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A Sound Foundation Through Early Amplification

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SoundRecover2: Description and verification protocols

Susan Scollie, Ph.D.
Danielle Glista, Ph.D.
Andrea Bohnert, Ph.D.
Jace Wolfe, Ph.D.

Abstract

In this paper, we describe a new adaptive nonlinear frequency compression processor that has been developed by Phonak, called SoundRecover2. We discuss the role of speech recognition and sound quality measurement in evaluating this processor. We also describe the fitting procedures that we are using to fit this processor in our current collaboration to examine outcomes with SoundRecover2. Fitting examples and fitting data from our three clinical sites are described, and resources that provide technical descriptions and fitting protocol information are incorporated.

Introduction

As hearing aid signal processing continues to evolve, we find ourselves looking at outcome measures other than speech perception, including recent emphasis on domains such as sound quality and listening effort. These alternative outcome measures have been aimed at studying newer issues in hearing aid fitting that are not well-assessed by measures of speech recognition, including bandwidth, frequency lowering, and noise reduction, to name a few. In the past, our field examined hearing aid outcome by measuring unaided versus aided test results, and for most losses, measurement of the difference between unaided and aided was fairly simple to measure because the change was rather large. So we moved on, and we looked at the differences between hearing aids with linear and amplitude compression, and then further to hearing aids with amplitude compression and specific signal processing turned on versus off. As we turn our efforts away from studies focused on aided versus unaided and instead to measuring differences between signal processing options, the degree of change we are measuring appears smaller. It has been of recent value, therefore, to consider that the subjective side of fitting, including sound quality, might be an important domain of outcome in addition to sound audibility. This is true when comparing today's generation of frequency lowering signal processors.

In our work, we use the term "frequency lowering" as an umbrella term for any type of frequency lowering signal processor, and acknowledge that there are many sub-types within this processing category. A recent review explains the various frequency lowering processing types available in current-generation hearing aids (Alexander, 2016). Specifically for SoundRecover2, recent technical descriptions of the processor are available, and explain this new scheme in more detail than will be covered in this chapter (Rehmann, Jha, & Allegro Bauman, 2016). SoundRecover2 builds upon Phonak's original frequency lowering processor that was originally released to market as "SoundRecover". This older processor is now sometimes called "SoundRecover1" to help distinguish it from the more recently developed SoundRecover2. SoundRecover1 splits the signal at a cutoff frequency, and applies a frequency compression ratio above this, as shown in the second row of Figure 1. For example, inputs at 10,000 Hz can be lowered to 4000 Hz. In contrast, inputs near the cutoff frequency might not be lowered much as all, because the processor is nonlinear, so the highest-frequency inputs are lowered more than the inputs near the cutoff. This is a processor that is fairly well understood, and has been studied in children who use hearing aids (Davidson, Firszt, Brenner, & Cadieux, 2015; Glista et al., 2009; Wolfe et al., 2010; Wolfe et al., 2011).

