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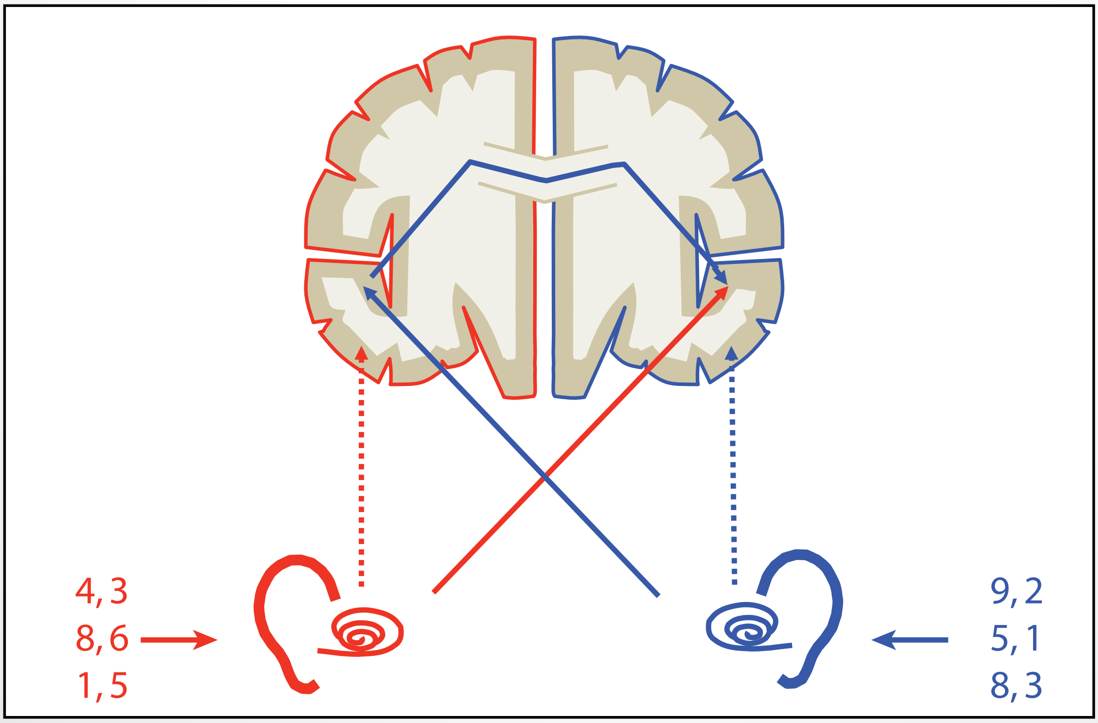

DICHOTIC LISTENING AND MULTIPLE SCLEROSIS

SYCLE SET TO LAUNCH IN CANADA

ADAPTIVE DYNAMIC RANGE OPTIMIZATION (ADRO): AN ALTERNATIVE STRATEGY TO WDRC

CHOLESTEATOMA: A FAMILY'S JOURNEY

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The days are getting shorter in the northern hemisphere; still, we are pleased to offer you the fall issue 4 of *CHR*. As has been the norm for *CHR*, there are four articles featured. The first is by Frank Musiek PhD and Diane Cheek BA, who is now a doctoral student. Both are at the University of Arizona. I have fond recollections of a week-long summer course in Central Auditory Testing that I took from Dr. Musiek while in graduate school. He was a visiting professor and he "taught that course like ringing a bell." He really kindled a fire inside (not under) me to study further in the fascinating field of audiology.

One of the many things taught by Musiek is the topic of dichotic listening. The listener hears a simultaneous presentation of different digit pairs presented to both ears. The digits are taken from the numbers 1–10 (excluding 7 because of its two syllables). There are two assumptions with dichotic listening: (1) the left temporal lobe in most people is dominant for speech and language, and (2) during (and only during) dichotic listening, the contralateral routes to opposite hemispheres suppress the ipsilateral pathways. Right ear information traverses a direct contralateral route to the dominant left temporal lobe. Left ear information however, goes to the non-dominant right temporal lobe, and then has to go through the corpus callosum in order to arrive at the left temporal lobe. As a result, most listeners exhibit a slight right ear advantage (REA). Many children with learning disabilities will yield a larger REA, due to the fact that the corpus callosum in these cases may not yet be well myelinated. Musiek and Cheek's article is called "Dichotic Listening and Multiple Sclerosis." Given that MS significantly affects white matter myelination, dichotic digits testing can be used by audiologists to monitor the course of the disease and also, to validate the listening deficits and hearing concerns expressed by those who have MS. The whole topic of dichotic listening is a fascinating one, and we are privileged to have this article by Musiek and Cheek in this issue!

Our next article is about a new kid on the block, who has arrived in the neighbourhood of office management software in Canada called Sycle. It was fun to meet up with them at the recent 2015 AHIP Symposium. You'll see their ad in this issue as well. I was curious to hear about them, and they agreed to an interview between their CEO and yours truly. Sycle arrives from the USA and started there in 2001. In coming to Canada, one hurdle Sycle had to overcome was the issue of handling our own unique third party insurance billing. Sycle is beginning its Canadian foray in Ontario, where it has now deals with insurance providers such as Assistive Devices Program (ADP) and Workers Safety and Insurance Board (WSIB). "Get out of the way; they're coming through."

