Candidacy, Selection, and Verification of SoundRecover Options

Joshua M. Alexander, Ph.D.
Boys Town National Research Hospital
Omaha, Nebraska USA

3rd Phonak Virtual Audiology Conference
May 12, 2009
Overview

• What is frequency compression?
  – What can be gained (why use it)?
  – What can be lost?

• Goals that weigh cost-benefit which should translate into a more successful fitting

• SoundRecover Fitting Assistant to help in achieving these goals
What is Frequency Compression?

- Nonlinear: compression ratio (CR) ≠ in/out
Why Use It?

• Provide access to information that would otherwise be inaudible
  – Limits in high-frequency gain before feedback
  – Severity of loss
  – Dead regions

• While the compressed information may not precise, the goal is to provide enough of it for top-down processes to reduce the possibilities and use other acoustic cues and context to fill in the missing content.
What is the Information?

Broadband Frequency specific
Why Use It?

• Mild to moderate losses
  – Extend the bandwidth of information
    • ‘Ultra’ high frequencies beyond the bandwidth normally achievable with conventional amplification
      – Frication energy, esp. for children learning language
        » Stelmachowicz et al., 2001
      – Most adults in this population benefit or perform the same with frequency compression on fricative identification
        » Alexander et al., 2008
      – Perceived speech and music quality
        » Moore & Tan, 2003; Ricketts, 2008
Extend ‘Ultra’ High Frequencies

\[
\text{ch i l d r en l i k e s t r a w b e r r ie } /z/\]

1k 2k 3k 4k 5k 6k 7k 8k 9k
Why Use It?

• Moderately severe or greater losses
  – Extend the bandwidth of information to that normally achievable with conventional amplification

• Mid-frequency information
  – Some vowels with a high second formant (front vowels) and consonants co-articulated with front vowels
  – Bursts and rapid formant transitions associated with stop consonant and affricate releases
  – Formant transitions associated with glides and liquids
Extend Mid Frequencies
What is the Tradeoff?

- Formant alteration, vowel reduction

Original

1.5 kHz start, 2.2:1

1.5 kHz start, 3.7:1

1.9 kHz start, 1.9:1
What is the Tradeoff?

- Reduced spectral contrast
What is the Tradeoff?

- Flattened formant transitions
- Formant alternation (vowel reduction)
- Reduced spectral contrast
- Must also consider what hearing loss does to the signal (spectral smearing):

Frequency

Time

Encoder

Decoder

Hearing Aid

Impaired Cochlea

(Constructive Distortion)

(Destructive Distortion)
A Successful Fitting

... will depend upon giving the patient more than is taken away

- \( p(\text{Success}) = \text{New Info} - \text{Constructive Distortion} \)
- Maximize the former while minimizing the latter
A Goal for Selecting Frequency Compression Settings

- Settings are limited to 12-15 preset combinations of start freq. and CR.
- The “optimal setting”
  - Maximizes amount of information in the audible frequency range (input bandwidth)
  - Using a combination of the 1) highest start frequency and 2) lowest compression ratio to get the job done
  - Fits the bandwidth of compression into the region of audibility (not much more, not much less)
Family of Frequency I-O Curves

Input Frequency

Output Frequency

Max Audible Output
SoundRecover Fitting Assistant

• Uses a **fuzzy logic model** for selecting the optimal SoundRecover setting. **Based on 4 variables:**
  – Audible output bandwidth
  – Audible input bandwidth
  – Start frequency
  – Compression ratio

• Acknowledgements
  – Darcia M. Dierking, Au.D.  (a)
  – Andreas von Buol, Ph.D.  (b)
  – Meredith L. Spratford, Au.D.  (a)

(a) Boys Town National Research Hospital, Omaha, NE, USA,
(b) Phonak AG, Staefa, Switzerland

For your free copy, email: SRassist@gmail.com
Assumptions

• Frequency compression *precedes* gain
  – Shifted frequencies are subject to the same gain, amplitude compression, and output limits (MPO) as the regions they are moved to
  – If audibility can be achieved at a given frequency with SoundRecover *off*, then audibility can also be achieved at that same frequency with SoundRecover *on*
## Device Limits

<table>
<thead>
<tr>
<th></th>
<th>Min Start</th>
<th>Max Start</th>
<th>Max Input</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Naída UP</strong></td>
<td>1.5 kHz</td>
<td>4.0 kHz</td>
<td>6.0 kHz</td>
</tr>
<tr>
<td><strong>Others</strong>*</td>
<td>1.5 kHz</td>
<td>6.0 kHz</td>
<td>10.0 kHz</td>
</tr>
</tbody>
</table>

