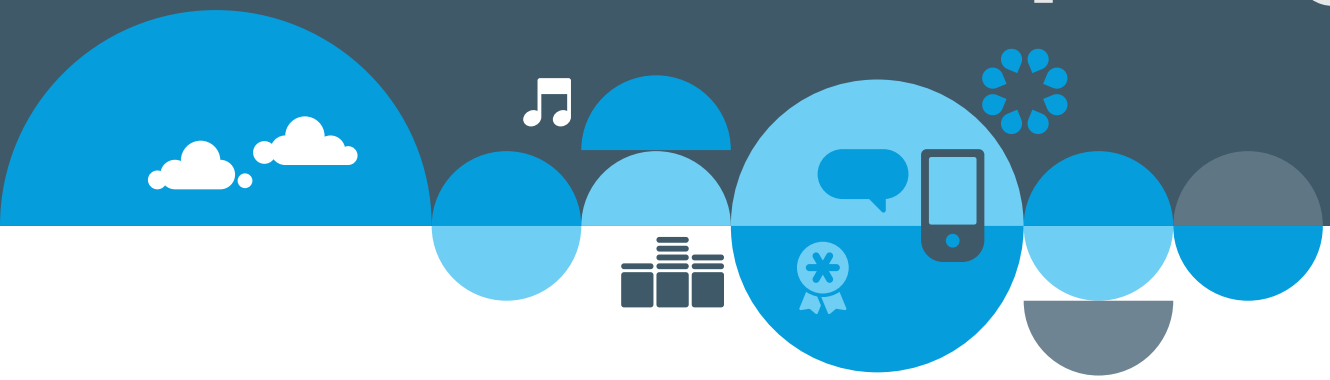
Sonic Spotlight



Reverb Reduction – Reduce the lingering ring that affects sound quality

Reverberation of sound exists in many places. It occurs not only in larger auditoriums and halls, but also in smaller spaces, like offices and kitchens. Reverberation happens when sound reflections multiply due to hard surfaces in the environment. The reflections impact sound quality and can be especially bothersome to hearing aid users. Speech, music, and other signals may lose their intended clarity and sound smeared. To counteract these unwanted effects of reverberation, patients may be instructed to move closer to the speaker, use an assistive listening device, or restyle the room with soft furnishings – helpful strategies to hear better, but not always possible to do. Now, Sonic offers a simple solution to control reverberation in any setting. Read on to see how the new Reverb Reduction algorithm stops excessive reverberation in its tracks – and returns the clarity to amplified sound – all with the press of a button.

What is reverberation?

We have all experienced reverberation at one time or another – think of the resonating acoustics in a gymnasium or auditorium. But what is it, exactly? Reverberation is the continuation of sound after the source has stopped. More simply, it is the prolongation of sound. By nature, sounds will reverberate in any environment with hard or reflective surfaces. The hard surfaces create reflections of sound that accumulate and blend together. The combined reflections smear the original signal and cause a lingering 'ring', until they eventually decay over time. It is easy to hear the effect when the original sound stops and the reflections carry on. Reverberation of sound is natural and unavoidable. Unless a sound is produced in a free field where no reflections can occur, reverberation will accompany that sound.

Reverberation vs. echo

Reverberation and echo are terms that are often used interchangeably, but are not exactly the same thing. Arising from the same sound source, they will occur at different points along a continuum of time. For an echo to be produced, it must travel a distance of 55 feet (17 m) from the reflective surface (e.g., a canyon wall), before returning the same distance again to be heard. Consequently, an echo is a reflection of sound that arrives back to the listener more slowly, delayed by some time after the direct sound. Echoes occur generally beyond 100 milliseconds following the initial onset of sound.[1] The brain perceives the time-delayed sound of an echo as a distinct, individual signal. In contrast, the brain perceives reverberation in combination with the original signal as one single sound. These reflections, characteristic of reverberation, occur faster because they travel a shorter distance, arriving back at the ear more rapidly in under 100 ms. A signal without reflections, as produced in a free field, is described as 'dry', and tends to sound unnatural. Small amounts of reverberation actually create a more natural sound and can be helpful when listening – they give a sense of space to the sounds by providing perceptual awareness about the characteristics and size of the room. However, excessive amounts of reverberation will interfere with speech intelligibility, even for people with normal hearing. Table 1 shows a visual analogy of the differences in signal characteristics between a dry signal, an echo, and varying amounts of reverberation.

