Audibility, discrimination and hearing comfort at a new level: SoundRecover2
Julia Rehmann, Michael Boretzki, Sonova AG

5th European Pediatric Conference
Current Developments and New Directions in Pediatric Audiology
Berlin, June 2016
Content

- SoundRecover
- SoundRecover2
  - Adaptive function
  - Perceptual effects and benefits
  - Fitting
  - Verification
Thanks a lot
to Siddhartha Jha, Silvia Allegro
to Susan Scollie, Danielle Glista, Marianne Hawkins, Jace Wolfe, Andrea Bohnert, Simone Ebbing
SoundRecover
Audibility Restoration

Hearing threshold percentiles of 8249 audiograms

Amplification
Frequency compression
Two strategies for audibility restoration

- Less gain required
- Larger residual dynamics
- Less prone to output distortion
- More acoustic stability (less feedback)
- High frequency sounds less sharp
- Ear’s processing quality higher

**Amplification**
- Output level increases

**Frequency Lowering**
- Frequency is lowered
- Output level is adjusted

SoundRecover: Non-Linear Frequency Compression

Input frequency kHz  

Output frequency kHz

\[ CR = \frac{\Delta x}{\Delta y} \]

Input frequency kHz

Output frequency kHz

Foutmax

CF

1

0.1

1

10
SoundRecover: Non-Linear Frequency Compression

Input frequency kHz 0.1 10

Output frequency kHz 10

Input frequency kHz 0.1 10
SoundRecover: Non-Linear Frequency Compression

- SoundRecover is static.
- Within a hearing program one and the same compression scheme is applied to all sounds.
Phoneme Perception Test: Tests and Stimuli

**Audibility test**
Above which level are the test sounds audible?

**Distinction test**
How discriminable are audible test sounds?

**Recognition test**
Above which level are audible test sounds intelligible?
Haubold, Schmitt (2012): Effects of frequency compression

Aided versus unaided: Significant increase of audibility

Threshold dB SPL

Whiskers: Recognition
Bars: Detection

Frequency compression
none
off
on

Amplification
none
Ambra

sh 3 kHz
sh 5 kHz
s 6 kHz
s 9 kHz

Significant increase of audibility
Haubold, Schmitt (2012): Effects of frequency compression

Frequency compression: Significant improvement of /s/ audibility
Haubold, Schmitt (2012): Effects of frequency compression

Frequency compression: Significant improvement of /s/ recognition

- Threshold dB SPL
- Frequency compression: none, off, on
- Amplification: none, Ambra

Whiskers: Recognition
Bars: Detection
Frequency compression: Perceptual trade-offs

Audibility
of high frequency sounds

Distinction
of audible high frequency sounds

Clarity:
Audibility and distinction
of high frequency sounds

Comfort:
Familiarity
of low and mid frequency sounds
Limitations of SoundRecover

- Severe to profound hearing loss with no responses beyond 2 kHz
- No lowering to audible frequency range
Limitations of SoundRecover

- Cut-off frequencies below 1.5 kHz:
  - Considerably unfamiliar sound quality
  - Considerable portion of harmonics (overtones) lose harmonic relationship
  - Formant structure of vowels is affected considerably.
  - Vowels sound unfamiliar, can be misunderstood.

- Therefore minimum cut-off frequency of original SoundRecover has been set to 1.5 kHz.

