# Best practice protocol

April 2016

Pediatric verification for SoundRecover2

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 (CT) and a compression ratio (CR) (Figure 1). The CT is the starting point of the compressed region of the signal. Below the CT, the signal processed by the hearing aid is unaltered in frequency. Above the CT the signal is compressed in frequency using a constant CR.

The newest generation of the SoundRecover feature is <u>adaptive</u> non-linear frequency compression, and is referred to as SoundRecover2. SoundRecover2 retains the essence of the original SoundRecover: it protects the structure of low-frequency sounds (such as vowels) and compresses high–frequency sounds (such as fricatives). SoundRecover2 is unique in that the area of protection and the starting point of compression are not fixed, as they are in SoundRecover. Instead, they are adapted based on the input signal (Figure 1). For this purpose, SoundRecover2 has two cut-off frequencies, referred to as CT1 and CT2. Based on the energy distribution of the incoming signal, the adaptive SoundRecover2 processor instantaneously determines whether CT1 or CT2 will be used (Rehmann, Jha & Allegro Baumann, 2016). This adaptive feature rapidly allows SoundRecover2 to selectively apply frequency compression to vowels versus consonants in running speech.
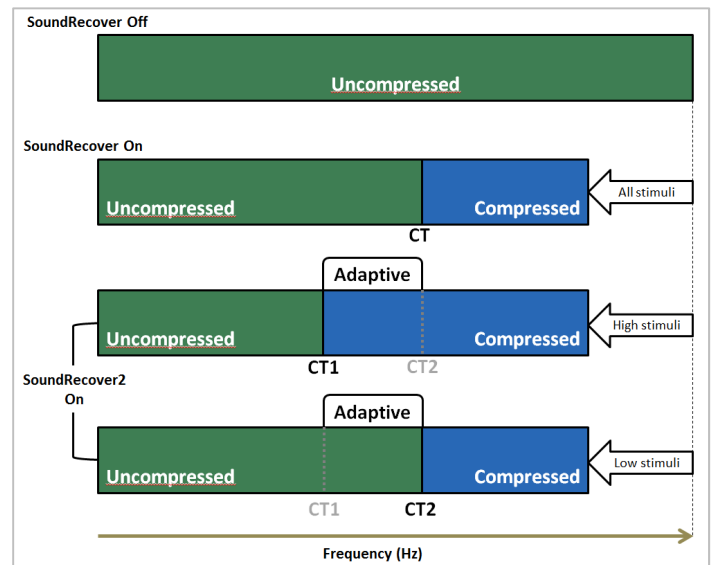
Figure 1. Conceptual illustration of the frequency location of energy in the aided signal, with SoundRecover off (top), SoundRecover on (second from top), and the two alternative frequency compression modes used within SoundRecover2 (bottom two). For SoundRecover2, the terms "High stimuli" and "Low stimuli" indicate stimuli with more high- or low-frequency content, respectively.

The functional principles of SoundRecover and SoundRecover2 are similar: to protect the harmonic structure of speech across the largest bandwidth possible. In SoundRecover, this was handled by applying a CT value that ranged from 1500 to 6000 Hz, depending on the entered audiogram. In SoundRecover2, the system can automatically switch between two configurations of frequency compression depending on the spectrum of the incoming signal. This is done adaptively, selecting CT1 for high-frequency dominant signals to restore audibility or selecting CT2 for low-frequency dominant signals (Figure 1). This prevents the application of frequency compression to low-frequency signals, which may not require frequency lowering to improve audibility.

Within the fitting module of the Target software, SoundRecover2 settings can be enabled/disabled and fine-tuned for a given fitting. Two sliders are available for adjusting SoundRecover2 (Figure 2):

1) The Audibility-Distinction Slider: This is the upper slider in Target software. It is a hybrid slider that adjusts the frequency location of CT1 and CT2 and the strength of the CR. More frequency lowering is applied as the slider is moved to the left, and less is applied as the slider moves to the right.

2) The Clarity-Comfort Slider: This is the lower slider in Target software. It further fine-tunes adaptive SoundRecover2 settings, mainly by adjusting the frequency location of CT2. As the slider is moved to the right, the overall strength of SoundRecover2 is made weaker.

