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Audiology PRACTICES

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"Mrs. Jones, would you like to take care of the cost today or conveniently pay over time?"

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"Mrs. Jones, we have two ways you can pay over time, subject to credit approval. The first is CareCredit, a healthcare credit card that you can use again for your healthcare needs at the dentist, vet, optometrist and more. The second is an Allegro Credit Term Loan, which allows you to make a set monthly payment until the balance is paid in full, at which time the loan is considered closed. Which would you prefer?"

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Here's a quick look at the features of the two financing options.

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Deferred interest options (6, 12, 18 or 24 months) (on purchases of $200 or more)	✓	
Waived interest loans (6, 12, 18 or 24 months)		✓
Fixed payment options with a reduced APR (24, 36, 48 or 60 months)	✓	
Standard installment Loans (12, 24, 36, 48 or 60 months)		✓

* Subject to the representations and warranties in your agreement with CareCredit including but not limited to only charging for services that have been completed or that will be completed within 30 days of the initial charge, always obtaining the patient's signature on in-office applications and the cardholders' signature on the printed receipt.

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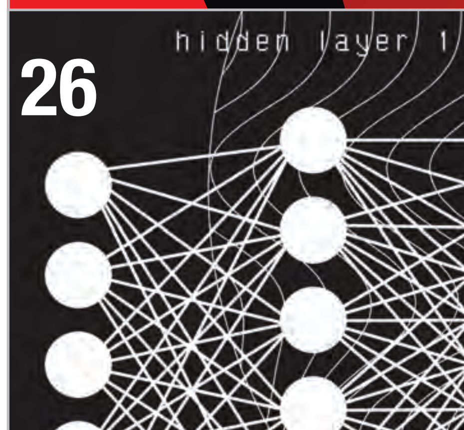
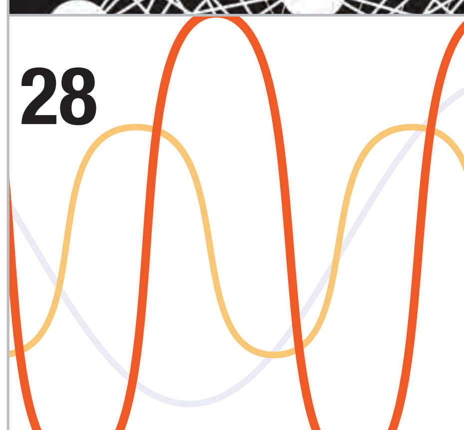
Features





HAMILTON CAPTEL

Compelling Data Connecting Hearing Loss and COVID-19

Studies have already shown sudden sensorineural hearing loss, vestibular balance dysfunction and tinnitus to be linked to COVID-19. What's more – these conditions are more prevalent than many realized early on in the pandemic.

In one study, 10% of patients self-reported persistent changes to their hearing status or tinnitus when surveyed 8 weeks after their discharge from the hospital following treatment for COVID-19.*

This new white paper, sponsored by Hamilton® CapTel®, explores emerging data and studies linking hearing loss to COVID-19, the long- and short-term effects on patients and its impacts on hearing healthcare professionals and clinical practice.

Get the white paper now at **HamiltonCapTel.com/ADA821**

*Kathleen Faulkner, Ph.D., "COVID-19 and Hearing Loss: What We Know Now" Hamilton CapTel, April 2021

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Contact Your Legislators!

Urge them to support the **Medicare Audiologist Access and Services Act** (H.R. 1587 and S. 1731)

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The Medicare Audiologist Access and Services Act of 2021 (H.R. 1587 and S. 1731) will remove unnecessary barriers, allowing patients to receive appropriate, timely, and cost-effective audiologic care. This legislation can improve outcomes for beneficiaries by allowing direct access to audiologic services and streamlining Medicare coverage policies so that audiologists can provide the full range of Medicare-covered diagnostic and treatment services that correspond to their scope of practice. The legislation would also reclassify audiologists as practitioners, which is consistent with the way Medicare recognizes other non-physician providers, such as clinical psychologists, clinical social workers, and advanced practice registered nurses.

Support the future of audiology! Contact Congress today and express your support for H.R. 1587 and S. 1731.

Visit chooseaudiology.org/support and contact your congressperson today!

Victor Bray, MSC, Ph.D., FNAP.

Address to AuDacity 2021 Attendees

Note: This President's Column is adapted from the Presidential Address at the recent Academy of Doctors of Audiology annual meeting in Portland, Oregon.

Hello fellow Academy members. As my Presidential year is closing out, let me say that serving on the Board of Directors as part of ADA's leadership team has been, and continues to be, a great opportunity to represent our profession and advance our causes. Thank you for giving me the privilege to hold this office for 2021.

What of the state of our Academy? The state of the Academy is good!

In communications to members, earlier this year we took time to investigate the proposed changes in Florida law regarding distribution of hearing aids. Our due diligence led to the Issues Brief and Town Hall meeting on State Laws and Hearing Aid Sales. This eye-opening exercise exposed for all our members the information that federal rules allowing direct-to-consumer distribution of hearing aids preempt state law restrictions on DTC or OTC. Our effort was effective in leveling the playing field for our members by sharing information that was being closely held by others, to their advantage and our detriment.

In advocacy, we continue to lead the multi-organization legislative initiative to advance our profession through MAASA. As part of this effort, this summer we participated in a first-time, unified, Town Hall on MAASA, with AAA and ASHA leadership, that was open to all 15,000 audiologists. We are closer than ever to achieving our objectives of recognition for full scope of practice, direct access by our patients for our services, and practitioner status within the Medicare system. But being so close is no guarantee of success and the political climate in Washington DC is volatile. At the time of this writing, decisions are being made that may deal audiology in, or cut hearing healthcare out of, the pending reconciliation bill.

We all know that ADA has always been a leader in advancing the professional practice of audiology.

- Forty-five years ago, ADA championed the private practice of audiology, including the right to both recommend and dispense amplification devices.
- Thirty years ago, ADA championed the educational transition from a masters-degree profession to a doctoral-degree profession, creating the Au.D. degree.
- A decade ago, ADA championed professional recognition as Limited License Physician status under the Audiology Patient Choice Act. But that great step forward was a bit too much for many of our colleagues and we are now collaborating with them on advancement to the intermediate step of practitioner status.

It is on the topic of practitioner status that I would like to speak with you today. If, and more appropriately when, the necessary change occurs and we advance from 'allied health, diagnosticians, supplier, other,' we would be more appropriately placed with other healthcare practitioners such as psychologists, physician assistants, and nurse practitioners. With this higher level of recognition would come additional rights and additional responsibilities. The question I have for you today is: How are we, as a profession, preparing for this transition? What is the plan?

Looking forward, I know what some major issues are that we need to address, but I don't know the answers. I am bringing these issues to your attention so that you can start to think about them and maybe contribute to creating a plan with solutions.

My first area of concern arises from my early career phase as a clinician and clinical director. What are the clinical procedures we should be doing? How do we know that these are the best ones and that we are doing them when appropriate? The answers are that clinical procedures, incorporated into clinical protocols, are derived from our clinical standards of care documents. Clinical Practice Guidelines establish the standards of care and are developed following the rigorous process recommended by the Institute of Medicine.

Looking to optometry, for example, one can find Clinical Practice Guidelines for "Comprehensive Adult Eye and Vision Examination" (51 pages), "Comprehensive Pediatric Eye and Vision Examination" (67 pages), and "Eye Care of the Patient with Diabetes Mellitus" (133 pages), all developed and maintained through the American Optometric Association. These recommendations for patient care are synthesized from the best available research and current scientific evidence, combined with expert clinical opinion. These recommend appropriate steps in the diagnosis, management, and treatment of patients with various healthcare conditions within the profession's scope of practice. Where are our parallel audiology documents for ears and hearing and balance?

We must get serious about Clinical Practice Guidelines to which we all are held accountable, including clinical standards of care flowing from evidence-based decisions, incorporating best practices. One measure of success of advancement of audiology as a doctoring healthcare profession will be when we create our first Clinical Practice Guideline, following the IOM protocol, that we collectively agree to follow. This is what practitioners do in healthcare.

My second area of concern arises out of my mid-career phase as a researcher and executive in the hearing aid industry. As you know, the industry refers to Hearing Healthcare Professionals, combining audiology and hearing instrument specialists into one group. Why? From an industry perspective, the business is not about audiology's concerns of the diagnosis, treatment, and management of persons with hearing and balance disorders. The business is about revenues and profit from device sales. From an industry perspective, there is not a significant difference between the two professions as customers and some studies have concluded there may not be much difference between the two professions in hearing aid outcomes.

Why is this? My belief is that it is because there are many audiologists who operate at the peak scope of practice of the hearing instrument specialist, not at the peak scope of practice of the audiologist. Audiologists, with their higher education and greater scope of practice, can perform at a much higher level than hearing instrument specialists and should routinely have better patient outcomes, but that is not a universal pattern. One measure of success of advancement of audiology as a doctoring healthcare profession will be when we routinely show better clinical outcomes by all audiologists, compared to non-audiologists.

Again, let me speak to optometry. In the continuum from opticians, to optometrists, to ophthalmologists, we would all say that optometry is closer to ophthalmology than opticians. But in the continuum from hearing instrument specialists to audiologists to otolaryngologists, most of us would say audiology is perceived to be closer to hearing instrument specialists than otolaryngologists. As mentioned above, we must have standardized, best practice clinical protocols and we must adhere to these protocols, creating distance between us and hearing instrument specialists and closing the gap with the other ear doctors, the otolaryngologists. This is what healthcare practitioners do to separate themselves from technicians.

My third area of concern arises out of my current career phase in audiology education and academic administration. I, and a few others, are alarmed that the size of our profession today is essentially the same as it was two decades ago. During this same time, other healthcare professions have grown their workforce by 70%. What is the matter with our profession that it is not thriving? Part of the problem is that we have a supply chain problem; there are not enough audiology students in the pipeline and there are no plans to increase the pipeline with quality applicants. Another problem is that audiology is not attractive; it continues to be a low-paying profession in the voodoo land of 'other' in healthcare.

As an educator with an eye toward creating a better profession, I am looking for the better student. I seek the student with undergraduate training in the biomedical sciences along with knowledge of human and social factors. Unfortunately, we can't recruit these students because a career choice of optometry, pharmacy, physical therapy, podiatry,

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Brian Taylor, Au.D.

Keeping Up with Moore's Law

Since the beginning of the digital hearing aid era more than 25 years ago, audiologists have witnessed remarkable progress in signal processing capability. Driven mainly by Moore's law, a doubling of computer capacity every 12 to 18 months, hearing aid manufacturers launch a new platform at about the same pace as this decree would suggest: Every year and a half to two years, most manufacturers bring a more powerful chip to market with an array of new features and enhancements to old ones.

This incremental progress results in better sound quality, improvements in signal to noise ratio calculations and devices that are more cosmetically appealing – traits that expand hearing aid candidacy and improve wearer outcomes.

Today, this incremental progress is so common that we often take it for granted. But when you stop and think about it, a hearing device acquired in 2022 is much more sophisticated than one purchased in 1997. Not only do today's hearing aids come in a range of stylish form factors, most have direct streaming capability and several features that automatically know the difference between quiet and noisy listening places.

Despite all this innovation, there are still limitations to how much any manufacturer can do with any new platform. That is, hearing aid manufacturers must make some tough choices about how their hearing aid can process sounds and what features are operating under the hood. Figure 1 represents the three broad, interconnected categories in which manufacturers develop and commercialize new features.

Figure 1. The three interconnected categories of hearing aid features.

Let's examine these three categories in more detail. First, core signal processing refers to the features in hearing aids that restore audibility of sound, improve the signal to noise ratio and listening comfort. Features involving gain, output and compression that are always working behind the scenes to shape and amplify sounds fall into this category. Core signal processing is the workhorse of the hearing aid. It is always operating, shaping sound into the wearer's individual residual dynamic range.

Second, we have wireless connectivity. This is the technology used to wirelessly transmit sound directly into the hearing aid. Wireless connectivity is also used by a pair of hearing aids to communicate

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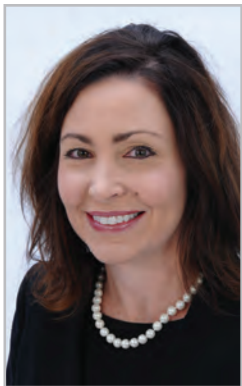
Stephanie Czuhajewski, MPH, CAE, Executive Director



Don't Wait to Advocate in Your State—Join Your State Audiology Association Today and Get a Discount from ADA

Licensure requirements, scope of practice, telehealth, insurance mandates, and many consumer protections are determined by state statutes and regulations. While federal laws can preempt the state in certain circumstances, state laws have by far the greatest day-to-day impact on audiologists and their practices.

State audiology associations play an essential role in protecting and advancing the profession of audiology, evidence-based hearing and balance care, and patient access to audiology services. State organizations cannot perform these critical functions without active, engaged, and committed members—and a lot of them.

While ADA staff and volunteers play a supporting role in monitoring and advocating on state policy issues that impact members and stakeholders, well-resourced state audiology associations are far better positioned to act, because they have the historic and practical knowledge of given state policy issues and the standing and credibility as constituents and local experts to build relationships that address both policies and politics at the state level.

Increasing the influence of ADA members within state audiology associations will help align federal advocacy initiatives such as the Medicare Audiologist Access and Services Act (MAASA) with state laws that govern the services that audiologists deliver and dictate how those services are delivered, so that audiologists can practice in a manner that reflects their extensive training, education, and expertise.

Three things that you and your colleagues can do immediately to fortify state advocacy efforts include the following:

1. Join or renew your membership in your state audiology association.
2. Volunteer your time and talent to strengthen your state audiology association.
3. Make financial contributions to support your state association PAC, lobbyist, or other state advocacy initiatives. These costs are beyond those typically covered by membership alone.

To recognize, support, and encourage ADA member participation in state audiology associations, ADA is offering a $50 discount on ADA 2022 membership dues renewals for members who also commit to join or renew their state audiology association membership for 2022. ADA is also offering a $200 discount on ADA practice memberships for practices with four or more audiologists who participate in their state association for 2022. Please contact Parker Allen at pallen@audiologist.org for more information and to claim this offer.

ADA members are hands-down the strongest audiologist advocates for their patients and for policies that improve patient outcomes and support evidence-based practices in the delivery of audiovestibular care. Thank you for all you do for your patients and your profession, and Happy Holidays!■

OPTIMIZING SOUND IN SIGNAL PROCESSING AND HEARING AID FITTING

By Laura Winther Balling, Ph.D. and Dana Helmink, Au.D.

The Widex MOMENT™ hearing aid platform brings two major innovations in sound. With the introduction of the TruAcoustics™ fitting formula, it provides an easier, more accurate way to adjust gain to the individual hearing loss and the acoustics of the individual ear canal for all users, but with a special focus on those using instant tips. The solid fitting of TruAcoustics provides the necessary foundations for the most revolutionary innovation in MOMENT: the radical reduction of signal processing delay implemented in the PureSound™ program for mild-to-moderate hearing losses.

These innovations are the latest in a long history of focusing on sound quality. This focus means that all design choices are made with the purpose of creating the most natural sound possible: a sound at the eardrum that is accurate, complete, and free from distortions. Design choices such as the decision to build a filter bank in the time domain and setting a sampling rate as high as 33.1kHz ensure that sound quality is not only maintained but exceeds what many considered necessary in hearing aids.

Choosing a time-domain filter bank initially makes it more challenging to optimize power consumption and some aspects of signal processing, compared to the more commonly used frequency-domain filter banks, but ultimately this complements the human auditory system and helps optimize sound quality. Combined with the highest sampling rate in the industry, which significantly reduces artifacts in the signal that would otherwise need to be fixed, this has enabled Widex to have a market-leading processing delay (2.5 ms on average), which was even further reduced with PureSound. In this article, we show how these two major innovations in sound quality – reduction of delay and individualized gain calculation – show effects across technical measurements, laboratory studies and real-life use.

The Physics of Delay and Why It Matters

Processing delay arises in digital hearing aids because signal processing takes time, generally with average delays in the range from 5 to 8 ms (see left panel of Figure 1). This is well below the threshold where the auditory and visual signals become mismatched, so with an entirely closed ear mold, delay is not a problem. However, in open and vented fittings, it does become a problem, because the delayed amplified signal mixes with the direct sound that reaches the eardrum through the venting, resulting in an audible artifact known as comb-filtering. This arises because the two sound sources are out of sync and in turn add up or cancel each other out, making the gain-frequency curve resemble the teeth of a comb (see right panel of Figure 1). The perceptual experience is a tinny, artificial sound.

