Pediatric verification considerations for instruments with SoundRecover (non-linear frequency compression) using the latest Audioscan Verifit® tests

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What is SoundRecover?

The aim of SoundRecover (non-linear frequency compression) is to take high-frequency sounds that the child is unable to hear, and compress them to a lower frequency region where the child can hear better. SoundRecover also seeks to give greater audibility of high-frequency everyday sounds such as birdsong or warning beeps. SoundRecover compresses the signal above a specified cut-off frequency. The amount of compression applied to this high-frequency band is specified by the compression ratio. The spectrum below the cut-off frequency remains uncompressed in the frequency domain to avoid vowel artefacts [1, 2]. It is important to note that when fitting SoundRecover to children using DSL v5, a different pre-fitting algorithm is used compared to adults. This automatic pediatric fitting of SoundRecover is based on data collected from Glista et. al. [1] and is implemented in Phonak fitting software (iPFG 2.0 and above).

Verifying hearing instruments with SoundRecover

Like all pediatric fittings, it is important to verify hearing instruments with SoundRecover in order to check that prescription targets are met and that the child has access to the important speech frequencies. As SoundRecover compresses the high frequencies above the cut-off frequency into a lower frequency range, verification graphs will look different compared to conventional graphs. The aim of this report is to provide guidance to electroacoustic verification of hearing instruments with SoundRecover. Particular attention will be paid to a new verification option implemented in the Audioscan Verifit® software, which has been developed to help verify frequency lowering technology, such as SoundRecover. However, the principles can also be applied to other verification systems. A more general guide to verifying hearing instruments with SoundRecover can be found under [Downloads] on: www.naida.phonak.com

New procedure for verifying frequency lowering instruments

Previously, verification using live voice productions of /s/ and /sh/ has been recommended when evaluating the separation of /s/ and /sh/ sounds across SoundRecover settings [3]. A new verification option is now available in the Audioscan Verifit® to supplement the live voice option. The new procedure uses modified speech test stimuli to assist with verification and adjustment of frequency lowering devices. Specifically, the new test stimuli are comprised of bands of high-frequency speech energy at specific centre frequencies: 3150, 4000, 5000, and 6300 Hz (refer to Figure 1 for an illustrative example). The mid-frequency regions of the speech test stimuli have been 'notched out' to allow for better visual representation of the speech bands. Verification using the modified test signals with and without SoundRecover enabled can assist in illustrating the effects of SoundRecover. For example, when SoundRecover is off, the high-frequency speech bands will be measured and visible at the nominal frequency; when SoundRecover is on, the bands will appear at a lower frequency. It is recommended that clinicians familiarize themselves with frequency response curves from hearing instruments with SoundRecover on, as they will look different than traditional frequency response curves. See Appendix 1 for an excerpt from the Verifit® User Guide (version 3.4).

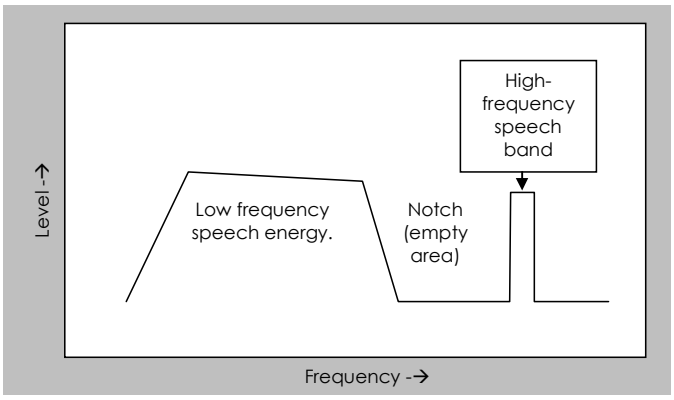
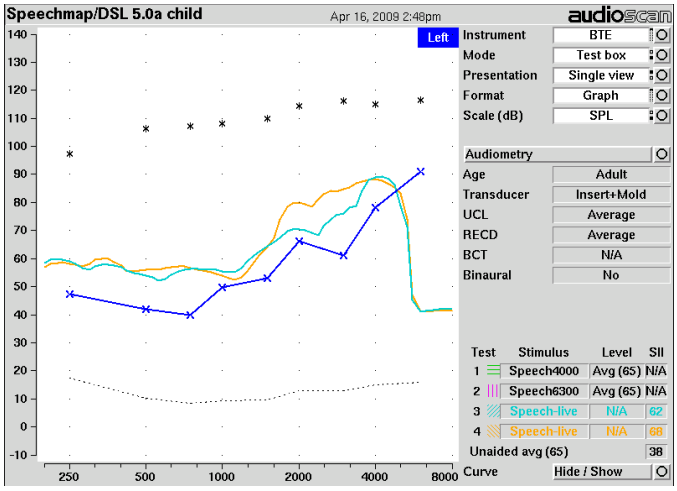