These two sliders are tied to one another; settings offered in the lower slider are recalculated for each position of the upper slider, in order to distribute the slider choices within a "tradeoff triangle". Further details on the configuration of this triangle, and its implications for slider design are described by Rehmann et al (2016).
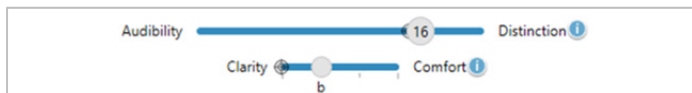

Figure 2. Sliders that control the SoundRecover2 processor within Target software.

Using vowels to illustrate SoundRecover2

Vowels are highly harmonic signals, with a harmonic present at each multiple of the talker's fundamental frequency. For example, a female talker may have a fundamental frequency (F0) at approximately 200 Hz, with harmonic energy present at multiples of the F0, such as 400, 600, and 800 Hz and so on. Depending on the position of the mouth's articulators, certain regions of these harmonics will be naturally amplified, producing formant bands.

Illustrations of the formants for the vowel /i/ are shown in Figures 3a and 3b for a female talker. By comparing a spectrogram of the unaided /i/ (3a) to an aided spectrum (3b) of the same signal, we can interpret the formant frequencies to be approximately 230 Hz for F0, 450 Hz for the first formant (F1), and a complex of the second and third formant (F2-F3) in the 2600 to 3400 Hz region. When the /i/ stimulus is aided without SoundRecover, the frequency positions of these formants remain the same.
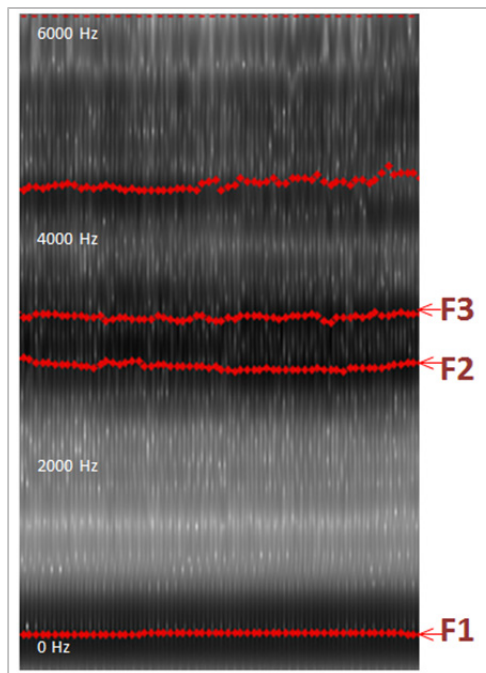

Figure 3a. A spectrogram of the vowel /i/ illustrating the approximate location of the first three formant frequencies. (Spectrogram was created with Praat® software).
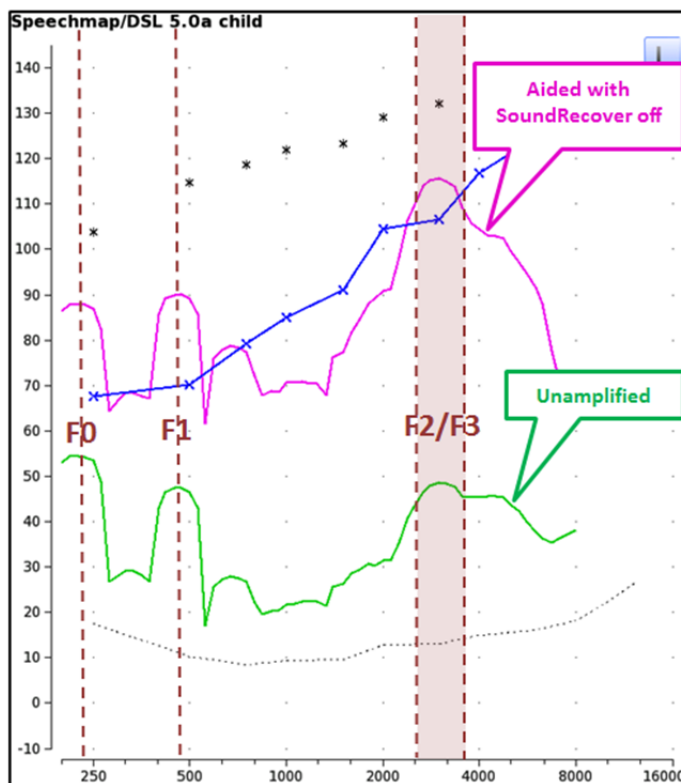

