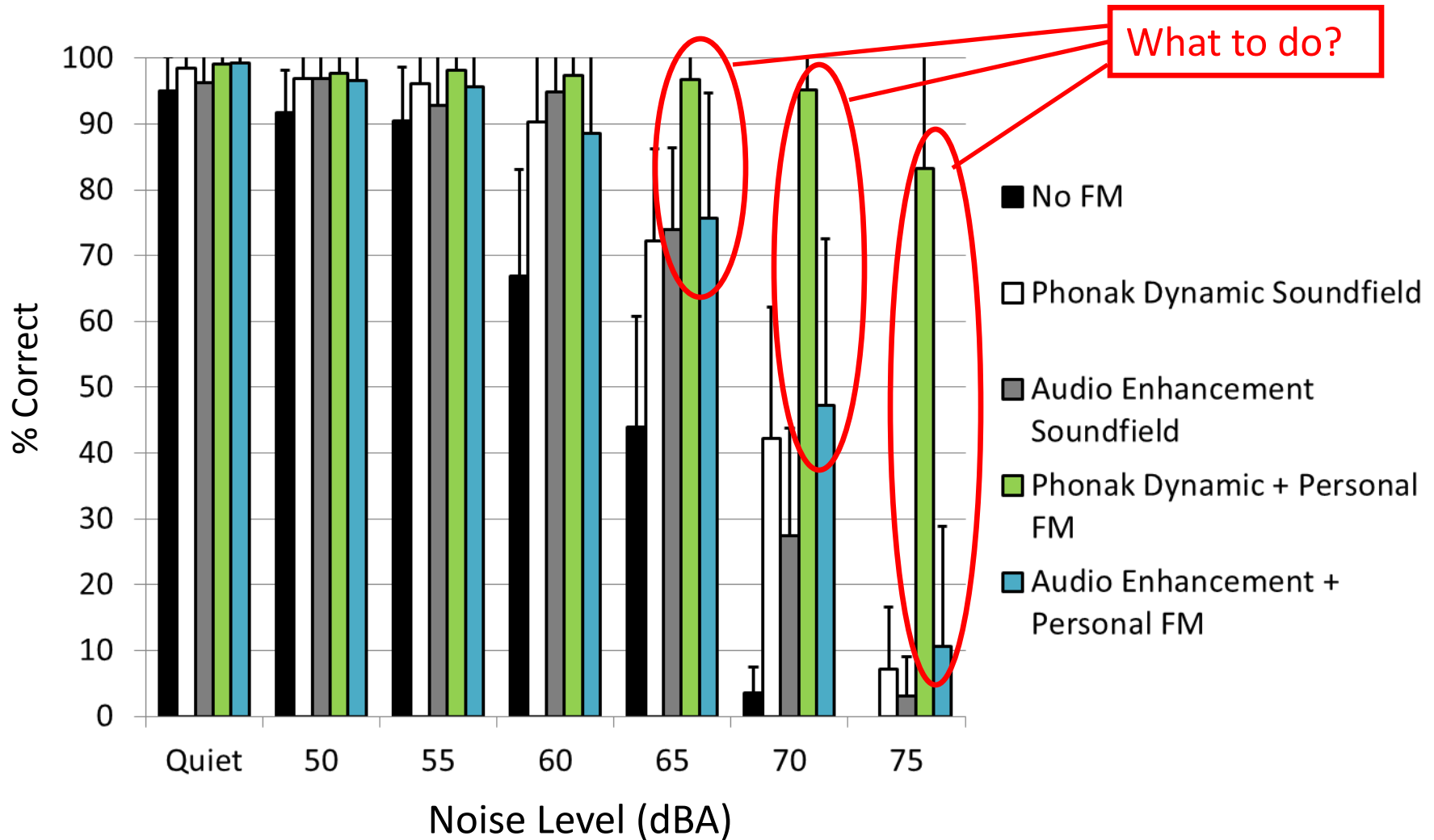


Results

- Phonak CADS + personal FM and personal FM alone are both better than Audio Enhancement CADS + personal FM at 60, 65, 70, and 75 dB A.
- Possible causes?
 - Loss of adaptive (Dynamic) FM
 - Loss of noise pre-processing at inspiro.
 - Insufficient input from audio output of AE Elite II to inspiro

