SONIC Spotlight

SmartMusic Pro

A new fitting rationale and program for hearing aids on the Extend platform

Are your patients satisfied with their hearing aids when listening to music? Since hearing aids are primarily designed to amplify speech, they can miss the mark when it comes to music.
To optimize the amplification of musical signals, Sonic introduces **SmartMusic Pro**. Continue reading to learn about this innovative fitting rationale and new program in EXPRESS*fit*® Pro.

Health benefits of music

Listening to music is a universally enjoyed activity no matter one's age or background. But did you know it provides many health-related benefits? If you think that it might be able to lower stress, reduce anxiety, elevate one's mood, and make people happier, then you are on the right path. Research has shown that listening to music indeed has physical effects. It can reduce depression and help in pain management (Siedliecki and Good, 2006), lower the level of stress-related hormones like cortisol (Linnemann et al., 2015), and ease pain post-operatively (Liu and Petrini, 2015). Music listening has been linked to a beneficial effect on blood pressure, heart rate, and respiratory rate (Bradt and Dileo, 2009). And as reported in the scholarly review titled "Mozart, Medicine and Music" from the journal *Medical Principles and Practice*, listening to pleasurable music has been shown to improve cognitive performance in areas such as attention, processing information, spatial reasoning, and recognition memory (Pauwels et al., 2014). Clearly, powerful health benefits abound from this simple, unassuming, and easily accessible activity.

Music and hearing health

In relation to hearing healthcare, the benefits listed above can serve to strengthen and support a person's physical, emotional, and cognitive health, but only if they are "tuning in." That is why the topic of music during a hearing aid evaluation is more than just learning about your patient's hobbies and interests. It offers a gateway to a more meaningful discussion to understand their overall attitude, lifestyle, and listening needs beyond communication for speech in quiet or speech in noise. So not only is it important to gauge your patients' current interests for and engagement in music, but it is also equally important to find out if they have recently become disinterested or disengaged from music-related activities to any extent due to their hearing loss – or their hearing aids.

What's the scope?

The World Health Organization's (WHO) long-anticipated World Report on Hearing (WRH) gives a broad perspective on the impact of hearing health globally, and the outlook is alarming. The report from March 2021 states that hearing loss currently affects more than 1.5 billion people worldwide. Of this population, over 400 million have moderate or higher levels of hearing loss requiring audiological care – and that figure will nearly double by 2050. By that time, the estimated numbers will climb to 2.5 billion with hearing loss, and over 700 million needing care. Therefore, in the next thirty years, approximately one in four people will be living with some degree of hearing loss. The scope of hearing loss worldwide seems distressing, but there is good news. **The WRH states that innovative, cost-effective technological and clinical solutions via a professional can improve the lives of most individuals with hearing loss** (WHO, 2021).

The crossroads of hearing loss, music, and hearing aids

Considering this information, hearing health and music becomes a worthy topic of discussion for many patients who enter your practice seeking care. It may be especially worthwhile to counsel patients who present with mild to moderate losses, since only 15% to 30% of adults with these levels of hearing loss obtain hearing aids (Chien and Lin, 2012; Bisgaard and Ruf, 2017) and untreated hearing loss has serious effects on a person's overall health and well-being. Besides the reduced ability to hear speech, neglecting hearing loss can lead to depression (Cosh et al., 2019) and impact cognitive function (Lin et al., 2013), whereas treatment with hearing aids can provide many benefits to ameliorate those negative impacts (Amieva and Ouvrard, 2020).

Music perception with hearing loss

Persons with hearing loss may not realize that listening to music with their residual, unaided hearing can cause them to miss out on the nuanced details of sound. Aspects such as loudness, pitch, melody, harmony, rhythm, tonal quality, and lyrics become more difficult to perceive due to distortions caused by a sensorineural hearing loss – and the difficulties grow as the severity of the loss increases from mild to profound (Gfeller and Knutson, 2003). It's easy to conclude that these factors can contribute to a loss of interest or reduced engagement in music over time. Unfortunately, simply turning up the volume on the music player will not resolve all issues with reduced frequency ranges, timbre, clarity, or comfort. Needless to say, it may disturb others nearby!