Figure 3b. Unaided (green) and aided (pink) measurements of the vowel /i/ (SoundRecover turned off) measured on the Audioscan® Verifit 2 system. Vertical dashed lines have been used to illustrate the approximate location of F0, F1 and the F2–F3 region.

When SoundRecover is applied, formants falling above the CT will be subject to frequency lowering, resulting in a compressed vowel formant space. Hearing aid users may report this as having a "closed" or unnatural sound quality. SoundRecover2 can

adaptively protect the upper formants of vowels, depending on where the CT2 parameter is set. The vowel formants receive less frequency compression with SoundRecover2. Depending on the CT2 settings of SoundRecover2, vowels may receive little or no frequency compression, and may be acoustically similar to their frequency location without SoundRecover. Therefore, compression with SoundRecover2 may result in a more natural vowel formant structure and sound quality.

Figure 4 illustrates the importance of the CT2 parameter in preserving vowel formant structure by comparing SoundRecover processing to SoundRecover2. For illustrative purposes, a vowel stimulus (/i/) has been measured for each processor and with SoundRecover turned off, using the Audioscan® Verifit 2 system. With SoundRecover off (pink), the upper formants of the /i/ peak at about 3000 Hz. The SoundRecover processor (orange) provides frequency lowering which is always active, resulting in lowering of the peaks of /i/ to just above 2000 Hz. With the new SoundRecover2 processor enabled (blue), the /i/ is recognized as a low-frequency stimulus that does not require frequency compression. The F2-F3 region of the /i/ is not lowered, and overlaps the SoundRecover off condition for most frequencies. These three conditions would likely have different sound quality of vowel sounds for the listener.
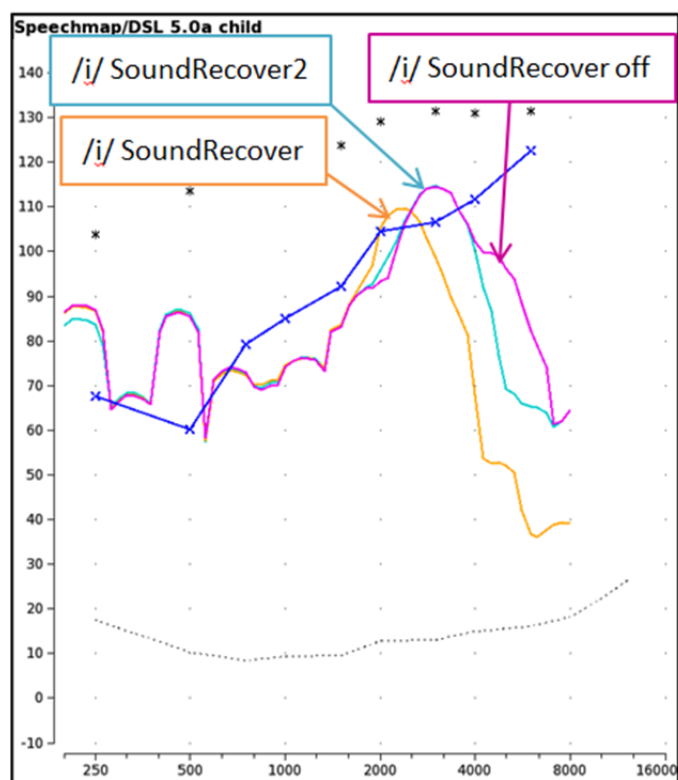

Figure 4. An aided measurement of the vowel /i/ measured for a SoundRecover setting (orange), with SoundRecover2 enabled (blue) and with SoundRecover turned off (pink) on the Audioscan® Verifit 2 system.