Figure 1: Illustration of the Audioscan Verifit® Frequency Lowering Verification Test

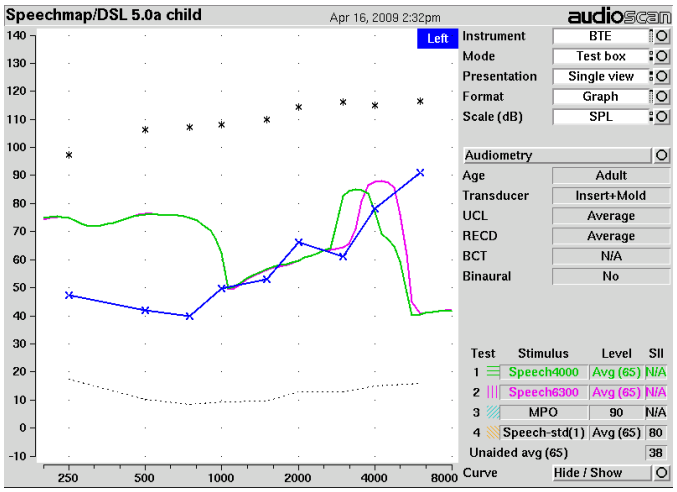
Verification examples using SoundRecover

For the purpose of the following illustrations, a sloping high-frequency hearing loss was entered into the Verifit® software as well as Phonak iPFG fitting software. The gain for average level speech and the maximum power output (MPO) was adjusted to approximately match DSL v5 targets [4]. Using the iPFG Junior Mode, Phonak Naida V SP behind-the-ear (BTE) hearing instruments were programmed with SoundRecover enabled. Note: SoundRecover default settings within the Junior Mode iPFG software have been derived from previous research on nonlinear frequency compression technology [1, 3]. The following screen captures (Figures 2 through 5) illustrate the utility of the new Verifit® test signals, compared to the live voice production option, when verifying hearing instruments with SoundRecover at various settings.

Figure 2: Electroacoustic verification of the default SoundRecover setting of 3200 Hz (cut-off frequency), 2.4:1 (compression ratio)

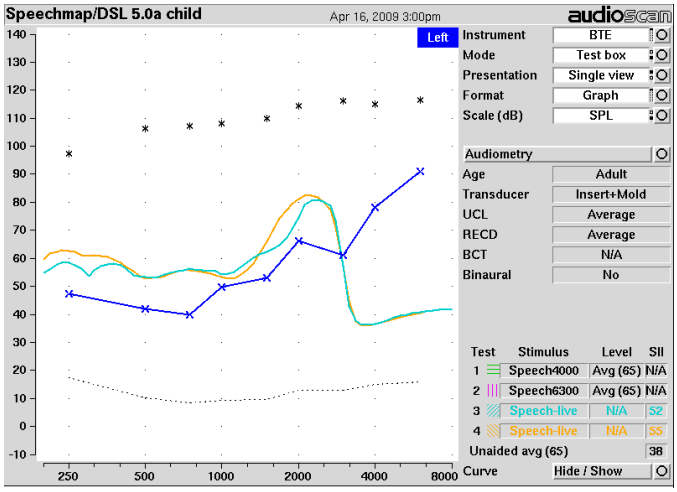


Live voice productions of /s/ (blue) and /sh/ (yellow). A distinct peak for the sound /s/ can be observed at approximately 4000 Hz. The bandwidth for the sound /sh/ is distinguishable from that of /s/ (a broader bandwidth is noted for /sh/).