The problem of delay is not an easy one to fix, because processing necessarily takes time. It is also not a problem that the hearing industry has focused on solving, possibly due to a consensus that delays below 10 ms are tolerable (Stone & Moore, 1999, 2002, 2003, 2005; Stone, Moore, Meisenbacher, & Derleth, 2008). However, "tolerable" sound is not the same as ideal sound, so Widex developers set out to reduce delay, taking advantage of the Widex choice of a time-domain filter bank and high sampling rate to create a signal-processing pathway with mean delay below 0.5 ms. The result is a smooth gain-frequency curve (see blue line in

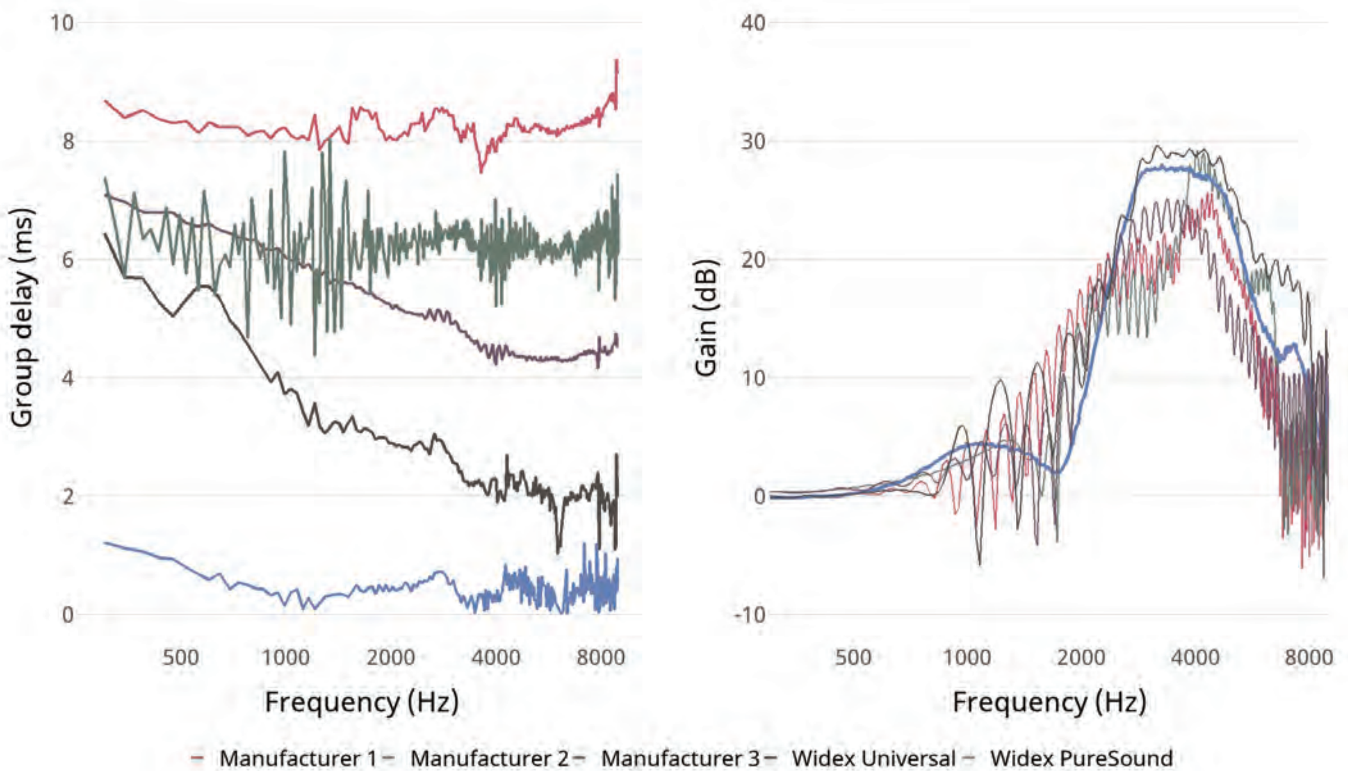


Figure 1: The left panel shows group delay by frequency for five top hearing aids, while the right panel shows the comb-filtering that is the result of the longer delays. For more detail, please see Kuk and Slugocki (2021)

Figure 1) and a natural sound without comb-filtering. This ZeroDelay™ signal processing is implemented in the PureSound program, which is targeted towards hearing aid wearers with mild-to-moderate hearing losses, who are likely to have the open and vented fittings where comb-filtering is a problem – and are also more likely to hear the improvement in sound quality.

Delay and Hearing Experience

The measurements illustrated in Figure 1 show a clear advantage for Widex PureSound, but a key question is of course how the signal-processing speed translates into the hearing experience of the wearers. To test this, we conducted a series of studies, investigating perceived sound quality, speech intelligibility in realistic conditions, and neural response using EEG.

In a guided walk study (Balling, Townend, Stiefenhofer, & Switalski, 2020), we included 21 participants: 13 in the PureSound target group of new and experienced hearing aid users with mild-to-moderate hearing loss, and eight with normal hearing in order to gauge the similarity between PureSound and unamplified sound. Participants indicated their preference for PureSound vs. standard delay processing in 20 different scenarios, including listening to speech in quiet and different types of noise, to own voice, to different ambient noises and to specific sounds in the environment. In all scenario types, the majority of preferences were for PureSound, and there were overall significantly more preferences for PureSound compared to standard delay. Most strikingly, 85% of participants with hearing loss and 100% of normal-hearing participants indicated an overall preference for PureSound.

In short, the research showed a clear sound quality preference for PureSound. However, it remains important to verify that this preference does not come at a cost of reduced speech intelligibility, also because, in order to keep delay ultralow, PureSound operates with an omnidirectional microphone. This choice is justified by the fact that the SNR improvement resulting from directional processing is low for the open and vented fits for which PureSound is appropriate (e.g. Magnusson, Claesson, Persson, & Tengstrand, 2013).

Speech intelligibility was investigated using the repeat portion of the Quick Repeat-Recall test (Quick RRT), testing three realistic signal-to-noise ratios (Kuk, Ruperto, Slugocki, & Korhonen, 2020). The test compared PureSound to top-of-the-line hearing aids from two other manufacturers that include directional processing. The results for 21 participants

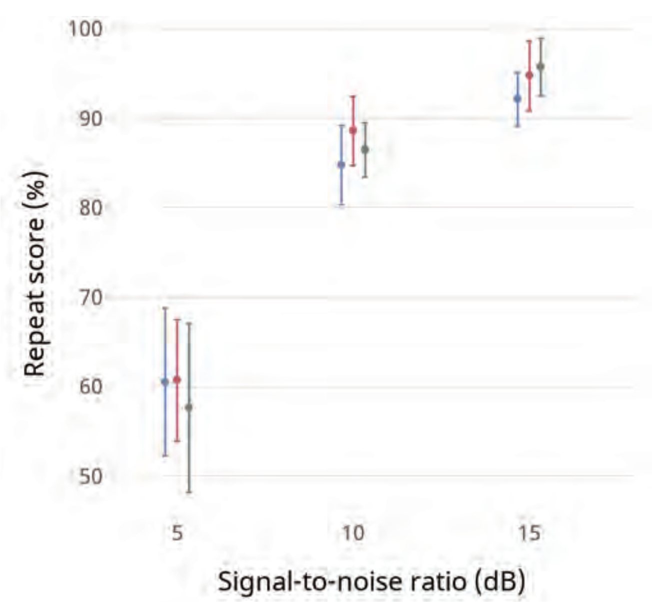


Figure 2: Repeat score from the Quick RRT. Circles represent the mean score, with error bars indicating 95% confidence intervals.

with mild-to-moderate hearing loss are illustrated in Figure 2 and show no significant differences between the three types of processing in any of the three realistic SNR conditions.

Together the two results show the PureSound program to have superior sound quality, with speech understanding on par with other leaders in the industry. To further understand these results, an EEG study (Slugocki, Kuk, Korhonen, & Ruperto, 2020) compared PureSound with the same two hearing aids as in the Quick RRT study, which have delays of 8 ms (Manufacturer 1) and 5 ms (Manufacturer 2). This study focused on the envelope-following response (EFR), the neural representation of the stimulus envelope, which should be more robust for less distorted signals. This is exactly what Figure 3 shows: The envelope of the /da/ stimulus in red is much more clearly matched by the neural envelope-following response for PureSound (top panel), while the EFR is distorted for the other hearing aids.

A more accurate neural representation of the envelope has been associated with more robust speech comprehension (Song, Skoe, Banai, & Kraus, 2011); thus, the EFR advantage for PureSound signal might contribute to the performance on the Quick RRT. Similarly, a more faithful neural representation may also contribute to the sound quality preference for PureSound observed in the guided walk study.

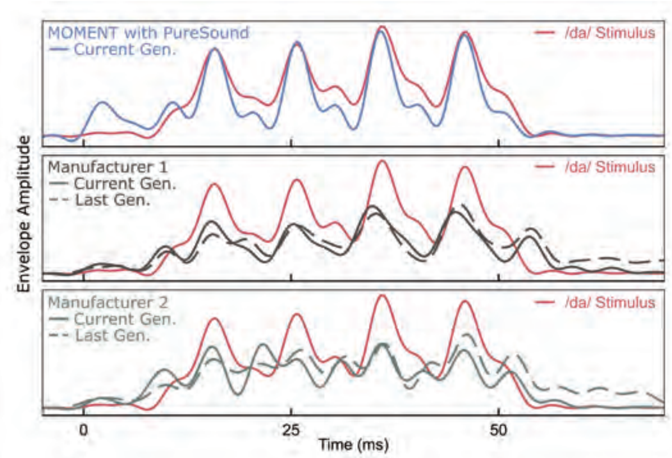


Figure 3: Envelope-following response for PureSound, compared to Manufacturer 1 (average delay 8 ms) and Manufacturer 2 (average delay 5 ms).

Individual Variation in Gain with Instant Ear Tips

While PureSound processing is ideal for individuals with mild-to-moderate hearing losses, the MOMENT platform is focused on sound quality for all hearing aid users, not just for this group. One particularly important consideration throughout the hearing loss range is the choice of ear tip and how this interacts with the acoustics of the individual wearer's ear canal.

As a basis for understanding this – and developing appropriate solutions – we conducted a large-scale study of how instant ear tips affect the gain at the eardrum with real-ear measurements for 58 ears (Balling, Jensen, Caporali, Cubick, & Switalski, 2019). Among other things, the study measured the vent effect (VE), the difference in real-ear aided response (with streamed sound) between a setup with just the hearing aid in the ear and a setup with the hearing aid in the ear and the ear completely occluded with impression material. This comparison indicates how much of the amplified sound escapes the ear.

The results are shown in Figure 4. The top left panel shows the average VE for all instant ear tips, which occur in the order that we would expect, with the open ear tips (red) showing the largest VE and the double domes (gray) the smallest. What is more interesting, however, is the variation between individual wearers that becomes apparent when considering each ear tip individually in the remaining panels. For each ear tip, there is substantial variation between individual ears, indicating that the amount of amplified sound "escaping" through the vent varies substantially between individuals. This applies to all types of instant ear tips, but it is

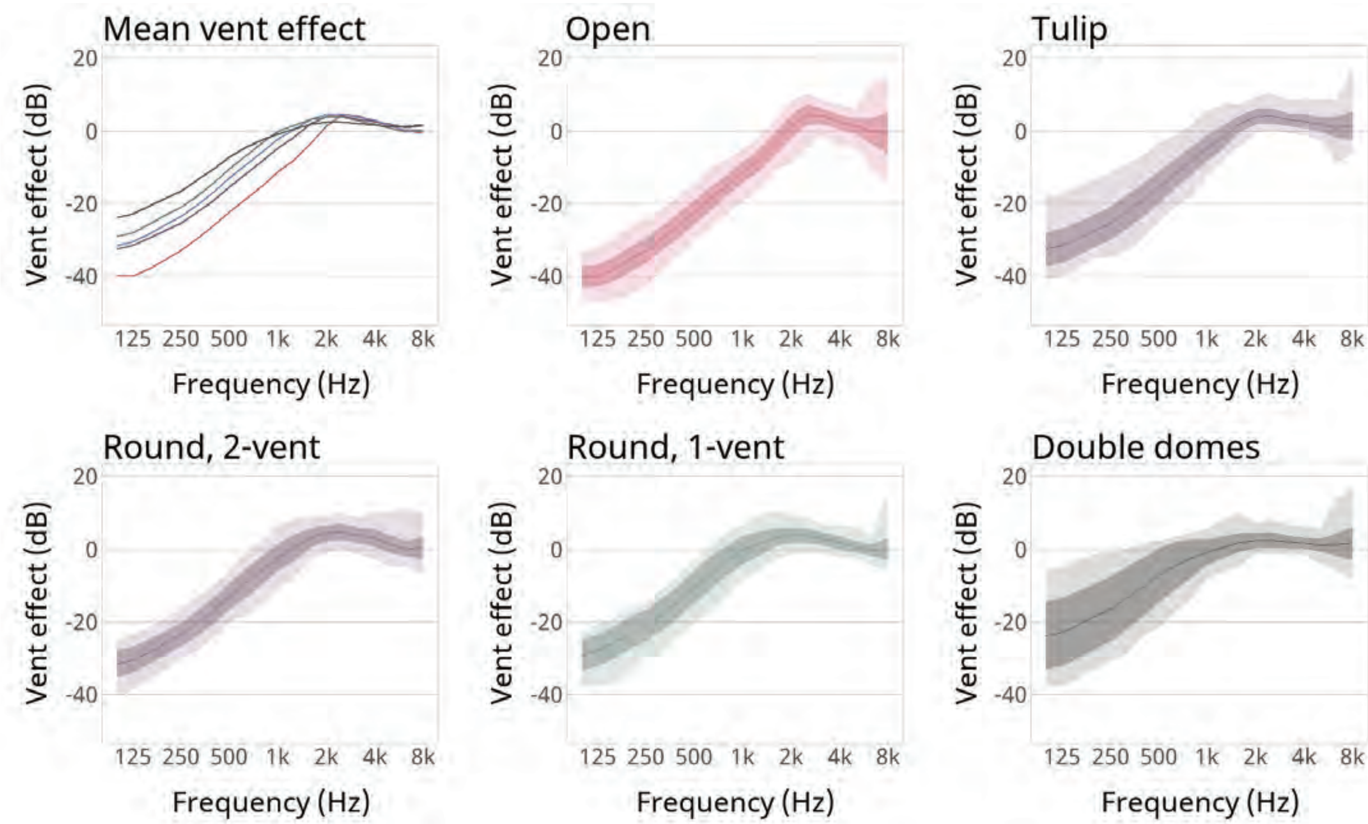


Figure 4: Vent effect measurements in 1/3 octave bands for different instant ear tips. The top left panel shows averages for all instant ear tips, the remaining five panels show mean (solid line), +/- 1 standard deviation (darker shaded area) and the full range of observed measurements (lighter shaded area).

particularly pronounced for the double domes, which are almost entirely occluded for some individuals and much more open for others.

The implication of these measurements for clinical practice is that the hearing care professional may choose an instant ear tip and expect it to behave in a certain way, but the individual fitting may give very different gain than expected. Given the results shown in Figure 4, this is expected to occur for many, if not most, instant ear tips, irrespective of brand. To avoid this problem and allow gain that is individualized to each hearing aid user, the Widex TruAcoustics fitting algorithm uses the feedback test to estimate the vent effect in the individual ear canal and adjust the gain accordingly. This results in a precise individualized fitting, where gain is not only adjusted to audiometric thresholds, but also to the specific anatomy of the individual wearer's ear canal. Correct calculation of gain for soft, normal and loud input is of course central to an accurate and natural sound.

Sound Experiences in Real Life

While measurements and study results like the ones reviewed here are important, and we do all we can to make them as relevant to real life as possible, it remains crucial to also gauge the experience of hearing aid wearers in their daily lives. To this end, we conducted a survey of 101 experienced hearing aid wearers who tried out the Widex MOMENT hearing aids in normal use (Balling, Townend, & Helmink, 2021). The hearing aid wearers were fitted with MOMENT hearing aids and answered a range of questions about their experiences with both their own existing hearing aids and the MOMENT hearing aids. The Widex emphasis on sound quality should result in high ratings of sound quality satisfaction and naturalness for the MOMENT hearing aids, which is exactly what we see in Figure 5.