We also have a wonderful article written by the mother of a young fellow with long standing cholesteatoma. Her article is called "Cholesteatoma: A Family's Journey," and it details the events – the three surgeries in all so far – that he (Rowan) has gone through. We often read about cholesteatoma through our textbooks and other scientific literature. It's not all too often however, that we get to read about it first-hand, as we follow the events from surgery to surgery. It's also heartening to hear some praise for Canada's health care system and the medical (and audiological) intervention Rowan received throughout his journey. Have a read; you'll likely like it.

Just when you thought it was over, I had to weigh in with an article about Adaptive Dynamic Range Optimization (ADRO). I first became aware of ADRO over a decade ago. It was already five years since I had left my position at Unitron in Kitchener Ontario, and I was writing the 2nd edition of my little book *Compression for Clinicians*. Upon reading about ADRO, I became fascinated by the fact that it utilizes *linear gain* in order to minimize distortion of the input speech signal to the hearing aid. In so doing, it provides an alternative to the ever-popular use of wide dynamic range compression (WDRC). ADRO was first implemented in cochlear implants, but soon thereafter, it was utilized in a digital chip that was manufactured by DSP Factory in (Waterloo Ontario!) for use in hearing aids. Today it is not utilized by any of the big players in the hearing aid manufacturing sector, but it is being sold by Hearing Lab Technology LLC in the USA. Oticon, however, presently uses a "floating linear compression" which has some similarities to ADRO. It is also an attempt to minimize input distortion, but we will not cover that topic in this issue. Instead, it is hoped that Oticon can submit an article on their "SpeechGuard™ in the near future.

Ted Venema, PhD,
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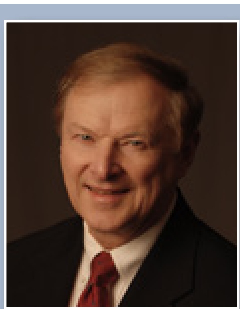
Dichotic Listening and Multiple Sclerosis

By Frank E. Musiek, PhD, CCC-A, and Diane E. Cheek, BA



About the Authors

Frank E. Musiek is professor, Dept. of Speech Language and Hearing Sciences University of Arizona. He is internationally known for his many formative contributions in auditory processing disorder and neuroaudiology. He is the 2007 AAA recipient of the James Jerger Career Award for Research in Audiology, the 2010 recipient of "The Honors of The American Speech, Language and Hearing Association for his contributions to Audiology and Auditory Neuroscience", and recipient of "Book of the Year Award" for the 2007 Handbook of Central Processing Disorder Vol. I and II *(with Gail Chermak co-editor). He has published over 200 articles and book chapters in the areas of auditory evoked potentials, central auditory disorders, neuroaudiology and auditory neuroanatomy. He has authored or edited 11 books. He has served on numerous national and international committees, editorial boards and task forces including chairing the 2010 AAA task force for clinical practice guidelines for CAPD and co-chairing the AAA Global Conference in 2012 and 2014.*

Diane E. Cheek will be a second-year student in the Doctor of Audiology program at the University of Arizona this fall. She graduated with honors from the University of West Florida with a Bachelors of Arts in International Studies and served in the United States Air Force before discovering the discipline of audiology. Diane enjoys all aspects of diagnostic and rehabilitative audiology, particularly matters concerning central auditory and speech processing. She has assisted with research investigating infant speech perception using cortical auditory evoked potentials and is currently investigating the modulating effects that attention has on the mediocochlear reflex in children. In the Neuroaudiology Lab, Diane works with dichotic listening tests and investigates their various clinical applications. This past academic year, Diane served as the University of Arizona's Student Academy of Audiology (SAA) secretary and is looking forward to leading SAA as president in the upcoming year. Outside of school, she stays active with many philanthropic efforts aimed at advancing the audiologic health of southern Arizona's and northern Mexico's underserved communities.

INTRODUCTION

The motivation for this article comes from informal observations and interactions with audiologists and patients with multiple sclerosis (MS). These observations made by the first author of this article indicate that audiologists, at least some audiologists, are not aware of the possible auditory consequences related to MS. Despite a fair amount of literature devoted to hearing difficulties associated with MS many audiologists do not adequately evaluate these patients and therefore fall short in properly managing them. This is especially of concern when in fact, sensitive tests such as dichotic listening are available to evaluate patients with MS. It should be remembered that in most instances audiologic tests like dichotic listening is not utilized to diagnose or help diagnose MS. Rather, in individuals already diagnosed with MS, when auditory symptoms occur, they can determine if the hearing deficit is a result of advancing MS or something else. Our focus here is to discuss dichotic listening and review its value in MS to remind the audiologist of his or her potential role in helping the MS patient with auditory problems.

WHAT IS MULTIPLE SCLEROSIS?