A "dry" signal without reverb.	SONIC Everyday Sounds Better
A signal with long echo. The different reflections can be distinguished as individual signals.	SONIC Everyday Sounds Better
A signal with too much reverb. All reflections add up to one "smeared" sound signal. Intelligibility is significantly reduced.	SONIC Everyday Sounds Better
A signal with "just enough" reverb. Intelligibility is maintained and the reverb adds a sense of space to the signal.	SONIC Everyday Sounds Better

Table 1: Visual analogy of signal characteristics

Reverberation components

Direct vs. indirect sound - One factor that influences listening in enclosed spaces is the proximity of the listener to the sound source. When a signal of interest (e.g., speech or music) reaches a listener's ears directly from the source, it is called direct sound and is the easiest – loudest and clearest – to hear. When the listener hears a part of that signal a short time later, it is called indirect sound. Indirect sound can be broken down into two components: early reflections and late reflections. Early reflections are softer, and arrive between 10 – 100 ms later than the direct sound. They commonly improve speech intelligibility and promote a natural sound quality. Late reflections occur beyond 100 ms of the direct sound and often negatively affect speech intelligibility. The ratio of early versus late reflections depends on the size and characteristics of the room, and on the proximity of the listener to the sound source.[2] Chances are, if a person is listening in a small room, the direct sound will predominate, making listening easier. However, if one is listening in a large reverberant hall, the direct sound may not reach the listener's ears at all. Rather, the indirect sound will predominate – which is softer and consists of only reflections – and will increase the likelihood of poorer sound quality and speech perception (Figure 1).

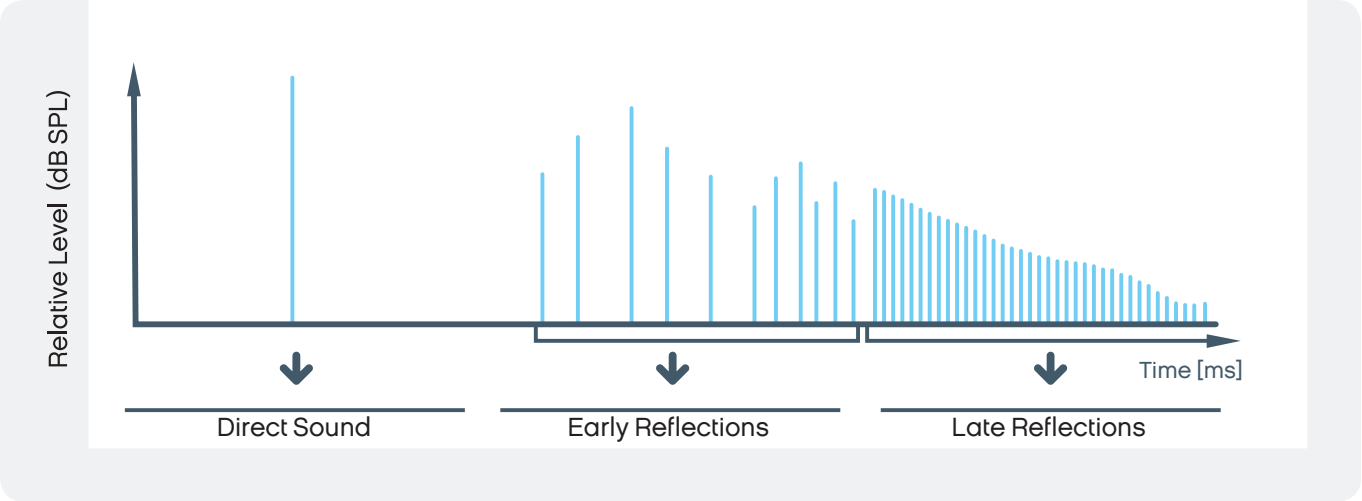


Figure 1: Components of reverberation[3]

Room acoustics - Another factor that influences listening in enclosed spaces is the room acoustics. One description of room acoustics is the reverberation time. Reverberation time (RT) is the metric that establishes how reverberant a particular room is. It is defined as the time required for a sound in a room to decrease by 60 decibels after the original source stops generating sound.[4] The standard designation for reverberation time is 'RT60' and is generally expressed in seconds or fractions of a second.