* Others includes Naída SP, Audéo-Yes, Nios, and Exélia Art

- Max input is **always** $\leq$ (start + 4.5 kHz)
- Odd exceptions when start = 1.5 kHz
Example: Audiogram
Step 1: Adjust the Hearing Aid Gain

a. Disable SoundRecover in the iPFG software.

b. Adjust output to match prescriptive targets (without feedback) as you normally do.

c. Run verification software with speech input at average presentation level.

d. Locate frequency at which aided speech spectrum (peak or average) intersects the audiogram. (This is the "Maximum Audible Output Frequency".)
Disable SoundRecover
SoundRecover “off”
Step 2: Find the Optimal Setting

a. Select hearing aid model from the drop down menu. If monaural fitting, select "None" for the other ear.

b. Enter the value (in Hz) from step 1d in the “Maximum Audible Output Freq.” box.

c. Enter up to 3 preset start frequencies (in kHz) and compression ratios from the iPFG software.

d. Identify the optimal setting
# Instructions for using the SoundRecover Fitting Assistant

## Step 1: Adjust the Hearing Aid Gain

- a. Disable SoundRecover in the iPFG software.
- b. Adjust output to match prescriptive targets (without feedback) as you normally do.
- c. Run verification software with speech input at average presentation level.
- d. Locate frequency at which aided speech spectrum (peak or average) intersects the audiogram.
  
  *(This is the "Maximum Audible Output Frequency")*

## Step 2: Find the Optimal SoundRecover Setting

- a. Select hearing aid model from the drop down menu. If monaural fitting, select "None" for the other ear.
- b. Enter the value (in Hz) from step 1d in the "Maximum Audible Output Freq." box.
- c. Enter up to 3 preset start frequencies (in kHz) and compression ratios from the iPFG software.
  
  **Hint:** Press "Tab" instead of "Enter" to move from Left to Right.
  
  **Hint:** One starting point is to select the default setting from the iPFG software and the settings immediately to the left (stronger) and right (weaker).
- d. Identify the optimal setting.
  
  **Hint:** If the optimal setting is the strongest or the weakest of the three, consider evaluating an additional setting that is stronger or weaker, respectively. Repeat as necessary.

**FYI:** For each setting, this software estimates the maximum audible input frequency and selects the most optimal of these based on how close their corresponding output frequencies are to the maximum audible output frequency. For those settings that exceed a certain tolerance, recommendations are made with regard to setting the start frequency and compression ratio.

**FYI:** Of the settings within the tolerance limits, the next consideration is given to the maximum audible input frequency. Settings within a certain percentage are considered equal. Final consideration is given to the setting with a combination of the highest start frequency and lowest compression ratio.

---

For your free copy, email: SRassist@gmail.com
Select Hearing Aid Model

<table>
<thead>
<tr>
<th>Right Ear</th>
<th>Select Model: NONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max freq (Hz)</td>
<td></td>
</tr>
</tbody>
</table>

**SETTING A**

<table>
<thead>
<tr>
<th>START (kHz)</th>
<th>CR</th>
<th>Max. Audible Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**SETTING B**

<table>
<thead>
<tr>
<th>START (kHz)</th>
<th>CR</th>
<th>Max. Audible Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**SETTING C**

<table>
<thead>
<tr>
<th>START (kHz)</th>
<th>CR</th>
<th>Max. Audible Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

No Setting is Optimal
Maximum Audible Output Freq.

<table>
<thead>
<tr>
<th>Setting</th>
<th>Start (kHz)</th>
<th>CR</th>
<th>Max. Audible Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>SETTING A</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>SETTING B</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>SETTING C</td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

No Setting is Optimal

SoundRecover Fitting Assistant v1.0
Joshua M. Alexander, Ph.D.
Daniel M. Dierking, Aud.D.
Andreas von Buel, Ph.D.

BOYS TOWN National Research Hospital
Software Default Setting
Default SoundRecover Setting

4.6 kHz start, 2.8:1

SR off
SR on

Unusable Input BW
Adjust SoundRecover
Enter Preset Options

Select Model: Naida SP

**Maximum Audible Output Freq. (Hz)**
3100

<table>
<thead>
<tr>
<th>Setting</th>
<th>START (kHz)</th>
<th>CR</th>
<th>Max. Audible Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.3</td>
<td>2.3</td>
<td>4970</td>
</tr>
</tbody>
</table>

*Setting A: Recommend lower start or higher CR*

<table>
<thead>
<tr>
<th>Setting</th>
<th>START (kHz)</th>
<th>CR</th>
<th>Max. Audible Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Setting</th>
<th>START (kHz)</th>
<th>CR</th>
<th>Max. Audible Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No Setting is Optimal

For your free copy, email: SRassist@gmail.com
Identify the Optimal Setting

Right Ear
Select Model: Naida SP

Maximum Audible Output Freq. (Hz)