Music perception with hearing aids

Because hearing loss can change the way listeners hear their favorite songs, hearing aids fitted by trained hearing care professionals are a viable technical and

clinical solution to improve the audibility of sound – which satisfies the WRH requirement stated earlier. Listening to music with hearing aids has been found to be more pleasurable but is not a perfect solution (Feldmann and Kumpf, 1988; Leek and Tufts, 2008). Unfortunately, even hearing aids properly fitted for speech can fail to deliver the essence of songs (e.g., melody, lyrics, sound quality) satisfactorily. This goes beyond the fact that hearing aids are designed to amplify a narrower range of speech frequencies (250 Hz to 8000 Hz) compared to the greater frequency range for numerous instruments (20 Hz to 18,000 Hz) as depicted in Figure 1. The reality is that music has different spectral and loudness characteristics than speech, as summarized in Table 1.

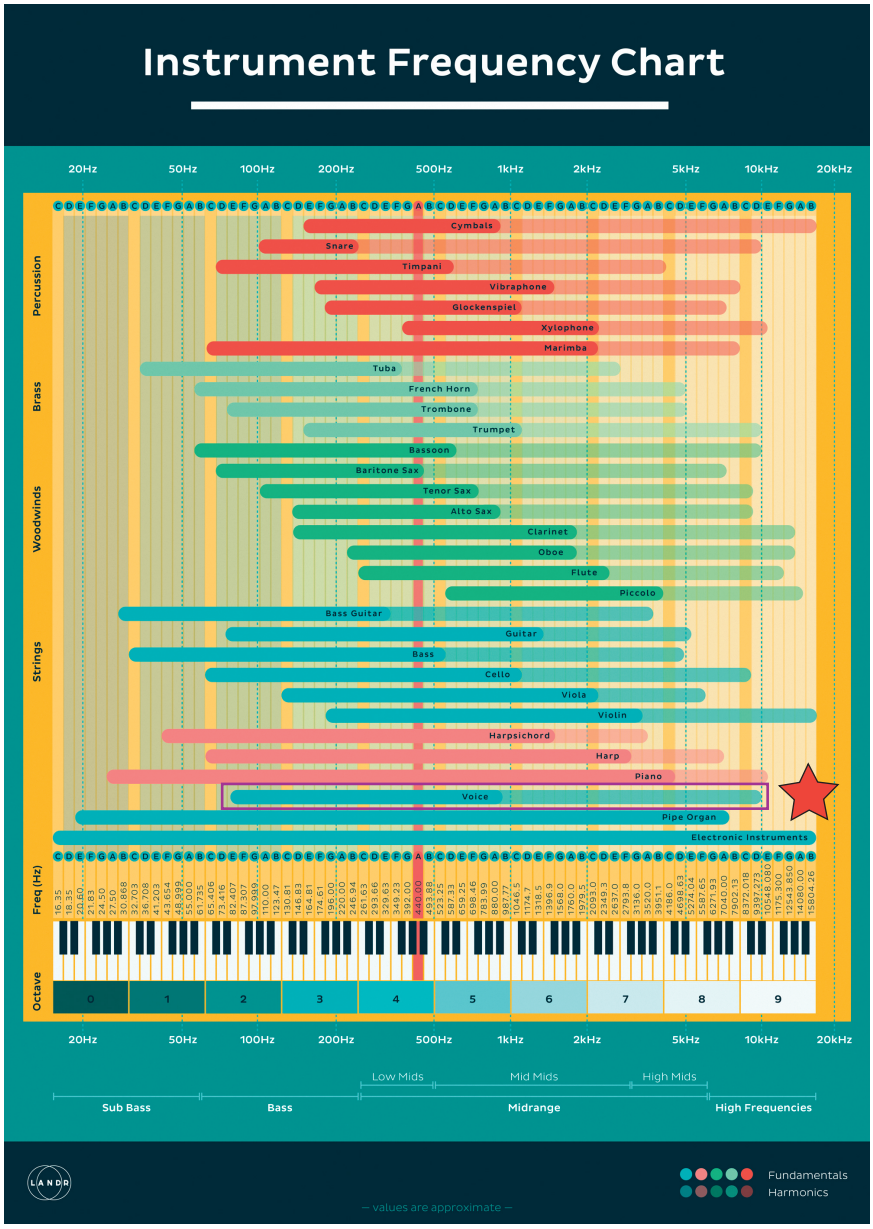


Figure 1: Approximate frequency ranges for voices in comparison to musical instruments; Image reprinted with permission from LANDR (2016).

Differences	Speech	Music
Frequency	Smaller differences in the overall spectral range and output from the human vocal tract	Larger differences in the overall spectral range and output from various instruments
Perceptual	Fewer variations between low-frequency vowels and high-frequency consonants	Greater variations between fundamental frequencies and corresponding harmonics
Loudness	Normal growth of volume from soft to loud	Increasing growth of volume from loudness summation
Crest factor	Smaller difference in between the peaks in a spectrum and the average value decibels (~12 dB)	Greater difference in decibels between the peaks in a spectrum and the average value (~18-20 dB)
Intensity	Smaller intensity ranges from soft to loud levels	Larger intensity ranges from soft to loud levels

Table 1: Differences between speech and music (Chasin, 2003).

The differences described in Table 1 can be adversely affected when amplified by a hearing aid due to several factors. Per Chasin and Russo (2004), the most notable causes are due to 1) nonlinear compression characteristics (compression ratio, compression threshold) implemented in a fitting rationale designed for speech signals; and 2) an input dynamic range that is too low, which limits the louder peaks of music before signal processing occurs, causing distortion and affecting the overall sound quality. Typically, the limit is set at 95 dB which is suitable for loud speech but too low for the peaks of live music.