The left panel shows the degree of satisfaction with the sound quality of the hearing aids, with a significantly different distribution of ratings for own hearing aids compared to the MOMENT hearing aids. If we translate the satisfaction into scores from 1 to 7, the mean satisfaction is 6.0 for the MOMENT hearing aids, corresponding to a mean rating of 'Satisfied'. For own hearing

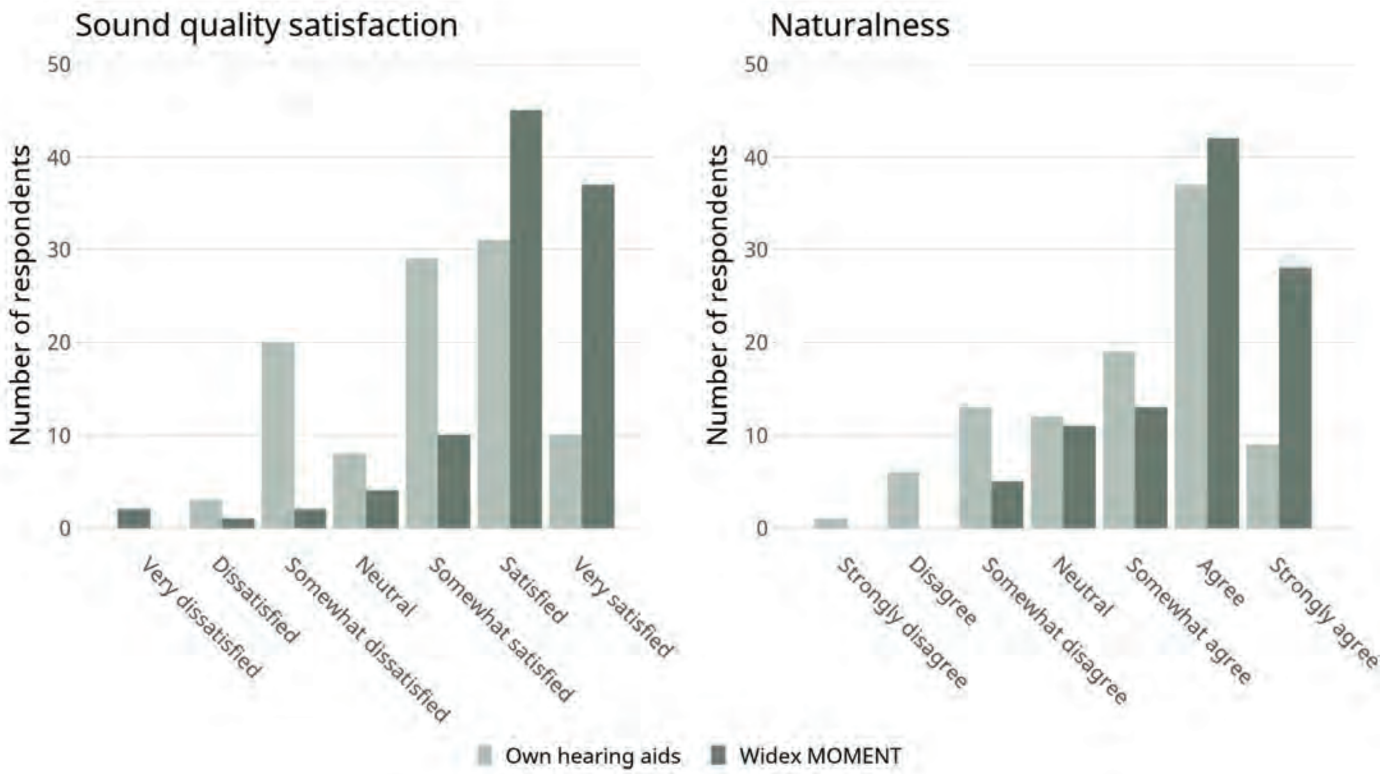


Figure 5: Ratings of sound quality satisfaction and naturalness from 101 experienced hearing aids users for their own hearing aids and Widex MOMENT.

aids, the mean is 4.9, corresponding to a mean rating just below 'Somewhat satisfied'. Focusing on the high end of the scale, the number of wearers who are very satisfied with the sound quality is almost four times as high for MOMENT as for own hearing aids. All in all, 91% indicate that they are satisfied with the sound quality of MOMENT.

The right panel shows the respondents' agreement with the statement "I find that sounds are natural with my own hearing aids/ the Widex MOMENT hearing aids." Again, we see a significantly different distribution of answers, with a mean rating of 5.8 for MOMENT and 5.0 for own hearing aids. This difference is particularly striking in view of the fact that the hearing aid wearers are habituated to their own hearing aids, and as such could be expected to find them more natural.

The high sound quality ratings are undoubtedly partly a result of the innovations in signal processing and fitting in the MOMENT hearing aids, but also a consequence of earlier design choices. To explore the development over time in more detail, a comparison between sound quality ratings in surveys of consecutive platforms of hearing aids is shown in Figure 6 (based on data from Balling et al., 2021; Balling, Townend, & Switalski, 2019; Kuk, Lau, Seper, & Sonne, 2016). This focuses on the top two ratings of 'Satisfied' and 'Very satisfied', and on those users whose own hearing aids were other brands than Widex. For all generations, the sound quality satisfaction is significantly higher for the Widex hearing aids, demonstrating the real-life effect of a design focus on sound quality. In addition, we see an increase in the proportion of respondents who are satisfied or very satisfied from platform to platform, with a particularly large jump from 2018 to 2020, which may be ascribed to the introduction of TruAcoustics in fitting and ZeroDelay processing in the PureSound program.

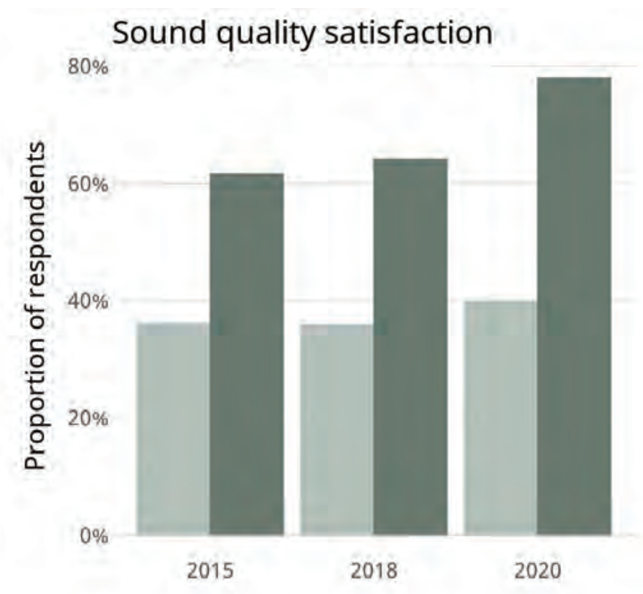


Figure 6: Sound quality satisfaction across generations of hearing aid platforms.

Conclusion

Building on decades of sound-quality focused development, the MOMENT platform enables sound to be handled differently depending on the hearing loss, with TruAcoustics adjusting gain to the acoustics of the individual's ear canal, and ZeroDelay processing virtually eliminating comb-filter distortion. These approaches optimize the signal for a truly individualized sound quality, showing clear advantages in technical measurements that translate into great individual hearing experiences in both lab studies and real life. ■

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WHY PLACE A MICROPHONE IN THE EAR CANAL?

A Review of the M&RIE Receiver

By Laurel Christensen, Ph.D. and Jennifer Schumacher, Au.D.

INTRODUCTION AND RATIONALE

In 2003, ReSoundAIR™ was introduced as the first small, behind-the-ear (BTE) hearing aid with a thin tube that could be coupled to the ear using a completely open dome. At this time, approximately 80% of the hearing aids fit in the US were custom, in-the-ear hearing aid styles, as suggested by the sample surveyed in Kochkin (2002). Custom in-the-ear hearing aids were popular because of their relatively small size, but occlusion was a common side effect that kept people who purchased hearing aids from using them (Kochkin, 2000). The combination of the open dome fitting and digital feedback suppression in ReSoundAIR solved the occlusion problem while also providing cosmetic appeal with the thin tube and small size (Nelson, 2005). Today, it is commonplace for these small, thin-tube hearing aids to place the receiver in the ear. This style, that can still be worn completely open, is known as a receiver-in-the-ear (RIE) hearing aid. In 2019, RIE hearing aids made up 78.4% of the hearing aids dispensed in the US (Strom, 2020), completely reversing the trend toward fitting custom in-the-ear products.

Unfortunately, while solving one major problem for users of hearing aids, RIE and BTE hearing aids created another one. The microphones on BTE and RIE hearing aids are located above the user's ear. This means that sounds processed by the hearing aid are not filtered by the user's pinna and ear canal. This change in the natural location of incoming sounds impacts sound quality and ultimately interferes with a listener's spatial perception.

To better understand why hearing aid microphone location matters, a review of outer ear acoustics is worthwhile. The pinna and ear canal shape and amplify sound due to their resonant effects. Resonance varies due to the length of the ear canal and the shape and size of the pinna, thus resonant effects are unique to every person. In general, the combined effect of the ear canal and concha resonances results in an approximately 15 dB increase in SPL at the ear drum from 2000 to 5000 Hz (von Békésy, 1960). Hearing healthcare professionals (HCPs) insert a microphone in the ear to measure these resonances as part of our hearing aid fitting because the individual differences matter for an accurate fitting.

Imagine a situation where there are several sounds in the environment, like the living room in your home. There might be a TV on and then some conversation happening. For a listener with normal hearing, it is quite easy to switch attention between the TV and the conversation.

One reason for this is that listeners with normal hearing can interpret the varying spatial relationships between sound sources. Without these spatial cues, listeners feel as if all the sound is "inside their heads" rather than externally located in the environment. Listeners lose the ability to detect depth and details of sound if spatial cues are taken away. Stated simply, a listener loses spatial perception without pinna acoustics. While spatial perception is not required for listeners to experience better audibility with hearing aids, Gatehouse and Noble (2004) have pointed out that it is important that listeners can "locate, identify, attend to, and switch attention between signals so as to maintain communicative competence and a sense of connection with their surroundings" (p. 86). Indeed, MarkeTrak 10 found that the strongest factor driving user satisfaction was "hearing aid performance and sound," which includes the ability to tell the direction of sound (Picou, 2020).

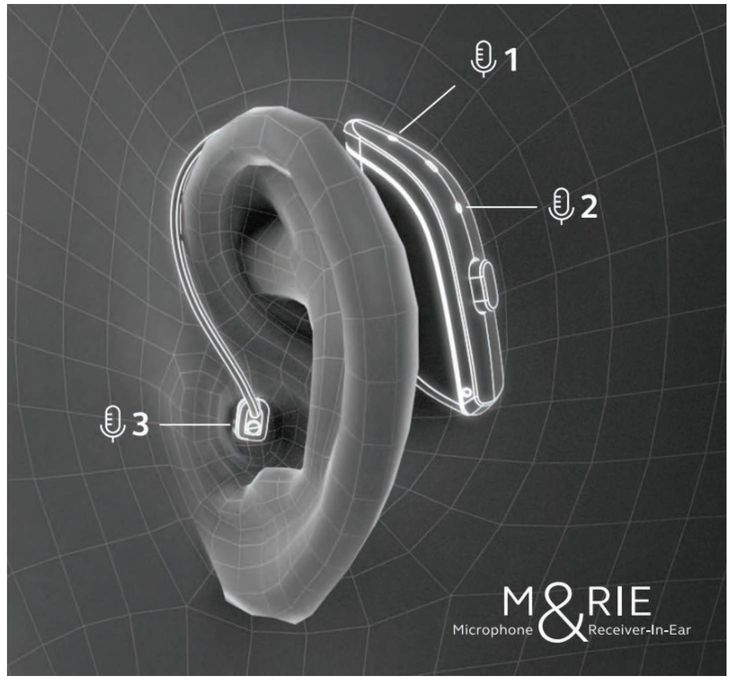

Figure 1. Illustration of the ReSound ONE hearing aid and microphone-in-receiver (M&RIE). Two microphones (1 and 2) are located on the top of the hearing aid, while the third microphone (3) is built into the receiver module that sits inside the user's ear canal.

The pinna and ear canal also impact sound source localization. Due to the different wavelengths of sound and the shape and size of the ear, head and body, frequencies above 1000 Hz are "shadowed." How much they are shadowed depends on the location of where the sound is coming from, and these changes are our clues to localization. The technical term for this unique shaping is the head-related transfer function (HRTF). No two people have the same HRTF, meaning that every person hears in a way that is unique to them. These cues help us with localizing sound sources, sound source separation, determining what sounds natural to us, and perceiving auditory distance. In fact, hearing via one's own HRTFs is the only way to truly experience immersive, natural sound. Ask any gamer about the importance of spatial perception and they will talk at length about headphones with special listening features that incorporate processing with HRTFs to create a more realistic experience. This type of audio incorporated into headphones allows a gamer to hear approaching footsteps and exactly the distance and direction they are coming from. It can mean the difference between living and dying "virtually."

ReSound ONE microphone and receiver in ear (M&RIE)

ReSound has a history of taking inspiration from the natural ways we hear and listen. Therefore, we developed a receiver with a built-in microphone to be placed inside the ear canal in one small wearable module, putting the sound pick-up location where it naturally belongs. The microphone-and-receiver-in ear (M&RIE) is an option on ReSound ONE RIE hearing aids. ReSound ONE features two microphones on the body of the RIE device, while using M&RIE as a third microphone that picks up sound at the entrance of the ear canal (Figure 1). The sound input from M&RIE is shaped by the user's own unique acoustic cues for individualized sound quality, spatial perception and localization. The M&RIE microphone is active in quiet and moderately complex listening environments, where spatial hearing contributes importantly to the listening experience. In noisier situations, the directional microphones on the hearing aids are activated for an additional signal-to-noise ratio (SNR) advantage.

Current RIE and BTE hearing aids often employ a feature based on the directional microphone system to "recreate" the spatial cues of the pinna. These pinna compensation techniques shift the directivity patterns of the hearing aid microphones, based on estimates of an average adult HRTF for sound in the horizontal plane. M&RIE differs from this technique by preserving the user's actual acoustic cues in three-dimensional space, so that it is similar to listening with an open ear. Figure 2 shows measurements taken inside the ear canal of a listener as sound is presented 360 degrees around the head in the horizontal plane. The measurements indicate the intensity of the sound at varying frequencies and azimuths for an open ear, a RIE hearing aid using pinna compensation and a M&RIE hearing aid. Note how the color patterns, which represent the sound intensity, more closely match between the open ear and M&RIE plots. While the pinna compensation algorithm has a general pattern similar to the open ear, there is more detail preserved in the M&RIE measurement.

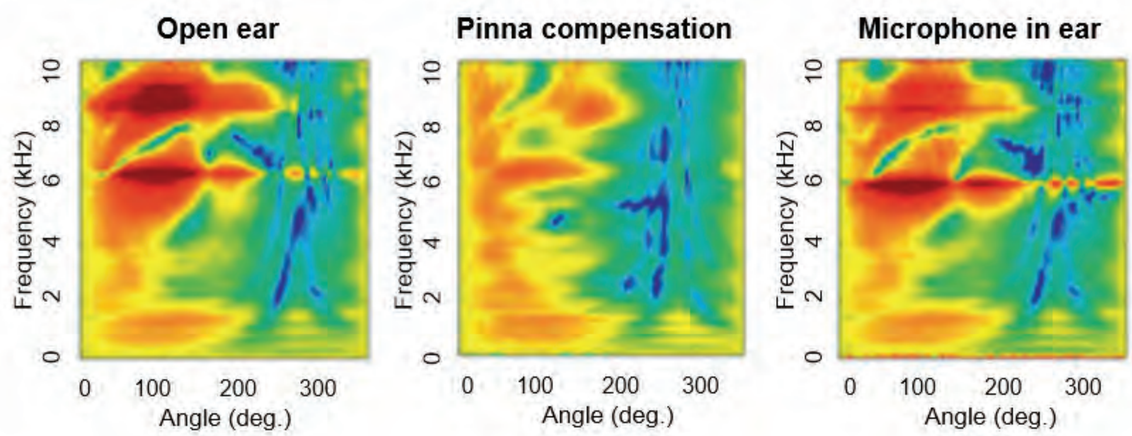

Figure 2. Three-dimensional in-ear measurements of sound presented 360 degrees around the head and body. Sound intensity is indicated by color, with blue = low intensity and red = high intensity. These plots show how the head related transfer function (HRTF) impact sound intensity at varying frequencies and azimuths. From Groth (2020).

CANDIDACY

The placement of a microphone in the canal within the receiver module is made possible by digital feedback cancelation. People with hearing losses ranging from mild to severe can benefit from M&RIE; like any hearing fitting, the coupling to the ear canal depends on the balance between need to reduce occlusion, likelihood of feedback, and need for low frequency gain. For this reason, there are two fitting ranges for M&RIE, which are displayed in Figure 3. For users with normal hearing or a mild hearing loss through 1000 Hz (indicated by the light grey range), a closed dome, tulip dome, or micromold should be fitted. The closed dome and tulip dome provide the same degree of openness, with a 10 dB vent effect at 500 Hz. Note that high frequency thresholds for these users should not exceed 70 dB HL, as there will be virtually no attenuation in the feedback path from the receiver back to the M&RIE microphone with an open fitting. For users with moderate-to-severe hearing loss in the low frequencies (indicated by the dark grey range), a power dome or closed micromold should be fitted and in this case, high frequency thresholds can exceed 70 dB HL, as seen on the figure.

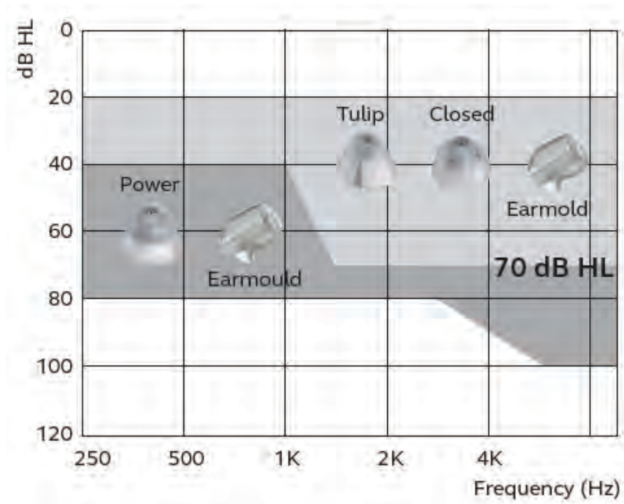

Figure 3. Fitting ranges for the M&RIE receiver. The light gray range indicates the fitting range for listeners with normal hearing to mild hearing loss in the low frequencies who are candidates for open fittings. The dark gray range indicates the range for listeners with moderate-to-severe low frequency hearing loss who are candidates for closed fittings.