As an inflammatory demyelinating disease of the central nervous system (CNS), MS can be unpredictable with regard to which sensory systems are affected and disease progression. Worldwide, it affects approximately 2.3 million people with an average age of onset of 30 years, making it the primary neurological insult in young and middle-aged adults.[1] Prevalence rates of MS increases with latitude; therefore, age-adjusted estimates in the US can range from 47 per 100,000 in Texas to 177 per 100,000 in Minnesota.[2,3]

MS is largely viewed as a white matter pathology, with demyelinating lesions forming along the myelin that sheathes neural fibers in the brain, brainstem, and spinal cord.[4] These lesions routinely develop in particular CNS areas such as the periventricular, juxtacortical, infratentorial (brainstem to include the cerebellum), and spinal cord areas, affecting both motor and sensory modalities.[5] However, MS is not solely restricted to CNS white matter. Lesions have also been discovered within gray matter and along the white-gray matter demarcation early in the disease process although the exact pathologic mechanism for these lesions is unknown.[6–8] Theorized mechanisms for these gray matter lesions include myelinotoxin-induced degeneration independent of white matter pathology and secondary axonal insult following overlying white matter pathology.[7]

Gray matter is also subject to atrophy due to the disease process, which Sailer et al.[9] report as being most significant in areas with high white matter lesion volume, notably, the frontal and temporal lobes. Specifically, they found that both superior and medial temporal gyri exhibited the most atrophy within the temporal lobe, even in patients with mild disability. Charil et al.[10] report similar findings when they examined the relationship between white matter lesion load and cortical thickness in 425 MS patients. They found an inverse correlation between white matter lesion volume and underlying gray matter atrophy with significant associations in areas such as the cingulate gyrus, insula, and temporal lobe.

SYMPTOMS AND AUDITORY INVOLVEMENT

Due to the indiscriminate nature of these pathologic changes, an individual with MS may experience an array of symptoms and difficulties with varying degrees of severity. These include tingling, numbness, imbalance, bladder dysfunction, and visual changes. Diagnosing MS involves the identification of demyelinating lesions that demonstrate dissemination in space and time. That is, lesions must arise in two separate CNS areas at two different periods of time, both of which can be confirmed by magnetic resonance imaging (MRI) (for complete diagnosis criteria, see Polman et al.[5]).

The auditory system is not immune to the pathologic changes that occur with MS, though symptoms of auditory impairment may be the most subtle.[11] Demyelination along the myelinated portion of the auditory nerve can result in hearing loss, but this occurs only in a small number of patients (up to 4%) and tends to be transient and of mild degree.[11,12] More commonly, MS patients may first experience functional auditory deficits before the more overt and disabling neurologic symptoms develop.[13] For example, up to 54% of MS patients readily report hearing difficulties, particularity in background noise, despite having normal audiometric thresholds.[11,14] Identifying these subtle functional deficits, especially in the newly diagnosed, could aid in the monitoring of disease progression and therapy effectiveness.[15] One tool within our audiologic test arsenal suited to detect these deficits is dichotic listening. But before we can discuss the clinical utility of dichotic listening, we must first discuss *how* and *why* such tasks work.

THE CORPUS CALLOSUM

Our two cerebral hemispheres are joined by an immense network of predominately myelinated nerve fibers that make up an axonal tract called the corpus callosum (CC). The human CC is estimated to have more than 200 million such fibers which serve as the mechanism through which interhemispheric transfer of cortical information travels.[16] Myelinated fiber diameters range from 0.4 to 15 µm, with the thicker fibers having faster neural conduction rates between hemispheres.[16] Fiber myelination is typically not complete until the adolescent years of a child's development up to which point children may exhibit slowed interhemispheric transfer.[17]

Since most CC fibers are homotopic in nature, whereby they facilitate communication between equivalent areas of each hemispheric region, the CC transforms into a topographically organized structure.[16] With this perspective in mind, the CC can be divided into five anterior-to-posterior sections: rostrum, genu, trunk, sulcus (also termed *isthmus*), and splenium. It is primarily within the sulcus where fibers responsible for transferring auditory information can be found.[18] Hemispheric communication is vital for proper auditory processing since each hemisphere is specialized for different processing tasks; Gestalt processing such as pattern recognition is accomplished in the right hemisphere while the left hemisphere performs detailed, analytic processing such as speech segmentation.[19] The CC also facilitates heterotopic connections where neural fibers from one hemispheric area connect to a dissimilar area in the opposite hemisphere.[20]

For example, heterotopic connections between right inferior temporal cortex, site for visual recognition, and left Broca's and Wernicke's areas, sites for language processing, are thought to facilitate visual-auditory matching and naming.[21]

Nerve fiber composition, diameter, and density are not homogeneous across the CC. While the CC contains an overwhelming preponderance of myelinated fibers as a whole (~95% myelinated), a higher proportion of thinner, unmyelinated fibers can be found in the genu relative to the other callosal sections (~16% unmyelinated).[22] Additionally, as one travels anteriorly to posteriorly, fiber diameters increase with the faster conducting fibers (>3 µm) residing in the trunk, sulcus, and splenium.[16] With regard to fiber densities, small diameter fibers have a peak density in the genu while large diameter fibers are most plentiful in the midbody of the CC.[22] Overall, the CC's immense, yet intricate network of fibers is what enables our auditory system to efficiently process dichotically presented stimuli.

