Smart hearing for people with severe-to-profound hearing loss

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Abstract

ReSound ENZO 3D™ is part of a hearing ecosystem providing evidence-based solutions for people with severe-to-profound hearing loss, who are the most reliant on amplification. The range of connectivity options, compatibility with Cochlear™ cochlear implant, and opportunities for personalization and enhanced assistance from their HCP at their convenience are unmatched in any other hearing aid for severe-to-profound hearing losses. This paper presents three ReSound ENZO 3D users and illustrates how particular aspects of this unique hearing aid have enriched their lives.

Today's hearing aids are generally targeted toward the active "baby boomer", and this makes good sense. In the US, this generation is turning 70 at the rate of 10,000 people per day[1] and a large proportion of them experience hearing loss that can be helped with amplification. Worldwide, roughly half of the general population has a hearing loss exceeding 35 dBHL by the age of 70[2]. However, for severe and profound hearing losses, the age distribution looks quite different. In fact, half of those with severe and profound hearing loss are between the ages of 18 and 65 years, with fewer than 40% older than 65 years[3]. This means that there is no prototypical individual with severe or profound hearing loss. They are baby boomers, Gen-X and Millennials. They are at all life stages. They are in school. They are in the labor force. Their preferences in terms of amplification are highly variable. One thing they do have in common is that they depend on their hearing aids in their daily lives. In short, their communication needs are what both hearing care professionals (HCPs) and hearing aid manufacturers would characterize as "demanding". In spite of this need, hearing aids for severe and profound hearing losses have historically been last in line in terms of new technology developments.

As the only smart hearing aid for severe and profound hearing losses, ReSound ENZO 3D changes all that. ReSound ENZO 3D is part of a hearing ecosystem providing evidence-based solutions for people who are the most reliant on amplification. Fitting tools such as preset amplification modes and a low frequency boost option are convenient ways to quickly find the best starting point. Binaural Directionality III with Spatial Sense ensures improved hearing in noise with preserved awareness of surroundings, resulting in a more natural listening experience. A full range of digital wireless accessories and Made for iPhone® functionality provides astonishing benefit in situations where people with very severe hearing losses struggle the most: on the phone, in noisy conditions and when at a distance from what they want to hear. Finally, ReSound ENZO 3D offers users a wide range of possibilities to customize their hearing aid settings as well as to conveniently seek extra help from their HCP via the ReSound Smart 3D™ app and ReSound Assist.

In developing hearing aids for individuals with severe and profound hearing loss, it is a given that a high amount of maximum gain and output must be available, and that the hearing aids must be reliable and stand up to everyday use. However, because of the diversity of this severity group, other needs and desires are not as obvious. To this end, ReSound has conducted thorough qualitative research with members of this group. Common themes that were revealed included positive and appreciative attitudes toward amplification, and an acceptance of hearing loss. In addition, there is a strong desire to make the most of residual hearing ability combined with technology to "get on with it". Not surprisingly, people with severe and profound hearing losses develop strategies to cope with limitations in their hearing. Many of these strategies are positive, such as paying attention to contextual cues, lip-reading, or manipulating the environment. However, there are also many that are less positive, such as dominating conversations in order to know what they are about, or, conversely, withdrawing from challenging situations. ReSound ENZO 3D offers technology that supports positive coping strategies and eliminates or reduces need to rely on less positive strategies. This paper presents three ReSound ENZO 3D users and illustrates how particular aspects of this unique hearing aid have enriched their lives.

ReSound GN

Clarity and sound quality

Oscar is 23 years old and has worn hearing aids since grade school, although his hearing loss is most likely congenital. His family runs a farm, and he often pitches in during breaks from college, where he studies agriculture. Oscar was satisfied with his previous hearing aids and recognized the benefit they provided. However, there were situations he found difficult. One example was that he struggled to follow informal classroom discussions. In this situation, he reported that the speaker changes quickly and not always predictably, and the person speaking could be behind him, on either side of him, or in front. One of his coping strategies is to look at whomever is speaking, but he did not think his hearing aids supported his ability to locate and turn his attention to different people speaking very well. He often found himself straining to follow the quick changes in speaker and topic, which limited his ability to participate. Oscar also expressed a sense of discomfort in situations where he needed to be aware of what was going on around him, such as when cycling in traffic or working on the farm. Generally, Oscar found sounds to be loud enough with his hearing aids, but lacking in clarity. He experienced hearing and communicating as quite effortful. In his words, "Where hearing is a passive activity for hearing people, for me and for people like me it is an activity you have to do. It's work."

