Auditory Access for Infants and Toddlers Utilizing Personal FM Technology

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Thanks to Dr. Jane Madell
Beth Israel Medical Center, NYC
AMPLIFICATION ASSUMPTIONS

• Early/appropriate amplification
  – is the single most important habilitative tool.
  – is dependent on the child, and communication environment and NOT hearing loss
AMPLIFICATION
ASSUMPTIONS

• When the talker and listener are close and it is quiet
  – *Standard hearing aids* work well for patients with mild to severe hearing loss
  – *Cochlear implants* work well for patients with severe and profound hearing loss
AMPLIFICATION
ASSUMPTIONS

• An *FM system* will improve auditory access for *every person* with impaired auditory function by reducing the negative effects of distance and noise.
GOAL OF ASSISTIVE TECHNOLOGY

- Improve auditory access
- Improve access to language
- Lay foundation for auditory academic learning
- Facilitate socialization
- Facilitate information access/extended learning
- Safety
TECHNOLOGY GOALS

• In summary,
  – Reduce sensory deprivation
  – Maximize use of residual hearing
  – Provide input for auditory learning
FACTORS THAT EFFECT AUDITORY LEARNING AND PERCEPTION

- Hearing loss
- Access to auditory information
- Auditory deprivation
- Language
- Amplification
- Auditory environment

• Which of these can we control?
WHEN IS AMPLIFICATION NEEDED?

• When talker and listener are more than a few feet apart
• Difficult listening situations
• School
• Car
• Dinner table
• When sick or tired
• When hearing is fluctuating
• Any situation in which listening is critical
WHY FM?
### FM Improvement (with CI)

#### 24 Children

<table>
<thead>
<tr>
<th></th>
<th>Mean improvement</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 dB in quiet</td>
<td>24%</td>
<td>8-44%</td>
</tr>
<tr>
<td>50 dB +5 S/N</td>
<td>23%</td>
<td>8%-60%</td>
</tr>
<tr>
<td>50 dB 0 S/N</td>
<td>19%</td>
<td>8-24%</td>
</tr>
<tr>
<td>35 dB 0 S/N</td>
<td>31%</td>
<td>20-68%</td>
</tr>
</tbody>
</table>

Data from Beth Israel Medical Center, NY, NY; compliments of Dr. Jane Madell, Director
Accessing the Auditory Environment

- Distance between a parent and child
- Background noise ongoing
- Poor acoustics (reverberation)
The Distance Problem

• Distance is a great obstacle to speech understanding

• Audibility and intelligibility decrease as the distance from the speaker increases

• At a certain distance, the background noise can effectively mask the talker’s voice
# Sources Of Noise at Home

<table>
<thead>
<tr>
<th>Home Noise</th>
<th>External Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>People talking</td>
<td>Traffic</td>
</tr>
<tr>
<td>Heating systems</td>
<td>Aircraft</td>
</tr>
<tr>
<td>Cooling systems</td>
<td>Wind</td>
</tr>
<tr>
<td>Appliances</td>
<td>Playgrounds</td>
</tr>
<tr>
<td>Movement of furniture</td>
<td>Sirens</td>
</tr>
<tr>
<td>Toys</td>
<td></td>
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</tbody>
</table>
What Is Signal-To-Noise Ratio?

Also Called Speech-To-Noise Ratio
• **Signal-to-noise ratio** (SNR)
  – relationship between the primary auditory signal to background sounds
  – The more favorable the SNR, the more intelligible the spoken message
• Adults with normal hearing
  – require a SNR of approximately +6 dB in order to hear the spoken message as consistently intelligible.

  – desired signal needs to be about twice as loud as background sounds.
Children

- Children need a much more favorable signal-to-noise ratio in order to receive intelligible speech
- SNR needs to be approximately +15 dB to +20 dB
- desired signal needs to be about 10 times louder than background sounds!
Children who need improved SNR

- Typical children
- Children with
  - any type and degree of hearing problem
  - ear infections
  - unilateral hearing loss
  - auditory processing problems
  - learning disabilities
  - attention problems
  - visual disabilities
  - behavior problems
  - developmental disabilities
  - first language is not the language of the speaker
Unfortunately, typical classrooms have an *inconsistent* and poor signal-to-noise ratio of about +4 dB.