<table>
<thead>
<tr>
<th>Setting</th>
<th>START (kHz)</th>
<th>CR</th>
<th>Max. Audible Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting A</td>
<td>2.3</td>
<td>2.3</td>
<td>4970</td>
</tr>
<tr>
<td>Setting B</td>
<td>2.0</td>
<td>2.2</td>
<td>5699</td>
</tr>
<tr>
<td>Setting C</td>
<td>1.7</td>
<td>2.1</td>
<td>6000</td>
</tr>
</tbody>
</table>

*Setting A: Recommend lower start or higher CR

Setting B is Optimal

SoundRecover Fitting Assistant v1.0

BOYS TOWN National Research Hospital
Step 3: Verify the Aided Output

a. Enable SoundRecover and select the optimal setting from step 2.

b. Verify that the maximum audible output frequency with the SoundRecover "on" is close to that assumed in the calculations.
Optimal SoundRecover Setting

2.0 kHz start, 2.2:1

SR off
SR on
Too Weak SoundRecover Setting

2.3 kHz start, 2.3:1

Output is essentially identical as the optimal setting, yet has 700 Hz less information from the input!
Stronger Sound Recover Setting

1.7 kHz start, 2.1:1

SR off
Optimal SR
Too Weak SR
Stronger SR
Recall the assumption that shifted frequencies are subject to the same gain, amplitude compression, and output limits (MPO) as the regions they are moved to.
MPO and SoundRecover

1/3 Octave Bands

- Expected Freq.
- Actual Freq.
MPO Comparisons

SR off
2.0 kHz, 2.2:1
1.5 kHz, 3.2:1
(Different start frequencies)
MPO Comparisons

SR off
1.5 kHz, 2.0:1
1.5 kHz, 4.0:1
(Different compression ratios)
Left Ear

- Mildly sloping hearing loss
- SoundRecover settings:
  - 4.6 kHz, 2.8:1 (default)
  - 3.8 kHz, 2.7:1 (stronger)
  - 5.7 kHz, 3.0:1 (weaker)
Adjust Gain and Find Maximum Audible Output Frequency
Identify the Optimal Setting

**Left Ear**
Select Model: Naida SP

<table>
<thead>
<tr>
<th>Setting</th>
<th>START (kHz)</th>
<th>CR</th>
<th>Max. Audible Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4.6</td>
<td>2.8</td>
<td>8880</td>
</tr>
<tr>
<td>B</td>
<td>3.8</td>
<td>2.7</td>
<td>8240</td>
</tr>
<tr>
<td>C</td>
<td>5.7</td>
<td>3.0</td>
<td>7034</td>
</tr>
</tbody>
</table>

*Setting B: Recommend higher start or lower CR
*Setting C: Recommend lower start or higher CR

SoundRecover Fitting Assistant v1.0
Joshua M. Alexander, Ph.D.
Dorcas M. Dierking, Au.D.
Andreas von Buol, Ph.D.
Mercedes Carrasco, Au.D.

BOYS TOWN
National Research Hospital
Verify

Speech, SR off
Speech, SR on
MPO, SR off
MPO, SR on
Fitting Report

<table>
<thead>
<tr>
<th>Ear</th>
<th>Maximum Audible Output Freq. (Hz)</th>
<th>Start Frequency</th>
<th>Compression Ratio</th>
<th>Maximum Audible Input Freq. (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>3100</td>
<td>2.0</td>
<td>2.2</td>
<td>5699</td>
</tr>
<tr>
<td>Left</td>
<td>6000</td>
<td>4.6</td>
<td>2.8</td>
<td>8880</td>
</tr>
</tbody>
</table>

Right Model: Naída SP
Left Model: Naída SP

5-May-2009

BOYS TOWN
National Research Hospital
Right Model: Naida SP  
Left Model: Naida SP  
5-May-2009

<table>
<thead>
<tr>
<th></th>
<th>Maximum Audible Output Freq. (Hz)</th>
<th>Start Frequency</th>
<th>Compression Ratio</th>
<th>Maximum Audible Input Freq. (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>3100</td>
<td>2.0</td>
<td>2.2</td>
<td>5699</td>
</tr>
<tr>
<td>Left</td>
<td>6000</td>
<td>4.6</td>
<td>2.8</td>
<td>8880</td>
</tr>
</tbody>
</table>

Fitting Report
Binaural Fittings

• Options:
  – Maximize information for each ear independently
    • Potential for introducing conflicting information between the two ears
  – Select the same setting for both ears
    • Select a compromise between the two ears
    • Select the optimal setting for the better ear
References


Thank You!

For your free copy of the SoundRecover Fitting Assistant
Email: SRassist@gmail.com