Hearing Aids for Tinnitus Patients: It’s Not Just About Speech

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Introduction

• Progressive Tinnitus Management, or PTM (Henry et al 2005, 2008), is a five-stage hierarchical process that assists the audiologist in identifying and providing the least intensive management strategy sufficient to provide the patient adequate relief. The five levels of PTM are:
  1 - Triage
  2 - Audiological Evaluation
  3 - Group Education
  4 - Tinnitus Evaluation
  5 - Individualized Support

• Level 2 of PTM includes amplification for appropriate patients.

• The beneficial effects of amplification for patients with tinnitus are believed to result from the amplification of ambient environmental sounds (Background Sound).

• Furthermore, additional uses of sound (Interesting Sound, Soothing Sound) cannot be effective for managing tinnitus unless the sound is audible.
Introduction

The Neurophysiological Model (Jastrebof)

“We react not to the absolute strength of a sound but rather to the strength of that sound relative to the strength of other sounds in the environment.”

Because the tinnitus signal is not as strong when it is embedded in a background of sound, negative activation of the limbic and autonomic nervous systems also is not as strong, thereby reducing tinnitus disturbance.
Progressive Tinnitus Management

Benefits of Environmental Sound Enrichment:

1. **Reduce Auditory Contrast.** By reducing the contrast between the level of the tinnitus and the level of the surrounding sound background, *the tinnitus is perceived as less loud.*

2. **Reduce Internal Auditory Gain.** By increasing the level of the surrounding sound background, amplification at all levels within the auditory system decreases. As a result, *the tinnitus is perceived as less loud.*

3. **Restore Lateral Inhibition.** By increasing the level of the surrounding sound background, additional neuronal activity is produced, resulting in increased lateral inhibition, thereby decreasing spontaneous firing of inactive neurons and reducing or eliminating another potential generator of tinnitus; *the tinnitus is perceived as less loud.*
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The tinnitus is perceived as less loud.
# Hearing Aids and Tinnitus Relief

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>At Least <em>Some</em> Relief</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>Moderate to Major/Complete Relief</td>
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</tr>
<tr>
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<td>17%</td>
<td></td>
</tr>
<tr>
<td>No Relief</td>
<td>39%</td>
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</tr>
<tr>
<td>Made Worse</td>
<td>2%</td>
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Hearing Aids and Tinnitus Relief

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- Ricketts (2011): When asked to guide the dispenser to provide a “natural sound quality,” users guided the dispenser to provide essentially no gain.
- Kochkin et al (2011):
  - 58% of aid users reported having no verification at the initial aid fitting.
  - “If comprehensive audiological services [best practices] are used to fit hearing aids, there is a stronger probability that the subject with tinnitus will derive benefit from their hearing aids to treat their tinnitus.”
Hearing Aids and Tinnitus Relief

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  – “If comprehensive audiological services [best practices] are used to fit hearing aids, there is a stronger probability that the subject with tinnitus will derive benefit from their hearing aids to treat their tinnitus.”
“On a scale of 1 to 10, where 1 means your hearing aids provide *no* tinnitus relief and 10 means your hearing aids provide *complete* tinnitus relief, how would you rate the amount of tinnitus relief provided by your hearing aids?”
Proprietary Algorithms

What impact, if any, might the use of Proprietary Prescription Algorithms have on tinnitus relief?

2006: 70% of dispensers reported fitting their patients’ hearing aids with the manufacturer’s proprietary algorithm.

2011: 58% of patients reported their dispenser did not verify the fitting of their hearing aids.
Proprietary NAL-NL1 vs. REM NAL-NL1: Vendor 1

Dramatic UNDER-fit using proprietary NALNL1 algorithm.
Proprietary NAL-NL1 vs. REM NAL-NL1: Vendor 2

Dramatic UNDER-fit using proprietary NALNL1 algorithm.
The veteran stated that the hearing aids, initially verified with VeriFit speech mapping for NALNL1, provided no tinnitus relief. Although there appears to be acceptable audibility for soft speech sounds through 3 or 4 kHz, standard REIG revealed a significant under-fit when compared to NALNL1 prescribed gain targets (65 dB SPL input).
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After reprogramming: On a 1-10 scale where 1 means my new programming provides no tinnitus relief and 10 means my new programming provides complete tinnitus relief, the veteran rated the tinnitus a 10, confirming that after reprogramming the aids were providing substantial tinnitus relief. The veteran stated the tinnitus was now manageable with the hearing aids.
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For tinnitus patients, it’s not just about the audibility of speech.
The veteran reported that the aids provided minimal hearing benefit and actually *made the tinnitus worse*.