Figure 5 displays the SoundRecover2 fine-tuning controls within Target. The settings shown are the parameters used for the SoundRecover2 curve in Figure 2. Audibility and distinction were tuned with the upper slider in Figure 3, resulting in a CT1 value of

2.7 kHz and a CR of 1.2:1. Sound clarity and comfort were adjusted with the lower slider, resulting in a CT2 of 4.6 kHz. Together, these settings produce a fitting that applies frequency compression above 2.7 kHz (CT1), for high-frequency dominated signals, while frequency compression is applied above 4.6 kHz (CT2) when low-frequency dominated signals are detected. The applied compression ratio is fixed to 1.2:1 (CR) for either cut-off frequency. SoundRecover2 settings can be fine-tuned by moving the sliders to the right (to position the CT1/CT2 at a higher frequency) or left (to position the CT1/CT2 at a lower frequency).
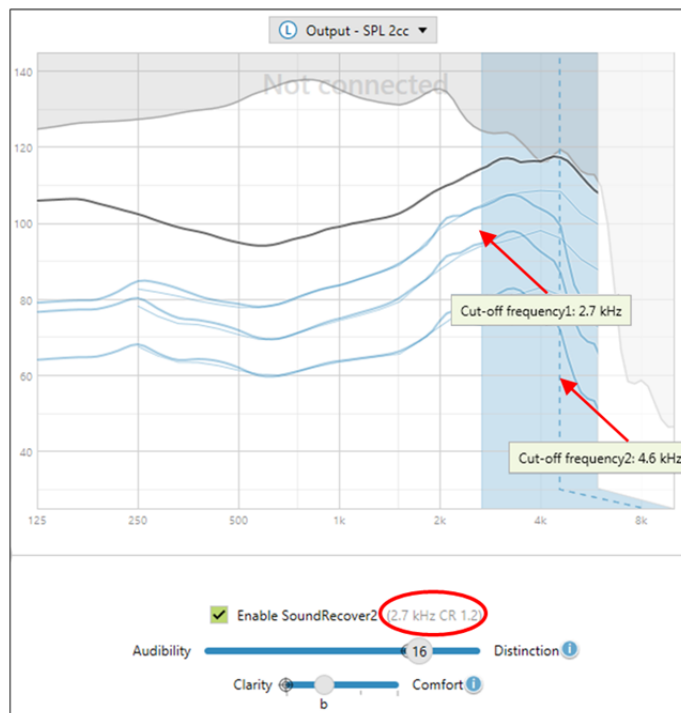

Figure 5. A screen capture of the SoundRecover2 tab within the fitting module of Phonak Target software showing the two perceptual sliders for the adjustment of audibility/distinction and clarity/comfort. The on-screen cursor has been used to highlight the values associated with the CT1 and CT2. The sliders have been used to program all SoundRecover2 parameters. Numeric CT1 and CR values can be found above the upper slider (circled in red).

As with any pediatric hearing aid fitting, routine clinical verification is necessary to ensure that an appropriate amount of gain and output is provided across frequencies. We recommend the use of a validated prescriptive formula as the starting point of any fitting. We also recommend a few additional verification steps to verify that an optimal amount of frequency lowering is provided. This can help ensure that each child has access to important speech sounds needed when developing speech and language skills.

The aim of this report is to discuss recommended stimuli, procedures and outcomes in the verification of hearing aid fittings with SoundRecover2. Particular attention is paid to the new verification stimuli implemented in the Audioscan® Verifit software, which have been developed to assist with verification of frequency lowering technology such as SoundRecover2. The principles discussed in this report may also be applied to other verification systems.

New procedures for verifying

Various stimuli have been recommended for verification of frequency lowering, including isolated high-frequency sounds (Glista and Scollie, 2009). This report outlines a protocol for using pre-recorded, calibrated speech signals, /s/ and /ʃ/, available in the Verifit 2 system (Scollie et al., 2016). Current clinical guidelines recommend that the fitter maximize the output bandwidth available to the listener prior to activating SoundRecover2 through the use of validated prescriptive targets (AAA, 2013). The fitter can then determine the frequency at which the output of the hearing instrument falls below audibility for a given audiogram, or the "maximum audible output frequency" (MAOF: McCreery et al., 2014; McCreery et al., 2013).