- A classroom’s signal-to-noise ratio can vary minute by minute from about +5 dB to worse than -20dB, depending on teacher and pupil positions and background noise.
Reverberation

• Reverberation is the reflection of sound waves off of hard surfaces
  – high ceilings
  – untreated windows
  – chalk boards
  – concrete
  – tile floors
Reverberation

enclosed space

Direct sound
Reverberation
Implications

Decreased Speech Perception → Decreased Comprehension → Reduced Language
Two Ways to Manage, Improve, and Control the Signal-To-Noise Ratio (SNR)

• **Positioning:**
  – Remain, physically, as close as possible to the desired sound source -- ideally within 6 inches
  – This can work well for an infant who is being carried
  – **Unfortunately,** physical positioning does not work in many situations where talker and child cannot remain in fixed positions
• **If you cannot remain consistently very close to the child, use a remote wireless microphone:**
  
  – A remote microphone, placed or worn within 6 inches of the desired sound source, allows the listener to remain, *technologically* close to the talker while providing a physical extension of distance hearing.
CLOSE MICROPHONE

• Reduces negative effect of
  – distance
  – noise
  – poor acoustic environment

• Improved ability to attend to an auditory task
DO PEDIATRIC AND ADULT EVALUATIONS DIFFER?

- Do you need a complete audiogram?
- Are electroacoustic and real ear data sufficient?
- Do children need to hear different things than adults?
- Monaural vs binaural?
- FM?
FM’s for Infants

- Noisy homes
- Reduced negative effect of distance
- Reduced negative effect of noise
- Improved speech signal
- Increased parental output
The Evaluation Process

- Selection
- Verification
- Validation
Selection

- Not all systems are equal
- What works for one child may not be best for another child
- No one FM solution meets all needs
Internal FM Receiver Configurations

• Ear level
  – HA with integrated FM
  – CI with integrated FM
    • (Not yet)
  – FM only
Internal FM Receiver Configurations

- Body
  - Button transducers
  - BTE transducers
• Soundfield
  – Room

  – Personal
External FM Receiver
Configurations

• Integrated audio shoe
  +FM receiver

• Two pieces
  – (audio shoe + FM receiver)

• Cube adaptor (for CI only)
• Body worn FM
  – Direct audio input (DAI)
  – Neckloop
  – Silhouette
Factors in Making a Selection

• Internal Receivers
  – Pros
    • Fewer parts
    • Ease of use
    • Ease of maintenance
    • Compatibility is assured
  – Cons
    • If something breaks the whole system is down
    • Inability to wear primary device alone
Factors in Making a Selection

• External Receivers
  – Pros
    • Can use primary device alone
    • Can use FM alone if HA is being repaired
    • Can put FM onto different HA if HA is being sent for repair or a new HA is purchased
  – Cons
    • Easier to lose parts
    • More possible parts for repair
    • Compatibility and connectivity
    • May require additional battery
    • If device is agency owned – where can it be used?
Receiver Selection Decisions

- Direct input system
  - Always with the child
  - Always in the appropriate place
  - Monitoring issues with CI
Receiver Selection Decisions

- Room soundfield system
  - Provides assistance to everyone in the room
  - Works best when close to the loudspeaker
  - Easily monitored
  - Not best for HI kids
Receiver Selection Decisions

• Personal desk top system
  – No compatibility problems with HA or CI
  – Can be easily monitored
  – Must be carried around room as child moves
  – Not appropriate for infants
Transmitters

- Boom
- Lavaliere
- Clip on
- Hand held
- Table top
Factors in Making a Selection

• Transmitters
  – Boom
    • Pros
      – Always in the correct position
      – Noise cancelling
    • Cons
      – May interfere with lipreading
      – Not popular with teachers
Transmitters cont.

• Lavaliere
  – Pro’s
    • 2\textsuperscript{nd} best choice for placement
    • Ease of use by teacher or speaker
    • Microphone options – degrees of directionality
    • Reminder to parents to TALK, TALK, TALK
  – Con’s
    • Some people do not like wearing things around their necks
    • External noise from clothing, jewelry etc
Transmitters cont.

• Clip on
  – Pro’s
    • People like it
    • Microphone options for degrees of directionality
  – Con’s
    • Almost always in the wrong place
    • External noise from clothing, jewelry etc
    • Microphone cord serves as the antenna so it has to be fully extended to work optimally
    • Greater potential for the microphone cord to break
Transmitters cont.

• Hand Held
  – Pro’s
    • Can be easily handed to different speakers
  – Con’s
    • Talker needs to remember to hold near mouth
    • Requires one hand – intrudes on talker’s freedom of movement
    • Potential for external noise
    • Not possible with young children
Transmitters cont.