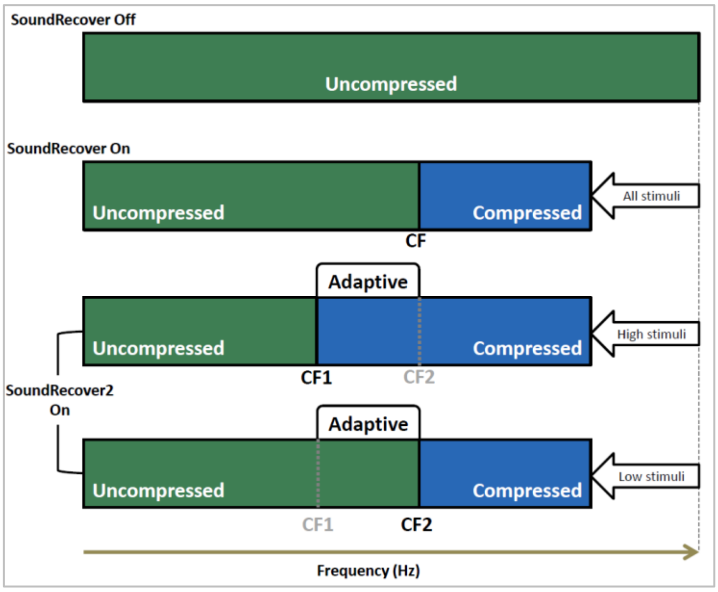

Figure 1. Conceptual illustration of the frequency location of energy in the aided signal with SoundRecover off (top), SoundRecover on (second from top), and the two alternative frequency compression modes used within SoundRecover2 (bottom two). For SoundRecover2, the terms "High stimuli" and "Low stimuli" indicate stimuli with more high- or low-frequency content, respectively. (Figure from Glista et al., 2016a, used with permission)

The newer SoundRecover2 processor also applies non-linear frequency compression. However, it applies two different strengths of compression, and can alternate between these two strengths in real time. This is illustrated in the bottom two rows of Figure 1; the hearing aid will rapidly switch between these two states, stronger and weaker. This adaptation has been designed to apply the weaker setting to low-to-mid-frequency sounds, and the stronger setting for high- frequency sounds.

Why might we want this type of adaptation? Consider how this could be used for speech sounds such as "isisisi". For many hearing losses, the /i/ sound probably does not need much frequency lowering in order to be fully audible to the listener—in fact, it might not require frequency lowering at all. The weaker side of the processor can therefore be set accordingly, and uses weak settings that can preserve most of the normal harmonic and formant relationships within the vowel. This has the potential to produce a sound quality that has very little degradation and that is quite similar to vowels heard with frequency lowering turned off. In contrast, the /s/ portion of this sound will receive the stronger setting of the processor, which can be stronger to ensure that the /s/ sound is audible. On this side of the processor, we can follow fitting philosophies that are similar to how we would set the original, non-adaptive SoundRecover1 processor. In this aspect of the fitting, we can connect to the goal of providing a broad bandwidth of audible speech cues to support speech reception and production in young children who are learning speech and language through hearing aids. Integrating both sides of SoundRecover2, this adaptive processor allows us to

think about providing access to difficult-to hear fricatives, while aiming to provide a natural sound quality and full audibility for vowels.
In the early prototype stage of evaluation of the SoundRecover2 processor, the importance of sound quality was considered and discussed in two ways. First, it might have an overall impact by improving sound quality of these fittings in general. Second, and more specifically, it was speculated that for hearing aid users with significant losses, the "release" of the strength of frequency compression for vowels might permit the use of even stronger settings for fricatives, because the overall sound quality would not be adversely affected compared to that of a fixed processor at strong settings. Recall that the setting strength of SoundRecover1 was originally limited to no stronger than 1500 Hz and 4:1 to prevent extremely strong settings that could negatively impact sound quality more than the developers felt was warranted. Does this mean that SoundRecover2 could possibly use even stronger settings in the "strong" side of its adaptive processing? These are some of the reasons why this was developed, and were important to consider in trials of the processor to see if such outcomes happen when the hearing aid is used with patients.

To date, we know that the SoundRecover2 processor produces a measureable improvement in sound quality, and we have projects in progress that show that listeners with normal hearing clearly perceive an improvement in sound quality as the SR2 processor is set to adapt based on the frequency of the incoming signal (Glista et al., 2016b). We have also tested several listeners who are audiometric candidates for frequency lowering. In these listeners, we see good ratings for frequency-compressed speech, perhaps because they are candidates for these types of processors (Glista et al., 2016b). We also see that fine tuning produces good sound quality and some early evidence that the adaptive feature of SoundRecover2 produces better sound quality at some settings. These studies are in progress, and further data will continue to inform our understanding of the impact of SoundRecover2 settings on sound quality. Regardless of the final outcome, it does appear that measurement of sound quality can be an effective way to understand the impact of this processor.