In this protocol, we verify the hearing aid with a running speech signal such as the ISTS, to determine the MAOF range. Specifically, the MAOF range spans from the point at which the long-term average speech spectrum (LTASS) crosses threshold to the point at which the peaks of speech cross threshold, as shown in Figure 6. This range can then be used as a target region in which to place the calibrated /s/ stimulus during verification and fine-tuning (Scollie et al., 2016).
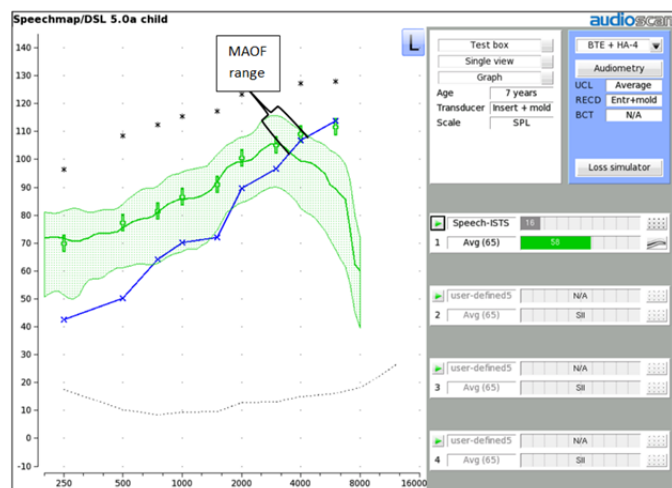
Figure 6. The hearing threshold line, together with the aided LTASS for a given fitting, allows for visualization of the MAOF range. Here, the measurement has been completed using the ISTS speech passage presented at 65 dB SPL. Peaks and valley measurements for the LTASS have been displayed.

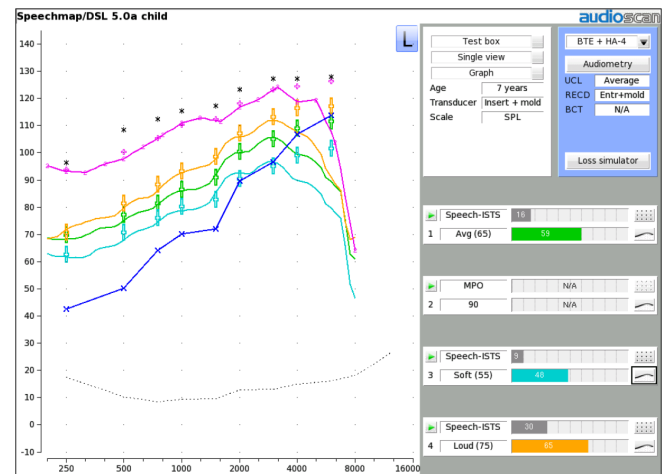## Verification Example with SoundRecover2

The following set of figures illustrates a SoundRecover2 fitting for a listener with a sloping high-frequency hearing loss. The output for soft, average and loud level speech and the maximum power output (MPO) have been adjusted to meet DSL v5.0 targets (Scollie et al., 2005) using a Phonak Naida V90-SP behind-the-ear (BTE) device.

Summary of Recommended Verification Protocol:
1. Complete fitting and verification with SoundRecover2 turned off.
2. Determine candidacy for SoundRecover2 using the /s/ stimulus.
3. Activate SoundRecover2 and complete fine-tuning.

Detailed illustration of Protocol:

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 (Figure 7).

Figure 7. Hearing instrument verification with SoundRecover2 turned OFF using the ISTS at 55 (blue), 65 (green) and 75 (orange) dB SPL and the MPO (pink).