CORPUS CALLOSUM'S ROLE IN DICHOTIC LISTENING

When auditory input is simultaneously presented to the right and left ears, information from each ear will travel through the central auditory nervous system (CANS) primarily along contralateral (crossed) pathways which begin their contralateral ascent at cochlear nucleus. Contralateral pathways within the CANS are greater in number than ipsilateral (uncrossed) pathways and are believed to have an inhibitory effect on ipsilateral afferent activity during dichotic listening.[23] Given that the left temporal lobe is the site for language processing in a large majority of individuals, right ear auditory input will directly ascend via the contralateral pathway to the left hemisphere for language processing.[24,25] Left ear auditory input, on the other hand, will first be delivered to the right hemisphere only to then traverse the CC in order to reach the left hemispheric processing centers.[18] Figure 1 shows the auditory pathways involved during dichotic listening. Since the right ear has a direct pathway to the left hemisphere, it is generally afforded an advantage over the left ear in dichotic listening tasks. This right ear advantage (REA) demonstrates the cerebral lateralization and hemispheric asymmetry found in non-pathologic individuals who have language specialization in the left hemisphere.[26,27] Conversely, lateralization to the right hemisphere is revealed during dichotically presented non-verbal stimuli, such as music, and lends itself to a left ear advantage (LEA).[28] LEA may also be found in non-pathologic individuals who process language in their right hemisphere.

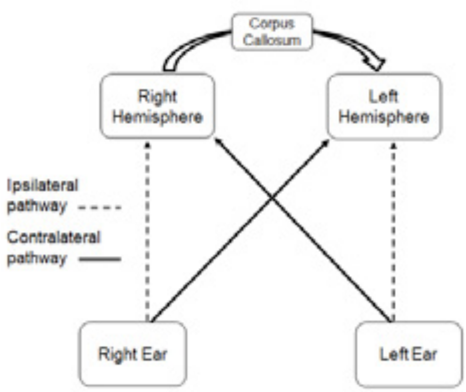


Figure 1. Auditory pathways in dichotic listening

Handedness may offer clues into which hemisphere is dominant for language processing, and thus, which ear advantage should be revealed: 95% of right-handers have left hemispheric processing (revealing a REA), 60% of left-handers have right hemispheric processing (revealing a LEA), and 20% of left-handers have bilateral processing (revealing a no-ear advantage, or NEA).[29] In summary, dichotic listening tasks were designed to evaluate the right-left laterality index and can reveal impairments of interhemispheric transfer if pathology exists anywhere along the central auditory pathway, to include the CC.

DICHOTIC LISTENING IN THE MS POPULATION

The myelin-rich content of the CC makes it a common target for demyelinating MS lesions. As the myelin sheathes surrounding CC fibers deteriorate, neural transmission rates along the fibers slows down.[11] Signs of demyelination along the CC's inner surface have been observed on MRI in 55–95% of MS patients.[30] The CC is also subject to global atrophy during the disease process, even in the early stages of MS when individuals only exhibit mild disability.[31,32]

Putting this all into context, a lesioned or atrophic CC that is left ill-equipped to perform rapid interhemispheric transfer of auditory information to the left hemisphere will typically exhibit a reduced LEA and/or an enhanced REA. In most individuals, left ear auditory input that is delivered contralaterally to the right hemisphere will need to traverse the CC to the left hemisphere for speech processing. If the CC cannot facilitate this interhemispheric transfer, then left ear input will fail to reach the left hemisphere for processing and a patient's performance in identifying left ear stimuli will suffer.

Conversely, given that right ear auditory input is delivered directly to the left hemisphere via contralateral pathways, an impaired CC will bear no negative impact on dichotic listening performance with regard to right ear stimuli. In fact, impaired interhemispheric transfer can enhance the identification of right ear stimuli among MS patients.[33] This enhancement is thought to be a result of a release from central competition between the two cerebral hemispheres.[33] That is, in non-pathologic CCs auditory information crossing from the right to the left hemisphere competes with the auditory information that is contralaterally delivered to the left hemisphere. However, patients with impaired interhemispheric transfer are spared this right hemisphere competition, and this is the driving force behind their enhanced right ear performance relative to normal controls on dichotic listening tasks. An extreme REA could also be interpreted as an extreme left ear deficit in situations where right-left interhemispheric transfer is severely impaired.[34] Such test results can occur in MS patients, depending on the location and severity of damage along central auditory pathway. Figure 2 shows the results on dichotic digits of a MS patient with an extreme left ear deficit.

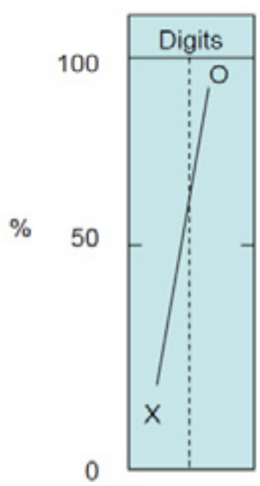


Figure 2. X = left ear. O = right ear.

Dichotic listening deficits as described above are well documented in MS patients. Generally, these patients exhibit reduced LEA and either normal or increased REA using syllable and digit pairs as stimuli.[15,18,33,35–37] This suggests an interruption in interhemispheric transmission from the right to left hemisphere due to demyelinating lesions resulting in a release from central competition.[34] Studies using MRI and diffusion tensor imaging have also associated atrophic CCs with greater left ear deficits and right ear enhancements.[34,38,43] This is not surprising considering that CC atrophy in MS patients is global in nature and not confined to a particular callosal area.[40]

But how sensitive are dichotic listening tests to MS pathology? For that, we can turn to studies that have investigated this very question in patients without MS given that CANS damage, regardless of etiology, will evoke similar dichotic listening deficits. Musiek[44] administered the Dichotic Digits test to 21 patients with either cortical or brainstem lesions and found that almost 81% of the cohort exhibited deficits with the deficits being more prevalent among those with cortical lesions. Upon closer examination of those with cortical lesions, Musiek[44] found that 6 of the 10 patients with unilateral lesions had significantly larger deficits for the ear contralateral to the lesion than for the ipsilateral ear while both patients with bilateral lesions exhibited bilateral deficits. Similar contralateral deficits have been seen with the Staggered Spondaic Word dichotic listening test in unilateral lesioned patients of varied pathology.[45] Musiek[44] also administered the Dichotic Digits test to 21 subjects with cochlear hearing loss and found specificity to be 81% and 95% when abnormal test score criterions of <90% (for normal hearing subjects) and <80% (for cochlear hearing loss subjects) were used, respectively.