Two properties will affect RT: the amount of reflective or absorptive surfaces within the space, and the size of the space. Absorptive surfaces (e.g., carpets, soft furniture, curtains etc.) will absorb sound and prevent it from reflecting back into the environment, promoting a short RT. Reflective surfaces (e.g., tiled flooring, walls, high ceilings etc.) will do the opposite – reflect the sound and lengthen the RT. Regarding room size, smaller spaces will typically have a shorter RT, and larger spaces will have a longer RT, as shown in Figure 2. Generally, larger spaces need additional absorptive surfaces to reduce the RT, compared to a smaller space.
Speech sounds best in environments with a low RT (0.8 – 1.1 seconds), music sounds better with a higher RT (1.2 – 2.0 + seconds). Using this knowledge, theaters and concert halls often install sound systems to control or enhance the acoustic environment for the condition.

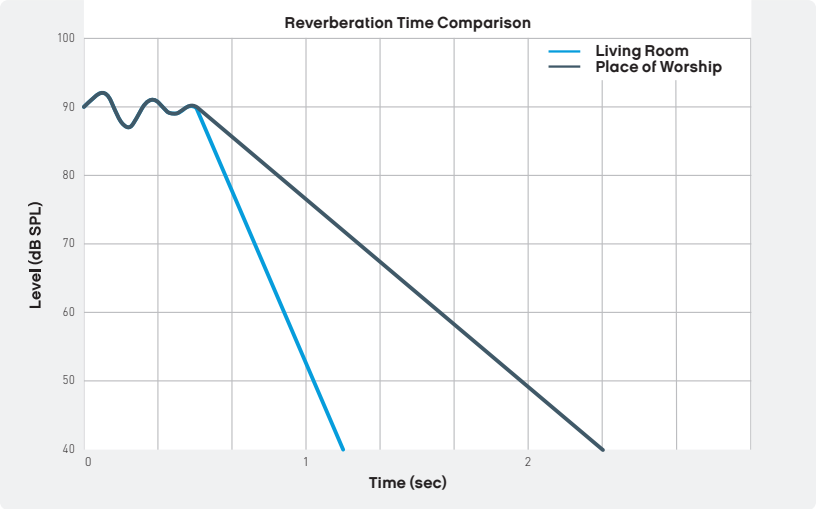


Figure 2: Reverberation Time (RT) in two typical settings. Reverberant signals will have a shorter RT in a living room (blue line) and longer RT in a place of worship (black line).[5]

Effect of reverberation on speech intelligibility

Reverberation has a negative impact on speech perception and listening comfort.[6] Speech becomes difficult to understand in reverberant conditions, especially for those with hearing impairment.[7] Reverberation can eliminate, mask, or distort segments of the speech signal that impart intelligibility: waveform envelopes smooth; formant transitions smear; and low frequency energy masks high frequencies.[8] This deterioration of the speech signal becomes apparent when looking at speech waveforms both with and without reverberation. Figure 3a shows a dry signal of a sentence; Figure 3b shows the identical speech signal, but in highly reverberant conditions. Compared to the dry signal, the speech waveform containing reverberation shows a smoothed envelope. The reverberant energy of intense low-frequency sounds masks the less intense consonants, causing speech to sound smeared.