SoundRecover2 is still undergoing clinical and laboratory evaluations. We have more to learn, and learning everything we need to know about benefit, acceptability, vowel recognition, own voice production, and sound quality will take many studies over many years. Our early studies have mainly focused on developing clear fitting and fine tuning protocols so that clinical trials with SoundRecover2 can go forward with a strong basis in systematic fitting. We need protocols for fitting and fine tuning, and procedures for matching and comparing SoundRecover1 and 2 to create well-controlled studies. For these purposes, a consensus Best Practices verification protocol has been developed in collaboration with Phonak, Jace Wolfe, and Andrea Bohnert (Glista et al., 2016a). The stimuli and rationale behind this procedure is also described in a recent AudiologyOnline article as well (Glista, Hawkins, & Scollie, 2016). This protocol uses calibrated /s/ and /sh/ signals (downloadable from www.dslio.com) that were matched in level to real productions of these sounds in the ISTS signal (Holube, Fredelake, Vlaming, & Kollmeier, 2010). Clinicians who are accustomed to verifying with procedures previously described for frequency lowering (Glista & Scollie, 2009) might consider these newer procedures, which are more appropriate for use with adaptive procedures (Alexander, 2016).

Our fitting protocol starts with fine tuning the hearing aid to provide the broadest possible bandwidth with SoundRecover turned off. An example of this is shown in Figure 2. The top pane shows the hearing aid fine-tuned to achieve the closest possible match to the DSLv5 target. However, the hearing aid rolls off in the high frequencies, and the /s/ is not audible. We assess this by finding a region of the fitting called the Maximum Audible Output Frequency (MAOF; McCreery et al., 2013). In our protocol, we have adapted this concept to use an MAOF range, by considering the point at which the long-term average speech spectrum (LTASS) crosses threshold at the lower end of the range and the point at which the peaks of speech cross threshold at the upper end of the range (Figure 2). The MAOF range is used as a target region in which to evaluate /s/ audibility. If the upper shoulder of the calibrated /s/ test signal (i.e., the entire /s/ signal) falls within this MAOF range, we would conclude that frequency lowering signal processing is likely not necessary. In contrast, if the /s/ is only partially audible, or fully inaudible as shown in the top pane of Figure 2, we activate the SoundRecover1 or 2 processor. The final step is to fine-tune the strength of SoundRecover1 or 2 to find the weakest possible setting that places the upper shoulder of /s/ into the MAOF. The result of this fine-tuning is shown in the second pane of Figure 2.

