The information presented in this whitepaper applies to products manufactured by GN that are comparable with equivalent technology as ReSound. For further information, see reference list.

Natural Directionality II brings ReSound Key users the great hearing they deserve

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ABSTRACT

A misconception about hearing aids is that there is an "entry level", as if the needs and desires to communicate and navigate in a hearing world develop as experience with hearing aids grows. ReSound recognizes that everyone deserves a great, individualized hearing experience, which is why ReSound Key™ is packed with high quality sound based on our Organic Hearing philosophy. This paper reviews how Organic Hearing contributes to ReSound Key, and details how Natural Directionality II helps to open up the world of better hearing and communication to even more clients.

Introduction

It's finally summer and you are attending a large, outdoor gathering hosted by a friend. You are enjoying catching up with everyone after a long winter. There is a flurry of activity at this party, with many sounds happening all at once – chatter from other groups, laughter, children playing as they run around among the adults, perhaps some music. There is a lot to listen to! Assuming your hearing is good, there would be some distracting noises, but you would most likely be able to focus on and understand the speech or sound that most interested you. Your "ears" (the peripheral auditory system) would be responsible for detecting all these incoming sounds, but your higher-level cognitive auditory system would focus, organize and process them all. You could switch your focus to different sounds from one moment to the next, depending on shifts in conversation or the start of one of your favorite songs in the background.

Now imagine one of your clients with untreated hearing loss in the same situation. They would likely struggle to keep up with conversation, not just because parts of speech are hard to hear and are being covered up by other noises, but also because they would not be as efficient in filtering out competing noise. They would require more time and cognitive resources to keep up with the natural shifts of content and speakers in a dynamic group conversation. Hearing loss has been shown to interfere with the cognitive process of filtering out multiple sound sources.[1] This means the person is bombarded with all those sounds at once and is less able to separate them or select which sounds matter most to hear.

They might rely heavily on a spouse to help them understand what is being said. Perhaps they would pretend to understand without getting to truly feel included in the group. You may find them on the fringe of the party, observing rather than participating. Or, frustrated and exhausted with trying to keep up, they may decide to save themselves the hassle and embarrassment of not hearing well and just stay home.

This example highlights the vital importance of hearing aids – not just in restoring audibility for speech and other sounds, but in promoting connections and confidence in people with hearing loss. At ReSound, we use the concepts behind auditory system function and human listening behavior to inspire the design of our entire hearing ecosystem. We call it Organic Hearing. While hearing aids cannot replace the auditory system, they can be built to support our natural listening abilities and behaviors as much as possible. By designing all our hearing aids in alignment with our Organic Hearing philosophy, you as the HCP have the tools to guide and support every individual client. ReSound Key is an entry point into this design concept of Organic Hearing.

Supporting how the ear works

Twenty Let's start with the foundation of any hearing aid – the amplification system. This feature underpins the entire hearing experience by prescribing how sounds are amplified. ReSound introduced the first commercially available hearing aid using wide dynamic range compression (WDRC). This idea was based on research showing that the healthy inner ear functions as a non-linear amplifier, allowing humans to hear a wide range of sound intensities.[2,3] Therefore, like the human ear, WDRC provides different levels of amplification depending on the intensity of the input sound. Softer sounds receive more amplification, and louder sounds receive less. While WDRC has become the industry standard for amplification and is widely available today, the ReSound design evolved beyond input level-dependent amplification to specifically mimic the filter structure of the human cochlea. This "map" of filters can separate and process sounds in a similar way as our own auditory system. As a result, our Warp compression system – named for the technique by which the filters are "warped" to replicate the filter structure of the auditory system – can provide natural, preferred sound quality compared to other techniques.[4,5]