Children with Hearing Loss

CADS vs. CADS + Personal FM



Potential Upgrade

Alternative Solution: Wear two mic/transmitters

Digimaster X

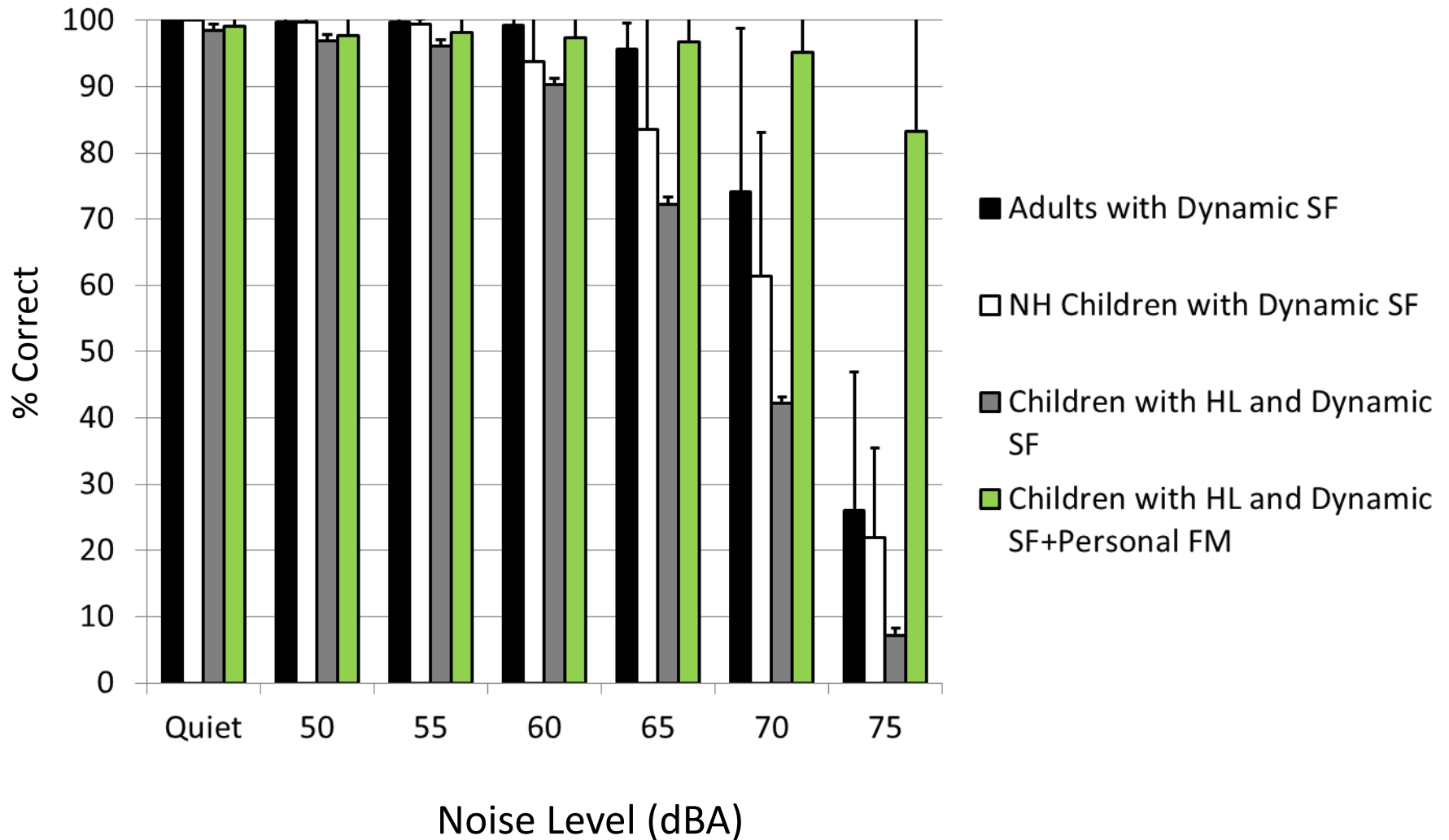


Plugs into the audio input port of existing CADS.

Inspiro delivers signal to Digimaster X and to personal FM receiver

Good News!

Children with Hearing Loss vs. “Gold Standard”



Conclusions/Clinical Implications

- Adults understand speech in noise better than children.
- Children with NH understand speech in noise better than children with HL.
- CADS improve speech recognition in noise for all subjects.
- Dynamic CADS provide better speech recognition in noise than fixed-gain CADS.
- Personal FM provides the largest improvement in speech recognition in noise.
- Phonak Dynamic DM5000 + Personal FM provides better performance in noise than AE Elite II + Personal FM.
- Little to no speech recognition in noise improvement with Phonak CADS + Personal FM vs. Personal FM alone.
 - But CADS may improve classroom acoustics in real world.

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- Erin Schafer, Ph.D., Audiologist



Thank You for Your Attention!



www.heartsforhearing.org