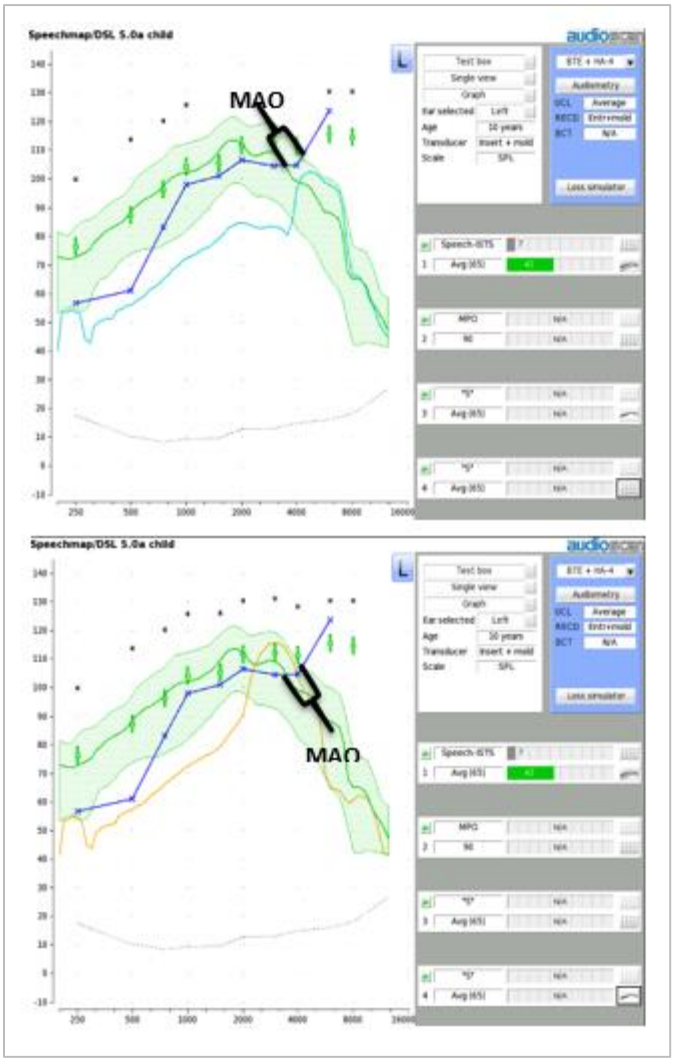

Figure 2. Example of the main steps of fitting and fine tuning a SoundRecover2 processor. Top pane: fitting with SoundRecover2 turned off to assess fit to targets and audibility of female /s/. Bottom pane: fitting with SoundRecover2 turned on and fined tuned, as measured for the same /s/ stimulus. Note that the aided ISTS stimulus is displayed with the processor turned off in both panes to assess the MAOF available without frequency lowering signal processing.

In this final fine-tuning step, we avoid using a stronger-than-necessary setting, creating a fitting that uses the weakest possible strength of SoundRecover, which produces an audible /s/ within the MAOF range. In clinical practice, this procedure is fastest with a continuously played (i.e., looped) /s/ while fine-tuning, to minimize the amount of clinical time added to the fitting process. This takes on the process of a "search"; the search process would reject the "too weak" and "too strong" settings. Figure 3 shows an example of the aided /s/, produced by settings that would be rejected as either too strong or too weak, in comparison to a selected and fine-tuned setting. In summary, we strive to strike a balance; in our experience and from our research data, we have learned that the weakest possible settings that ensure audibility of /s/ strike an effective balance between improving audibility and optimizing sound quality.

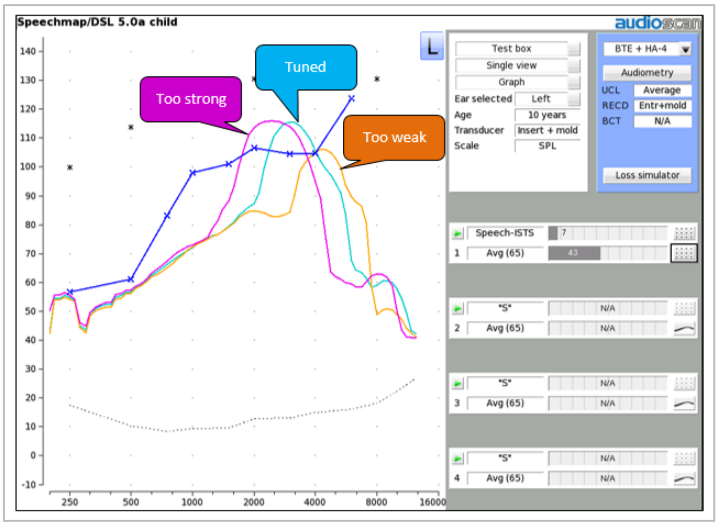

Figure 3. Example of the impact of choosing different strengths of the SoundRecover2 processor. These three sequential measurements of the /s/ stimulus have been done with SoundRecover2 enabled and set to varying strengths of processing using the hearing aid programming software. Within the fine-tuning process, the settings labelled as "Too Weak" and "Too Strong" would be rejected.

Our early experiences with attempting to apply this same finetuning protocol for SoundRecover2 have involved coming to consensus within our lab and with our collaborators to agree on a common fitting protocol (Glista et al., 2016a). We continue to use this protocol for setting the overall strength of SoundRecover2, and also to match the overall strength of SoundRecover1 and 2 in controlled studies. In our current protocol, we are routinely doing an ear-by-ear fitting by unlinking the two ears and adjusting the strength of the frequency compressors to optimize audibility in each ear. The control sliders (Figure 4) are both set up as a stronger/weaker setting and are hybrid slides that control more than one signal processing parameter at the same time (Rehmann et al., 2016). We adjust the "Audibility" slider first because it has a stronger overall effect on the frequency location and audibility of /s/. The "Clarity" slider is then adjusted. This mainly controls what the processor classifies as a low-frequency stimulus. If it is set too far toward the right, the SoundRecover2 processor might classify too many stimuli as low frequency, and the stronger setting will not be activated often enough. This can have the result of limiting /s/ audibility even though the processor is active. A careful search for settings that allow /s/ audibility when both sliders are activated is one step in ensuring appropriate settings that allow the processor to provide audibility of /s/.