EFFECTS OF NON-CALLOSAL INVOLVEMENT

As previously discussed, MS may leave patients with non-callosal white matter lesions, gray matter lesions, or atrophy of the temporal lobe in addition to callosal degeneration. Another region along the central auditory pathway susceptible to MS lesions is the brainstem, with the pons and medulla oblongata seeming to be most affected.[46,48] In one study of 68 MS patients with periventricular lesions, 71% also had lesions in the pons and 50% with lesions in the medulla oblongata.[49] As expected, dichotic listening deficits have also been demonstrated in patients with brainstem lesions. Jacobson et al.[35] found REAs in 80% of their MS cohort (16 of 20 patients) all of whom had brainstem lesions and abnormal auditory brainstem responses (long latencies and irregular morphologies). The fact that about half of Jacobson et al.'s cohort who exhibited REAs did not have accompanying lesions in the cerebrum makes a case for brainstem lesions being capable of interrupting interhemispheric transfer before higher level processing can take place.

While test-retest reliability of dichotic listening tasks has been shown to be 0.85–0.90, sensitivity within the MS population is less predictable.[50] That is, there tends to be high variability with regard to degree of lateralization across studies. Factors likely influencing this variability warrant a brief discussion.

HETEROGENEITY OF DICHOTIC PERFORMANCE

First and foremost, it must not be forgotten that some cases of MS may not affect the auditory pathway at all. Dichotic listening in these patients would presumably be normal. But with the help of imaging technology, researchers can better determine which CNS structures are affected and select cohorts based on their findings. However, even after carefully selecting for disease location, a cohort's disease progression can influence the degree of lateralization seen within studies.[38] For example, patients in Lindeboom and ter Horst's[36] study demonstrated greater REA than those in Barkhof et al.'s[38] study. It was postulated that the longer disease duration and severity among Lindeboom and ter Horst's[36] patients may have resulted in the greater lateralization of right ear stimuli.[38] This may be due to a greater impairment of interhemispheric transfer and a release from competition of left ear stimuli.

Another variable is the degree and location of CC atrophy. Callosal atrophy was found to be associated with greater LEA suppression, with suppression being most profound when the posterior section of the CC was affected.[40] The relationship between greater LEA suppression and posterior CC atrophy was also found by Reinvang et al.[42] These studies highlight the tonotopic nature of the CC whereby interhemispheric fibers carrying auditory information are generally located in the CC's posterior section.[18] Looking at the CC as a whole, Rao et al.[41] found that only when the CC atrophied to less than 5 cm^2 in size did significant left ear suppression occur relative to controls (6.27 cm^2 mean CC size in healthy individuals[51]). MS patients that maintained a callosal area of at least 5 cm^2 did not significantly differ in performance compared to control subjects.

Lastly, the characteristics of the dichotic stimuli can certainly influence dichotic listening performance. Rubens et al.[15] point out that word pairs that share greater phonetic and acoustic similarity (can/pan versus ship/door) will result in greater test sensitivity for interhemispheric dysfunction. Test sensitivity would increase not only as a result of greater ipsilateral pathway suppression from the minimal contrasting pairs, but more difficult stimuli would reduce ceiling effects and better expose laterality differences between pathologic and non-pathologic individuals. Test sensitivity can also be improved by achieving better temporal synchrony between stimuli onsets since poor alignment can result in an artificial right ear deficit.[18] For example, after finding that simultaneous onsets generally produce a 14% REA in control subjects, Berlin et al.[52] determined that this REA could be overcome when left ear onsets lagged right ear onsets by as little as 30 msec. During these moments of stimuli dyssynchrony, true dichotic listening is lost and the full inhibitory effect of ipsilateral pathways by the stronger contralateral pathways may be reduced.[19] Consequently, enough auditory information may ascend ipsilaterally during these dyssynchronous moments to falsely elevate ear performance.[19]

SUMMARY

To conclude, patients with MS are often overlooked as a population having functional auditory deficits. However, reports of subtle hearing difficulties in those suspected with or have been newly diagnosed with MS should prompt audiologists to include dichotic listening in their audiologic test battery. This is because damage to central auditory pathways can occur even in patients experiencing only mild MS symptoms.[9,31,32] Performance on dichotic listening tests can be used to help monitor disease progression and validate patient concerns of having increased listening difficulties. All in all, the value of dichotic listening should not be overlooked in the MS population given its relatively strong sensitivity to detect abnormalities that may otherwise be undetectable with other audiologic tests.