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 (Figure 8). If /s/ is outside of this range, proceed to step 3.
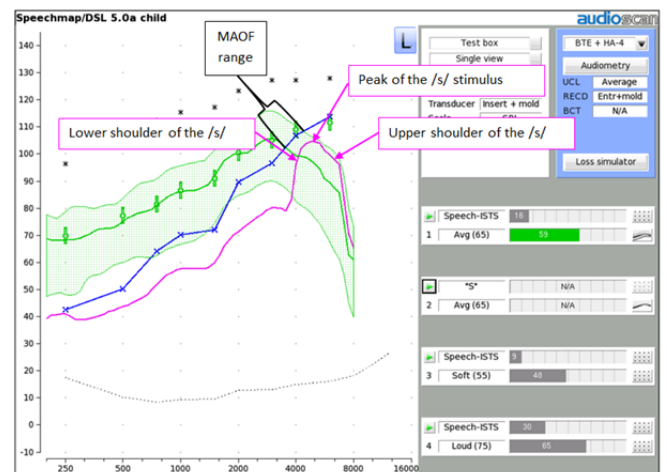
Figure 8. The aided ISTS is measured using an input level of 65 dB SPL (green). The verification display has been configured to display the peaks of speech, which helps in determining the MAOF range. SoundRecover2 is deactivated and the /s/ is measured at 65 dB SPL (pink). For this case, the /s/ does not fall within the MAOF range and is not audible. This fitting would be deemed a candidate for frequency lowering.

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 (Figure 9). 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. Helpful tips: it is easiest to leave the /s/ stimulus running when exploring different SoundRecover2 settings. Accuracy is best with the NoiseBlock feature set to off or mild.
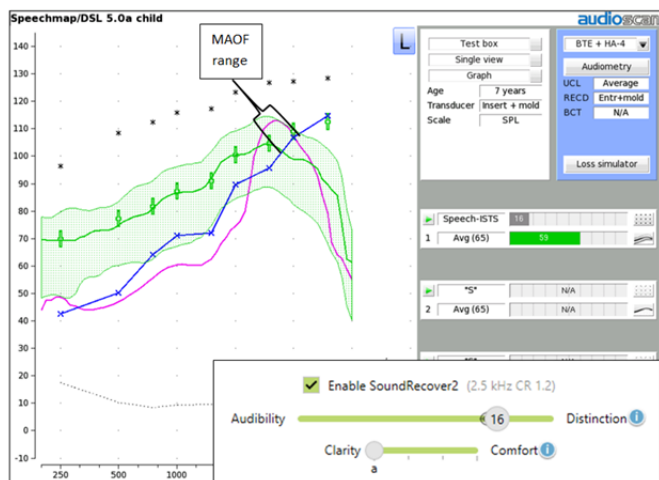

Figure 9. The upper Audibility-Distinction slider is adjusted until the /s/ stimulus (pink) is made audible and the upper shoulder falls at the upper limit of the MAOF range.

Summary

The protocol outlined in this document applies SoundRecover2 only if a calibrated /s/ is inaudible without use of a frequency lowering processor. The protocol also suggests that clinicians fine-tune SoundRecover2 to find the weakest possible SoundRecover2 setting that provides improvement in the audibility of high-frequency sounds, when compared to the same fitting with SoundRecover2 turned off. Pre-recorded and calibrated stimuli available for use with hearing aid test systems such as the Audioscan® Verifit are suitable in determining candidacy for frequency lowering processing and can assist in the fine-tuning of frequency lowering fittings (Scollie et al., 2016). These stimuli were designed to be used with the verification steps outlined in the above protocol. This individualized fitting approach considers the hearing loss severity of the listener and the device characteristics for a given fitting when choosing an optimal SoundRecover2 setting. It may be possible that further verification steps are needed to assist in the fine-tuning of SoundRecover2 fittings. Some of these further fine-tuning steps are discussed as frequently asked questions (FAQ), below.

FAQs:
After completing steps 1–3 of the protocol, the hearing aid wearer is reporting vowels sounding "closed" or unnatural. What fine-tuning steps may be helpful in this case?

The fitter can adjust the Clarity-Comfort slider to ensure that an optimal balance between audibility and naturalness is achieved for the listener. By default, the clarity-comfort slider is set to "a"; this verification step will help determine if a setting of "b", "c" or "d" will improve the quality of vowel sounds. Compared to the "a"

position, the settings of "b"–"d" use sequentially higher-frequency settings of the CT2, which broadens the frequency region that is left intact when the input signal is low-frequency dominated. This adjustment is therefore expected to improve sound quality, but if set too high may reduce the effectiveness of the frequency lowering processing within SoundRecover2. When the harmonics of speech are compressed due to frequency lowering, this can often create a "closed" sounding signal for the listener. Protecting the harmonic structure of vowel sounds through SoundRecover2 can result in an improvement in the sound quality, or a more "open" sounding signal.