The researchers note that other digital signal processing (DSP) parameters such as feedback cancellation algorithms, frequency lowering, and number of channels may impact the sound quality. In addition, features such as noise reduction and directionality may attenuate music signals that should not be reduced. The combination of these elements can contribute to muffled lyrics, inadequate and/or uncomfortable volume dynamics, or music that sounds shrill, harsh, dull, or empty.

Sonic hearing aids and music

Although hearing aids are primarily designed to amplify speech, many DSP settings inherently complement music signals as well. For example, Sonic hearing aids incorporate **a broad frequency response** which helps contribute to the perceived naturalness of music (Moore and Tan, 2003; Killion, 2009). A frequency response up to 10 kHz can convey many musical sounds robustly, considering an extended range piano with 108 keys spans from 16 Hz to 7902 Hz, and all open strings on a violin, viola, cello, bass, and ukulele fall within that broad range as well (Suits, 1998).

In addition, the latest Sonic hearing aids include a joint-compression system. This wide dynamic range compression architecture uses two level-estimation systems at the same time, depending on the modulation characteristics of the signal. For signals with a higher modulation rate (e.g., speech, music), the compressor uses **broadband level estimation** to rapidly estimate the input signal. This strategy preserves the contrast and maintains the level differences in the original signal, resulting in natural amplification of speech or musical signals (Schaub, 2010). For signals with a lower modulation rate, the compressor uses **24-band level estimation** which limits the amplification of narrowband or broadband noise with high-resolution multichannel compression. Note that certain genres of music (e.g., rock) may contain signal components with a modulation rate much like noise. In those cases, it is likely that a mix of both estimation systems may occur.

Concerning compression speed, Sonic hearing aids measure the incoming wideband signal and **adjust the gain in real time** to apply the precise amount of amplification needed for the hearing loss. The compression strategy quickly follows the level of the signal to preserve the relationships between different levels of the musical signal from soft to moderate to loud. The result is that music is amplified to an appropriate range of levels at the appropriate time for the patient as defined by the EXPRESS*fit* Pro fitting software and any fine-tuning adjustments made during the fitting.