- **Table top**
  - **Pro’s**
    - Picks up signal from multiple speakers who are close
  - **Con’s**
    - Signal is not as good as that from a close mic
    - Not appropriate for infants and toddlers
Recommendations

- Infants (less than 8 months)
  - Less than severe HL – may not need FM
  - Severe to profound HL
    - Body worn integrated FM/HA (button transducers)
      - Reduces feedback
      - More durable
    - BTE HA with FM only if you do not need to reduce high frequencies because of feedback
Our Recommendations

• Toddlers
  – BTE HA with FM
    • Select HA first to provide optimal benefit
    • If integrated FM is available – great
    • If FM and audio shoe are integrated – very good
  – Body worn system if needed to reduce feedback
  – CI + FM
Transmitters

- Boom mic
- Lavaliere
- Clip on – with lots of direction
The FM Evaluation

- Electroacoustic measures
- Real Ear measures
- Behavioral measures
FM VERIFICATION

Electroacoustic Measures

• FM performance with HA’s should be verified through the use of real ear or 2cc coupler measurements

• The signal used to verify the FM performance should be the same one used to verify the hearing aid performance

• Contact FM and/or HA Test Box Manufacturers for specific procedures
POINTS TO REMEMBER

• Because of compression in both the hearing instrument and the transmitter, “transparency” of the FM may not be possible.

• When adjusting the gain and output of the FM signal you MUST consider the greater input level into the FM microphone due to placement.
  – 80 dB SPL rather than 65 dB SPL for a boom or chest level mic

• The manner in which the FM transmitter will be used must be considered when adjusting the FM gain.
ADJUSTING FM GAIN

![Diagram showing frequency response with different gain levels]

- **Maximum FM Gain**
- **Minimum FM Gain**
- **HA alone**
ADJUSTING FM GAIN

FM gain control 14dB range

- Increases FM gain
- Decreases FM gain
FITTING AN FM (cont.)

- ASHA recommends 3 fitting strategies or protocols for FM fittings (Guidelines for Fitting and Monitoring FM Systems, ASHA 2003)
  - Equal Output
  - Equal Gain
  - 10 dB FM advantage
DEMONSTRATING BENEFIT

- Electroacoustic measurements
- Real ear measurements

- Are we done yet?
DEMONSTRATING FUNCTIONAL BENEFIT

• Factors
  1. Test room set-up
  2. Microphone placement
  3. Test materials
  4. Hearing aid/CI alone (R, L, B)
  5. FM and HA/CI
Behavioral Measures

• *Is it loud enough?*
  – Soundfield noise band thresholds
    • unaided
    • With technology - Right, Left, Binaural, + FM
  – Speech thresholds
    • Music
    • Ba, Sh, S
    • Spondee words or objects
    • Familiar objects
    • Body parts
Speech Perception

*Is it clear?*

- Infants - VRISD
- Toddlers
  - Monosyllabic words
  - Sentences
    - Potato Head task
    - Picture
    - Repeat back
Test Conditions

– Monosyllabic words
  • 50 dB HL Quiet
  • 35 db HL Quiet
  • 50 dB HL +5 SNR

– Sentences
  • 50 dB HL Quiet
  • 35 db HL Quiet
  • 50 dB HL +5 SNR
  • 50 dB HL +10 SNR
Selecting Speech Test Materials

• Goal of the evaluation
  – Obtain the best possible test results
  – Compare to typical peers
  – Compare to other HI peers
  – Monitor progress
  – Monitor auditory learning
  – Monitor function in different listening conditions
## FM - CI Evaluation

<table>
<thead>
<tr>
<th></th>
<th>Cl (R) (L)</th>
<th>Cl or HA (R) (L)</th>
<th>Cl+HA Cl + Cl</th>
<th>Cl+HA+FM Cl+Cl+FM</th>
<th>Test Stimulus</th>
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<tbody>
<tr>
<td>Warble tone</td>
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<tr>
<td>500 Hz</td>
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<td>1000 Hz</td>
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<td>3000 Hz</td>
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<tr>
<td>4000 Hz</td>
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<tr>
<td>Speech Perception/Quiet</td>
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<tr>
<td>50 dBHL</td>
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<td></td>
<td></td>
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<tr>
<td>35 dBHL</td>
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<tr>
<td>Speech Perception/Noise</td>
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<tr>
<td>50 dB + 5 S/N</td>
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</table>
# Functional Listening Evaluation
*(Adapted from Johnson and Von Alman)*