Figure 3a: Dry signal without reverberation

Figure 3b: Signal with reverberation

Effect of reverberation on hearing aids

Studies from previous decades show that reverberation affects listening performance and hearing aid benefit.[9, 10] Reverberation can be classified as a type of noise – an unwanted signal that interferes with a desired signal, i.e. speech.[11] As such, it can be regarded as affecting the signal-to-noise ratio of a listening environment. Persons with hearing impairment rely on a higher signal-to-noise ratio for speech intelligibility, and are at a disadvantage in reverberant conditions: speech intelligibility, sound quality and listening comfort become compromised with aided listening. For example, Hawkins and Yacullo (1984) found that directional microphones are less effective in separating speech from noise under reverberant conditions.[12] Later, Ricketts (2000) similarly found that both reverberation and different configurations of competing noise sources significantly affect directional benefit and listening performance – concluding that an inverse relationship exists with RT and directional benefit/performance.[13] In another study examining distance and reverberation, Ricketts and Hornsby (2003) found that the directional benefit for the listener decreases with increasing distance from the speaker in moderate (RT60=0.9 sec) reverberant conditions.[14] Seldom does reverberation occur in isolation of other signal-degrading elements in a listening environment. But whether or not reverberation exists alone, in combination with diffuse/competing noise, or with increasing speaker-to-listener distance, it puts aided listeners at a disadvantage for understanding speech, even with directional microphones purposefully designed to help in noise.

Reducing reverberation

The Reverb Reduction algorithm from Sonic is a reduction system; therefore it will reduce - not cancel - reverberation. Developing a system to effectively reduce reverberation requires multiple design considerations. The following describes how it works.

Locates reverberation

Reverberation is frequency dependent. Therefore the Reverb Reduction algorithm operates in four different independent frequency bands to find its location. This method targets frequency ranges most likely to contribute to reverberation – commonly the lower frequencies. The benefit is that it helps to preserve speech in the higher frequency bands in such cases. The cut-off frequencies between bands are 625 Hz, 1526 Hz, and 6250 Hz (Figure 4).

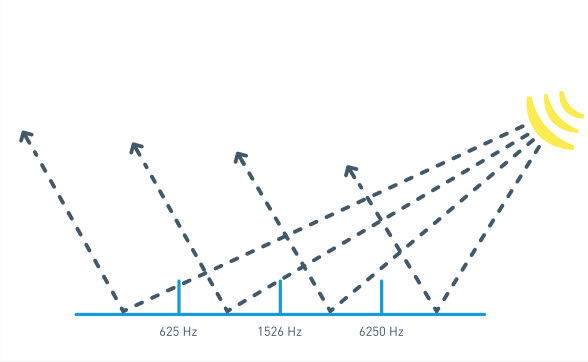


Figure 4: Reverb Reduction frequency bands

Identifies reverberation level

In each band, the algorithm identifies the level of reverberation in the signal. The manner in which sound decays makes reverberation easy to distinguish from a speech signal. Whereas speech loses intensity with uneven variability over time, reverberant sounds decay at a constant, exponential rate over time (Figure 5).

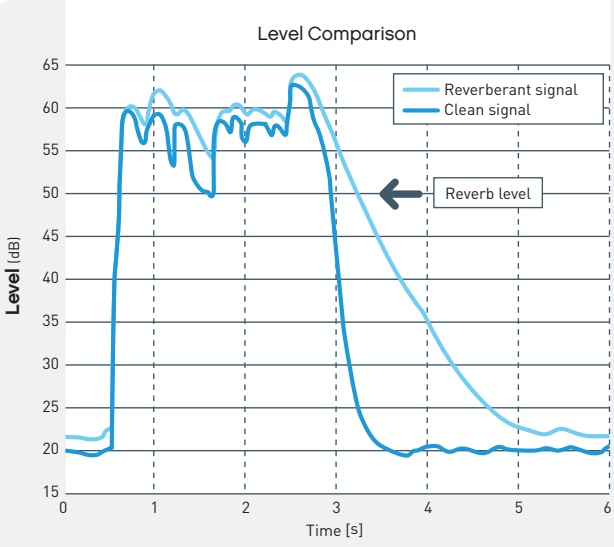


Figure 5: The Reverb Reduction algorithm identifies the level of reverberation in an input signal

Reduces signal level

Once reverberation is identified and its level is determined, the algorithm applies attenuation. It reduces most, but not all, of the reverberant signal (Figure 6). Too much – or too little – reduction may negatively affect sound quality. From the algorithm's established limits, the fitting software provides a fine-tuning control to adjust the appropriate amount of attenuation for the individual needs of the patient (described in the next section).