Looking back: Music programs in SoundDNA products

Up to this point for existing products, Sonic has provided two program options that can be added to one of four memory slots in the hearing aids to optimize the amplification of music: the **Music** program for listening to recorded music and the **SmartMusic** program for listening to live concerts (Figure 2). The programs can be accessed via push button, remote control, or app as needed. Although both programs offer gain offsets and feature settings for musical environments compared to the Universal program, their underlying compression strategy is based on a fitting rationale for speech.

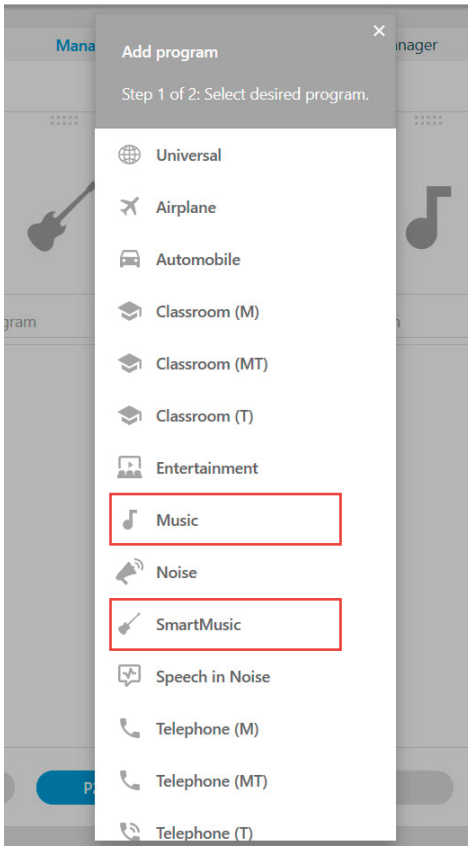


Figure 2: Music programs in SoundDNA products.

The SmartMusic program takes advantage of an increased input dynamic range in product technology levels 100 and 80. The input dynamic range is configured to adaptively expand to 113 dB SPL to accommodate louder signals and prevent distortion. This is desirable because the industry-standard upper limit of the input range – typically set at 95 dB for speech signals – is too low for the louder music peaks and has the potential to compress the input signal before processing. While compression is applied for soft, moderate, and loud inputs according to the selected fitting rationale, the program's gain settings include an adjustment to address loudness summation and listening comfort for live music signals. Microphone selections include either omni or a fixed hypercardioid polar setting, and adaptive noise reduction is not available.

The Music program optimizes the gain and automatic features for listening to the stereo at home or indoors. Therefore, it does not include an adjustment for loudness summation of live music. All automatic features are turned off and the microphone is set to omni-directional. Compression is applied for soft, moderate, and loud inputs according to the selected fitting rationale, and an increased input dynamic range is available in technology levels 100 and 80.

Looking forward: SmartMusic Pro in Extend products

Products on the Extend platform can now benefit from an advanced approach to optimize music. SmartMusic Pro is a new listening program comprised of four main elements to improve the amplification of music compared to previously offered programs.

1. Music fitting rationale for sound clarity

The most notable development is a new fitting rationale designed specifically for music, which forms the basis for the amplification in SmartMusic Pro. This contrasts with the two previous music programs which use the selected speech fitting rationales (e.g., NAL-NL2, DSL v5.0, Best Fit Fast) offered in EXPRESS*fit* Pro as the basis for amplification. Using speech rationales may limit the music listening experience in some circumstances because 1) the threshold level where compression starts – although suitable for speech – creates a smaller dynamic range than what is suitable for the intensity range of music; and 2) speech rationales typically compress the signal at all input levels, which has drawbacks for music clarity.

The overall goals of introducing a new fitting rationale in SmartMusic Pro are to restore the audibility of soft musical inputs, to prevent distortion and discomfort for loud inputs, and to keep moderate input levels transparent (clear, detailed) and comfortable. We can achieve this by applying compression thresholds and ratios in a different way to better address the characteristics of music.