We recommend that fitters listen to the hearing aid during this fine-tuning step. For example, during coupler-based fittings the fitter can use listening headphones connected to the hearing aid test box to judge the sound quality of a running speech passage across different settings prior to selecting the final placement of the clarity-comfort slider. During real-ear measurements the fitter can use patient feedback, while listening to the hearing aid using headphones to determine if fine-tuning of the clarity-comfort slider achieves better sound quality. A setting of "a" will always achieve the greatest sensation level for /s/; for this reason it is important that the fitter re-measure the /s/ stimulus when fine-tuning the clarity-comfort slider to observe any important changes in /s/ audibility.

Figure 10 illustrates a case where adjustments to the clarity-comfort slider improved the overall sound quality of vowel sounds and created a more "open" sounding fitting as judged by the fitter. The final setting choice was made based on a compromise between sound quality improvement and high-frequency audibility. The /s/ stimulus remains audible and within the MAOF range at a setting of "b" on the slider. Repeated measurement of the /s/ stimulus across all clarity-comfort settings was completed. As the clarify-comfort slider was fine-tuned towards "comfort", audibility of the /s/ stimulus was reduced. For the settings "c" and "d", the audibility of /s/ is compromised and therefore neither would be recommended as the final setting.
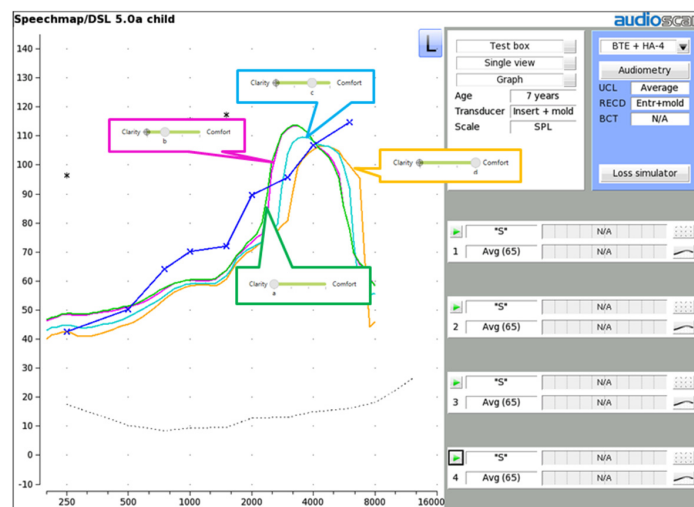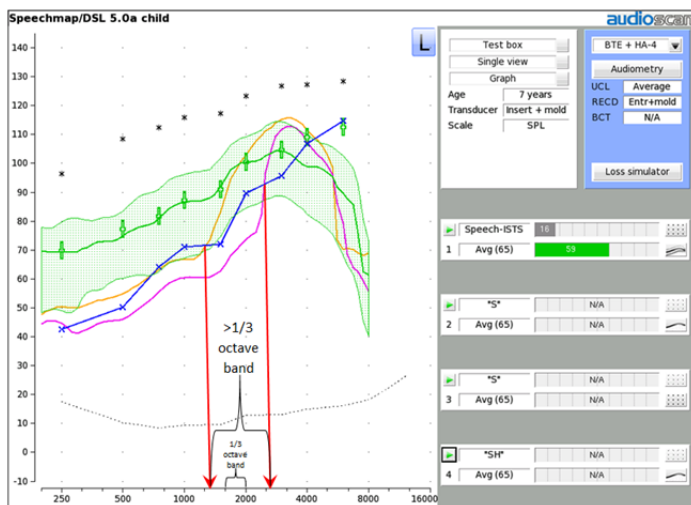

Figure 10. Illustrates aided measurement of the /s/ stimulus with SoundRecover2 active and across the clarity-comfort slider settings: "a" (green), "b" (pink), "c" (blue) and "d" (orange).

How can the fitter evaluate whether a SoundRecover2 fitting has provided adequate /s–sh/ separation?