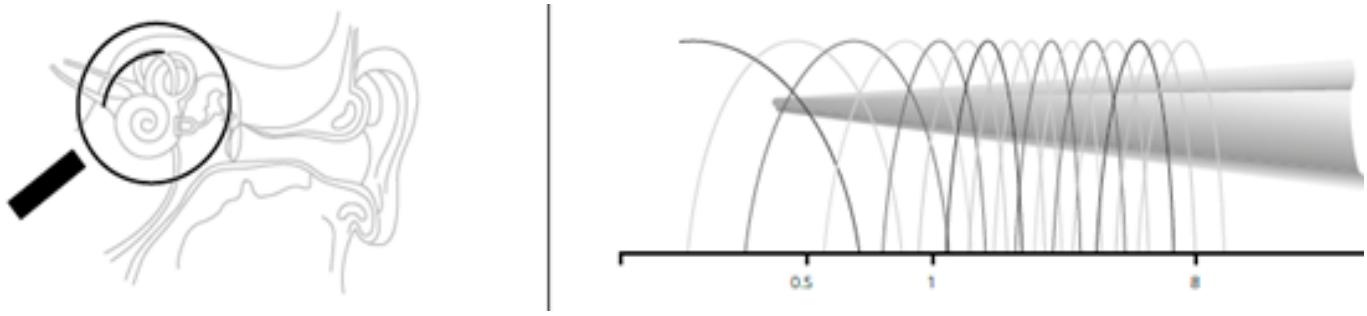


Figure 1: The Warp compression system mirrors the model of the critical bands of the cochlea within the frequency range of the hearing aid. While ReSound Key sums these bands into a fewer number of channels for the HCP to control, the underlying frequency resolution of the system retains the resolution of the auditory system.

Supporting how we listen

In addition to mimicking biological functions of the ear, a key concept of Organic Hearing is that our solutions leverage and support the natural ways we listen. Because our everyday acoustic environments are dynamic, so is our natural behavior in these environments. The sound we think is most important at one moment may be noise a moment later. As an example of how this is true, Skagerstrand et al[6] studied what noises and sounds hearing aid users considered to be annoying. Study participants kept daily logs of sounds that were annoying to them. While analysis of the logs revealed 18 categories of noises that were identified by the study participants, the most frequently cited annoying noises were speech and voices, and television/radio. The dilemma is clear. The very sounds that people most want to hear can be the same sounds that they sometimes do not want to hear. How can a hearing aid system help rather than interfere with the brain's natural ability to focus on sounds, suppress sounds and shift attention among sounds?

The microphone mode used in the hearing aids is one variable that can work for or against natural listening strategies. The conventional use of microphone mode in most modern hearing aids is to automatically apply a directional response when the surroundings are noisy, and an omnidirectional response when in quiet conditions. If two hearing aids are worn, this same approach is applied for both ears. This rationale seems logical given that directionality is well-proven to improve speech understanding in noise when speech is in front of the hearing aid user, especially if the noise is behind the user. The improvement in speech understanding when using directional microphones in these conditions is known as directional benefit. However, there can also be a directional deficit when the sound of interest is not in front, moving or changing from source to source, as is usual in conversation among several people. Archer-Boyd et al[7] proposed that a minimum signal-to-noise ratio (SNR) for sounds not in front of the user is necessary for directional hearing aids to be usable in real life. As these authors point out, hearing aid design should be compatible with listener behavior, and directional microphones that don't allow users to monitor their environment lead to issues in the form of slower orientation and more mistakes in locating new sounds of interest around them. Additional issues with automatic directionality for real life use can be that the decision-making done by the hearing aids to change the microphone modes is inconsistent with the hearing wearer's listening goals, and that it is too slow to keep up with dynamic listening environments.

Natural Directionality II compliments our listening behavior

ReSound Key features Natural Directionality II in the All Around listening program. This mode is designed on the concept of the "better ear" in binaural hearing. Let's go back to the party for a moment. You are listening to a person in your group tell a story when suddenly a group next to yours bursts out in laughter. The increase in noise means you would make some slight changes in your listening behavior to continue following along with the person's story. You would likely lean in closer to the person you were listening to, perhaps tilting one of your ears towards them. This gives you a "better ear" advantage, where the speech comes in more clearly in that ear with less background noise than the other ear. Your brain can then use this clearer stream of speech to help you understand what is said.