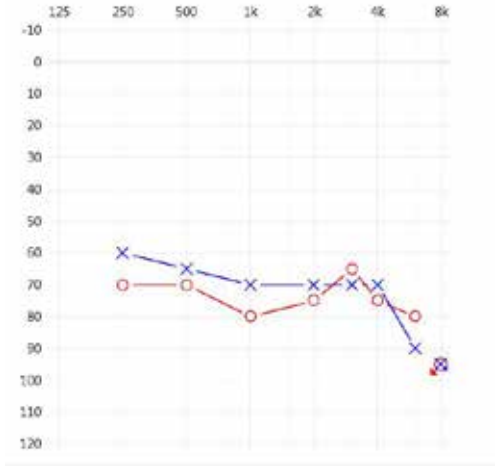

Figure 1. Oscar's audiogram

Oscar was fit with ReSound ENZO 3D 988 hearing aids. This model is a high power behind-the-ear (BTE) hearing aid. His HCP fit him with a semilinear compression scheme, which lowers compression ratios slightly compared to the regular ReSound WDRC strategy. Although WDRC is appropriate even for severe-to-profound losses[4,5], some individuals – like Oscar - prefer the sound experience with lower compression ratios than would otherwise be prescribed by the proprietary Audiogram+ rationale or other fitting prescriptions for WDRC[6]. This is why Smart Fit software provides three different amplification schemes. Persons with very severe hearing losses most often have long-term experience with amplification, and may have much stronger preferences than the typical hearing aid user with a mild or moderate hearing loss.

Oscar's main criticisms of his previous hearing aids had been a lack of clarity, effortful listening, and a feeling of insecurity in some situations due to not being aware of what was happening around him. ReSound ENZO 3D provides him with Binaural Directionality III and Spatial Sense, unique sound processing that allows him to hear in a more natural way, and addresses his wishes for his hearing aids. Although directionality in hearing instruments is a proven way to improve hearing in noise and increase clarity of the desired sound, it comes with drawbacks. One of these drawbacks that Oscar experienced with his previous hearing aids was that sounds occurring outside the directional beam are more difficult to hear and also more difficult to locate[7,8,9,10]. Because a significant proportion of active listening time is spent attending to sounds that are moving or not in front[11], directionality sometimes prevents hearing aid users from hearing what they want to hear.

ReSound has followed a unique path in applying directional microphone technology that does not focus on maximizing signal-to-noise ratio (SNR) benefit in controlled and contrived environments. The approach to using directional technology taken by ReSound is continually refined to consider how listeners will experience it in real-life, with the goal of providing the most natural listening experience possible. A hearing aid user is not just two ears. Therefore, the entire human auditory system is considered in the design, from the acoustic effects of the shape and location of the external ears on the head to the power of binaural processing by the brain.

Binaural Directionality III[12] is the third generation of the microphone mode control strategy that meets the goal of providing a natural hearing experience. Like Binaural Directionality II[13] it steers the microphone configuration of two hearing instruments to support binaural sound processing by the brain. It is the only truly binaural strategy, taking advantage of scientifically proven listening strategies incorporating acoustic effects and auditory spatial attention strategies[14,15,16,17,18]. The possible outcomes include a bilateral omnidirectional response with Spatial Sense, a bilateral directional response, or an asymmetric directional response. These outcomes were derived from research regarding the optimal microphone responses of two hearing instruments in different sound environments.

It might be questioned to what extent those with severe-to-profound hearing loss might benefit from advanced technologies like Binaural Directionality III and Spatial Sense. Given that the degree of hearing loss might severely restrict the audibility of the effects of special processing, this is a valid question. Binaural Directionality III has previously been demonstrated to provide individuals with mild-to-moderate hearing loss improved speech recognition in noise while greatly improving audibility of sounds not in front relative to the most advanced binaural beamforming technologies[19]. For those with more severe loss, it was observed that absolute performance on speech-in-noise recognition was unsurprisingly worse. However, the ben-

efit relative to other advanced directional technology was clearly shown[19]. Regarding Spatial Sense, performance on a localization task showed that those with severe-to-profound hearing loss did benefit as well[20]. The magnitude of the average benefit was smaller than for those with milder losses, but there are two important considerations. One is that a great variation in benefit was observed. While some individuals showed no benefit, others benefitted similarly to those with milder hearing loss. The other considera-