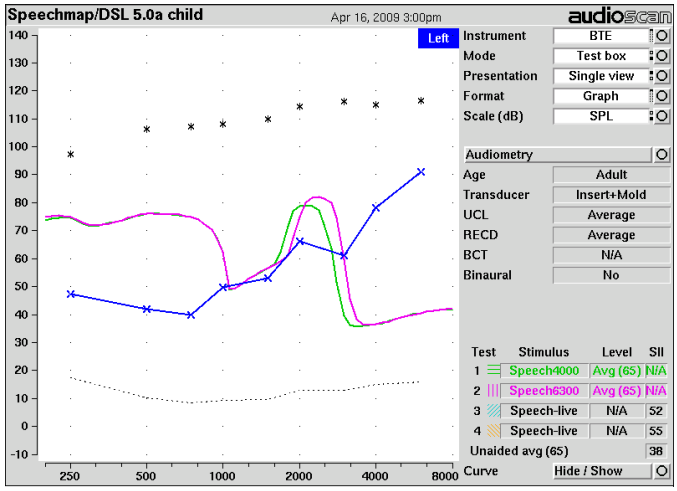


Frequency specific speech bands for 4000 Hz (green) and 6300 Hz (pink). The 6300 Hz band has been lowered to approximately 4000 Hz; 4000 Hz band has been lowered to approximately 3000 Hz. The two bands remain distinguishable from each other (with a slight amount of overlap).

Figure 3: Electroacoustic verification of a stronger SoundRecover setting of 1900 Hz (cut-off frequency), 4:1 (compression ratio)



Live voice productions of /s/ (blue) and /sh/ (yellow) with SoundRecover. A distinct peak for the sound /s/ can be observed at approximately 2000 Hz. The bandwidth for the sound /sh/ is no longer entirely distinguishable from that of /s/ (the bandwidth /sh/ is much like that for /s/ for this SoundRecover setting). This indicates that the SoundRecover setting may contribute to sound confusions for this hearing loss and should be fine-tuned.



Frequency specific speech bands for 4000 Hz (green) and 6300 Hz (pink) with SoundRecover. The 6300 Hz band has been lowered to approximately 2500 Hz (similar to the /s/ sound); the 4000 Hz band has been lowered to approximately 2000 Hz. The two bands are almost entirely overlapping for this SoundRecover setting; this agrees with the live speech measurements and indicates the need for further fine-tuning of the SoundRecover setting.

Figure 4: Direct comparison of the frequency specific band of 6300 Hz (pink) and a live production of /s/ (blue)

In this example, both stimuli have been lowered to approximately 4000 Hz for this SoundRecover setting. These two measures have similar peak values and appear to have similar value in evaluating the amount of frequency lowering. This indicates that the frequency specific band of 6300 Hz may be used as a substitute for live production of the sound /s/ in evaluating the effects of SoundRecover.