Compression threshold (CT): Compared to a linear hearing aid that applies the same amount of gain regardless of the level of the input signal (a 1:1 relationship), nonlinear compression applies different amounts of gain to soft, moderate, and loud sounds. The point at which the level of the output is lower than if no compression had been applied is the compression threshold – also known as a kneepoint. In the new music fitting rationale, compression kneepoints are set using a special test signal whose spectral content from 20 Hz to 20,000 Hz is representative of music (defined in the standard IEC 60268-1). The broadband kneepoint levels used in SmartMusic Pro are 40 dB SPL for soft, 65 dB SPL for moderate, 90 dB SPL for loud, and 105 dB SPL for very loud input. For speech rationales, they are generally 50-, 65-, 80-, and 90 dB SPL, respectively. Basing the kneepoints on a music spectrum instead of a speech spectrum addresses factors important for music including audibility, sound quality, and a more suitable dynamic range.

Compression ratio (CR): To amplify music and keep it clear and detailed at comfortable loudness levels, a nonlinear fitting rationale can be designed to apply gain with a 1:1 CR relationship in between certain input level ranges. Such an implementation helps to preserve the transparency of the original signal to the greatest extent possible and provides a more linear sound to improve the perceived sound quality of music (Greasley et al., 2019). To accomplish this goal, the new rationale in SmartMusic Pro provides a linear compression window between moderate and loud input levels, which is a range where music listening levels commonly occur. The linear region with no compression on the input levels between moderate and loud is ideal for listening to music at typical volume levels and keeping the transparency of the signal intact during amplification. Still, compression (limited to under 3.0 CR) will occur between soft and moderate input levels to provide appropriate audibility for the hearing loss, and a slight amount of compression (limited to under 2.0 CR) will also occur for louder inputs between the loud and very loud kneepoints. This strategy increases the dynamic range, which is limited by the Maximum Power Output (MPO).

Figure 3 shows the insertion gain for a moderate sloping loss with the previous SmartMusic program using NAL-NL2 compared to the new SmartMusic Pro rationale. Notice the differences especially between the middle and bottom curves, which correspond to moderate and loud inputs indicated by the green and purple arrows respectively. Applying compression in this manner for SmartMusic Pro contrasts with traditional speech rationales that apply compression at all levels. It also decreases the risk of artifacts or distortion from compression that could diminish the sound quality of music. For the user, the settings optimize the compression of music at soft, moderate, and loud input levels across frequencies to help improve the transparency, or clarity of sound.

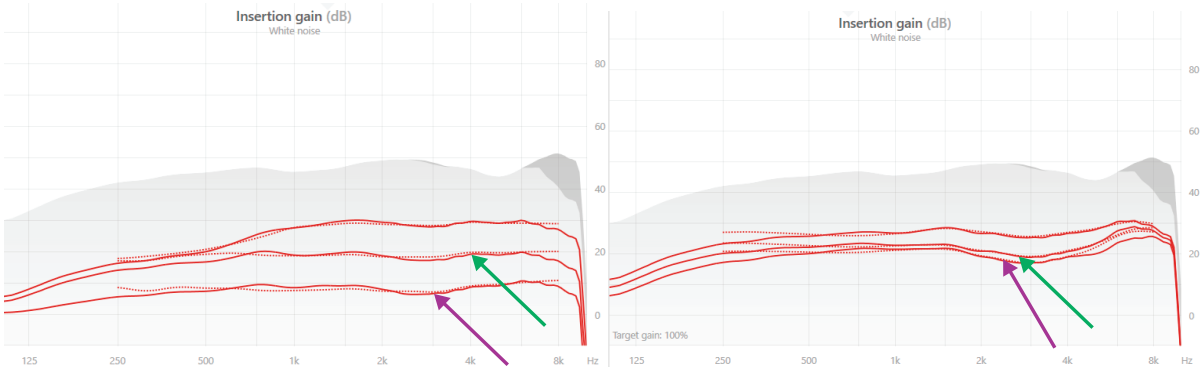


Figure 3: Insertion gain for SmartMusic (L) vs. SmartMusic Pro (R) for a moderate sloping sensorineural hearing loss (N4 Standard Audiogram) and power domes (Bisgaard et al., 2010).