BENEFIT

For users that are candidates, there is substantial evidence that M&RIE provides benefits compared with listening with microphones above or behind the ear in four areas: sound quality, localization, listening effort, and wind noise reduction.

Sound Quality

The first studies on M&RIE tested the idea that customization of pinna cues would lead to better outcomes on measures of sound quality and spatial perception, compared to a pinna compensation algorithm (Groth, 2020). Five normal-hearing participants evaluated overall sound quality and spatial sound quality of M&RIE under headphones using a sound quality evaluation method developed by Legarth et al. (2012). To make this test possible, the sound stimuli for each listening condition were filtered for

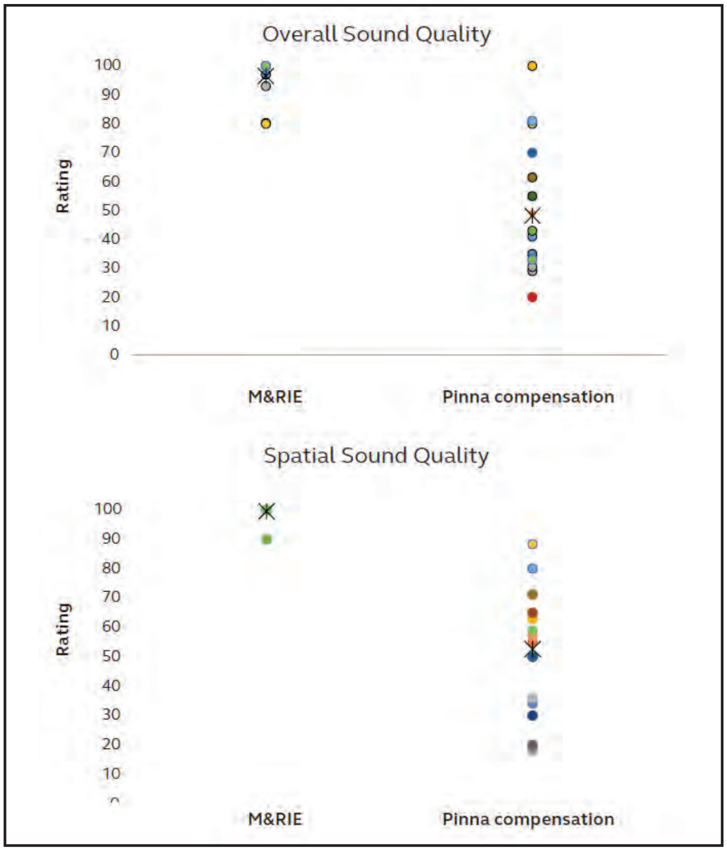

Figure 4. Individual participant ratings of overall sound quality and spatial sound quality for the M&RIE and pinna compensation. The black "X" shows the mean rating for each condition. Consistently favorable ratings with a small distribution were observed for the M&RIE. More variation in the results with pinna compensation reflect the variation of individual differences in how sound is filtered by the listener's individual anatomy. From Groth (2020).

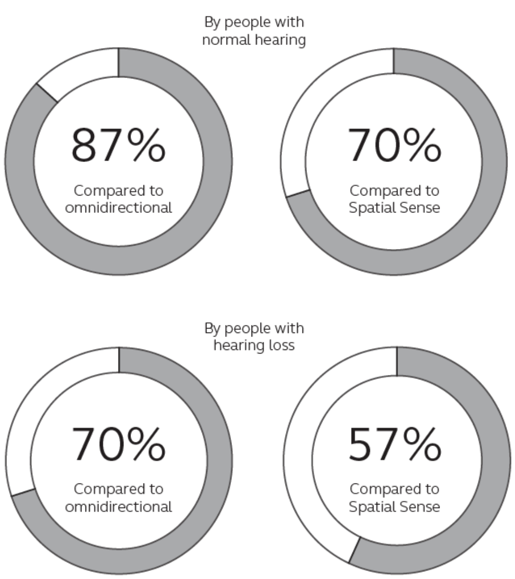

Figure 5. The listeners with normal hearing showed a strong preference for M&RIE over both omnidirectional and pinna compensation (Spatial Sense) when asked to rate sound quality of three sound scenarios (cafeteria with talker, traffic, train station). The preference for M&RIE was statistically significant compared to the other two programs ($p < 0.05$). The listeners with hearing loss also showed a preference for M&RIE compared to omnidirectional, which was statistically significant ($p < 0.05$). There was a less marked preference for M&RIE compared to Spatial Sense, though this difference was not significant. From Jespersen et al. (2020).

each individual participant from varying distances and directions. This created a custom set of filters for each of the five listeners' ears, that could then mimic M&RIE microphone placement and RIE microphone placement above the pinna (pinna compensation). For overall sound quality, they were to listen for clarity, timbre and naturalness. For spatial sound quality, they were to listen for ability to localize sounds, definition of sound, and spaciousness or sense of the room. The stimuli included an office scene, a cafeteria scene and jazz music. Results can be seen in Figure 4. The average overall quality rating and the average overall spatial quality rating for M&RIE was twice as high as for pinna compensation. What is most striking is the lack of variability in the M&RIE rankings versus the pinna compensation. The ratings of pinna compensation across individuals ranged from poor to nearly as good as M&RIE. This variation is an expected finding because when people have very different anatomical characteristics than the average HRTF, the sound delivered via pinna compensation will be less natural and of inferior quality to that picked up at the M&RIE microphone location.

To determine if the results discussed above would hold when participants were fitted with hearing aids and M&RIE, Jespersen et al. (2020) carried out a sound quality test with ten normal-hearing listeners and ten listeners with bilateral mild-to-moderately sloping sensorineural hearing loss. The participants listened to three sound scenes - a cafeteria setting with a target talker, traffic noise and a train station – with three different hearing aid programs: omnidirectional, pinna compensation (ReSound Spatial Sense feature), and M&RIE. The participants were asked to rate sound quality using attributes such as naturalness, clarity and spatial perception in a paired comparison task.

Results from this experiment are shown in Figure 5 for participants with normal hearing (top row) and participants with hearing loss (bottom row). Data across the listening scenarios were combined for a total of four comparisons. M&RIE was the top choice for sound quality in three out of four comparisons. The listeners with normal hearing preferred M&RIE 87% of the time over omnidirectional and 70% of the time over Spatial Sense, which was a statistically significant preference in both cases. The listeners with hearing loss also showed a preference for M&RIE, with M&RIE chosen 70% of the time over

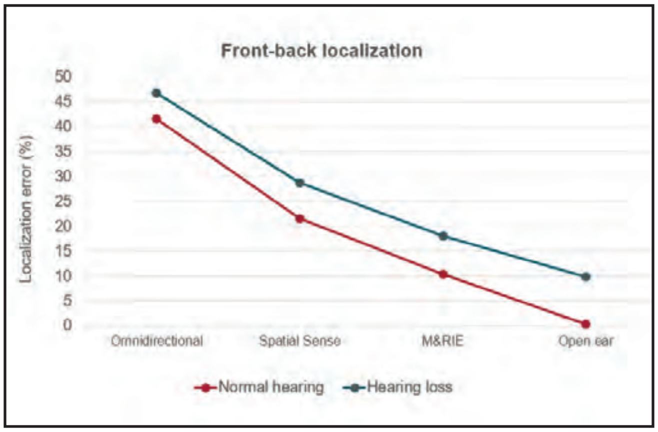

Figure 6. Front-back localization errors for participants with normal hearing (blue) and hearing loss (red). Lower values indicate better localization. Both participant groups performed poorest in omnidirectional mode and performed best with no hearing aids (open ear). Significantly less errors were observed in M&RIE as compared to omnidirectional mode. Open ear performance was significantly better than omnidirectional and Spatial Sense but was not different from M&RIE. Adapted from Jespersen et al. (2020).

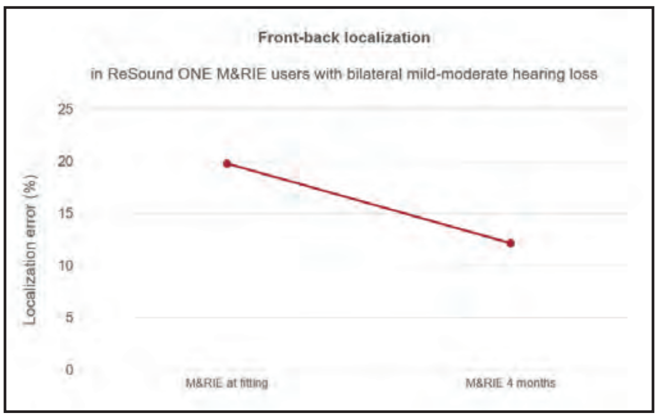

Figure 7. Front-back localization errors (in %) for participants with hearing loss at fitting with M&RIE after four months of wear time with M&RIE. Front-back errors were 19.8% at fitting and 12.2% at the four-month follow up. The improvement in front-back localization following four months of use was statistically significant ($p < 0.05$). Adapted from Jespersen (2021).

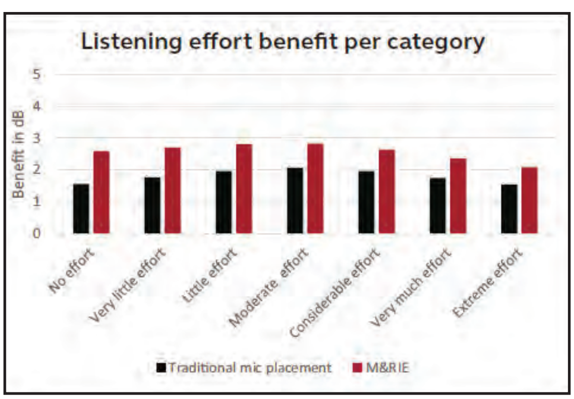

Figure 8. Listening effort benefit for traditional microphone placement versus M&RIE using Adaptive Categorical Listening Effort Scaling (ACALES) procedure. When participants reported "No effort" during the listening task, M&RIE showed more than 1 dB of benefit over the traditional receiver, while situations requiring "Extreme effort" showed less than a 0.5 dB difference. From Quilter et al. (2021).

omnidirectional and 57% of the time over Spatial Sense, though this difference was only statistically significant in the M&RIE/omnidirectional comparison. At the conclusion of the data collection, comments from the participants in both hearing groups suggested that M&RIE was chosen based on reduced background noise, increased clarity of speech and better spatial perception.

Localization

The ability to locate the source of a sound in an environment is often a difficult task for people with hearing loss, and one that can be degraded by hearing aid use because of the loss of pinna cues (Akeroyd, 2014). However, localization performance has been shown to improve in users fitted with M&RIE, as compared to hearing aids with traditional microphone placement at the top of the device.

Jespersen et al. (2020) conducted an evaluation of localization comparing unaided, omnidirectional, Spatial Sense, and M&RIE conditions. Ten adults with normal hearing and ten adults with bilateral mild to moderate sensorineural hearing loss participated in the study. The listeners were seated in an array of 12 loudspeakers spaced 30 degrees apart and listened to short bursts of white noise. Their task was to identify the loudspeaker from which the sound originated. Localization performance was measured in "front-back error," which reflects the percent of time confusions between front and back sound locations were made. The results are shown in Figure 6. Note that lower scores indicate less errors and therefore better localization.

Both participant groups performed poorest in omnidirectional mode and best with no hearing aids (open ear). The mean percent of front-back errors in the group with normal hearing was 42% in omnidirectional, 22% using Spatial Sense and 10% using M&RIE, with 0% errors in the unaided condition. The group with hearing loss had mean percent of front-back errors of 47% in omnidirectional, 29% using Spatial Sense, 18% using M&RIE and 10% while unaided. The pattern of performance was similar between the two participant groups, which demonstrates how microphone placement on the top of a hearing aid can alter localization cues for even people with normal hearing. M&RIE significantly improved front-back localization in both groups over omnidirectional mode ($p < 0.05$). In addition, unaided open ear performance was significantly better than omnidirectional and Spatial Sense modes for both participant groups; however, there was not a significant difference in unaided and M&RIE performance. M&RIE was the only hearing aid condition that allowed users to localize in a way similar to the open ear.

An additional investigation into localization performance was conducted as part of a two-year longitudinal study following twelve adult users fit with ReSound ONE and M&RIE (Jespersen, 2021). Localization using M&RIE was evaluated at the initial fitting (as in the above study) and after four months of wear time. The results can be seen in Figure 7. The front-back error score at the fitting with M&RIE was nearly 20%, which is very similar to the score for participants with hearing loss using M&RIE from Jespersen et al. (2020). After four months of wearing ReSound ONE with M&RIE, front-back localization errors decreased to 12%. This improvement in front-back localization was statistically significant ($p < 0.05$), suggesting that users can gain benefit from M&RIE following an acclimatization period of use.

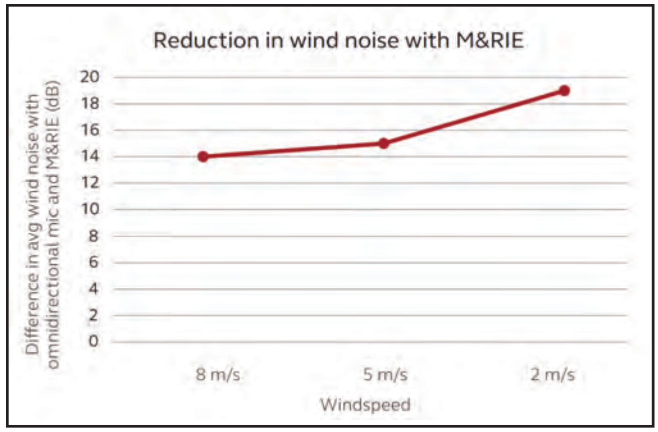

Figure 9. Reduction in wind noise with M&RIE compared to omnidirectional microphone on the RIE at different wind speeds. From Groth (2020).

Listening effort

Listening effort can be defined as the mental resources deliberately allocated for listening and attending to auditory tasks (Pichora-Fuller et al., 2016). People with hearing loss can expend a lot of effort when listening in noisy or complex situations, which is correlated with increased listener fatigue (Hornsby, 2013). Various laboratory experiments suggest that hearing aids do appear to reduce listening effort, though it is less clear how particular features (e.g., digital noise reduction) may contribute (Hornsby, 2013; Desjardins & Doherty, 2014; Desjardins, 2016). It was hypothesized that M&RIE could reduce listening effort for hearing aid wearers, due to its inclusion of user-specific auditory cues. To test this idea, an investigation was carried out at Hörzentrum (Hearing Center) Oldenburg in Germany (Quilter et al., 2021). Twenty-four experienced hearing aid adult users with bilateral mild-to-moderate hearing loss participated in the study. The participants were fit with ReSound ONE hearing aids. The Adaptive Categorical Listening Effort Scaling procedure (ACALES) (Krueger et al., 2017) was used to measure listening effort in three conditions: unaided, a traditional receiver and M&RIE. ACALES measures subjective listening effort as a function of signal-to-noise ratio (SNR) – as SNR becomes poorer, listening effort tends to increase. On this test, a lower dB SNR score means less listening effort was needed in that condition. Compared to unaided listening, there was a 2.6 dB reduction in listening effort for M&RIE, and a 1.8 dB reduction for the traditional receiver. This reduction in listening effort was statistically significant when compared to unaided ($p < 0.05$), though not different between the two receiver conditions. However, upon examination of listening effort ratings between the two receivers, M&RIE shows a consistent trend towards better scores, especially in conditions where less listening effort was required (Figure 8). This suggests that M&RIE may provide an advantage over a traditional receiver in less noisy or complex situations that users typically spend most of their time listening.

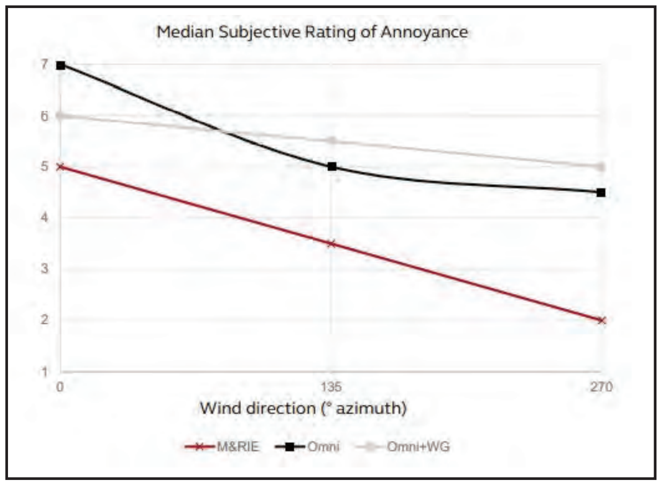

Figure 10. Median subjective ratings of annoyance with three conditions: M&RIE, omnidirectional and omnidirectional + Wind Guard (WG) in 5 m/s wind from 0°, 135° and 270° azimuth. Lower ratings are better. M&RIE was rated significantly better than omnidirectional and omnidirectional + WG at all azimuths. The differences in ratings between omnidirectional and omnidirectional + WG were not significant. From Andersen et al. (2021)..