KEY POINTS – DICHOTIC LISTENING AND MULTIPLE SCLEROSIS

- Worldwide, multiple sclerosis (MS) is the primary neurological insult in young and middle-aged adults and is indiscriminate with regard to which central nervous system structures are affected

- About half of MS patients readily report functional hearing deficits, notably in background noise, yet audiometrically less than 5% exhibit measurable hearing loss

- Subtle auditory deficits may appear before the more overt and disabling symptoms of MS, making identification of these deficits in the newly diagnosed helpful in monitoring disease progression and therapy effectiveness

- Although corpus callosum is a prime target for demyelinating MS lesions, pathologic lesions and atrophy can occur anywhere along the central auditory pathway to include the auditory nerve, brainstem, non-callosal white matter, and underlying gray matter

- On dichotic listening tasks MS patients generally exhibit left ear deficits and increased right ear advantages due to an interruption of normal interhemispheric transfer of auditory information and a release from central competition between the two cerebral hemispheres
- Dichotic listening's sensitivity, specificity, and test-retest reliability make it a valuable and appropriate tool to be included in test batteries for the MS population

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Sycle Set to Launch in Canada

Sycle's Ridge Sampson in conversation with Ted Venema

This summer marks a big milestone for one of the most influential, long-standing software companies in our industry. Sycle, the number one audiology and hearing care practice management solution in the US and UK, is set to launch in Canada. Ahead of its release, *CHR*'s editor-in-chief, Ted Venema sat down with Sycle cofounder and CEO Ridge Sampson to chat about the company's mission, goals and what the Canadian hearing care community can expect from this pioneering software developer.

Ted Venema: Let's begin by telling me a little bit about yourself and your background.

Ridge Sampson: My background is in photography and digital advertising. I'm actually Canadian myself. I got my start shooting photography in Toronto. I moved to California shortly thereafter and made the transition into advertising. Being in San Francisco, I witnessed the transition from print to digital and formed my own agency focusing on the latter. In Silicon Valley it's kind of tough to avoid the startup / software bug. It's infectious. So when I saw the opportunity to start Sycle back in 2001, I also found myself surrounded by some of the best talent the industry had to offer. It was a perfect storm.

TV: Wow, so Sycle has been around for quite some time. How did it all get started?

RS: The advertising agency I started was hired by a large hearing care business. After working with them for quite some time on branding and marketing, my business partner and I realized that there was a need for marketing automation and business management software in the field. Over coffee in a cafe in San Francisco, we began mapping out the first version of Sycle. It was all designed to leverage new technology so as to automate as many tasks in the office as possible. That was our goal.

TV: And today you're an industry leader?

RS: I think we can safely say that we are the number one audiology and hearing care office management software in the world based on the number of customers we have. We are approaching 7,000 locations worldwide in eight countries and counting. We have offices in San Francisco, CA, Vancouver, BC, and Birmingham, AL. The team continues to grow as does our customer base. It's been, and continues to be, a thrilling ride.

TV: How did Sycle get its name?

RS: That's a great question that we get a lot. Sycle is a combination of two words – System and Cycle. It represents the automation, marketing, and patient retention capabilities that we built into the software from day one.

TV: What have been your main struggles or challenges?

RS: In the early days, it was educating potential customers that the cloud is the safest place to house data. We were pioneers in this area. But once people started to see the cost and security benefits of housing data off site in the cloud, word spread quickly.

TV: Aside from those initial issues, what other challenges do you face today?

RS: Awareness. We find a lot of potential customers are very tied to their current system which often involves tracking everything on paper, spreadsheets and Google Calendar. We are working hard now to educate the industry on the many benefits of digitizing their practices. It's tough to let go of old habits. But that is why we make joining Sycle so easy and completely free of risk. We encourage people to just give it a go. We are even providing Canadian practices a remarkable deal – sign up now and pay nothing until 2016. The sooner you sign up, the more time you have to utilize Sycle free of charge to see if it is right for you.

TV: Why do you think Sycle has seen such success over the years?

RS: I think Sycle has seen a lot of success and such wide adoption because our customers understand what our mission is. It's not just about developing office software. It's about simplifying every business process so our users are able to spend more time with patients. We share this mission and we are partnering with our customers to help more people with hearing loss.

TV: You mentioned that it's all about simplifying business processes so hearing care providers can spend more time with patients. Can you give some examples?

RS: Yes. Take reporting as an example. Managing the books, tracking outstanding revenue, forecasting, ensuring that the business is profitable – this can be incredibly time consuming for a practice owner. We also build integrations with the other systems our customers need to use like QuickBooks and NOAH to eliminate double entry. With Sycle, the key reports you need, and business metrics you require, are built and maintained automatically based on the appointments and transactions you enter into the system every day. So without double entry or extra report maintenance, it's very easy to always know how the business is doing. Our customers tell us constantly that our easy reporting capability is one of the biggest time savers for them.

TV: What is Sycle bringing to Canada specifically?

RS: A lot! We were thrilled when we attended our first Canadian conference this year, the 2015 Association of Hearing Instrument Practitioners (AHIP) Symposium. We had prospects running up to our booth saying, "Where have you been?" and, "We need Sycle". It was a great feeling – and now we're here.

The Canadian market is an interesting one and we have developed specific features that cater to your specific needs. Insurance processing is a big one of course. I'd say that our Canadian insurance capabilities will be the biggest enhancement we deliver.

TV: Do you have any clinics in Canada currently using Sycle?