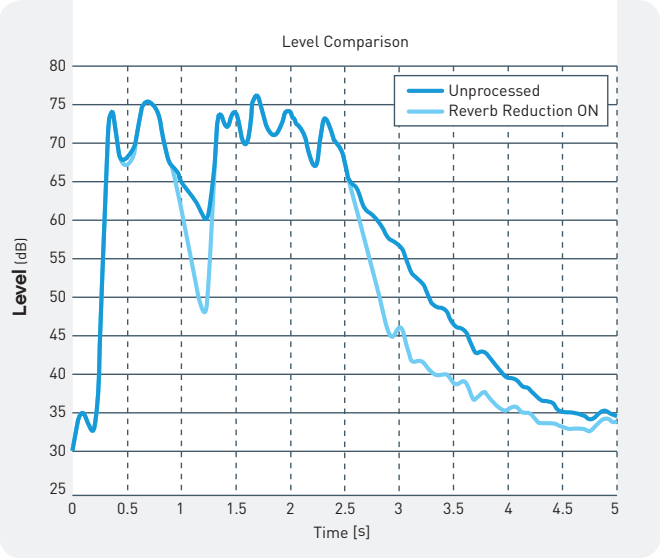


Figure 6: Level comparison between an unprocessed reverberant signal (dark blue line) and the same signal after Reverb Reduction is applied (light blue line)

Preserves speech

Reverb Reduction most effectively reduces reverberation in a range from 1 to 4 sec RT60 (from a typical classroom to gymnasium setting). It reduces only late reflections, and only during speech pauses, in order to preserve the speech components in the original signal (Figure 7a, b).

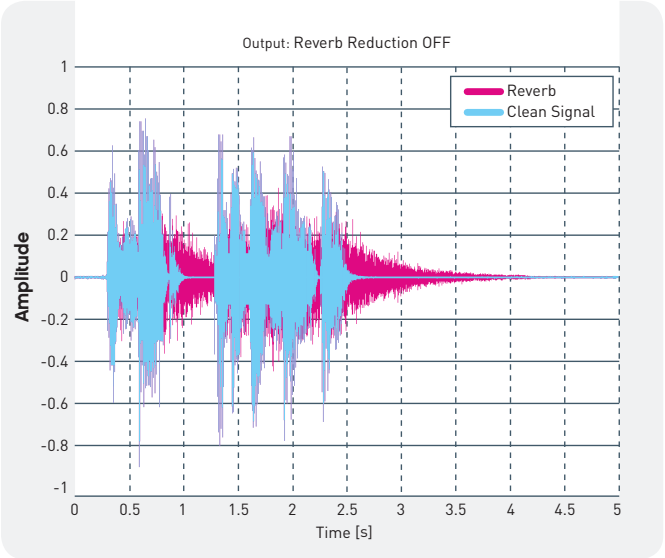


Figure 7a: A clean speech signal (blue) with its associated reverberation (pink)