Wind Noise Reduction

M&RIE provides natural wind noise protection because the microphone is located inside the ear canal where wind does not create as much turbulence over the microphone opening as it does on top of the pinna. The amount of wind noise reduction afforded by M&RIE was measured in a wind tunnel using an RIE hearing aid and M&RIE mounted on a KEMAR (Groth, 2020). The intensity level of wind noise was measured at varying angles around KEMAR, using three wind speeds: 2 meters per second (m/s), 5 m/s and 8 m/s. For reference, a wind speed of 2 m/s corresponds to a light breeze that can rustle leaves, while a wind speed of 8 m/s is a stronger breeze that can cause small trees to sway (University of Maine, School of Marine Sciences). Wind noise reduction was measured by comparing the intensity level of the wind at the omnidirectional microphones on top of the pinna, and with M&RIE located inside the ear opening. Figure 9 displays the average reduction in wind noise across all angles for the M&RIE versus the traditional microphone location on top of the pinna. At 2 m/s, wind noise was reduced by 19 dB by use of M&RIE, reduced by 15 dB in wind at 5 m/s and 14 dB in wind at 8 m/s.

Andersen et al. (2021) evaluated perceptual annoyance with wind noise using RIE hearing aids and M&RIE. Sixteen adults with normal hearing evaluated the sound quality of wind noise with a speed of 5 m/s, prerecorded on an acoustic manikin in a wind tunnel at three azimuths (0 deg., 135 deg., and 270 deg.). They used three hearing aid settings: traditional omnidirectional microphones with digital wind noise reduction (ReSound Wind Guard feature), omnidirectional without Wind Guard and M&RIE (also without Wind Guard). They rated the annoyance level of each listening condition using a 7-point Likert scale, with 1 = no noticeable wind and 7 = extremely annoying. Results for the study are displayed in Figure 10. Wind originating from in front of the listener (0 deg.) showed the greatest annoyance, while wind from behind (270 deg.) was rated as least annoying – this was regardless of microphone location or Wind Guard. The median ratings of annoyance ranged from 4.5 – 7 in omnidirectional mode, from 5-6 in omnidirectional + Wind Guard, and from 2-5 using M&RIE. This decrease in annoyance with wind noise from M&RIE was statistically significant compared to the other programs, regardless of wind direction ($p < 0.05$).

CONCLUSION

M&RIE is an innovative concept that gives hearing aid users the benefit of utilizing their own unique pinna cues in a small, cosmetically appealing over-the-ear device. M&RIE has demonstrated a variety of advantages for users – less perceptible wind noise and its accompanying annoyance, improvements in localization, especially after a period of acclimatization, reduced listening effort in noise, and better sound quality ratings related to naturalness, clarity and spatial perception. ■

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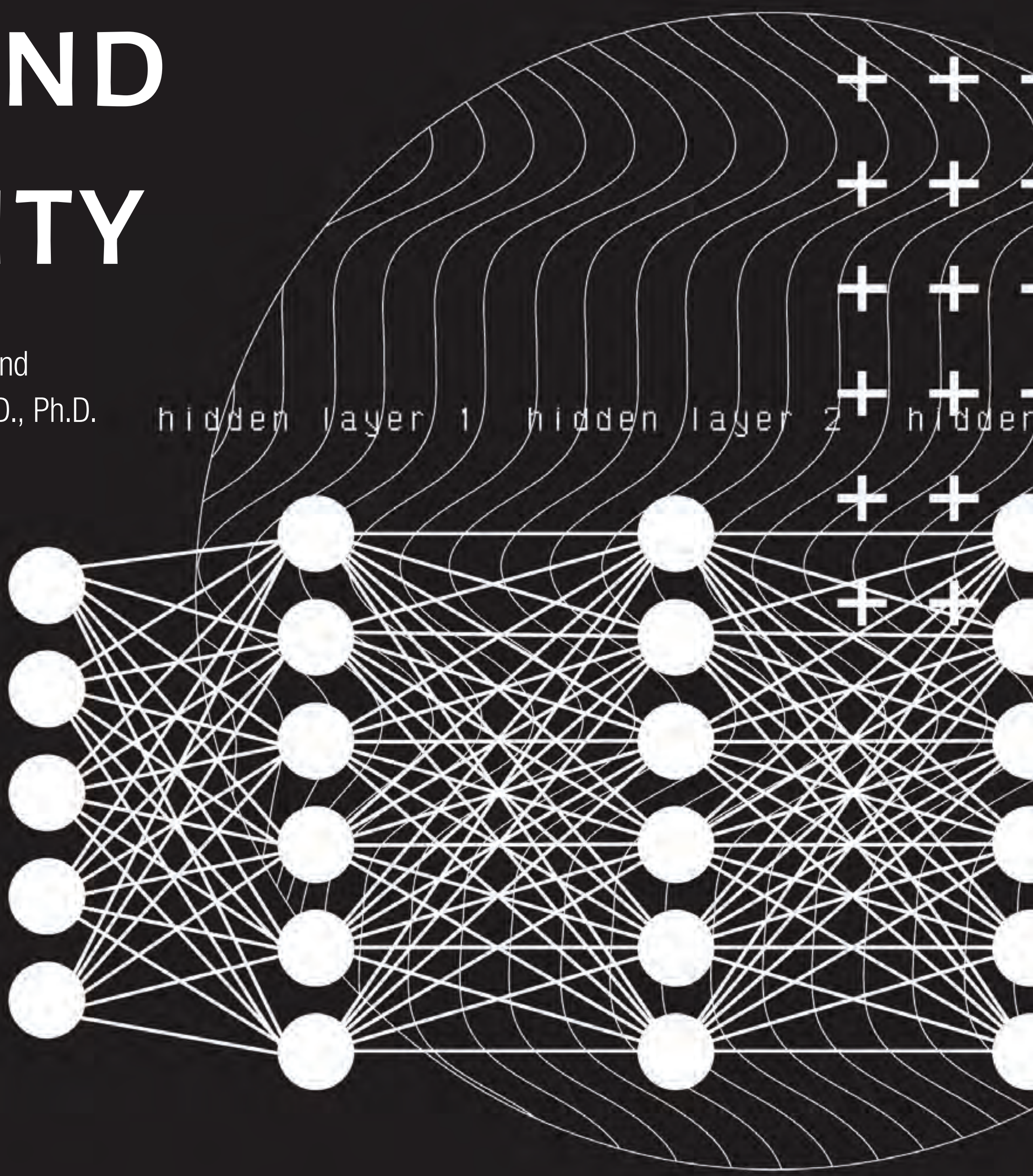
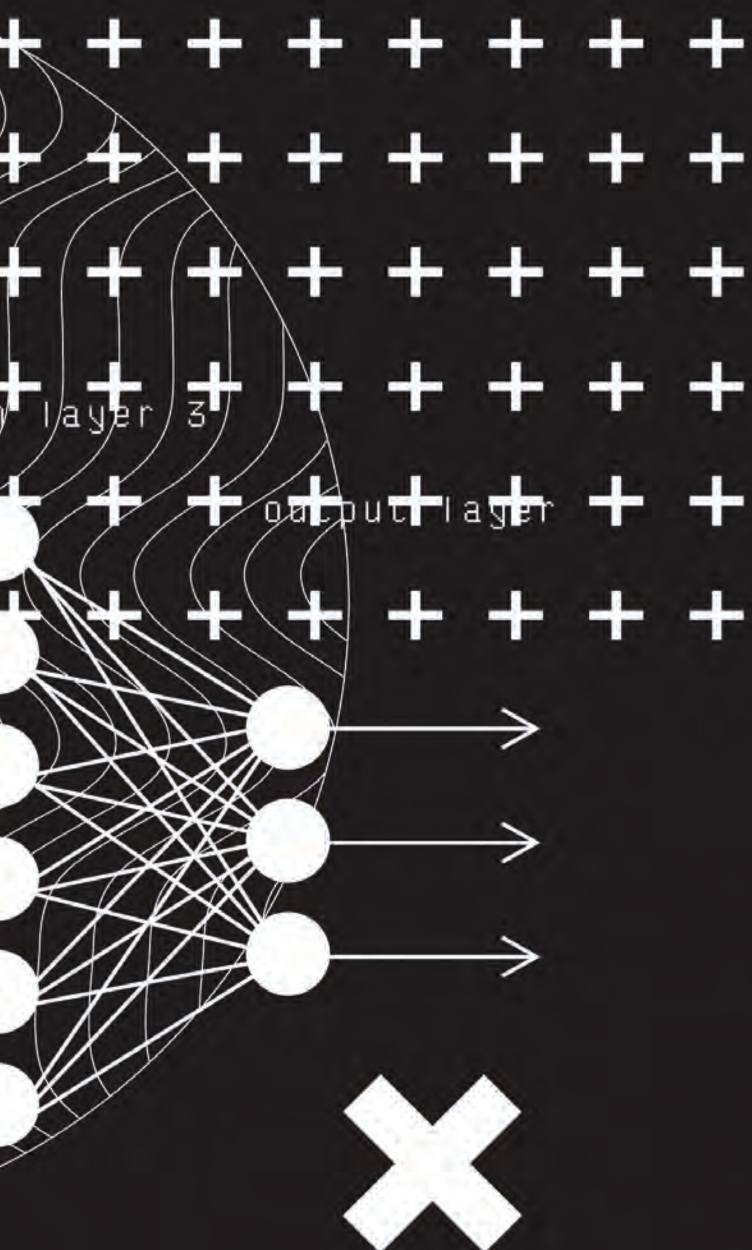
Deep Neural Networks + Sound Quality

By Douglas L. Beck Au.D. and
Virginia Ramachandran Au.D., Ph.D.





INTRODUCTION

Simply amplifying sound is insufficient to address speech-in-noise and other common listening and communication difficulties experienced by people with hearing loss and supra-threshold listening disorders. Specifically, to maximally understand Speech in Noise (SIN) requires an excellent signal-to-noise ratio (SNR). Despite significant advances in digital hearing aid technology and improved patient outcomes, hearing aid signal processing strategies are still constrained by physical size and power requirements (Picou, 2020).

Challenges inherent in the development of hearing aid signal processing strategies include a thorough and detailed understanding of how the brain uses audition and how the brain creates meaning from sound. Decades of hearing science research has identified auditory cues that *could* be used to facilitate auditory comprehension. However, what an individual brain actually *does* to comprehend sound and the exact meaning derived by a specific brain is not completely understood. Each human brain is unique. Although generalities can be defined and stated, the ability to understand speech in noise is a very complex process which includes hearing, hearing loss, physiology, anatomy, chemistry, knowledge, psychology, auditory processing, language and more.

By processing the auditory signal through the world's first on-board deep neural network (DNN) of the Polaris™ platform, Oticon More™ uses the intricacies of the auditory signal to better process sound. Research has shown that compared to two leading premium competitor hearing aids, Oticon More has faster adaptation, more access to speech via better signal-to-noise ratio (SNR) and preferred sound quality (Man, Løve, & Garnæs, 2021; Santurette et al, 2021). Previous publications addressing Oticon More have shown an improved SNR, improved selective attention, better memory/recall, and a more representative EEG in response to the true acoustic sound scene (Santurette et al, 2020).

DEEP NEURAL NETWORKS

While terms such as Artificial Intelligence (AI), Machine Learning (ML), and Deep Neural Networks (DNNs) are ubiquitous, their specific meanings vary based on context, understanding, and intent. AI might be thought of as the global ability of a machine to mimic human behavior. A specific type of AI, referred to as ML, occurs when computers learn to make improved accurate predictions or decisions based on precedent.

An advanced type of ML, referred to as deep learning, occurs via DNNs. DNNs attempt to imitate how biologic brains learn. Specifically, sensory systems (vision, hearing, tactile, smell and taste) nourish the brain with vast quantities of input data. The brain detects and defines patterns among the vast data set and the brain organizes the information.

Similarly, the DNN in every Oticon More was trained on 12 million speech sound samples and real-time speech processing decisions are based on the previously achieved deep learnings. With each decision the DNN self-checks to determine the accuracy of its predication. Through "successive approximation" the output becomes increasingly accurate, all without specific instructional algorithms (Andersen et al, 2021; Bramslow & Beck, 2021). DNNs are the engine for sophisticated functions such as virtual assistants, large area facial recognition, self-driving cars, dynamic weather prediction systems, and the speech processing system in Oticon More.

SIGNAL PROCESSING

When DNNs are used in auditory signal processing we achieve improved listener outcomes (Andersen et al, 2021). For Oticon More, the on-board DNN, coupled with Oticon's BrainHearing™ approach, have resulted in several measurable improvements relative to other premium hearing aid technologies (Man, Løve, & Garnæs, 2021; Santurette et al, 2021).

In a series of recent studies, the output of Oticon More devices was recorded for the left and right ears of a head and torso simulator (HATS) seated in the middle of an array of speakers. Depending on the specific study, either real-world recorded sound scenes or noise stimuli were represented via the speaker array, with target speech coming from different locations. The output of the hearing aids was used to examine the impact of the signal processing on a variety of metrics including speed of adaptation, access to speech, and sound quality.

The speed of adaptation impacts the ability of a hearing aid to act upon a signal so it can be adjusted to meet the needs of the user in a timely manner. The decision-making strategies used by a hearing aid impacts the speed with which it can identify and adjust to the environment, which impacts the SNR (and other factors) experienced by the user. Oticon More adapts to a changing sound scene 2-3 times faster than premium competitor hearing aids (Santurette et al, 2021).

Increased access to speech sounds is a requirement for improved speech understanding in complex acoustic situations. The output SNR of the studied hearing aids was calculated for target speech from the front (-15˚ azimuth) and from the side (-60˚ azimuth) in a background of noise. Under these circumstances, Oticon More was shown to have a similar SNR benefit as beamforming for signals coming from the front, while simultaneously, Oticon More demonstrated a better SNR than the competitors for speech coming from the side (Figure 1). In addition to providing more access to sound, Oticon More demonstrated overall improved SNR outcomes (Santurette et al, 2021).

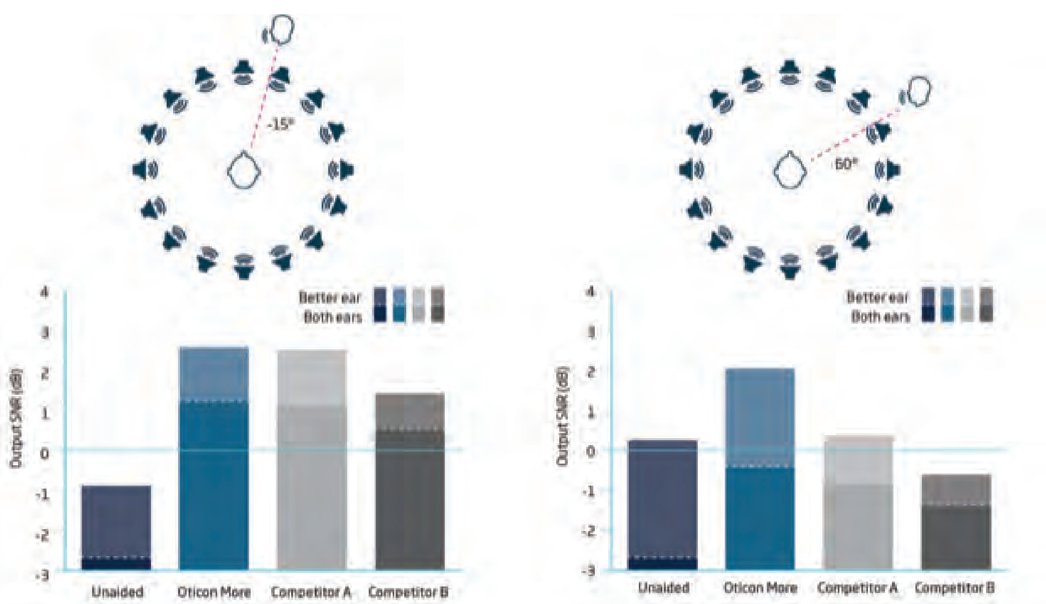


Figure 1 (from Santurette, S., Xia, L., Ermert, C. A., & Man K. L., B. (2021). Oticon More competitive benchmark. Part 1 – Technical evidence [White paper]. Oticon.)

SOUND QUALITY

Sound quality is a key issue when selecting hearing aids yet is notoriously difficult to quantify. The characterization of sound quality pivots on internal abilities and factors within the observer and external factors of the perceived physical sound including softness, loudness, brightness, clarity, fullness, nearness, spaciousness, naturalness, richness/fidelity, loud-sound comfort, own voice, hearing thresholds, auditory neural synchrony, middle ear status, listening ability and much more. Thus, measurement of sound quality depends upon using carefully chosen and clearly identified measurement strategies.

The sound quality of Oticon More was evaluated against two premium competitor devices using a previously validated assessment technique, the Multi Stimulus Test with Hidden Reference and Anchor (MUSHRA), adapted for listeners with hearing loss (Beck, Tryanski & Man, 2021). Twenty-two participants with various degrees of hearing loss evaluated the sound quality of Oticon More in a blinded preference test. Stimuli consisted of a variety of sound types including café, speech in noise, and conversation with a face mask. Audio clips were recorded on the HATS after being processed by the different manufacturer hearing aids. Listeners heard the sound samples under earphones and rated the sound quality of each stimulus. When averaged across condition, Oticon More was rated highest by nearly 8 out of 10 listeners (Man, Løve, & Garnæs, 2021).

SUMMARY

Oticon continues to build on our BrainHearing philosophy with Oticon More and its onboard DNN. In this report, the processing speed of adaptation, increased access to speech sounds and overall sound quality have been compared to two leading competitors. Oticon More demonstrated improved patient outcomes in these same measures. ■

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Acoustic Coupling: Fixed vs. Dynamic Venting

By Megan Adler, Au.D. and David Taylor, Au.D.