2. Gain equalization and loudness matching for sound balance

A hearing aid program designed for verbal communication should cater to the frequency range of speech and provide more amplification in that region. A program designed for musical compositions, however, should cater to the frequency range of music and shape the gain differently. SmartMusic Pro does just that. In essence, the program calculates more gain across the entire frequency range of the hearing instrument – but in a strategic way to satisfy characteristics that belong to a more robust music spectrum.

To start, its formula calculates the required gain depending on the hearing loss and the rationale selected in the Universal program (e.g., NAL-NL2, DSL v5.0, Best Fit Fast). Diverging from the Universal program gain settings, SmartMusic Pro then defines more low- and high-frequency amplification compared to the mid-frequency region most important for speech. In addition, it raises the gain curves slightly toward higher frequencies as a function of the input level. Finally, its overall loudness is matched to the overall loudness of the Universal program. So, although SmartMusic Pro will have more bass and treble for increased audibility, the frequency response is equalized across the bandwidth and the loudness matching allows the sound to remain relatively comparable between both programs. These paired actions balance out the overall sound level from bass-to-treble across the bandwidth, helping to preserve the natural sound of the original signal (Figure 4).

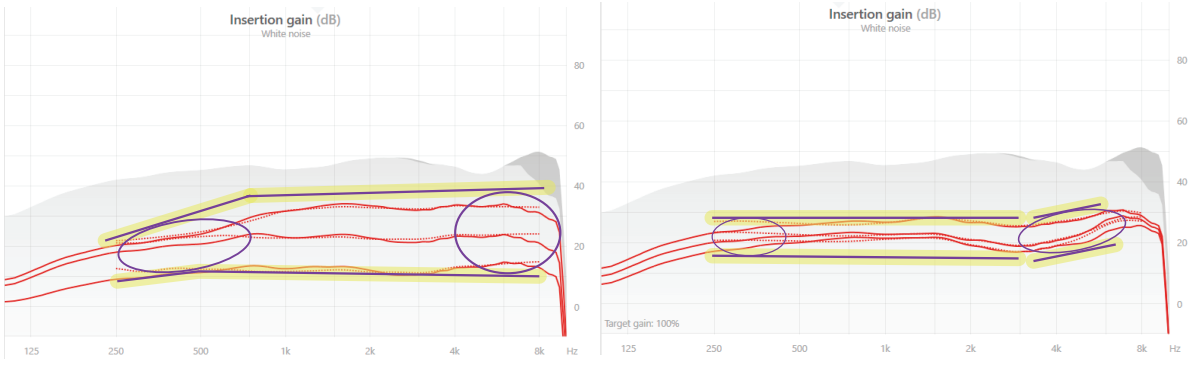


Figure 4: Gain equalization and loudness shaping for the Universal program with NAL-NL2 (L) vs. SmartMusic Pro (R) for a moderate sloping sensorineural loss (N4 Standard Audiogram) and power domes.

3. Extended input dynamic range to prevent distortion

The crest factor is an indicator of peak intensities in a waveform. Music has a larger crest factor, i.e., the difference in decibels between the peaks in a spectrum and the average (RMS) value, compared to speech. Therefore, an extended input dynamic range supports the peaks of a greater crest factor, allowing the resulting dynamic range of the output to be closer to the original signal. This feature, found previously in SoundDNA, carries over to SmartMusic Pro in technology levels 100 and 80 as well. To reiterate, the upper limit of this range adaptively expands to 113 dB SPL to accommodate louder signals and prevent distortion. The typical upper limit – set at 95 dB for speech signals – is not ideal for the louder music peaks and has the potential to compress the input signal before processing. As such, this setting helps to keep loud musical signals clear and limit artifacts for loud inputs.