RS: We do. About 40 clinics have been working with a beta program for the past year or so.

TV: The Sycle product offering is really quite robust. Can you tell us a bit about what the suite consists of?

RS: Absolutely. We are constantly evolving as a company. Our development team is always working to build new functionality that is native to the product. And as CEO, I'm always looking for great products and companies to partner with. Through these partnerships, with companies like PayJunction, HealthiPlan, QuickBooks and NOAH, to name a few, Sycle has launched over a dozen different products. They fit into four categories - Business Solutions, Marketing Solutions, Financial Solutions, and even Patient Care Solutions.

TV: Tell me a bit more about these 4 categories.

RS: We like to think of these as the four different categories of work that need to be done. We categorize all of our products into these buckets and we build tools to help simplify and streamline each. For instance, our scheduling and reporting tools fall under Business Solutions. Our automated patient communication mail pieces fall under Marketing Solutions. The Sycle-NOAH Sycle tool falls into Patient Care. And many of these products are free of charge - customers simply add on the functionality that works for their practice.

TV: What's next for Sycle?

RS: Well, we're really looking forward to spending more time in Canada growing our customer base here. We're looking at going into some other countries as well. As mentioned, I'm always on the lookout for new, innovative companies in the hearing care space to partner with. I think it's such an exciting time across the entire industry – there is so much great technology being developed these days. Sycle will continue to evolve with these new innovations and help deliver them to our customers.

Adaptive Dynamic Range Optimization (ADRO): An Alternative Strategy to WDRC

By Ted Venema, PhD

About the Author

Ted Venema taught at Conestoga College in Kitchener, Ontario, and was the founder and director of its program for hearing instrument specialists. He has a PhD in audiology from the University of Oklahoma. Ted frequently gives presentations on hearing, hearing loss and hearing aids and is author of the textbook Compression for Clinicians*, published by Cengage and now in its second edition.*

Some 10 years ago, Peter Blamey, PhD from Melbourne Australia introduced the strategy and performance of adaptive dynamic range optimization (ADRO). It was initially applied to cochlear implants and also to a "bimodal" way of amplification, involving a cochlear implant in one ear and a hearing aid in the other ear. Still later, its application extended to hearing aids per se. For first-hand information on ADRO as it began, the interested reader is referred to an early article on this whole topic.[1] ADRO is quite unique in that it offers an alternative to WDRC, in the form of a "sliding" usage of linear gain. Two main rules of "audibility" and "comfort" are applied to the output from this linear gain, and these rules are based on the client's subjective loudness judgements during the fitting. If the output exceeds the listener's comfort level, the linear gain decreases; if the output falls below the listener's audibility, the linear gain then increases. *The main thing to note is that unlike WDRC*, the gain for input speech is linear. The very nature of WDRC necessarily distorts the speech input sound waveform. The way in which linear gain is provided by ADRO; however, is intended to position the mean average of an input speech spectrum – free of distortion – into the client's reduced dynamic range. The purpose of this article is to introduce the concepts and procedures of ADRO; basically, how it works.

Before going further, two questions come to mind: (1) where is ADRO now, and (2) compared to WDRC, how would ADRO show up on Real Ear Measurement? With regard to (1), ADRO was originally implemented on the Toccata digital processor, developed by DSPFactory LTD in Waterloo Ontario! It was not adopted for usage by Unitron or other hearing aid manufacturers, until Interton picked it up. Today, ADRO is used and sold by Hearing Lab Technology LLC in the USA. They distribute hearing aids using ADRO through four different brands: Liberty Hearing Aids dispensed at Sam's Club, Assure Hearing Aids dispensed at Meijer's, America Hears Hearing Aids dispensed at Bristol PA and Bend Oregon, and at Walkers Hearing Aids dispensed through Cabela Hearing Ctrs. Regarding (2) we know the unaided speech input spectrum has a range or width of about 30 dB. The resultant aided speech output with WDRC is often narrower in width; this would be due to its method of compression. It may very well be that with ADRO, the range or width would also be narrower, but this would be due to the fact that the very loudest and very softest portions of the input speech spectrum are truncated or cut off. With ADRO, the main focus is the undistorted mean average of the input speech spectrum. Food for thought…

WDRC AND THE SPEECH SOUND WAVE FORM

For a hearing normal person, the dynamic range of the loudness growth is about 100 dB; for a moderate sensorineural hearing loss (SNHL, the hearing range remains only half this amount (40–60 dB), and this occurs mainly in the mid and high frequency regions. As a result, the client with this hearing loss is said to experience a more rapid than normal growth of loudness (Figure 1). WDRC projects the normal wider dynamic range to the reduced dynamic range of mild-moderate SNHL. It does this by means of having a low compression knee-point and a low compression ratio of usually 2:1.

WDRC "solves" the audibility problem.[1] It does this because it amplifies soft input sounds by a lot, average intensity input sounds by less, and loud inputs by little or nothing at all. In so doing, however, WDRC distorts the input sound wave form and this goes especially for the most important input of concern for those with SNHL; namely, speech! (Figure 2, top). As a sound, speech is complex, and is comprised of many different frequencies together. Also, speech is unique in that it changes or fluctuates rapidly in intensity over time. The sound waveform of ongoing speech can look fairly bizarre in its shape. In all sound waves, time is represented horizontally, from left to right. Amplitude is represented vertically. The peaks represent the louder portions, usually vowels and other voiced consonants, and the valleys represent the softest portions, usually the unvoiced consonants, such as */s/, /f/, /k/, /t/, /ch/*, etc. With WDRC (Figure 2, bottom), the valleys are amplified more than the peaks. While amplifying the softest portions of speech might seem to be just the thing to do with most high-frequency SNHL, the simple truth is that it is not. The bottom waveform of Figure 2 actually shows a distorted version of the top waveform! The peaks-to-valleys relationship is diminished and as a result, the crisp clarity of speech is muddied.