There are many considerations made when fitting hearing aids, which include the style and technology level of the hearing aid, acoustic coupling, the experience level and dexterity of the patient, the types of environments the patient encounters and the importance of streaming audio to the hearing aids. The audiogram may be the most important factor to consider in a fitting, and hearing care professionals (HCPs) know a very common audiogram has good low-frequency thresholds sloping to a high-frequency hearing loss. At first glance, many HCPs would fit the patient with an open earpiece or dome, especially if the person is a first-time user, to ensure good first-fit acceptance. Other HCPs may choose a partially vented or closed coupling to provide benefit in noise and/or improve streaming sound quality. Often there is a compromise between comfort and hearing performance.

Acoustic Coupling and Occlusion

One of the major complaints of hearing-aid users during the hearing aid fitting process is the occlusion effect (Winkler et al., 2016). In fact, according to MarkeTrak VIII data, occlusion is one of the top 10 factors correlated with user satisfaction (Kochkin, 2010). Occlusion can be defined both objectively and subjectively. Objectively, occlusion is the difference in sound pressure level between the occluded and the open ear during self-vocalization. This difference is present primarily at low frequencies. Subjectively, the occlusion effect is the change in perception of the user's own voice through sealing the ear canal, which can be evaluated via questionnaires or paired comparisons (Winkler et al., 2016).

Ricketts and colleagues (2017) describe the occlusion effect and its origin as follows: during vocalization, sounds can reach 120 to 130 dB SPL or more in the back of the throat, especially during production of vowels. Through bone conduction, these high intensity sounds travel to the mandibular condyle, adjacent to the ear canal. This bone-conducted signal then becomes an air-conducted signal by setting up vibrations of the cartilaginous portion of the ear canal. These vibrations are primarily low frequency. Normally, this energy is allowed to escape out of the open ear canal and does not contribute significantly to our perception of our own voice. However, when an object (such as a hearing aid or earmold) is introduced to the lateral portion of the ear canal, the energy cannot escape, and results in energy being reflected back to the eardrum and transmitted to the cochlea in the typical air-conducted manner.

One of the most important factors governing occlusion is the acoustic mass of the venting. Acoustic mass, also commonly referred to as acoustic inertance, is the effect of inertia in an acoustic system that impedes transmission of sound (ASA, 2016). Acoustic mass can be calculated using the following formula (Beranek, 1954).

$$Acoustic\ mass\ =\ Air\ Density\ x\ (\frac{Effective\ length}{Cross-sectional\ area})$$

It is important to think of acoustic mass not as a physical mass, but an inertial property of the system. To better understand the concept, imagine blowing through a drinking straw, a long tubular conduit with a small diameter. This task will require a stronger acoustic force, compared to a paper towel roll. As venting options are adjusted during the fitting process, clinicians are therefore adjusting the impedance of the coupling (and by extension, how well the fitting 'traps' low frequencies).

In order to combat an undesirable occlusion effect, a clinician may be inclined to decrease this impedance by decreasing the acoustic mass of the system. By definition, this allows for easier transmission of sound between the residual ear canal volume and the outside environment. Clinicians commonly do this by increasing the vent diameter, decreasing the length of the vent, or using an open dome. Because acoustic mass is calculated as a ratio of length and cross-sectional area, it is possible for a large diameter vent to have equivalent acoustic vent mass as a smaller diameter vent, with a shorter length. When a hearing aid user presents complaints of the occlusion effect, decreasing the acoustic mass of the venting is a viable solution, but it does not come without consequences.

It is important to keep in mind, these adjustments to acoustic mass will not only control how much sound escapes from the ear canal (i.e., 'vent loss'), but also the amount of direct sound that is able to enter the ear canal. See Figure 1 below for an example of vent loss across different couplings.

Considerations of Open Fittings

When open coupling or large venting is utilized, it should be considered how this coupling will create interaction between direct and processed sounds. In the case of open coupling, both direct and amplified sounds are superimposed in the ear canal. When two or more identical audio signals are presented offset in time, it will result in comb-filtering. In instances of comb-filtering, frequencies that are in phase are creating a summation effect, and for frequencies out of phase, the signals cancel and result in a notch in the frequency response. Comb-filtering occurs in the higher frequency range, as phase relationships become less correlated when wavelengths decrease in size (Fuston, 2021). Perceptually, the frequency response is altered in proportion to the amount of delay, and this phenomenon elicits an inferior sound quality relative to signals that are in-phase and without any evidence of comb-filtering. Occluded coupling minimizes the transmission of direct sound, thus minimizing the interactions of direct and amplified signals.

Consideration should be made regarding coupling effects on signal processing algorithms. If direct sound is allowed to dominate the amplified signal, the benefit of directionality, noise reduction, and other adaptive algorithms can be reduced (Bentler et al., 2006; Rickets, 2000). Additionally, vent sizes have an effect on compression ratios. Fortune

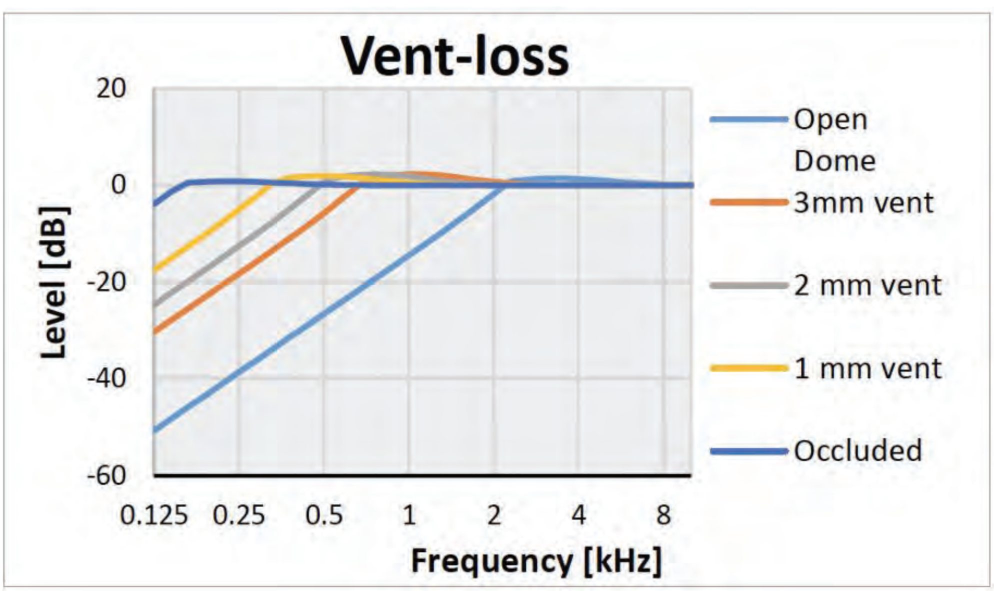

Figure 1. Sound escaping out of the ear (vent loss) with occluded, vented, and open fittings. (Woodward, 2018).

(1997) demonstrated this by evaluating compression ratios measured via real ear measures (REM) for different sized vents, from unvented to a 4.75 mm vent. When the compression ratios were measured via REM, the largest vent had lower compression ratios than the other vent sizes. For modern hearing instruments with wide dynamic range compression, less gain is applied to high input signals, creating more potential for the direct sound to dominate the balance between the amplified and direct signals as input levels increase. These compression effects are important to keep in mind, as the compression specifications in the fitting software may not coincide with the effective compression ratios, or the compression that the user is experiencing in real life, which are inclusive of these venting effects.

Feedback cancellation is also sensitive to venting. Relative to a custom earmold, maximum stable gain before feedback may be reduced by 25 dB with an open dome, and 15 dB with a closed dome (Blau et al., 2008). Feedback reduction algorithms allow for further gain increases but have the potential to produce artifacts and compromise sound quality, so a more closed fitting may be an advantageous approach when managing feedback.

Lastly, it should be considered how open fittings affect perception of non-acoustic inputs. As streaming technology has advanced over the past years and continues to evolve, users will expect a certain degree of performance from these features. In order for a clinician to optimize this experience, the coupling must coincide with the user's goals. Similarly to how an open fitting will allow for transfer of low frequencies to combat an undesirable occlusion effect, this ability for the low frequencies to escape may elicit an undesirable low-end response when streaming. In many instances, this may be a matter of balancing the user's goals between reducing occlusion and improving streaming sound quality.

With all these considerations in mind, often times, a hearing aid fitting requires compromise between satisfaction of own-voice perception (occlusion) and maintaining the aforementioned benefits of amplification and signal processing algorithms.

Dynamic (or adaptive) venting

HCPs and patients have become accustomed to digital hearing aids that can adapt their behavior based on the acoustic environment and the (presumed) intent of the user. This adaptive behavior, however, has never included acoustic coupling. As discussed above, an open fitting is better in some ways and a closed fitting in others; often an open *and* a closed fitting would be ideal for a patient, but switching back and forth between different domes or earpieces isn't manageable for the average patient, and would make it difficult for the HCP to provide an appropriate prescription.

Recent technological advancements have made a dynamic venting system for hearing aids possible, allowing for a single fitting that can adapt between open and closed venting. Phonak's ActiveVent™ receiver (compatible with Audéo P-R or P-RT) has a mechanical vent that opens or closes based on the environment or incoming streamed signal. This receiver solves the dilemma that many HCPs experience in the clinic, and now there is no need to compromise between an open and closed fitting.

Benefits of dynamic venting

A patient fit with a 'fixed' open fitting would experience a reduced perceived volume level and less full sound while streaming, due to the low frequency energy lost through the vent. In addition, such a patient would suffer from environmental sound entering the vent, interfering with the streamed audio input. Having an open vent in noisy environments is also problematic, because when low-frequency sound escapes the ear canal via the vent, it negatively impacts the directivity of the hearing aid (Ricketts, 2000).

ActiveVent has the ability to switch between the equivalent of a 3.5 mm vent (when open) or completely occluded (when closed). Figure 2 shows the frequency response of the ActiveVent in the open and closed states.

This dynamic behavior allows patients to avoid some of these negative results of 'fixed' open venting by adapting the acoustic coupling between the open and closed vent position

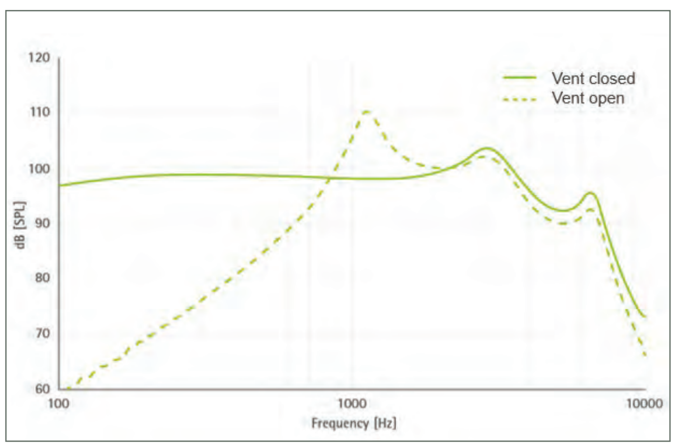

Figure 2. Frequency response of ActiveVent open versus closed.

to balance comfort and performance. When the vent is open, patients will experience the comfort of their own voice and the natural awareness of environmental sounds in quiet environments. When the vent closes, patients will have a reduced interaction between the amplified signal and direct sound, as well as reduced vent loss, in challenging communication situations. In addition, they will have an improved sound quality of streamed signals compared to a conventional acoustic coupling and an enhanced perception of the streamed signal when ambient noise is present (Latzel & Hobi, 2021; Winkler et al., 2016). Because the vent is not permanently closed, patients can also avoid some of the negative impacts of closed venting, such as the occlusion effect.

Just as HCPs must learn how to appropriately select and fit 'fixed' acoustic couplings, the unique nature of dynamic venting means that some considerations should be taken prior to selection and fitting.

Clinical Considerations

Lifestyle and audiogram

Since a dynamic venting system incorporates both open and closed fittings, the appropriate fitting range of the system will be influenced heavily by the degree of hearing loss appropriate for the open vent condition. In the case of ActiveVent, this includes patients with mild-to-moderate sloping high-frequency hearing loss, who might ordinarily be fit with an open or vented dome. As detailed above, the benefit of the system comes from having closed acoustics when communicating in a noisy environment or while listening to streamed signals, with open acoustics to utilize natural low-frequency hearing in other situations. Therefore, the ActiveVent receiver is ideal for clients who enjoy streaming and are in challenging situations, who might appreciate additional low frequency boost for streamed signals and reduced direct sound interference with the hearing aid signal processing in noisy environments. The patient should also be willing to use a rechargeable hearing aid, since the ActiveVent receiver is not compatible with zinc-air battery models.

Ear Anatomy and Physiology

The ActiveVent receiver can only be housed in a custom earmold (i.e., a SlimTip), and therefore ear canal size and shape may be a limiting factor for some patients. The use of a custom SlimTip helps minimize acoustic leakage when the vent is closed, which helps create the best experience possible. The mechanical switching of the receiver can be adversely affected by wax and moisture, so patients with very waxy ears or known chronic or recurrent middle ear pathologies would not be suitable for ActiveVent. In addition, the ActiveVent receiver is not recommended for clients that report problematic and severe tinnitus and/or reduced loudness discomfort levels, as the change in acoustic output when the vent opens and closes may be bothersome.

Maintenance

The HCP should consider whether a patient's dexterity will allow him/her to perform regular maintenance of the ActiveVent receiver. Cleaning is important to ensure better daily performance, extend the lifespan of the device(s), and prevents repair issues that can result from wax build-up and moisture. The patient should wipe the hearing aid(s) and earpiece(s) daily with a damp cloth and replace the wax filter(s) weekly.

Hearing aid fitting

When fitting ActiveVent, the vent defaults to open in some programs and closed in others, based on the intended use of the respective program. However, the software does allow for the flexibility of modifying the vent status in various programs. The HCP can also create manual programs with a defined vent state depending on the needs of the patient. This ensures the HCP is aware and in control of the acoustic coupling for the patient in any given program.

When fitting the ActiveVent receiver, the HCP should explain to the patient that there is a vent built within the receiver that opens and closes in response to the environmental sound or incoming streamed signal. The movement of the vent opening and closing creates a sound and is an indication that the ActiveVent receiver is functioning correctly. This sound can be demonstrated to the patient by switching between programs in the software.

Conclusion

Open fittings revolutionized the hearing aid industry by providing a solution for users that experience bothersome occlusion effects. Open fittings also give opportunity to allow direct, natural sound to enter the auditory system, allowing patients with residual hearing in low frequencies to hear naturally. However, open fittings do not come without consequences, such as the undesirable interaction between direct and amplified sounds, negative effects on signal processing algorithms, and reduced sound quality while streaming. Historically, HCPs and patients have had to choose to prioritize either comfort or performance when selecting acoustic coupling. Dynamic venting, like the ActiveVent receiver, allow for comfort and performance to be optimized for a patient with a single device and earpiece. ■

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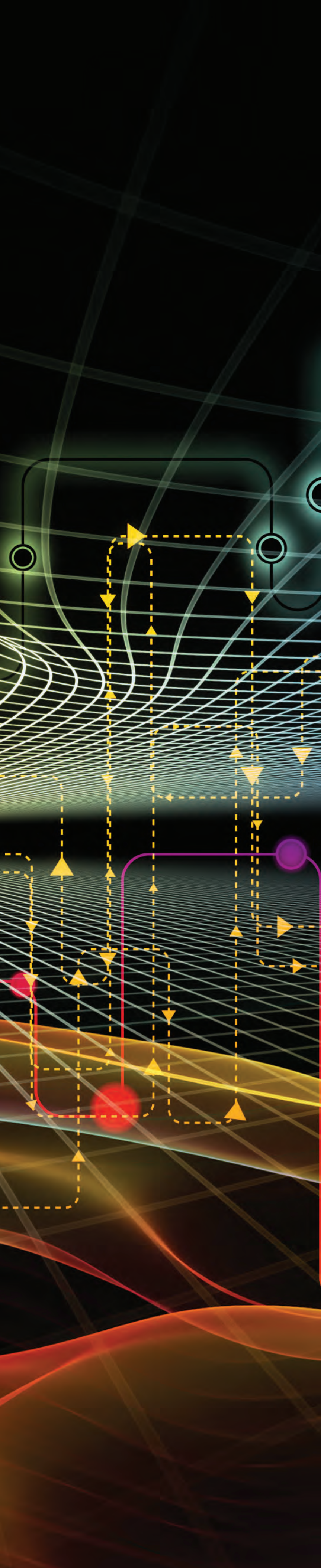
SPLIT-PROCESSING

A New Technology for a New Generation of Hearing Aid

By Eric Branda Au.D., Ph.D.



Hearing aids are continually evolving with every platform introduction. Each generation of hearing aid technology incorporates new approaches to managing the listening environment for the user. This is often a combination of chip design and algorithm development. Essentially, the goal is to provide the best speech intelligibility possible for each situation. This becomes more challenging with multiple talkers and more adverse noise conditions. Adding to the complexity of signal processing is that one cannot always assume the conversation partner is positioned in front of the hearing aid user. The hearing aid needs to dynamically adapt and adjust to the listening situation.