4. One dedicated program with preset feature settings for ease of use

Whereas the SoundDNA platform offers two music programs, the Extend platform offers one. SmartMusic Pro is suitable for music that is recorded, live, and streamed. It automatically adapts the hearing aid response for inputs originating from the microphone (e.g., via a loudspeaker) vs. streaming from a Bluetooth® device for a realistic sound experience depending on the source. Considering that two programs may be inconvenient for the user, especially when there is a limit of four program slots available, offering one single program can improve usability – and allow a memory slot available for another listening environment if needed (Figure 5).

Feature settings for this program are streamlined to optimize the sound quality of music: The microphone mode is set to an omni-directional mode, Radian and Impulse Noise Reduction settings are turned off, and the feedback manager is set to Medium by default. Like other listening programs, SmartMusic Pro can be adjusted using up to 24 handles on the Fine-Tuning screen (product dependent), keeping in mind that compression ratios for soft-to-moderate and loud-to-very-loud inputs are limited at a certain point and should not be exceeded (Figure 6).

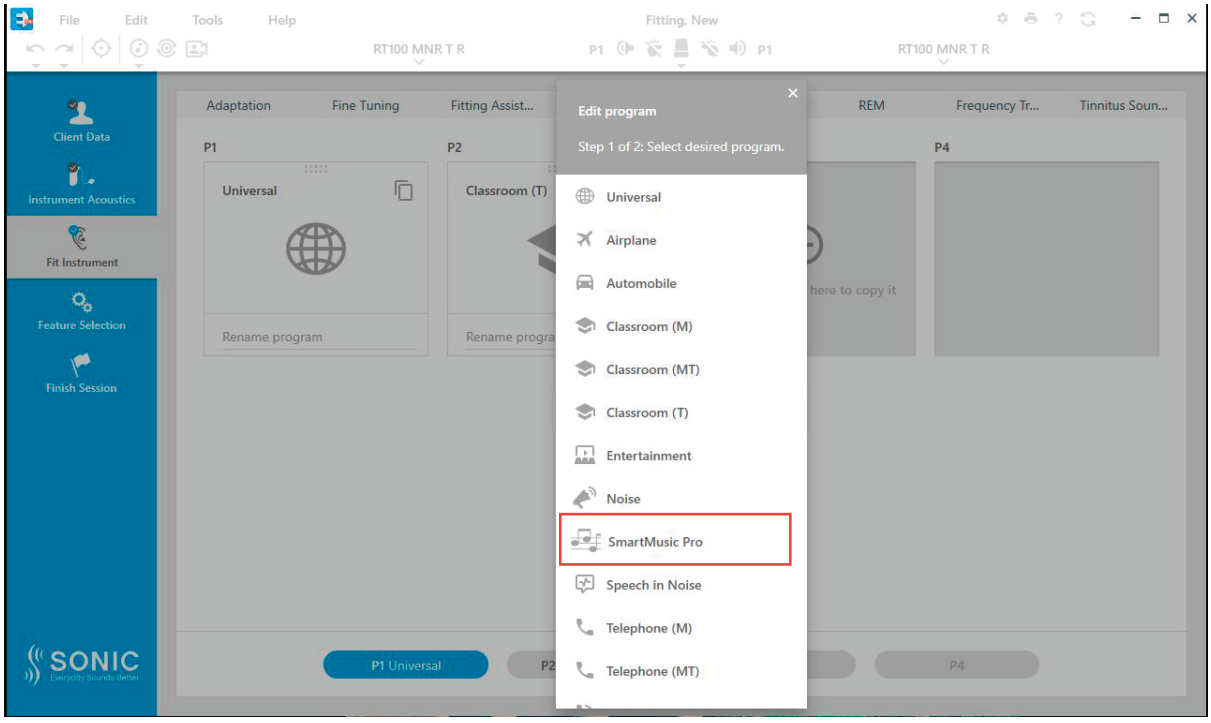
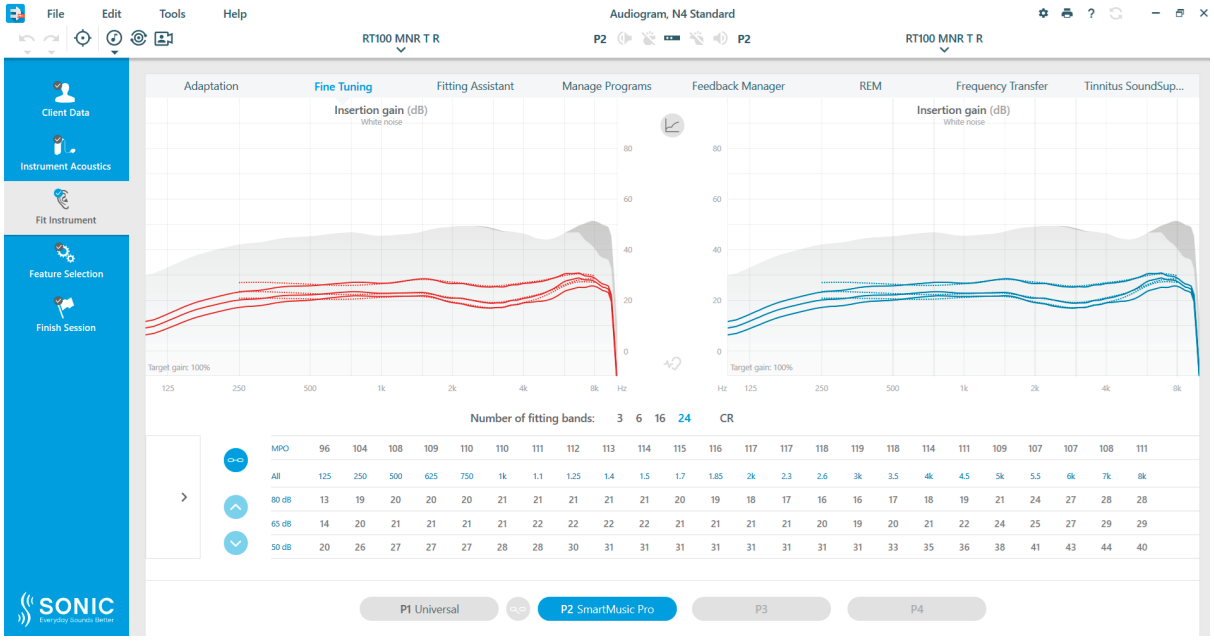