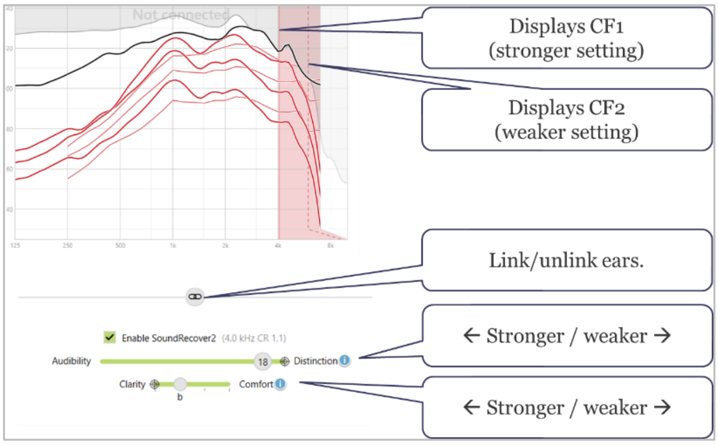

Figure 4. Software displays and controls that are relevant to SoundRecover2 fitting and fine tuning. The cutoff frequencies associated with the stronger and weaker states of the processor are shown, along with controls that link/unlink the two ears and those that adjust the strength of the processor.

Conclusion

This protocol is currently in use for research studies at three sites—Western University, Hearts for Hearing, and Mainz University. The question at hand is whether the protocol will be applied consistently. To date, 45 ears of participants enrolled in SoundRecover2 trials at these sites have received fittings, fine-tuning, and verification for both SoundRecover1 and 2. The nominal settings for both processors were logged at each site for further analysis. Descriptively, all three sites tuned both SoundRecover1 and SoundRecover2 processors to use stronger settings in the case of more severe hearing losses. Statistically, the main predictor of the cutoff frequencies after fine tuning was the degree of high frequency hearing loss in each ear, and the site was not a significant predictor[1]. This can indicate that following a systematic fine tuning protocol might promote consistency of fitting, allowing the processors to be fitted according to degree and configuration of hearing loss, and the best possible fit to targets, as primary factors. These projects are in progress and have been designed to evaluate the audibility impacts of these processors, but also to measure subjective outcomes such as preference and sound quality, in order to assess the non-audibility-focused aspects of SoundRecover2.

[1] Stepwise multiple regression was used to examine both site and high frequency pure tone average per ear as predictors of software settings of SoundRecover1 and 2. For SR1, high frequency hearing was correlated significantly ($p = .003$) with cutoff frequency settings although site of test was not ($p=.742$). For SR2, high frequency hearing was also correlated significantly with settings of the cutoff frequency 1 parameter ($p = .001$) although site of test was not ($p=.343$).

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Authors

Susan Scollie, Ph.D.
University of Western Ontario
London, Ontario, Canada

Danielle Glista, Ph.D.
University of Western Ontario
London, Ontario, Canada

Andrea Bohnert, Ph.D.
University of Mainz
Mainz, Germany

Jace Wolfe, Ph.D.
Hearts for Hearing
Oklahoma City, Oklahoma, United States

Editors

Anne Marie Tharpe, Ph.D.
Chair, Phonak Research Advisory Board
Professor and Chair
Department of Hearing & Speech Sciences
Vanderbilt University School of Medicine
Nashville, Tennessee, United States

Marlene Bagatto, Ph.D.
Research Associate and Adjunct Research Professor
National Centre for Audiology
Western University
London, Ontario, Canada