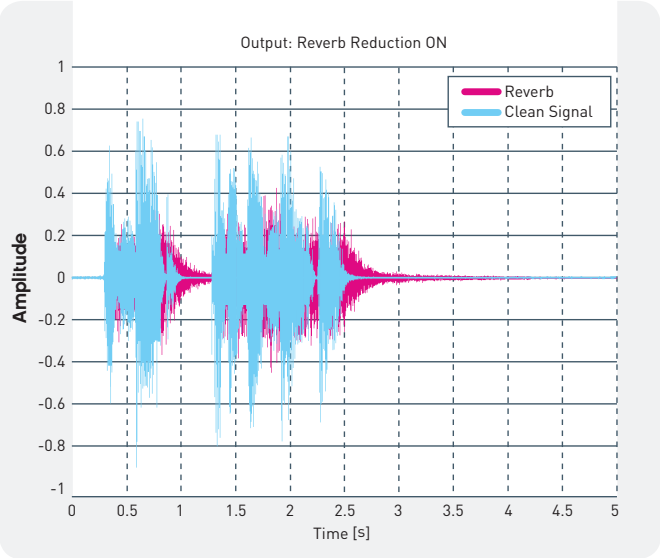
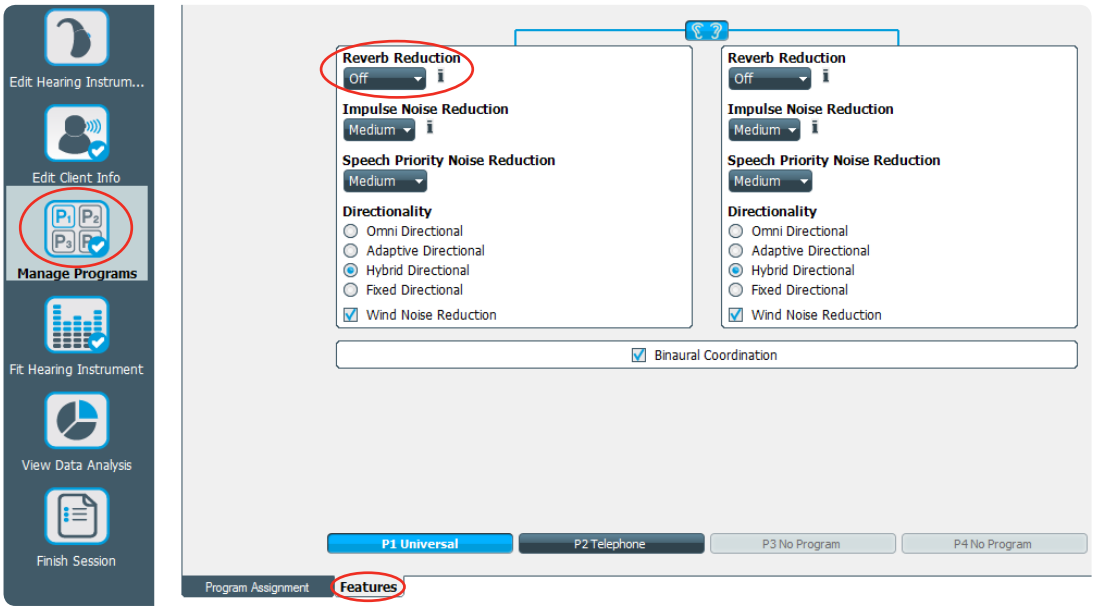


Figure 7b: When Reverb Reduction is on, less reverberation (pink) is present in the output signal. Speech cues (blue) once again become clear and listening comfort is preserved.

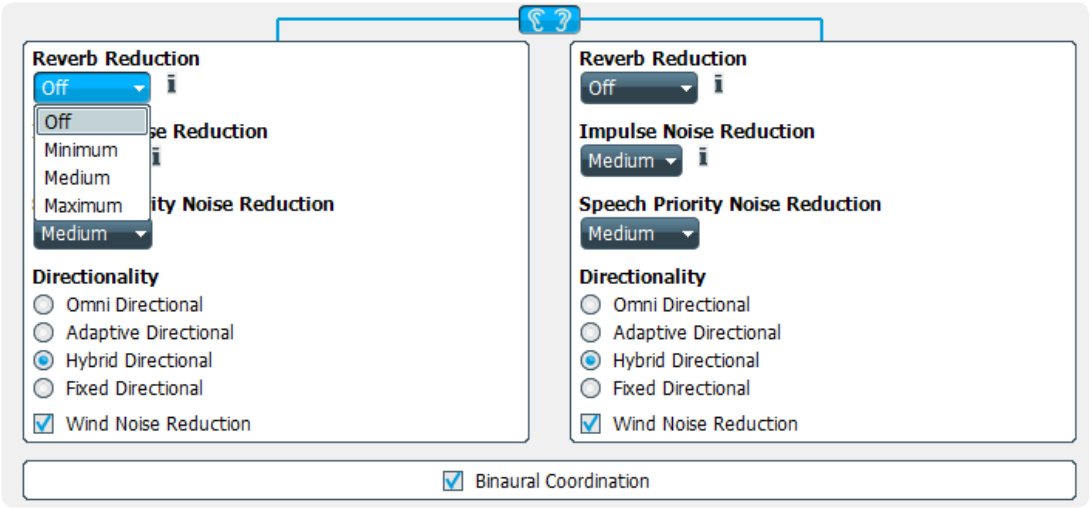
Reverb Reduction in EXPRESS*fit*

Sonic pledges to develop new features that are simple to use and easy to apply, and Reverb Reduction is no exception. In EXPRESS*fit*, go to the Features tab in the Manage Programs screen. Reverb Reduction is the first feature listed on the screen.