- Individuals with profound hearing loss need lower cut-off frequencies.
- **Reason to develop SoundRecover2!**
1 Adaptive Function

SoundRecover2
SoundRecover2

Compressive only if energy in upper frequency band is higher than in lower frequency band

Output frequency kHz

Input frequency kHz
SoundRecover2

Output frequency kHz

Input frequency kHz

/u/

linear
SoundRecover2

Output frequency kHz

Input frequency kHz

/ə/

linear
SoundRecover2

\[
\text{Input frequency kHz} \quad 0.1 \quad 10
\]

\[
\text{Output frequency kHz} \quad 10
\]

\[
\text{compressed}
\]

\[
/S/ \text{ at } 5 \text{ kHz}
\]

\[
\text{Input frequency kHz}
\]

\[
0.1 \quad 1 \quad 10
\]
SoundRecover2

Output frequency kHz

/S/ at 8 kHz

compressed

Input frequency kHz

[Graph showing frequency response with input and output frequencies and a note about /S/ at 8 kHz]
Both frequency compressors compared

![Graphs comparing frequency compressors](SoundRecover, SoundRecover2)
Advantage of less compression with SoundRecover2

Input frequency (kHz)

Output frequency (kHz)

SoundRecover

SoundRecover2
2 Perceptual Effects and Benefits
Perceptual Effects of SoundRecover2

SoundRecover2
• increases audibility of soft high frequency sounds and components of sound
• by that increases distinction of said sounds,
• by that supports recognition of said sounds,
• affects familiarity of compressed high frequency sounds
• affects familiarity of mid frequency sounds less than original SoundRecover
SoundRecover: Perceptual trade-offs

Audibility of high frequency sounds

Distinction of audible high frequency sounds

Clarity: Audibility and distinction of high frequency sounds

Comfort: Familiarity of low and mid frequency sounds
SoundRecover2: Perceptual trade-offs mitigated considerably

Audibility
of high frequency sounds

Distinction
of audible high frequency sounds

Clarity:
Audibility and distinction
of high frequency sounds

Comfort:
Familiarity
of low and mid frequency sounds
Study of Jace Wolfe et al. (2016)

• 14 subjects
  • Children - teenagers
  • Severe to profound high frequency sensorineural hearing loss
• Experimental conditions
  • SoundRecover
  • Mature prototype of SoundRecover2
• Metrics
  • Word recognition in quiet
  • Recognition of plural /s/
• Results
  • Improved word recognition in quiet with SoundRecover2
  • Improved recognition of plurals with SoundRecover2

Study at headquarters Stäfa

- 8 subjects
  - Average age 56.8 years
  - Symmetrical sensorineural or mixed hearing loss
  - Average hearing loss in frequency range 0.25 to 8 kHz higher than 90 dB
- Experimental conditions
  - SoundRecover
  - SoundRecover2
- Metrics
  - Phoneme Perception Test
    Detection of /sh/ and /s/ stimuli
    Recognition of /sh/ and /s/ stimuli
- Results
  - Improved detection of fricative stimuli with SoundRecover2
  - Improved recognition of fricative stimuli with SoundRecover2

Ebbing, S. et al. (2016). Internal research report. Stäfa
Study at headquarters Stäfa

Significant improvement of fricative audibilities

Threshold level dB SPL

Phoneme

Mid frequency kHz

SoundRecover

SoundRecover2
Benefits of SoundRecover2

SoundRecover2

• serves patients with profound hearing loss considerably better than original SoundRecover by
  • better audibility of high frequency sounds due to lower cut-off frequencies
  • better discrimination of high frequency sounds due to smaller compression ratios
  • more familiarity of mid frequency sounds due to adaptive linear or compressive processing of sound frequencies

• offers an extended fitting range

• better addresses needs of individuals with ski-slope losses and left corner audiograms
SoundRecover2

3  Fitting
SoundRecover2: Pre-calculation

- TARGET fitting software proposes SoundRecover2 settings based on studies on hearing performance with and preference of varied and tuned SoundRecover2 settings.
- Pre-calculated SoundRecover2 settings
  - make conservative use of remaining hearing sensitivity,
  - keep mid frequency components of harmonic sounds like vowels or tones natural,
  - substantially increase audibility of high frequency sounds, especially to users with severe to profound hearing loss.
SoundRecover2: Technical parameters