Recently, Signia introduced the AX platform of hearing aids to take the next step managing and augmenting the listening experience. The AX platform builds on former platforms, but also incorporates new approaches to processing. Part of the AX development was to look at how other industries approach sound and explore opportunities to expand on previous approaches.

Soundscape Analysis

A key component of AX processing is the analysis of the listening soundscape. Traditional processing uses modulation and level-based approaches to determine a classification of the listening environment of the wearer. Basically, hearing aids use a few select acoustic parameters to designate the soundscape into a limited number of classification buckets. Once in these classification buckets, appropriate algorithms can be applied. The obvious limitation is that soundscapes are extremely dynamic and far exceed the few classification categories commonly used.

The AX processing takes those factors of level and modulation into account in identifying the acoustic environment. However, other factors can further assist in evaluating the soundscape. Additional factors that AX analyzes are the signal-to-noise ratio, if the user is talking, overall ambient modulation of the environment, and if the hearing aid wearer is stationary or in motion. These additional factors allow for a more dynamic approach to managing the soundscape beyond a limited number of classification categories. Some of these features are implemented in a unique manner in the AX platform.

Motion Sensors

One of the unique tools used by the AX platform is an integrated motion sensor. Motion sensor technology is relatively new to hearing aids. The driving concept for using the motion sensor is to help identify the listening needs of the hearing aid wearer. In a typical conversation, the communication partner is directly in front of the hearing aid wearer. If one assumes a listening environment such as a restaurant or café, it is expected that it is a face-to-face conversation and there is likely some competing background noise. The hearing aid would consequently apply some directionality and noise reduction to help focus on the talker facing the hearing aid user and reduce the competing background sounds. However, if both parties are walking through the same listening environment while talking, the acoustic background has not changed, but they are no longer face-to-face. The listening situation, not the environment, has changed. The hearing aid now must adapt to speech coming from a different angle and provide for safety of the wearer while walking. In this example, directional microphones may be more of a hinderance than a benefit. For this situation, a motion sensor can detect that the hearing aid wearer is in motion and make the microphone more omni in nature. Using motion of the wearer to determine microphone mode helps with accessibility to sounds from the sides, even though the acoustic environment in this scenario is likely to be classified as a speech-in-noise situation.

Original approaches to motion sensors utilized those built into smart phones to detect motion. This information could then be transmitted wirelessly to the hearing aid to assist in the processing decisions. More recently, the motion sensor has been integrated into the hearing aid itself. The integrated motion sensor itself brings new challenges for the hearing aid platform. Along with the obvious need to detect motion, factors such as power consumption and device size also must be considered. Considering these factors, the AX platform uses an accelerometer to detect motion. The accelerometer essentially identifies changes in the wearer's acceleration in multiple directions while minimizing power consumption and space constraints (Branda and Wurzbacher, 2021).

Studies investigating the use of motion sensors in hearing aids have shown advantages for the wearer. Froehlich et al (2019) reported both laboratory and field measures using technology supported by motion sensors. The laboratory condition assessed user ratings on ease of communication and listing effort with the motion sensor in "on" and "off" conditions. Two listening situations were simulated. One was a restaurant situation with speech from the side. The other was a traffic situation with speech from the side and behind the listener along with traffic noise. In both conditions, participants rated understanding and listening effort significantly better with the motion sensor activated.

Own Voice Processing

The AX platform also uses Own Voice Processing (OVP) to identify when the hearing aid wearer is speaking or if someone else is talking. It comes as no surprise that the needs of the wearer differ between when they are speaking and when they are listening. However, it is not so easy for the wearer to manage hearing aid gain and output differently for these situations. The use of OVP can help mitigate this situation. If the conversation partner is speaking, then the hearing aid processes for speech at the programmed gain levels. However, if the wearer is speaking, then the hearing aid will adjust gain and compression to accommodate for the wearer's own voice.

A study investigating OVP evaluated own voice preferences for new hearing aid users (Powers et al, 2018). The users were asked to wear hearing aids in closed, vented and open conditions with OVP "on" and "off." With each condition participants were asked to rate their preference on a seven-point Likert-like scale (1=Very Dissatisfied, 4=Neutral, and 7=Very Satisfied). In all conditions, the OVP "on" preference was significantly higher than with the feature deactivated. Additionally, the closed fitting with OVP "on" was rated more preferable than an open condition with OVP "off."

Two New Approaches to Processing

Analyzing the soundscape is merely the first step in helping the hearing aid wearer hear well in any listening environment. The next step is how the hearing aid processes and manages the listening situation. The AX processor logically applies select algorithms for the listening environment as it identifies the situation. However, AX also takes two distinct approaches in how the processing is executed (Taylor et al 2021).

Processing in Parallel

The first core aspect of AX processing is a departure from traditional serial processing approaches. With the traditional approach, the sound is processed in a serial, or step-by-step manner. For example, as shown in Figure 1, the digital noise reduction algorithm may be applied to the input signal first, followed by compression. This serial processing could result in some algorithms undoing or exacerbating effects of the other algorithms and could consequently introduce artifacts.

Figure 1. The serial processing pathway of sound found in all hearing devices except Signia's AX.

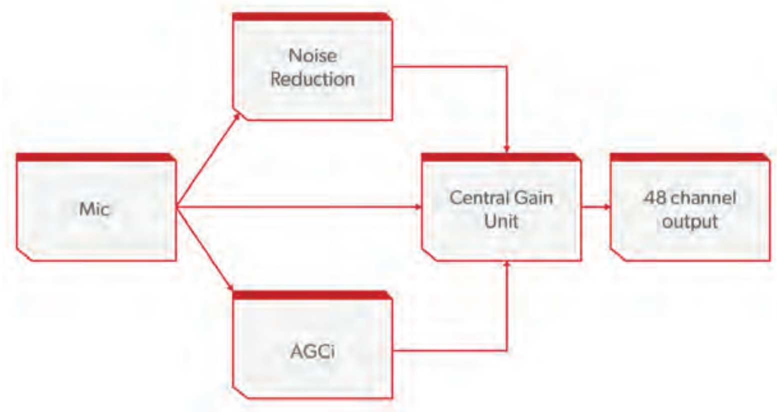


Figure 2. The parallel pathway of incoming sound in the AX platform. Note how the incoming signal is split compared to serial processing in Figure 1.

In contrast, the AX platform applies parallel processing, which is depicted in Figure 2. The signal is provided to each algorithm in a parallel fashion, so it is untouched by other algorithms. Following the application of the parallel processing, a central gain unit brings the entire signal together without the overlapping influences and artifacts. The result of parallel processing is a cleaner signal for the hearing aid wearer.

Split Processing

Along with the parallel processing, AX technology utilizes another innovative processing approach designed to address a common issue associated with hearing aids. Even with the most current technology, background noise is still an issue for hearing aid use (Picou, 2020). In general, digital noise reduction systems help with comfort in noise, but are not associated with improving speech intelligibility in noise. Improving speech intelligibility in noise is addressed with directional microphones.

Directional microphones, also referred to a beamformers, are used to improve speech intelligibility in background noise (Picou and Ricketts, 2019). Unilateral beamforming has been used more traditionally. In this case, the hearing aid has a front and rear microphone. Directional microphones (unilateral beamformers) are effective when the signal of interest, usually a person talking, is spatially separated from noise. Of course, in many demanding listening situations, it is impossible to spatially separate the talker(s) of interest from unwanted sound.

The AX platform, as mentioned, utilizes directional microphones. However, AX introduces a new approach to using the directional microphones. Traditionally, all input signals processed by the hearing aids would follow similar noise reduction and compression characteristics. That is, no matter if the input is speech, music or stationary noise like a fan, all the sounds are processed in essentially the same way — the input signal dominating the wearer's soundscape would drive classification and compression characteristics. With directional microphones, this also meant that sounds from the rear direction would receive some additional attenuation as the sound was processed, however, the same overall noise reduction and compression characteristics would be applied regardless of the direction of a sound source. With AX, the directional microphones are used to identify front and rear input signals as separate streams and consequently apply separate processing to each stream. This means that target sounds from the front which are typically speech are likely to receive compression and noise reduction better suited to a speech signal. The competing sounds from the rear field will have different noise reduction and compression characteristics applied. Applying appropriate processing to each individual stream helps the hearing aid wearer more easily distinguish the target speech signal from the competing background signals. Figure 3 is a schematic demonstrating how the AX split processing works.

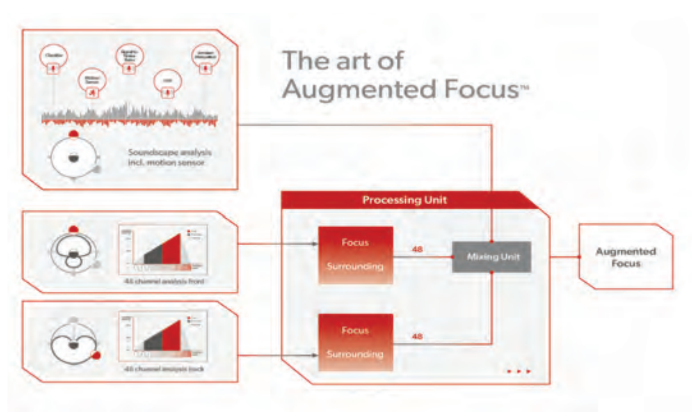


Figure 3. Augmented Focus, a new feature in the AX platform, separates input signals into two separate streams that are processed independent of one another. Each stream applies different amounts of compression and noise reduction.

Bilateral Beamforming

In addition to the split processing and parallel processing, the AX platform is designed with bilateral beamforming technology. In essence, each instrument in a pair of hearing aids has two microphones, just as with a unilateral beamformer. However, bilateral beamforming differentiates itself by utilizing the wireless connection between devices. Signia uses near-field magnetic induction to accomplish this full audio data sharing between devices, unlike other manufacturers who employ 2.4 GHz, which is prone to occasional sound quality issues when used for wireless communication between devices.

In bilateral beamforming, hearing aids share directional information to provide added benefit over the unilateral beamformer. Studies with earlier implementations of binaural beamforming have shown better speech understanding in noise for the hearing aid wearers – even when compared to adult listeners with normal hearing (Froehlich et al, 2014). It is worth noting that full binaural beamforming is often applied in the presence of loud background noise — typically when the intensity level reaches just over 70 dB SPL for about ten seconds, the bilateral beamforming system is engaged and the hearing aids go into a narrow directional mode. This application of bilateral beamforming is based on research that says that in situations with lower levels of background noise, the hearing aid should still provide some audibility for surrounding sounds and thus remain in a more omnidirectional pattern. Figure 4 illustrates the full audio data sharing capabilities of Signia's bilateral beamforming system and that in listening situations of relative high intensity, the directional pattern is quite narrow.

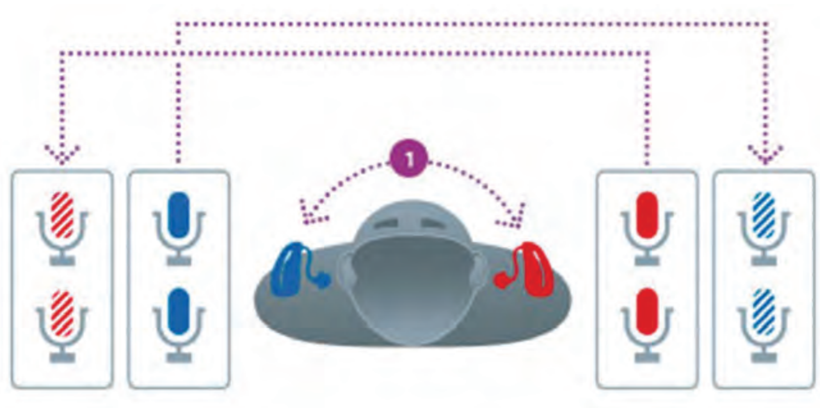


Figure 4. A key to bilateral beamforming is the combined analysis of the input of all four microphones independently for both the right and left ear—the combined advantage of an 8 microphone array that provides a narrow directional pattern when needed

AX Research Support

With the introduction of the AX platform, several studies have been conducted to evaluate AX performance in laboratory and real-world environments.

In one laboratory study, experienced hearing aid wearers compared AX processing with that of other newly introduced hearing aid technologies (Jensen et al, 2021a). The hearing aid wearers performed a modified American English Matrix test (Hörtech) using speech and laughter as the competing signals. With the AX processing, the hearing aid wearers scored significantly lower (better) speech reception thresholds than with other devices.

In the same study, the performance with AX processing with these same hearing aid wearers was compared to that of normal hearing participants using the modified American English Matrix test in two different listening situations. The first was designed as a moderate noise situation, similar to a cocktail party situation, and the second was designed as a louder, restaurant situation. For the moderate noise situation, the hearing aid wearers performed equivalently to normal hearing listeners. And for the louder noise situation, hearing aid wearers performed significantly better than the normal hearing listeners, consistent with previous investigations with binaural beamformers.

In a separate study (Jensen et al, 2021b), satisfaction ratings of experienced hearing aid users wearing their current hearing aids and AX platform hearing aids were compared. They were asked to first rate their own devices on a Likert-type scale (1 = "very unsatisfied", 7 = "very satisfied") with six categories as well as thirteen questions related to quality of life from the Speech, Spatial and Qualities of hearing questionnaire (SSQ, Gatehouse and Noble, 2004). Participants were then asked to follow a specific wearing schedule. They wore the new AX devices for two weeks followed by their own devices for one week and the AX devices again for one week. At the end of each wearing session they were asked to complete the same questionnaire. After the fourth and final wearing session they were also asked to complete forced choice preferences between devices for six different categories.

Results of the satisfaction scale showed a significant difference in favor of the AX platform for overall satisfaction, sound quality, speech intelligibility, and own voice. Questions regarding comfort and fit were not significant. For results of the SSQ questionnaire, all but one category were significantly different, and again in favor of the AX processing. The final forced choice questions indicated a 73% to 80% range of preferences for the AX platform and an overall preference of 78% for AX processing.

Conclusion

The AX platform introduces new processing approaches in addition to implementing proven technologies from previous generations. Laboratory and real-world investigations have shown benefits with the AX platform when compared to other technologies. In some listening situations, AX platform technology has been shown to outperform normal hearing listeners. It is with these innovations that AX brings technology to a new level while raising the bar for future generations of hearing devices. ■

Eric Branda Au.D., Ph.D. *is director, applied audiological research for Signia.*

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Dear Esteemed Hard of Hearing Consumer

BY KIM CAVITT, Au.D.

Dear Esteemed Hard of Hearing Consumer,

I am an audiologist and have been involved in this industry for over 30 years. I am very supportive of your initiatives to change the hearing aid delivery model and industry. I support the Medicare coverage in Build Back Better and the Over the Counter Hearing Aid Act and have fought for these initiatives. I desperately want all consumers to have access to accessible, affordable solutions for hearing loss.

I believe that you, the hearing aid consumer, have the following rights:

- You have the right to control your own hearing healthcare and amplification journey. YOU are the captain and providers are merely navigators. I, as a provider, do not have the right to judge your personal healthcare decisions.

- You have the right to have access to a wide range of amplification options, including telehealth and remote fitting, over-the-counter options, provider delivered amplification, personal sound amplification products, assistive listening devices, FM systems, and implantable devices. These devices should have technologic and manufacturing specifications to reduce the risks of over-amplification, as well as ensure the quality and integrity of the product.

- There should be clear labels on all products that explain the intended use of each class of product and provide warnings of the risks of improper use.

- If you seek an evaluation from an audiologist, you should receive a copy of your diagnostic audiologic evaluation and a copy of your plan of care.

- If you purchase hearing aids from a provider, those hearing aids should not be proprietarily locked. In other words, those devices are yours and you should be able to go to any provider for those aids to be adjusted or modified. At the very least, you should be informed that your devices are proprietarily locked prior to purchase. Ask about who and where the devices can be adjusted prior to purchase.

- Prices should be itemized and transparent and they should reflect the costs of the device as well as the separate costs of the evaluation, treatment and follow-up services. Long-term service should be an optional purchase.

- You have the right to see any provider and pay for the services they have rendered, yet not purchase a product from them. You should never be pressured to purchase.

- Every hard of hearing consumer does not require premium technology. Their communication needs may not warrant them. Providers have a responsibility to assess you and your listening and communicative situations and to find you the aids that best meet your individual listening needs at the most affordable price.

- You have the right to have access to value based amplification solutions that are audiologically appropriate for your type and degree of hearing loss, whether it is OTC, retail, telehealth or provider delivered.

- Provider driven care should be readily available and accessible. Providers should offer evening and weekend hours as well as telehealth services.

- Providers should consistently provide research evidence based care and treatment. You, as the consumer, have the right to demand that level of care. Cerumen management, speech in noise testing, inventories, cognitive screenings, electro-acoustic analysis and real-ear measurement should be the norm in every practice.

- Providers should utilize all available treatment options and delivery modalities, including telecoils, assistive listening devices, FM systems, over-the-counter products, and auditory rehabilitation.

- Providers should teach you how to use and care for the devices and should teach you listening and communication strategies to maximize your satisfaction and performance.

I, personally, support these consumer rights and will advocate with you for commonsense industry regulations that minimize risk, ensure quality and safety, and allow for increased access and affordability.