After reprogramming to prescribed NALNL1 targets, the patient reported that the aids provided complete tinnitus relief while wearing the reprogrammed hearing aids ("10" on the 1-10 scale).

Not surprisingly, the veteran also reported substantial improvement in hearing benefit.

After delivery of a bedside sound generator and sound pillow and instruction in their use, the veteran reported there was no need for further tinnitus management.
Reprogramming with Verification: #2

Initial Tinnitus Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value</th>
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<tbody>
<tr>
<td>TRQ Score</td>
<td>56</td>
</tr>
<tr>
<td>Awareness %</td>
<td>100</td>
</tr>
<tr>
<td>Disturbance %</td>
<td>100</td>
</tr>
<tr>
<td>Tot Disturbance %</td>
<td>100</td>
</tr>
</tbody>
</table>

Binaural behind-the-ear aids with slim tubes and open stock domes (open fit). The subject reported that the aids provided little hearing benefit and no tinnitus relief.

Custom canal lock earmolds with large vents were ordered and delivered prior to reprogramming.

After reprogramming to prescribed NALNL1 targets, the patient reported that the aids provided substantial tinnitus relief while wearing the reprogrammed hearing aids (“6” on the 1-10 scale).

One month later, the subject reported that while wearing the aids, the tinnitus was “about 30% what it is without the aids.”
Expansion and Tinnitus

- WDRC provides level-dependent amplification: softer signals receive more amplification than louder signals.
- Amplification of softer signals can increase the audibility of low-level environmental noise along with the noise generated by the hearing aid itself. Amplification of such low-level noise generally is considered detrimental to the patient. **BUT** ...
- Expansion can **reduce or even eliminate** the audibility of low-level Background Sounds, placing the tinnitus patient in an environment of disturbing silence.
Expansion and Tinnitus
Frequency Lowering and Tinnitus

Bentler (2010):

“Frequency-lowering is the generic term used to refer to current technologies that take high-frequency input signals - typically considered to be speech sounds - and deliver these sounds to a lower frequency region for improved speech understanding.”
Frequency Lowering and Tinnitus

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For tinnitus patients, it’s not just about speech.
Frequency Lowering and Tinnitus

Non-Linear Frequency Compression
Frequency Lowering and Tinnitus

Non-Linear Frequency Compression
Non-Linear Frequency Compression

Potential concern for tinnitus patients:
High-frequency output is limited above the highest compressed ("cut off") frequency all the time.
Frequency Lowering and Tinnitus

Spectral Feature Identification

Potential benefit for tinnitus patients:
Maintains high-frequency output all the time while replicating HF speech cues in a lower frequency range.
Frequency Lowering and Tinnitus

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Potential benefit for tinnitus patients:
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Frequency Lowering and Tinnitus