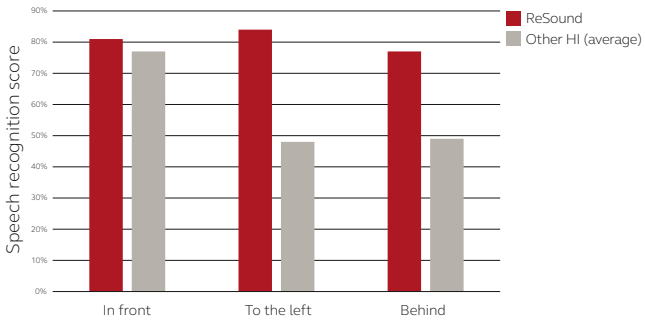

Figure 2. Results from a difficult speech recognition task, where participants had to locate and repeat sentences that were presented simultaneously from three different directions. When the target speech was in front, study participants performed equally well in locating and understanding the target speech with ReSound ENZO 3D as they did when wearing hearing aids with binaural beamforming. When speech originated from the left or behind the participant, performance with ReSound ENZO 3D far exceeded that when wearing the other hearing aids.

tion is that no individual did worse with Spatial Sense than without. This means that there is no potential harm in making the technology available regardless of degree of hearing impairment.

For Oscar, ReSound ENZO 3D made an impressive difference in the very situations where he had previously struggled. While his speech-recognition-in noise results with a conventional speech-in-noise test in the clinic were similar to those with his previous state-of-the-art directional hearing aids, he reported that in his daily life, he was able to follow conversations in classes and other activities with less effort. He stated that he did not feel "worn down" at the end of each day. He even remarked that "I almost feel like a normal hearing person" in describing the way in which he is able to follow what is happening around him without having to think about it in a deliberate way.

Bimodal hearing and connectivity

Amy is 48 and has had lifelong hearing impairment that progressed throughout her childhood and into adulthood. She did not wear hearing aids regularly until she was 17 years old. Today she is a bimodal user with a cochlear implant (CI) from Cochlear on one ear and the ReSound ENZO 3D 998 super power BTE on the other. She works as a cruise director so being able to talk with people and hear in noisy conditions is a top concern for her. Amy's audiologist fit her hearing aid by first mapping the CI, then fitting the hearing aid to NAL-NL2 targets and performing

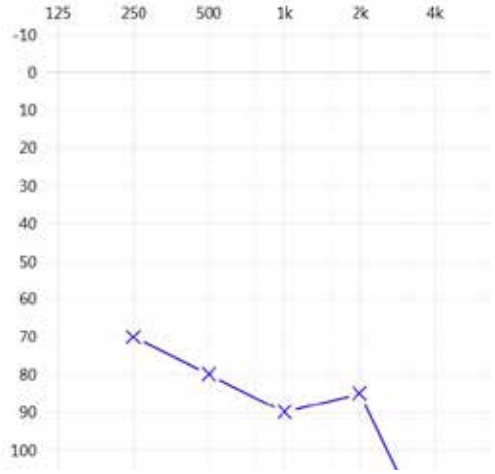

Figure 3. Amy's audiogram for the ear fit with ReSound ENZO 3D.

loudness balancing. Her default program also conforms to recommendations to use Softswitching, which automatically changes microphone mode to a directional response in noisy environments with speech in front[21].

Amy had always avoided phone communication before her current fitting. Her strategy was to use texting and emails rather than making a call. If she received a phone call, she would not answer but let it go to voicemail. Then she would listen multiple times to the voicemail message or even have someone else listen in order to be prepared for returning the call. She found that if she did not know in advance what the call was about, she could not understand well enough to complete the conversation at all. "It was like if you got a call from someone speaking a foreign language to you except that I could also not even hear the voice very well." Because Amy's implant is from Cochlear™ with the Nucleus 7 processor, she has a complete range of wireless streaming accessories that are compatible with both her implant and her ReSound ENZO 3D hearing aid. This includes receiving calls and audio from her iPhone®. "I avoided using my phone before. But now I have no hesitation picking up because I get the sound straight in my ears. And I would say to people, don't use the landline, even though it has volume control, because this way you get more clarity." Amy's experience with the phone mirrors results from Wolfe et al (2015), who tested bimodal users' speech recognition in quiet and in a noisy environment when listening to a mobile phone held up normally to the CI microphone versus streaming bilaterally via the ReSound Phone Clip+. The improvement with bilateral streaming averaged 25% in quiet and 23% in noise.