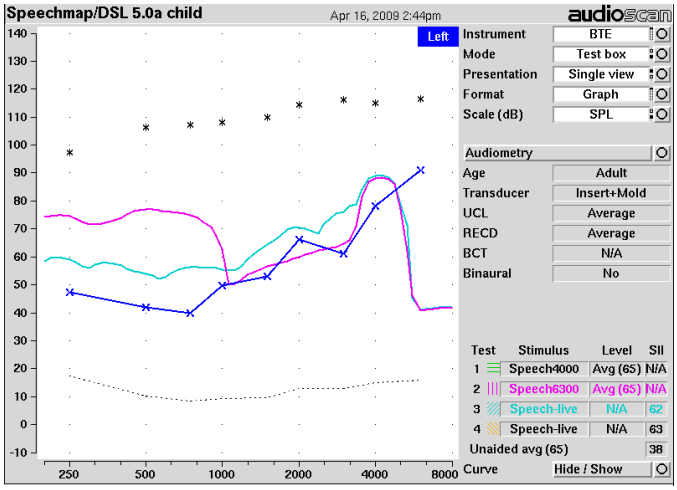
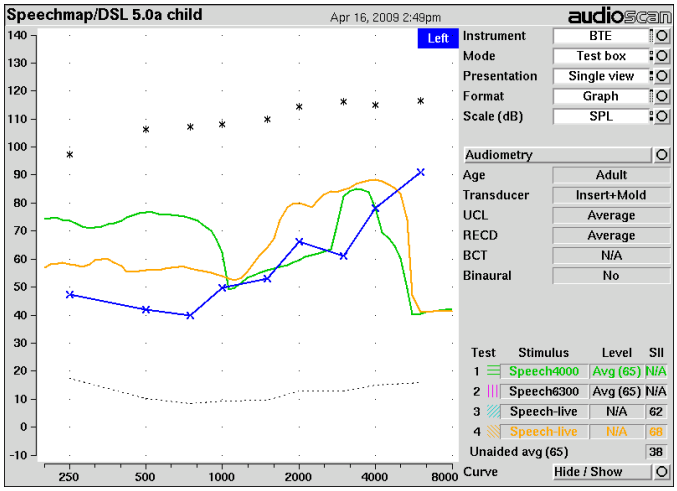


Figure 5: Frequency specific band of 4000 Hz (green) compared to a live speech production of /sh/ (yellow)



In this example, both have been lowered as a result of SoundRecover; however, the bandwidths for these stimuli are very different. This indicates that the frequency specific band of 4000 Hz cannot act as a direct substitute for a live production of the sound /sh/ in evaluating the effects of SoundRecover, but instead can serve as a calibrated measurement of a band of high-frequency energy similar to that of the sound /sh/. The test is controlled, repeatable and within a running speech context so is a useful addition to live voice.

Summary

The measurements presented above illustrate the following:

1. Live voice production of /s/ and /sh/ can be used to determine (a) whether the two sounds are audible, and (b) the amount of overlap created from a specific SoundRecover setting. Application of SoundRecover tends to increase the audibility of /s/ and sometimes of /sh/ as well. As the SoundRecover setting gets stronger, /s/ and /sh/ are subject to a greater amount of overlap and become more similar in appearance (i.e. the bandwidth of /sh/ gets smaller with more SoundRecover applied). When the /s/ and /sh/ bands overlap sound confusions can occur. In this case, it would be recommended to fine tune SoundRecover to make it weaker, so that these two speech sounds are not confused by the child.

2. The frequency specific speech bands, available in the new Verifit® tests, can be used to evaluate the amount of overlap for the /s/ and /sh/ speech sounds in the same way that live voice is used. As the SoundRecover setting gets stronger, the two bands (i.e. 4000 and 6300 Hz shown in the examples) are subject to a greater amount of overlap. Overlap between the 4000 and 6300 Hz tests (Figure 3) shows that the SoundRecover setting may be too strong, and indicates that the child may confuse /s/ and /sh/ sounds. Although the 3150 and 5000 Hz bands have not been used in the above examples, they can also be used to evaluate frequency lowering effects.

3. The frequency specific speech band of 6300 Hz appears to be a good substitute for a live voice production of /s/, when assessing whether /s/ is audible (note: an adult female speaker was used in the measurements). The peak for both stimuli (6300 Hz and /s/) is centered on a similar frequency value; this gets lowered by a similar amount across the SoundRecover settings for both stimuli. Clinicians who wish to have a calibrated substitute for live voice /s/ can be directed to use the 6300 Hz test.