Natural Directionality II allows listeners with hearing loss to take advantage of this strategy, too. One hearing aid is set to directional mode – a "focus" ear, while the other hearing aid is set to omnidirectional mode – a "monitor" ear. This gives the user benefits from both microphones in a single listening program. Less noise enters the hearing aid in directional mode, which improves the SNR for sounds in front of the listener. Simultaneously, listeners can maintain awareness for sounds occurring all around them due to the omnidirectional response of the other ear. This supports the natural listening strategies we use in a situation like the party. Sounds that a person wants to hear, including other people talking from our sides or behind us, occur about one-third of our active listening time during the course of a day.[8] Natural Directionality II supports this by allowing the user to detect a sound to their side or behind them and then give them the chance to decide if they should listen. If so, they can move their head in the direction of that sound and further benefit from the better SNR on the directional focus ear. If they had no awareness from the omnidirectional monitor ear, they may have never detected the sound in the first place, or at least not in time to switch their attention to fully hear and understand.

Studies of speech intelligibility using this microphone strategy have shown similar directional benefits for front-facing speech in a noisy environment as bilateral directional microphones.[9-12] In addition, users gain further advantages by having one ear in omnidirectional instead of two ears in directional. Lab studies of speech recognition when the target speech is not in front of the listener show a great advantage for the asymmetric

microphone mode.[11,13,14] Using directional microphones on both ears has been shown to reduce the audibility of speech that is not in front[15] while having a focus and monitor ear greatly improves the ability to hear off-axis speech.[14] The combination of auditory and visual information when locating a sound source has been shown to improve speech intelligibility in noise.[16,17] In fact, the idea of a focus and monitor ear with different directional responses is so compelling that it is even being explored for application to communication devices for people with normal hearing.[18]

The technology behind Natural Directionality II

Applying different microphone modes to each ear in a hearing aid fitting sounds simple, like something that could be achieved with any hearing aids. However, there are perceptual and technical challenges that would make this ill-advised. One issue is the difference in sound quality caused by the inherent low frequency roll-off of directional microphone systems in hearing aids. An important part of Natural Directionality II is Directional Mix. This feature provides a different microphone response based on frequency. In the low frequencies, the response remains in omnidirectional mode. This preserves low-frequency gain for a more full, rich sound quality.[19] Directional Mix also prevents the roll-off of low frequency gain for listeners who need more amplification in that region. Directionality is applied in the frequency region that is most important for speech intelligibility.[20]

Low frequencies are not only important for the sake of sound quality and audibility. Frequencies lower than approximately 1500 Hz contain critical timing information that helps us localize sounds.[21] Conventional full bandwidth directionality can disturb these cues because directional processing effectively cancels out low-frequency sounds as part of the strategy to reduce sounds behind the listener.[22] In addition, directional microphone systems that are based on digital technology take slightly longer to process the sound than when a hearing aid is operating only on a signal from one omnidirectional microphone. Therefore, Natural Directionality II synchronizes processing time between the focus and monitor ears to ensure that timing cues for localization are preserved even though the microphone responses between ears are different.

Natural Directionality II in real life

Two notable field studies of the Natural Directionality II approach in real life showed that the benefits of this type of fitting extend beyond the lab.[10,23] In both studies, participants were fit with hearing aids with two programs. One program followed the Natural Directionality II strategy with a focus and monitor ear, and the other program was bilateral omnidirectional. The order of programs was counterbalanced among the participants, who kept daily logs describing the listening environments they encountered, their subjective hearing performance in those environments including how much effort they used to listen, and their program preferences. One striking finding in both studies was a small but significant advantage in terms of listening effort for the program following the Natural Directionality II strategy across all types of environments. Furthermore, no participants rated the omnidirectional program as substantially better in terms of ease of listening even though participants in both studies on average encountered a much higher proportion of environments that would favor omnidirectional processing.

By combining each participant's reports of their listening environments with datalogging of usage time in the hearing aids, Kiessling et al[23] gained further insight on how the Natural Directionality II strategy might be preferred if listening demands are more dynamic. Fourteen out of nineteen participants (74%) in this study used both programs approximately equally, suggesting that they did not perceive much difference between bilateral omnidirectional and Natural Directionality II. These individuals reported that they either encountered mostly easier listening environments, or a balance of easy and challenging listening environments. However, the remaining five participants (26%) used the program that followed the Natural Directionality II rationale significantly more – as much as five times more – than the omnidirectional program. The daily journals revealed that these five participants reported being in challenging listening environments that would favor directional processing three to five times more frequently than environments where omnidirectionality might be preferred. This demonstrates how users intuitively might gravitate toward the response that best supports their natural way of listening. The fact that no participants used their omnidirectional program more suggests that Natural Directionality II is the better choice for everyday listening in a wide variety of conditions. Findings from the previously reported lab studies which compared to bilateral directionality strengthen this conclusion even more. People who use Natural Directionality II will always have access to an improved SNR for better hearing in noise while still being able to hear what is happening around them.