Individuals with any degree of hearing impairment benefit from being able to see who they are talking to, but those with severe-to-profound losses can potentially benefit the most. In fact, those with very severe losses rely as much on visual as on auditory information for speech understanding[23,24]. Amy also found that by adding visual cues via a video chatting app such as Facetime®, her conversations became even easier and more enjoyable. "But now if I Facetime with my sister, it's connected to my hearing aid and my implant and it's much clearer. I can pick up the words,

I can pick up the dialogue, it's so much clearer. And the background noise gets cut off completely." This is not surprising considering the degree of benefit for audio streaming combined with visual cues reported by Jespersen & Kirkwood[25]. Their study participants showed an additional average benefit of 23% when streaming bilaterally to hearing aids combined with Facetime relative to streamed audio only. Compared to using the phone acoustically at the hearing aid microphone unilaterally, there was an average improvement of more than 70%. This was true regardless

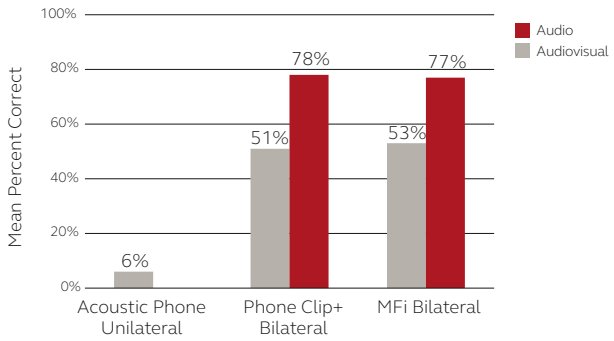

Figure 4. Compared to using the phone acoustically, bilateral streaming alone provides more than 45% benefit. By adding visual cues via a video chat app, more than 70% added benefit is attained.

of whether direct connection to the iPhone was used or whether the ReSound Phone Clip+ was used for the audio connection. This means that the benefit of the video chatting is not limited only to iPhone users, as any smartphone can stream audio to the ReSound ENZO 3D hearing aids as well as the Cochlear Nucleus 6 and Nucleus 7 processor via the ReSound Phone Clip+.

For Amy, the ReSound Multi Mic has also proven to be critical to her success with communication in many environments and particularly in her job. She reports using both the table mic mode as well as clipping the microphone onto her conversation partners with good effect. She recounted a story from one of her cruises about a dinner with guests at a long table. By placing the ReSound Multi Mic on the table further away from herself, she was able to converse not only with people directly beside her, but also with a couple who were sitting a couple of seats away. This was not something she had ever been able to do before. Amy was tested using the Hearing in Noise Test (HINT) with her bimodal fitting alone and with bimodal streaming to her ReSound ENZO 3D hearing aid and CI from the ReSound Multi Mic. The ReSound Multi Mic was placed in front of the speaker that delivered the speech material for the latter condition. With the bimodal fitting, Amy performed at an SNR of -3 dB, which in itself was impressive. However, with the ReSound Multi Mic, her performance improved to an astounding -23 dB SNR.

Added convenience and control

Steven is 63 years old and works as a property developer. He has a very busy schedule and is frequently away from home. Steven spends a lot of time driving and needs to take calls while in the car. This was challenging for him with his previous hearing aids. Usually, he tried to listen to the phone calls through the car's Bluetooth® but did not find it clear enough. Another issue he reported relates to the varying listening environments in which he finds himself. Apart from being in the car, he has a great need to be able to hear on the phone, he participates in frequent meetings where he must negotiate, and he often visits job sites where he is outdoors and there may be a good deal of noise from construction equipment. He has found himself trying to make volume adjustments or to try different listening programs that his HCP had put in his hearing aids in order to hear better in these different environments, but often just gave up because the effort involved seemed greater to him than any benefit. He stated that he didn't really know what was different about the programs and didn't understand or remember how he should be using them. Because his schedule is unpredictable and he is often away from home, he has not found it easy to seek additional help from his HCP. "If you need help, you need help. I guess my problem is just that it's so far away, so you