This step may be useful in addressing complaints of "lisping" or "slushiness" caused by too much frequency lowering in a given fitting. To evaluate /s–sh/ separation, it is recommended that measurements of /s/ and /sh/ be completed for the chosen SoundRecover2 setting. The spectrum of the /sh/ stimulus can then be compared to that of /s/ (Figure 11). A minimum 1/3 octave band separation between where the lower shoulders of /s/ and /sh/ cross the hearing threshold line is recommended. In the case where /s/ and /sh/ are not separated by 1/3 octave band, fine-tuning of the SoundRecover2 setting is recommended.


Figure 11. Illustrates aided measurement of the /s/ (pink) and /sh/ (orange) stimuli and the ISTS passage at 65 dB SPL. /s–sh/ separation is evaluated using the tick marks on the horizontal axis. Separation is measured from the point at which the lower shoulder of the stimuli cross the hearing threshold line. In this example, more than 1/3 octave band separation is observed between the /s/ and /sh/, which is judged as acceptable. This fitting should support successful distinction between these two sounds.

References

AAA. 2013. American Academy of Audiology Clinical Practice Guidelines: Pediatric Amplification.

Glista, D., and S. Scollie. (2009) Modified Verification Approaches for Frequency Lowering Devices. In Audiology Online. Vol. November. 1-11.

McCreery, R.W., J. Alexander, M.A. Brennan, B. Hoover, J. Kopun, and P.G. Stelmachowicz. (2014) The influence of audibility on speech recognition with nonlinear frequency compression for children and adults with hearing loss. Ear and Hearing. 35(4):440-447.

Stelmachowicz. (2014) The influence of audibility on speech recognition with nonlinear frequency compression for children and adults with hearing loss. Ear and Hearing. 35(4):440-447.

McCreery, R.W., M.A. Brennan, B. Hoover, J. Kopun, and P.G. Stelmachowicz. (2013) Maximizing audibility and speech recognition with nonlinear frequency compression by estimating audible bandwidth. Ear and Hearing. 34(2):e24-e27.

Rehmann, J., Jha, S. and Allegro Baumann, S. (2016). SoundRecover2 – the first adaptive frequency compression algorithm. Phonak Insight Paper.

Scollie, S., D. Glista, J. Seto, A. Dunn, B. Schuett, M. Hawkins, N. Pourmand, and V. Parsa. (2016) Fitting frequency-lowering signal processing applying the AAA Pediatric Amplification Guideline: Updates and protocols. Journal of the American Academy of Audiology, 27(3):219-236.

Scollie, S., R.C. Seewald, L. Cornelisse, S. Moodie, M. Bagatto, D. Laurnagaray, S. Beaulac, and J. Pumford. (2005) The desired sensation level multistage input/output algorithm. Trends in Amplification. 9(4):159-197.

Authors
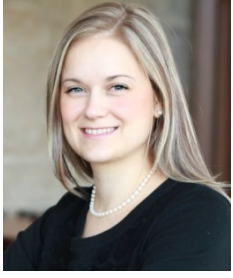
Dr. Danielle Glista is a Senior Research Associate in the Child Amplification Lab at the National Centre for Audiology and Research Professor in the School of Communication Sciences and Disorders.
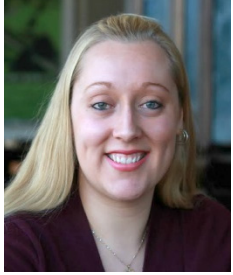
Marianne Hawkins is a Research Associate and Audiologist in the Child Amplification Lab at the National Centre for Audiology

Dr. Susan Scollie is the Director of the Child Amplification Lab at the National Centre for Audiology and Associate Professor in the School of Communications Sciences and Disorders.

Jace Wolfe, PhD, is the director of audiology at the Hearts for Hearing Foundation and is an adjunct assistant professor in the Audiology Department at the University of Oklahoma Health Sciences Center and Salus University.

Andrea Bohnert is the Senior MTA-F in Audiology and Pedaudiology at the University Hospital for ENT and Communication Disorders in Mainz, Germany and holds teaching posts at the University Hospital Mainz and the Teaching-Unit for Logopedics in Audiology

Julia Rehmann is an Audiological Engineer with Sonova AG, Stäfa, Switzerland.