Output frequency kHz

Input frequency kHz

Foutmax
CF2
CF1

CR = Δx/ Δy

0.1
0.1
1
1
10
10
SoundRecover2: Display in TARGET fitting software

Frequency compression

None
Adaptive
Static

CF1
CF2
Foutmax
Audibility of high frequency sounds

Distinction of audible high frequency sounds

Audibility

9

Distinction

Clarity

Comfort
Comfort:
Familiarity
of low and mid frequency sounds

Clarity:
Audibility and distinction
of high frequency sounds
4 Verification
Verification of SoundRecover2 with adults: Phoneme Perception Test

**Audibility test**
Above which level are the test sounds audible?

**Distinction test**
How discriminable are audible test sounds?

**Recognition test**
Above which level are audible test sounds intelligible?

<table>
<thead>
<tr>
<th>Frequency kHz</th>
<th>Audibility</th>
<th>Distinction</th>
<th>Recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>s</td>
<td>sh</td>
<td>asa</td>
</tr>
<tr>
<td>2</td>
<td>s</td>
<td>sh</td>
<td>asa</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>asha</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>asha</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Pediatric Verification Considerations for Instruments with SoundRecover2

Danielle Glista¹, Marianne Hawkins¹, Susan Scollie¹, Jace Wolfe², Andrea Bohnert³ and Julia Rehmann⁴

¹The University of Western Ontario, London, Canada
²Hearts for Hearing, Oklahoma, USA
³Mainz Medical School, Mainz, Germany
⁴Sonova AG, Stäfa, Switzerland

What is SoundRecover?

SoundRecover is a frequency lowering signal processing available in Phonak hearing instruments. The aim of SoundRecover is to lower high-frequency sounds into an audible range if these high-frequency sounds cannot be made audible via conventional hearing aid processing. SoundRecover was originally designed with two parameters: a cut-off frequency (CF) and a compression ratio (CR) (Figure 1). The CF is the starting point of the compressed region of the signal. Below the CF, the signal processed by the hearing aid is unaltered in frequency. Above the CF the signal is compressed in frequency using a constant CR.
Verification of SoundRecover2 in pediatric fittings

Step 1: Fit-to-targets and verify with SoundRecover2 turned off
Verify the shape and gain of the hearing aid with SoundRecover2 turned OFF, and fine-tune to targets.
Verification of SoundRecover2 in pediatric fittings

Step 2: Determine Candidacy

Measure the spectrum of the /s/ stimulus with SoundRecover2 OFF to determine if the /s/, including the upper shoulder, falls within the MAOF range using a standard speech passage at 65 dB SPL. If /s/ is outside of this range, proceed to step 3.
Verification of SoundRecover2 in pediatric fittings

Step 3: Fine-tuning SoundRecover2

With SoundRecover2 turned on, measure the spectrum of the /s/ at the default setting. If the /s/ does not fall within the MAOF range, adjust the Audibility-Distinction slider to use the weakest possible setting for achieving the desired audibility. Re-measure the /s/ to ensure that the chosen setting produces audibility of /s/ within the MAOF range. It is recommended that the fitter choose a setting where the upper shoulder of /s/ is closest to the upper limit of the MAOF range.
Summary
Summary

- SoundRecover is non-linear frequency compression. Its effect is static.
- SoundRecover substantially increases audibility and recognition of high frequency sounds.
- Familiarity of the heard decreases as the strength of SoundRecover is increased.
- SoundRecover does not serve individuals with profound hearing loss sufficiently.
- SoundRecover2 is adaptive and offers lower cut-off frequencies than SoundRecover.
- SoundRecover2 fitting parameters offer to balance two fundamental trade-offs of frequency compression:
  - Audibility versus distinction of high frequency sounds
  - Audibility and distinction versus familiarity of low and mid frequency sounds.
- SoundRecover2 outperforms SoundRecover when hearing loss is profound.
- In adults you can use the Phoneme Perception Test for verification of SoundRecover2.
- In pediatric fittings verification should follow the white paper of Glista et al.
Thanks a lot for your attention!