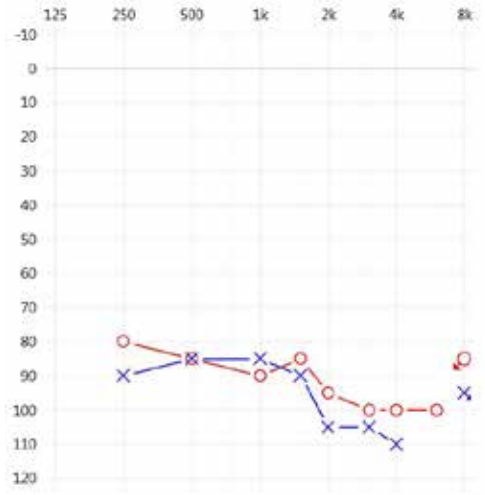

Figure 5. Steven's audiogram

get a bit reluctant. Plus the nature of my job, it's so hard to take the time off to go see them." Steven also recognized that his listening situations might require specific settings to be optimal for him. "The hearing aids are set up in a quiet room, it's not really everyday life. That's not really a benefit." As a regular smartphone user, he believed that he could most effectively find and try new settings on his own rather than having to go back-and-forth to his HCP. "They could just make an app on the phone, so you were able to do it yourself."

Steven was fit with ReSound ENZO 3D 998 super power BTE bilaterally. He also added a ReSound Phone Clip+ and a ReSound Micro Mic to his hearing system. Because of his need for hands-free phoning in the car, the ReSound Phone Clip+ seemed to offer the best solution because of the microphone to pick up his voice even though he did have an iPhone and could stream calls directly. This eliminated the need for him to hold his iPhone to have it near enough to pick up his voice well in the car. Apart from the streaming programs, Steven was fit with one program that

has Binaural Directionality III with Spatial Sense, and an additional program with Autoscope adaptive directionality, NoiseTracker II noise reduction, and WindGuard wind noise reduction. He downloaded the ReSound Smart 3D app to his iPhone primarily to be able to experiment with adjustments for different environments. Steven also accepted the ReSound Assist option[26], which would let him contact his HCP and ask for assistance remotely, without having to make a special visit.

After a week of wearing the hearing aids, Steven sent a request to his HCP using ReSound Assist. One observation was that he preferred a lower overall volume regardless of which program or listening situation he was in. By experimenting with the Sound Enhancer features in the ReSound Smart 3D app, he had also been able to find settings that he saved as favorites for some of his usual listening environments. Finally, he had also realized that the theater he sometimes attends has an induction loop system and wondered if he could connect to it to improve his experience. Acting upon his request, Steven's HCP fine-tuned his fitting in the Smart Fit software to have less volume, and a telecoil program was added. These settings were sent to Steven via the secure cloud connection, and he was able to download them to his hearing aids at his convenience while traveling. This allowed Steven to try out the new settings in his actual daily life environments. He had the opportunity to ask for further adjustments in this way if needed. At his next visit, Steven expressed great satisfaction with both the adjustment possibilities available to him in the app, as well as the opportunity to get help easily without having to make time for an extra visit.

Figure 6. Steven is able to make many of his own adjustments to his hearing aids, contact his HCP and get help remotely at his convenience by using ReSound Smart 3D app and ReSound Assist.

Summary

People with severe-to-profound hearing loss are highly dependent on amplification. They develop effective strategies for coping with hearing difficulties, and are interested in how technology can help them even more. ReSound ENZO 3D provides exceptional solutions that are of particular benefit. With the highest gain and output available today, ReSound ENZO 3D delivers clear sound that improves hearing in noise without limiting awareness of other sounds in the environment. The range of connectivity options, compatibility with Cochlear CI, and opportunities for personalization and enhanced assistance from their HCP at their convenience are unmatched in any other hearing aid for severe-to-profound hearing losses. The three users discussed in this paper illustrate how ReSound ENZO 3D can benefit people with the most severe hearing losses in ways that go beyond what conventional hearing aids have been able to provide.

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MK604972 Rev A 2017.10