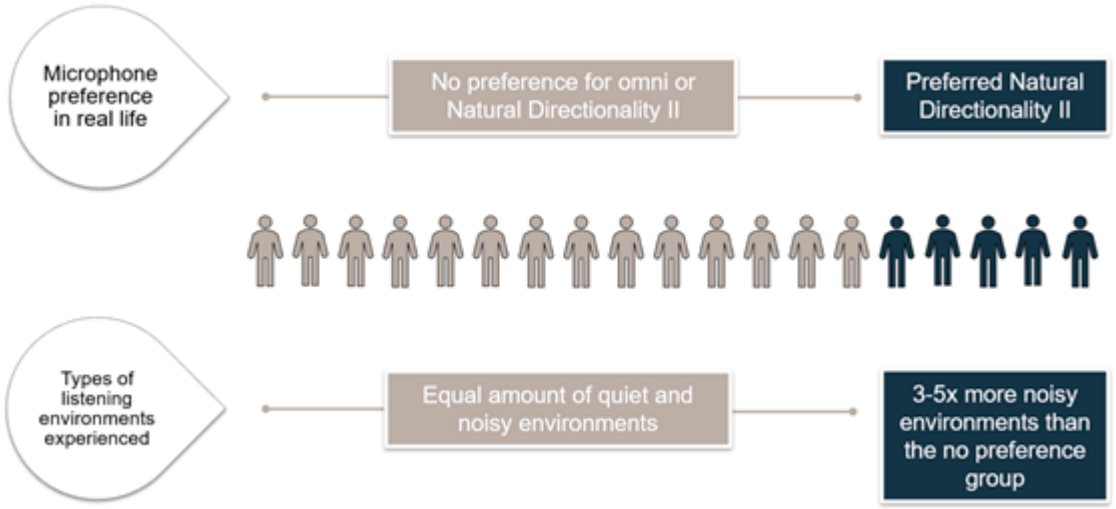


Figure 2: Five out of nineteen participants preferred the Natural Directionality II strategy over bilateral omnidirectional in a field study23. Those five participants experienced three to five times more noisy environments than the remaining fourteen participants who did not have a preference.

Finally, a field trial using ReSound Key showed how the daily hearing experience of people fit with Natural Directionality II extends beyond what they hear to how they feel.[24] Twenty hearing aid users used a smartphone app to report on their daily listening environments, their hearing, and how they were affected by their experiences. Because they were not always wearing their hearing aids, it was possible to see the difference ReSound Key with Natural Directionality II made not just in terms of hearing performance, but also in well-being. As seen in Figure 3, people reported feeling better about their hearing overall, but also less tired, less stressed, and more able to do what they wanted when wearing ReSound Key with Natural Directionality II than when not wearing hearing aids.

Overall today...



Figure 3: Participants in a field study with ReSound Key with Natural Directionality II rated their mood and well-being better when they had been wearing the hearing aids (green circles) than on days when they had not been wearing them (red circles).[24] The ratings on each question were significantly better with ReSound Key than without hearing aids.

Summary

The primary job of hearing aids is to restore audibility for the huge array of sounds people encounter every day. But better hearing isn't just about improving audibility – it's also about guiding a user in their own journey to feeling more confident and more like themselves again. To best support these concepts, the ReSound Organic Hearing philosophy draws on inspiration from the natural way the ear works as well as the natural ways we use our hearing to function in everyday life. ReSound Key rounds out the portfolio of solutions as an entry point into the Organic Hearing philosophy. Natural Directionality II uniquely applies directional technology to leverage the way we naturally listen. This ensures that users always have access to a "better ear" for whatever is important for them to hear, and that they can monitor and orient to their listening environments.

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