4. The frequency specific speech band of 4000 Hz does not appear to be a good substitute for a live voice production of /sh/ (at least for this speaker) because the bandwidth of the /sh/ is much wider than that of the 4000 Hz speech band. Clinicians who wish to have a calibrated substitute for live voice /sh/ are recommended to use the 3150 Hz test to establish audibility for the lower part of the /sh/ spectrum and the 6300 Hz test to establish audibility for the upper part. Use of the 4000 Hz test on its own may not be a good predictor of audibility of /sh/: the broad bandwidth of /sh/ frication may make it audible to the listener even when the 4000 Hz test band is not, either because of loudness integration across critical bands, or because of an audible lower shoulder of the /sh/ frication band.

5. Further research is needed to be able to quantify "how much" overlap is too much. The results for the measurements presented above should always be considered in combination with sound quality listening checks and user feedback (when available). The effects of SoundRecover (i.e. overlap of speech sounds) can likely be heard by most normal hearing listeners, especially for the strongest settings. It is likely that if two stimuli (previously separated) have been made undistinguishable in bandwidth or frequency content by SoundRecover, the listener will be unable to perceive a difference between the two stimuli as well.

Clinical implications

1. The Audioscan Verifit® Frequency Lowering Verification test appears to be a valid electroacoustic test that can quantify the degree and nature of frequency compression. The use of live voice productions of /s/ and /sh/ as a verification option is also recommended [3]. The following is important to note:

   a) The use of live voice productions of /s/ and /sh/ is recommended because of their face validity; however, this approach is not calibrated and varies somewhat with talker.

   b) The 6300 Hz speech band test shown here provides a good approximation of a naturally produced female /s/ sound.

   c) None of the frequency-specific speech bands provide a good approximation of /sh/, because they are narrower in bandwidth than a /sh/ sound. However, the 3150 Hz and 6300 Hz tests can be used in combination to establish audibility of /sh/.

2. The Verifit® tests indicate that with the Phonak default settings, all frequency band tests were made audible with SoundRecover on (when compared to results with SoundRecover turned off).

3. The low frequency portion of the frequency band tests clearly indicates that the low frequencies are not altered, showing that vowel sounds remain unaffected.

Suggested protocol for verification of hearing instruments with SoundRecover

1. Verify the shape and gain of the hearing aid using conventional measures of running speech with frequency compression at default settings.

2. Verify the maximum output using the MPO test, ignoring any results above the cutoff frequency.

3. Measure the 6300 Hz frequency band to determine if it is audible. If so, /s/ should also be made audible.

4. Perform other tests as needed for troubleshooting:

   i) If 6300 Hz is not audible, repeated tests at fine tuned settings may assist clinicians in discovering a setting that provides more audibility.

   ii) If subjective feedback indicates difficulty with /s/ and /sh/ confusion or excessive audibility of high-frequency sound, the frequency band tests may assist clinicians in discovering a setting that provides less frequency compression while maintaining some audibility for high-frequency sounds.

   iii) At the clinician's discretion, live voice productions of /s/ and /sh/ may have some value when the specific level and frequency location of these phonemes needs to be evaluated.

References

1. Glista, D., Scollie, S., Bagatto, M., Seewald, R., Parsa, V., Johnson, A. *Evaluation of nonlinear frequency compression: Clinical outcomes.* International Journal of Audiology, in press.

2. Simpson, A., Hersbach, A. A. and McDermott, H. J. *Improvements in speech perception with an experimental nonlinear frequency-compression hearing device.* International Journal of Audiology, 2005. **44**(5): p. 281-292.

3. Scollie, S., Glista, D., Bagatto, M., Seewald, R. *Multichannel nonlinear frequency compression: A new technology for children with hearing loss.* in R. Seewald and J. Bamford (eds.), *A Sound Foundation Through Early Amplification*: *Proceedings of the fourth international conference* 2007, pp. 151-159 Chicago, Illinois: Phonak AG.