Non-Linear Frequency Compression

Before

Spectral Feature Identification

Before
Frequency Lowering and Tinnitus

Non-Linear Frequency Compression

Spectral Feature Identification

Before

After

Before

After
Frequency Lowering and Tinnitus

Non-Linear Frequency Compression

Spectral Feature Identification

Before

After

Before

After
Frequency Lowering and Tinnitus

**NLFC**: Non-Linear Frequency Compression

**SFI**: Spectral Feature Identification
Frequency Lowering and Tinnitus

**NLFC:** Non-Linear Frequency Compression

**SFI:** Spectral Feature Identification

Does frequency lowering even make sense?
Frequency Lowering and Tinnitus

<table>
<thead>
<tr>
<th>Hearing Aid Feature</th>
<th>Real-World Benefit?</th>
<th>Wide Applicability?</th>
<th>Benefit Consistent?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directional</td>
<td>B+</td>
<td>B+</td>
<td>C</td>
</tr>
<tr>
<td>Noise Reduction</td>
<td>C</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Feedback Suppression</td>
<td>A</td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>Extended High Frequencies</td>
<td>C</td>
<td>D</td>
<td>D*</td>
</tr>
<tr>
<td>Frequency Lowering</td>
<td>C-*</td>
<td>D</td>
<td>D*</td>
</tr>
<tr>
<td>Trainable</td>
<td>C</td>
<td>C</td>
<td>B*</td>
</tr>
<tr>
<td>Wireless Technology</td>
<td>B</td>
<td>C-*</td>
<td>C*</td>
</tr>
</tbody>
</table>

(Mueller & Ricketts, 2012)

SFI: Spectral Feature Identification
Noise Management and Tinnitus

Fast-acting noise reduction technologies purport to work so quickly that they reduce the noise between the syllables of speech by up to 20 dB. As shown here, this may affect the audibility of Background Sounds for tinnitus management.

For tinnitus patients, it’s not just about speech.
Learning Volume Controls and Tinnitus

- Experience with learning VCs has suggested that many patients – especially new users – progressively turn their aids down and may eventually reach the point of minimal, if any, amplification over time.
- This concern has been addressed by some manufacturers who limit the maximum adjustment their aids can learn over time as shown below. However, 6 dB gain reduction is substantial and may be expected to impact the audibility of sound for tinnitus management.
- Audiologists are encouraged strongly to consider the possible impact of learning VC on sound input for tinnitus patients.
Automatic Adaptation and Tinnitus

Consideration:
If adequate tinnitus relief is achieved at 100% of target during the fitting, what may happen to that relief if the patient is sent home with a non-optimized frequency response to await automatic adaptation over several weeks or months?
Data Logs and Tinnitus Management

Average User Gain vs. Programmed (“Optimal”) Gain Setting
Use of Available Multiple Memories
Average Number of Hours Used per Day

Avg Time Spent per Memory

<table>
<thead>
<tr>
<th>Memory</th>
<th>Time Spent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60%</td>
</tr>
<tr>
<td>2</td>
<td>20%</td>
</tr>
<tr>
<td>3</td>
<td>15%</td>
</tr>
<tr>
<td>4</td>
<td>5%</td>
</tr>
</tbody>
</table>

Avg Daily Usage

- 14 hours
- 14 hours

Avg Battery Life

- Full Data Log: unknown
- Last 4 Batteries: 120 hours

User Volume

Input Level Distribution

Avg Input Level: 59 dB SPL, 59 dB SPL

16 dB Range

Average Input Levels

16 dB Range, 16 dB Range
Data Logs and Tinnitus Management

Average User Gain vs. Programmed (“Optimal”) Gain Setting
Use of Available Multiple Memories
Average Number of Hours Used per Day

Sound can only be effective for tinnitus management if it is audible.
# Data Logs and Tinnitus Management

## Sound Levels of Common Sounds

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAINT</td>
<td>20–30 dB&lt;br&gt;leaves rustling</td>
</tr>
<tr>
<td>SOFT</td>
<td>30–50 dB&lt;br&gt;whisper, quiet library, refrigerator*, quiet office*</td>
</tr>
<tr>
<td>MODERATE</td>
<td>50–70 dB&lt;br&gt;normal conversation, dishwasher, moderate rainfall, clothes dryer**</td>
</tr>
<tr>
<td>LOUD</td>
<td>70–90 dB&lt;br&gt;traffic, vacuum cleaner, alarm clock</td>
</tr>
<tr>
<td>VERY LOUD</td>
<td>90–120 dB&lt;br&gt;live concert, car horn, sporting event, snowmobile, MP3 player at full volume, power tool, lawn mower, hair dryer, blender</td>
</tr>
<tr>
<td>UNCOMFORTABLE</td>
<td>120–130 dB&lt;br&gt;jet plane takeoff</td>
</tr>
<tr>
<td>PAINFUL &amp; DANGEROUS</td>
<td>130+ dB&lt;br&gt;fireworks, gun shot, custom car stereo at full volume, ambulance, jackhammer</td>
</tr>
</tbody>
</table>