<table>
<thead>
<tr>
<th></th>
<th>Close/Quiet</th>
<th>Close/Noise</th>
<th>Distant/quiet</th>
<th>Distant/Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CI Alone</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>CI + FM</strong></td>
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</tbody>
</table>
Analyze the results

• Speech perception with FM + HA or CI should be better than HA or CI alone for soft speech

• Speech perception with FM + HA or CI should be better than HA or CI alone for speech in noise

• Speech perception in noise via the “FM alone” (receiver set to FM only) should be significantly greater than that obtained in noise with hearing aid or CI alone
INDIRECT MEASURES

- Sifter
- Pre School Sifter
- Hearing Performance Inventory for Children
- LIFE
- MAIS, ITMAIS
- Monitoring language levels
Summary

- The FM fitting protocol used should be determined by how the FM transmitter will be used.

- FM gain for hearing aids should be verified via real ear or 2cc coupler measurements.

- FM Benefit should be demonstrated through behavioral testing including thresholds measures and speech perception testing in noise and quiet.
Mark

- Normal hearing (PTA R 7 dB, L 6 dB)
- Word recognition
  - 50 dB (quiet) 100%
  - 35 dB (quiet) 84%
  - 50 dB +5 S/N 84%
  - 50 dB 0 S/N 64%
  - 35 dB 0 S/N 44%
Josh

• Mild conductive hearing loss
  – AC right 20 dB left 15 dB
  – BC right 4 dB left 6 dB

• Word recognition
  – 50 dB (quiet) 100%
  – 35 dB (quiet) 84%
  – 50 dB +5 S/N 88%
  – 50 dB 0 S/N 64%
  – 35 dB 0 S/N 56%
Lizzy 12 yrs

PTA  Right 65 dB   Left 74 dB

<table>
<thead>
<tr>
<th></th>
<th>Binaural</th>
<th>FM</th>
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<tbody>
<tr>
<td>50 dB</td>
<td>88%</td>
<td>100%</td>
</tr>
<tr>
<td>35 dB</td>
<td>52%</td>
<td>92%</td>
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<tr>
<td>50 dB+5 SNR</td>
<td>70 %</td>
<td>92%</td>
</tr>
<tr>
<td>Test</td>
<td>Value 1</td>
<td>Value 2</td>
</tr>
<tr>
<td>--------------</td>
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</tr>
<tr>
<td>PTA Right</td>
<td>84 dB</td>
<td></td>
</tr>
<tr>
<td>PTA Left</td>
<td>92 dB</td>
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<tr>
<td>PBK 50 dB</td>
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<td>100%</td>
</tr>
<tr>
<td>PBK 35 dB</td>
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<td>72%</td>
</tr>
<tr>
<td>Test Type</td>
<td>Binaural</td>
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<td>---------------------------------</td>
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</tr>
<tr>
<td>NU CHIPS Standard</td>
<td>64%</td>
<td>90%</td>
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<tr>
<td>NU CHIPS open set</td>
<td>56%</td>
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<tr>
<td>AB lists</td>
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<tr>
<td>vowels</td>
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<td></td>
</tr>
<tr>
<td>consonants</td>
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<tr>
<td>Whole words</td>
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</tbody>
</table>

**PTA**
- Right: 104 dB
- Left: 102 dB
<table>
<thead>
<tr>
<th>NU 6</th>
<th>Right</th>
<th>Left</th>
<th>Bin</th>
<th>FM</th>
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<tbody>
<tr>
<td>50 dB</td>
<td>72%</td>
<td>54%</td>
<td>80%</td>
<td>72%</td>
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<tr>
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<tr>
<td>50 dB</td>
<td></td>
<td></td>
<td>66%</td>
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<tr>
<td>recorded</td>
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</tr>
<tr>
<td>35 dB</td>
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<td>60%</td>
</tr>
<tr>
<td>live voice</td>
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<tr>
<td>50 dB +5</td>
<td></td>
<td></td>
<td>64%</td>
<td>54%</td>
</tr>
<tr>
<td>S/N</td>
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</table>
When should an FM be primary amplification?

- When hearing aids do not provide sufficient auditory access.
- When in a noisy environment.
- Pre - CI
OTHER FM ISSUES

- Wide band vs narrowband
- Multiple microphones
- Appropriate use of FM system
- Counseling (parents, teachers, family)
- Troubleshooting
- Preventive Maintenance
Thank you!