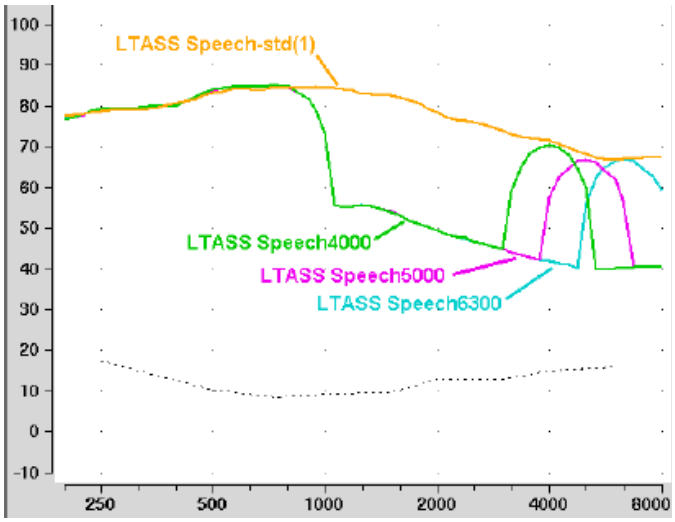
4. Scollie, S., Seewald, R., Cornelisse, L., Moodie, S., Bagatto, M., Laurnagaray, D., Beaulac, S., Pumford, J. *The desired sensation level multistage input/output algorithm.* Trends in Amplification, 2005. **9**(4): p. 159-197.

Appendix 1: Excerpt from the Verifit® Users Guide version 3.4.

Verifying Frequency Compression/ Frequency-Lowering Hearing Instruments in Speechmap

Frequency lowering is used when it is not possible to amplify the high frequency components of speech sufficiently to raise them above threshold. In this case, the high frequency components may be shifted to a lower frequency with a better hearing threshold where the available gain will render them audible.

Four modified versions of the Speech-std (1) test stimulus (Speech3150, Speech4000, Speech 5000 and Speech6300) are provided in Speechmap to assist in verifying and adjusting frequency lowering devices. In each of these modified test stimuli, the 1/3 octave band levels above 1000Hz are reduced by 30 dB, except for an isolated 1/3 octave band centered at the frequency indicated in the selected test stimulus' name. With these reduced band levels, the resulting LTASS produces a distinct "cavity" between 1000 Hz and the selected high frequency band, as seen below for the FM Boom test signal. For clarity, the Speech3150 curve is not shown.



To test frequency-lowering:

1. From the Speechmap screen, choose either "On-ear" or "Test box" Mode. (Review 17.9: On-ear or Test box Mode.)

2. Program the hearing instrument so that the frequency-lowering feature is inactive.

3. Select "Test 1" and choose 65dB from the level menu.

4. Choose Speech3150, Speech4000, Speech5000 or Speech6300 from the stimulus menu. Note that only the LTASS is shown for these stimuli and targets (if selected) have been suppressed.

5. Press "Continue" to measure and store the long-term signal-averaged result. If the isolated band does not appear in the Test 1 curve, it may indicate that the hearing aid has no gain at the selected band frequency. This does not mean that the hearing aid will be unable to transpose the band to a lower frequency when frequency lowering is enabled.

6. Program the hearing instrument to activate the frequency-lowering feature.

7. Select "Test 2" and select the same stimulus and stimulus level used in Test 1.

8. Press "Continue" to measure and store the long-term signal-averaged result.

9. The isolated band should now appear at a lower frequency and should reach or exceed threshold at its new location as shown below. Note that the "cavity" between 1 kHz and the isolated band may be partially or completely filled in by noise within the hearing aid which will make the isolated band appear less distinct in the test curves.

10. Once the frequency-lowering properties of the hearing instrument have been verified, use one of the Speechstd stimuli to verify aided speech audibility or target match (as described elsewhere in this section) for frequencies below the isolated band.