* www.nidcd.nih.gov/health/education  
** www.asha.org/public/hearing/noise/
“The data log revealed that the veteran spent 59% of his time in quiet environments when wearing the sound generators. Conversely, the veteran is around moderate sound levels only 16% of the time when wearing his sound generators. These data suggest that the veteran may not be making use of environmental sound enrichment to facilitate habituation to the tinnitus and/or for additional assistance in managing the tinnitus in problem situations.

The Neurophysiological Model and the three uses of sound as prescribed by PTM and how environmental sound enrichment may be utilized in conjunction with the in-ear sound generators for maximum tinnitus relief were reviewed with patient.”
Data Logs and Tinnitus Management

“The data log revealed that **the veteran spent 77% of use time in enriched sound environments** when wearing the sound generators. These data are **consistent with veteran’s reports that s/he is making use of environmental sound enrichment** to facilitate habituation to the tinnitus and/or for additional assistance in managing the tinnitus in problem situations.

The Neurophysiological Model and the three uses of sound as prescribed by PTM and how environmental sound enrichment may be utilized in conjunction with the in-ear sound generators for maximum tinnitus relief were reviewed with patient.”
This patient was in **soft** or **faint** environments well over half the time while wearing the aids.

Data logs can provide important information for sound enrichment counseling.

### Input Level Distribution

<table>
<thead>
<tr>
<th>Avg Input Level:</th>
<th>47 dB SPL</th>
<th>50 dB SPL</th>
</tr>
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<tbody>
<tr>
<td>26%</td>
<td>12%</td>
<td>41%</td>
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<tr>
<td>41%</td>
<td>24%</td>
<td>14%</td>
</tr>
<tr>
<td>45%</td>
<td>22%</td>
<td>8%</td>
</tr>
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</table>

### Average Input Levels

<table>
<thead>
<tr>
<th>dB SPL</th>
<th>0%</th>
<th>5%</th>
<th>3%</th>
<th>0%</th>
<th>0%</th>
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<td>&lt;40</td>
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<tr>
<td>40-49</td>
<td>26%</td>
<td>12%</td>
<td>8%</td>
<td>3%</td>
<td>5%</td>
<td>8%</td>
<td>14%</td>
<td>41%</td>
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<tr>
<td>50-59</td>
<td>41%</td>
<td>24%</td>
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* [www.nidcd.nih.gov/health/education](http://www.nidcd.nih.gov/health/education)

# Hearing Aid Accessories for Implementing PTM

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<tr>
<th>Vendor</th>
<th>Sound Generator</th>
<th>Bluetooth Streaming</th>
<th>Remote Microphone</th>
<th>TV &amp; Media Streaming</th>
<th>“Hard-Wire” Input</th>
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<td>Bernafon</td>
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<td>Siemens</td>
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<td>Sonic Innovations</td>
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<tr>
<td>Starkey</td>
<td>Yes</td>
<td>Stereo</td>
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<td>Unitron</td>
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<td>Stereo</td>
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</table>
Hearing Aid Considerations for Tinnitus Patients: Key Points

- It’s not *just* about the audibility of *speech*.
- Sound can *only* be effective for tinnitus management if it is audible.
- Consider these factors when fitting tinnitus patients:
  1. Fitting verification is critical to assure audibility of *sound* (*not just speech*).
  2. Standard hearing aid features may have a NEGATIVE impact on tinnitus relief.
     Such features include:
     a. Expansion
     b. Frequency Lowering Technology
     c. Fast-Acting Noise Management
     d. Learning Volume Controls
     e. Automatic Acclimatization Controls
  3. The hearing aid data log can provide valuable information for PTM / tinnitus counseling.
  4. Implementation of PTM may be enhanced by various hearing aid accessories.
Questions or Comments?

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Handouts may be requested via email:

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