Reverb Reduction is Off by default. To activate, simply select one of three attenuation levels found in the drop-down menu:

- Minimum
- Medium
- Maximum



Each increasing level gives stronger attenuation for reverberant sounds in the environment. Table 2 lists the amount of reduction applied for each corresponding level.

Level	Attenuation
Off	0 dB
Minimum	Up to 8 dB
Medium	Up to 14 dB
Maximum	Up to 20 dB

Table 2 : Reverb Reduction attenuation levels

It is recommended to keep the settings symmetrical for both ears of a binaural fitting. To maintain consistent changes between ears, use the linking button, shown here.

At all times, an 'Information' message appears beside the feature. The note indicates that Reverb Reduction is only available if Impulse Noise Reduction is turned off. Selecting a second listening environment may be necessary if both features are required to address individual patient needs. Please note that Reverb Reduction is not offered in all pre-set environments. Table 3 outlines which listening programs offer this feature.

Listening Programs With Reverb Reduction*	Listening Programs Without Reverb Reduction*
Universal	Telephone
Custom	Airplane
Quiet	Music
Noise	Automobile
Classroom	Entertainment
Classroom Telecoil	Accessory Programs

*Hearing Instrument and Model Dependent

Table 3: Listening Programs with and without Reverb Reduction in EXPRESS*fit*

Benefits of Reverb Reduction

Reverb Reduction supports hearing care professionals by providing a way to address reverberation wherever it may occur. Reverb Reduction gives additional benefits to hearing care providers, offering:

- An easy solution to reduce the negative effects of reverberation
- A choice of three selectable attenuation levels to adjust for individual patient needs
- An effective technique to help patients achieve greater overall hearing satisfaction

Likewise, Reverb Reduction offers numerous advantages to patients, including:

- A state-of-the-art hearing aid algorithm that controls reverberation in any setting
- Easier listening in environments with challenging acoustics
- Comfortable hearing in a variety of environments

When patients can enjoy their hearing instruments in even more situations, they experience a world where every day sounds better. Reverb Reduction is available in the Celebrate and Journey hearing aids from Sonic.

For a demonstration or to learn more, please contact your local Sonic provider.

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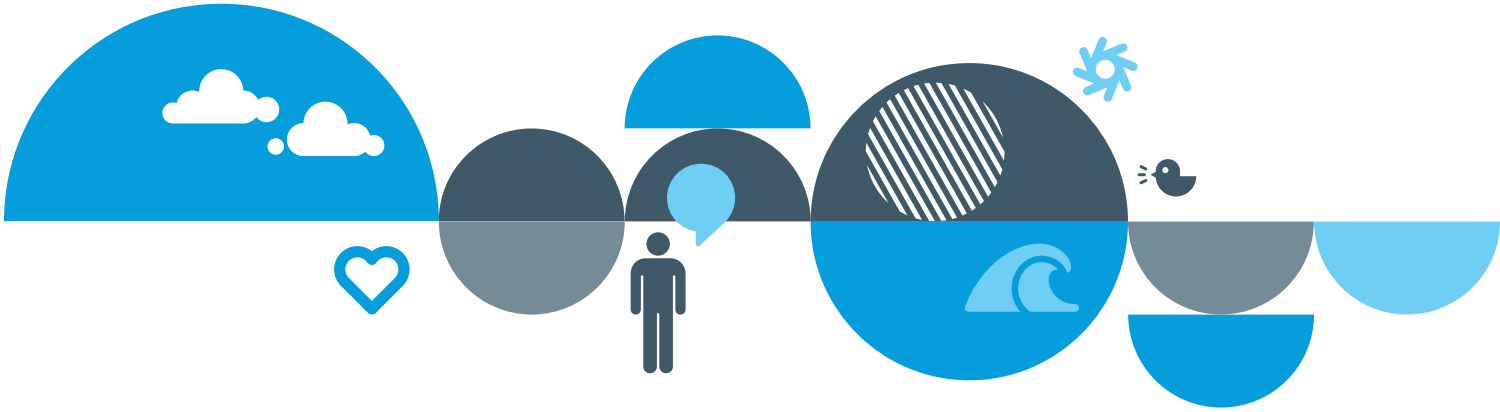

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