Figure 5: SmartMusic Pro Program selection in EXPRESS*fit* Pro.



Who can benefit?

SmartMusic Pro is suitable for both new and experienced hearing aid users. For example, the program can be introduced during a trial period with first-time users. If possible, encourage them to practice listening to music in a quiet setting initially – and to get comfortable with listening to recorded music from a stereo or streaming music from a smartphone – before listening to live music in a group or concert setting.

Experienced users who may be accustomed to using their Universal, Music, or SmartMusic programs depending on the environment should be counseled to activate SmartMusic Pro for all music-listening activities. And for users previously fit with hearing aids on the Extend platform (e.g., Radiant miniRITE T R), SmartMusic Pro can be added at their next fitting appointment, offering a new listening environment in one of four memories in place of their previous program(s) for music (requires EXPRESS*fit* Pro 2021.2 and later).

Summary

Sonic is committed to providing easy-to-use technologies that offer innovative solutions in various listening environments. The SmartMusic Pro program automatically works to:

- *Provide increased linearity at comfortable loudness levels, for clarity of musical signals*
- *Equalize the gain at low and high frequencies, to support bass-to-treble sound balance*
- *Increase the upper input limit for loud sounds, to prevent distortion**
- *Simplify settings into one program for recorded, streamed, or live music, for ease of use*

SmartMusic Pro optimizes sound quality and usability for music listening activities, so your patients can enjoy clear, balanced sound with their hearing aids. With Sonic and SmartMusic Pro, Everyday Sounds Better.

To learn more, please contact your local Sonic provider.

*Technology levels 100 and 80 only

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EXTEND Platform

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