But, with rights also come responsibilities. Providers need hearing impaired consumers to acknowledge and accept their roles. Consumer responsibilities include the following:

- Hearing aids, regardless of their cost, do not cure hearing loss. They maximize your communication and listening abilities. Your expectations of amplification should be realistic for the type and degree of hearing loss you exhibit. You have as much influence on the outcome and performance of amplification as does the provider and the devices themselves. Become an educated advocate.

- There are significant differences in the providers in this industry. Consumers should educate themselves on the differences between hearing aid dispensers, audiologists and physicians, over the counter, retail, telehealth and clinic delivery, their different roles in the delivery process, and their different motivations.

- The evidence suggests that patients have better satisfaction, performance and outcomes if they receive an evidence based audiologic evaluation and communication and functional needs assessment. In other words, you would, if possible, be best served to be evaluated by an audiologist prior to any purchase. These evaluation services are not completely covered by every insurance.

- If you experience tinnitus, dizziness, drainage from your ear, earwax buildup, a sudden or rapidly changing hearing loss, a hearing loss where one ear is poorer than the other, an ear deformity, or ear pain, please seek an audiologic evaluation and medical intervention prior to any over-the-counter, telehealth, mail order or internet purchase. Otherwise, you could be wasting your money or missing a treatable or serious medical condition.

- Over the counter hearing aids are NOT appropriate for every hearing loss. They are appropriate for mild hearing losses to moderate flat hearing losses. It is difficult to know this without an initial, provider driven audiologic evaluation. You may experience insufficient gain/volume, difficulties in noise, and feedback if your hearing loss is more significant. This will lead to poor performance and satisfaction. No one wants to see you waste your money on an inappropriate option.

- Over the counter hearing aids are NOT appropriate for children. Children have unique audiologic and communicative needs that require the professional intervention and engagement of an audiologist.

- There are pros and cons of purchasing hearing aids over the counter (OTC). If you purchase hearing aids over the counter, please understand that audiologists cannot adjust or modify all of these products. Also, it is important that you understand that providers will charge you for the care, treatment, and guidance we provide on these OTC products, even if it is to tell you that they are not appropriate. We cannot provide care at no charge.

- There are costs when you seek the evaluation and guidance of a provider. Many consumers currently demand free hearing tests, communication and functional needs assessments, and hearing aid evaluations and consultation. “Free” though was never really free. "Free" has only worked so far because of bundled pricing and provider driven care. The consumer who purchases products actually ends up paying for the evaluations of themselves and those of every other consumer who opted to not purchase products. When hearing aids are unbundled or itemized, the consumer may need to pay for the hearing test and they will need to pay for the communication and functional needs assessment or hearing aid evaluation/consultation, even if they opt not to proceed with a purchase. Providers cannot be expected to provide their doctoral level expertise at no charge.

- The evidence indicates that consumer have better satisfaction, performance and outcomes when they receive evidence based care and treatment. This includes inventories, verification, speech in noise testing, and auditory rehabilitation. Many providers, as a result, have a non-negotiable, no exceptions standard of care. It is our right as providers to practice in a manner which we know, through research, benefits the patient. Often, this is a level of care that is not covered by your insurer.

- You cannot expect for insurance to always pay for everything you want or need. They do not cover things, like connectivity or rechargeable batteries, that are merely for your personal comfort. The allowable rates within provider contracts with third-party payers often indicate the level of technology that we can provide. Insurance often does not cover our costs of premium technology and many payers do not allow in-network providers to allow you to pay the difference between basic and premium technology. This is not our rule, but theirs. Payers often do not cover long-term follow-up or service. They do not often cover batteries, battery chargers, earmolds, wax filters or accessories. They do not typically cover rehabilitation. Remember, insurance coverage is an agreement between you and your insurer. The provider is just executing that agreement, to the best of their ability, within the confines of their own contracts. Sometimes, you, the patient, are just financially responsible.

- If you want to minimize your out of pocket provider costs, you should personally take on as much of the daily care of the device as is possible. You should clean your hearing aids every day. You should keep them dry and free of hair products, perfumes, and sprays. You should change your own batteries or put them safely into a battery charger. You should replace your own wax guards and clean your own earmolds. You should follow the instructions outlined by your provider.

- Costco is typically a great option for purchasing hearing aids. Costco is an excellent retail solution. There are though better, more comprehensive options for audiologic and hearing care. Please note that Costco does not provide comprehensive communication and functional needs assessments, remove ear wax, offer CROS/BICROS options, evaluate or treat tinnitus or auditory processing issues, evaluate for or manage cochlear implants or bone anchored devices, and does not provide auditory rehabilitation or comprehensive counseling. They dispense hearing aids. Period.

The purpose of this letter is to improve the dialogue between audiologists and consumers. Speaking for my audiology colleagues, we want to help each of you maximize your hearing, listening and communicative abilities. We want to be partners in your success and help YOU navigate your hearing loss journey. We are available to evaluate, educate, manage and treat. But we both have to realize and appreciate our roles in this journey and be understanding and respectful of each other and those roles. I feel as though if you are successful, I will also be successful as well but we need our relationship to be a win-win for both of us.

Respectfully,

Kim Cavitt, Au.D.
Audiologist

HAVE YOU HEARD?

Exceptional Audiologists Honored at AuDacity 2021

AuDacity brought together exceptional audiologists from around the country, four of whom were recognized for their clinical, educational, advocacy, and professional contributions to audiology and the community.

Leo Doerfler Award

Judy Huch, Au.D., owner of Oro Valley Audiology was presented with the **Leo Doerfler Award** in recognition of outstanding clinical services in the community by a private practice audiologist.

"Dr. Huch provides high-quality hearing and tinnitus services to her community with a goal to help as many people as possible, regardless of their ability to pay," said ADA President, Dr. Victor Bray, "and her non-profit clinic, Grace Hearing Center, supports her humanitarian work and has improved hearing health equity in Arizona by providing free care to underserved populations."

In addition to making volunteer service a priority, Dr. Huch mentors others around the country into humanitarian work. She graciously shares her ideas and resources with anyone interested in developing non-profit clinics in their communities. She is a role model for both clinical services and community service and ADA is grateful for her contributions to ADA, audiology, and to her patients.

Joel Wernick Award

Richard Gans, Ph.D., founder and executive director of the American Institute of Balance received the **Joel Wernick Award** in recognition of his outstanding educational contributions within the profession of audiology.

"Dr. Gans is widely recognized as a leading authority on clinical and business topics related to the delivery of vestibular services and interprofessional, collaborative care," said Dr. Bray. " He has trained thousands of audiologists, physicians, and physical and occupational therapists—and most importantly he tirelessly donates his time to teach students and young professionals as a preceptor and mentor."

Dr. Gans has developed and taught several globally recognized vestibular diagnostic and treatment protocols. He has authored and presented hundreds of articles, textbook chapters, presentations, and workshops—more than enough to make anyone dizzy!

Craig W. Johnson Award

Bryan Greenaway, Au.D. received the **Craig W. Johnson Award** in recognition of his state and national advocacy efforts to serve the profession of audiology.

“Dr. Greenaway demonstrated a commitment to advocate for audiology even before his clinical training was completed,” noted Dr. Bray. “In fact, he went out of his way, literally, to complete an internship rotation on the opposite side of the country from his educational institution, and his fiancé, specifically to obtain experience scheduling and conducting legislative meetings with staff and members of the U.S. Senate and U.S. House of Representatives."

In addition to leading meetings with members of Congress to advance the Medicare Audiologist Access and Services Act (MAASA), Dr. Greenaway serves as the Legislation and Policy Chair for the Oregon Academy of Audiology (OAA), where he spearheaded a successful advocacy effort to prevent enactment of regulations that would mandate certification as a condition of licensure and preceptorship in the State of Oregon.

President’s Award

Tom Tedeschi, Au.D. received the **President’s Award** for his outstanding contributions to audiology throughout his professional career.

“Dr. Tedeschi is a real renaissance man and a man of many surprises,” said Dr. Bray, noting that outside of audiology, Dr. Tedeschi served as an Army Ranger and a decorated Vietnam War Veteran and a professional tennis player and one-time doubles partner of Ilie Nastase.

Dr. Tedeschi served as the Chief of Audiology at Children’s Hospital Medical Center of Akron, as an owner and partner in Akron ENT Hearing and Balance, and in highly successful roles within the hearing industry.

“For ten years, I had the opportunity to work side-by-side with Tom on education, training, and business development at Sonic Innovations,” said Dr. Bray. “Dr. Tedeshi has served as an exceptional liaison between professional associations and has made valuable contributions to advance audiology as a clinical doctoring profession, and we are grateful for his incredible service to our profession.”

Join or Renew Your State Association Dues and Receive a $50 Discount on ADA Dues

ADA believes that membership in your state audiology association is essential for your success and for success of the profession—so much so, that we will help minimize the cost to you! Join or maintain membership in your state audiology association and receive an immediate $50 discount on your ADA 2022 dues. Contact Parker Allen at pallen@audiologist.org for more information.

FDA Proposed OTC Hearing Aid Rule Comment Period Closes January 18, 2022; ADA Analysis Underway

On October 20, 2021, the U.S. Food and Drug Administration (FDA) released a Proposed Rule Establishing Over-the-Counter Hearing Aids (Proposed Rule) with a 90-day deadline for comments (due by January 18, 2022). The rulemaking process follows President Biden's Executive Order of July 9, 2021 and initiates implementation of the Over-the-Counter Hearing Aid Act, ADA-supported, bipartisan legislation that was passed and signed into law as part of the FDA Reauthorization Act (FDARA) in 2017. FDARA directs the FDA to create a category of Over-the-Counter Hearing and develop regulations of OTC hearing aids that do the following:

- Provide reasonable assurances of safety and efficacy;
- Establish output limits and labeling requirements; and
- Describe requirements for the sale of hearing aids in-person, by mail, or online, without a prescription.

ADA is diligently analyzing the Proposed Rule against the statutory requirements imposed by FDARA, alignment with ADA's commitment to the delivery of evidence-based audiology services, professional autonomy for audiologists, and patient access and choice, and the degree to which the Proposed Rule specifically mitigates concerns brought forward by ADA's 2021 Issue Brief, *State Laws and Hearing Aid Sales: Home Field Advantage or House of Cards*. ADA will hold a Members-Only Town Hall Session prior to the end of the comment period to present ADA's analysis of the Proposed Rule and ADA's draft comments for member input. Please contact Stephanie Czuhajewski at sczuhajewski@audiologist.org.

U.S. House of Representatives Passes Build Back Better Act with Medicare Hearing Benefit—Under Consideration in the Senate

On November 19, 2021, the U.S. House of Representatives passed an amended version of the Build Back Better Act (H.R. 5376) that includes several hearing-related provisions that would impact Medicare patients and audiologists, if ultimately enacted. The bill includes provisions that would add coverage of treatment services provided by audiologists and would reclassify audiologists as practitioners, two of the three provisions in the Medicare Audiologist Access and Services Act (MAASA). However, the Build Back Better Act does not include a provision to eliminate the physician order requirement for Medicare beneficiaries as a condition of coverage of audiology services.

The bill also includes the following hearing related provisions:

- To add hearing aid dispensers as 'qualified hearing aid professionals' eligible to provide hearing assessment services, as allowed by state licensure, subject to any additional requirements determined by the U.S. Secretary of Health and Human Services, including those relating to educational certification or accreditation.
- Coverage of hearing aids for individuals with moderately severe to profound hearing loss in one or both ears once every five years if furnished through a written order by a physician, audiologist, or other practitioner for devices that are determined appropriate by the U.S. Secretary of Health and Human Services
- Exclusion of hearing aids from competitive bidding when furnished by a physician or other practitioner to their own patients as part of a professional service

At the time of this writing, ADA, the American Academy of Audiology (AAA), and the American Speech-Language-Hearing Association (ASHA) are advocating for further amendments to improve beneficiary access to audiology services, and to support consumer protection, transparency, competition, and patient choice. Our groups are working to provide assistance and offer these recommendations as this legislation now moves over for consideration in the Senate. We will provide further updates on these advocacy efforts as the legislative process continues to evolve.

2022 Coding and Reimbursement Update Now Available On-Demand

Significant revenue cycle changes are ahead for 2022! This course, led by Dr. Kim Cavitt, focuses on the relevant coding, reimbursement, Medicare, and insurance changes for 2022. Evoked potential, E/M, and telehealth coding changes will be specifically addressed as will Merit Incentive Payment System (MIPS), and the new coverage policies of insurers and third-party administrators/provider networks.

Course Leader: Kim Cavitt, Au.D.
Upon completion, participant will be able to:

- List the new CPT codes for 2022.
- List the MIPS and Quality Clinical Data Registry (QCDR) codes for 2022.
- Analyze third-party network agreements and program terms.

Please visit www.audiologist.org for more information (must be logged in to view the course).

AuDacity 2021: Unleashed Ideas, Opportunities, and Action

ADA's 2021 AuDacity Conference, Audiology Unleashed, delivered unmatched education and networking opportunities for more than 400 members and guests from October 25 – 27, 2021 in Portland, Oregon—and access to more than 30-hours of online content. The AuDacity program focused on the role of audiology services as public health services with featured sessions on hearing health equity, interprofessional collaboration, health literacy, managing comorbidities, and improving awareness and access to care.

Keynote presenter, Dr. Kevin Franck, challenged ADA members to continue their "hop forward" approach to audiology service delivery and inspired us to unleash audiology's potential by "focusing on the advice and not the device." Keynote presenter, Claudia Gordon, shared her personal experience and diagnosis of permanent sudden hearing loss as a child, emigrating to the United States from Jamaica, barriers to access to audiology services, the discrimination and ableism that she encountered, and the encouragement that she received from her audiologist and the difference it made on her journey to become the first Black, Deaf, female attorney in the United States. AuDacity courses are now available on-demand for all registered attendees. For more information, please visit www.audiologist.org.

Planning is underway for **AuDacity 2022, October 21-23, at the Gaylord Texan in Grapevine (Dallas), Texas**. ADA is seeking volunteers to serve on the ADA Education Committee and help build the AuDacity 2022 Conference Program. ADA members from all specialties and backgrounds are invited to serve! If you are planning to attend AuDacity 2022, are willing to participate in 4-5 teleconferences per year, and are willing to assist with the review of course proposal submissions, then please contact Brian Doty at bdoty@audiologist.org.

▶ Please contact Stephanie Czuhajewski at sczuhajewski@audiologist.org for more information about ADA, ADA membership, and opportunities for advancing your audiology career through involvement with ADA.


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AuDacity 2021 Photo Gallery

PRESIDENT'S MESSAGE

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or physician assistant is far better than audiology. What that leaves us to recruit is undergraduates with degrees in pre-SLP. We simply cannot build the profession we want based on recruitment of the enlightened refugees of communication sciences and disorders programs. To get more and better students, a necessary step is transitioning audiology to an improved career choice by elevating the profession from 'other' to practitioner.

Why am I talking to you about these issues? Because the future of our profession depends on addressing these issues and solving our problems. I don't see the other audiology associations, who control clinical education and clinical care guidelines, addressing these problems. It's going to take leadership and perhaps outside pressure and that is what the Academy of Doctors of Audiology does best.

I ask that you begin to think about the future of our profession after MAASA, how to make it more rewarding, how to help it thrive and grow. I do not believe that this can be done on the path we are walking today. My charge to you and the Academy is to begin to think about where we want the profession to be in ten, twenty, and thirty years from now and determine what must be initiated to pave a new path for our desired future. Our profession's mindset and our actions can no longer be based on the outdated concept that audiology and speech-language pathology are two professions within the discipline of communication sciences and disorders. My call to action is the same as Goldstein's and Osborne's: model our profession and professional advancement on the other profession that treats a primary sense disorder: optometry.

In closing, I thank you for your time today and the honor to be your president and represent you this year. While ADA may be only 1/10th the size of AAA or ASHA audiology, you lead the others in doing what is important and what makes the big differences. We must achieve practitioner status and then complete the transformational process to truly becoming a doctoring profession practicing healthcare at the peak of our scope of practice. Do this next. Make it happen. Thank you. ■

EDITOR'S MESSAGE

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with each other. There are several different possible wireless transmissions within modern hearing aids, including telecoils, FM and Bluetooth. Transmission of signals via 2.4 GHz radio, the most common of which is Bluetooth, comprises much of this category. In addition, near-field magnetic induction can be used for audio transfer between hearing aids, which is an integral part of bilateral beamforming. Wireless connectivity benefits wearers by improving the signal to noise ratio of the listening situation and enables for easier use of smartphones and other listening devices.

Third, the category that has emerged most recently is personalization. The wearer's ability to fine-tune their device using data from similar fittings or interact virtually with their hearing care professional comprises the personalization category. Many of the most recent innovations in hearing aids, involving machine learning, can be placed in this category. Some experts believe these machine learning insights, once they become more user friendly, will enable the rise of self-fitting hearing aids.

This issue of *Audiology Practices* is devoted to recent developments from our hearing aid manufacturing partners. Each of the six leading hearing aid manufacturers was asked to contribute an article on a signature feature within their current product line. We were lucky enough to hear from five of them. Looking back at Figure 1, note how each manufacturer devotes considerable resources to one of the three categories, striving to bring meaningful, purpose-driven features to persons with hearing loss. As this issue demonstrates, it's good to know we have innovative partners in industry. ■

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