ADAPTIVE DYNAMIC RANGE OPTIMIZATION

ADRO is different. It does not use WDRC; instead it uses "linear" gain. In contrast to WDRC which gives different amounts of gain to soft, average and loud inputs sound intensities, linear gain gives the *same* gain for soft, average and loud input sound intensities. ADRO focusses on the most important part of the *input* dynamic range, where most of the cues required for *understanding what is being said*, are located. ADRO

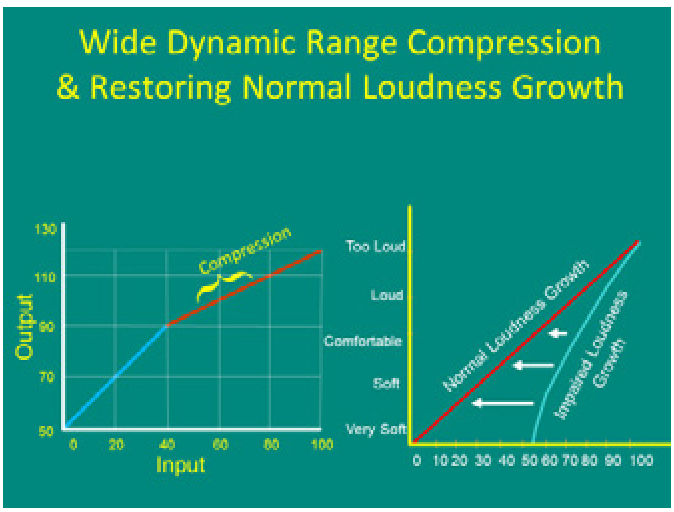

Figure 1. The left panel shows the Input/Output function of typical WDRC. With its low knee-point and low compression ratio, WDRC provides linear gain for only the very soft input up to 40 dB SPL. It provides less and less gain with progressively increased input levels. As the inputs increase from 40 to 100 dB, the outputs increase by half as much, from 90 to 120 dB SPL. If inputs increase by 60 dB and outputs increase by 30 dB, this would be a 2:1 compression ratio. The right panel shows normal and reduced dynamic range that is said to occur with mild-moderate SNHL. The larger dynamic range found with normal hearing enables a slower rate of loudness growth, from barely audible to too loud. In contrast, a more rapid growth of loudness results from the small dynamic range associated with moderate SNHL. This client would theoretically benefit from hearing aids that provided maximum gain for soft inputs, less gain for average inputs, and little or no gain at all for loud inputs (WDRC).

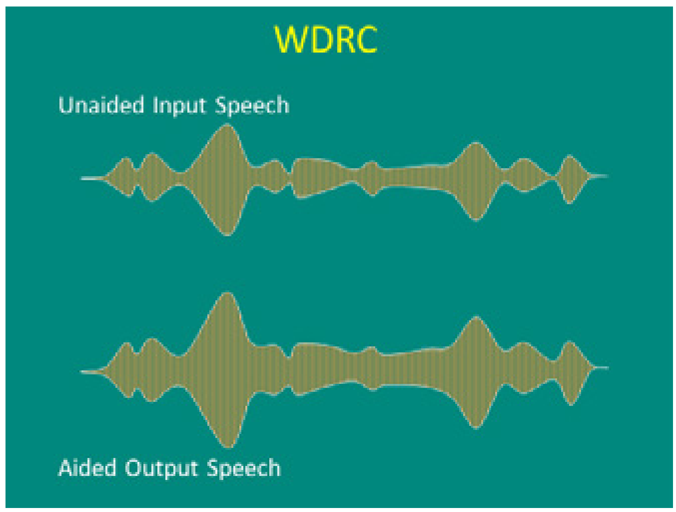

Figure 2. The top sound wave represents an example of a sentence spoken at an average conversational listening level. For the sake of humor, imagine someone saying, "My father can beat your father at checkers." The bottom sound wave represents the same sentence amplified by WDRC. Note how the overall sound wave is amplified, but peak-to-valley contrast is decreased.

accordingly changes the amount of its gain over time, always placing its *output* well within the listener's dynamic range of hearing. In other words, it *optimizes* the input dynamic range in order to be both audible and comfortable to the listener. In contrast to WDRC, ADRO does not distort the waveform of input speech (Figure 3).

The most important sounds for listeners are generally conversational speech and music. *ADRO uses linear gain in a very unique manner*, in order to ensure that aided speech and music are as undistorted as possible when being amplified. In this way, the aided speech is most intelligible and clear. Amplified music retains its original pitch, timbre, and rhythm. This minimally distorted input sound should then be amplified so that it is both audible and comfortable, within the listener's dynamic range. In plain English, this would mean, "neither too soft nor too loud." If one were to ask clients – even those with similar hearing losses – about those very words, one would find varying results, because people are individuals with different preferences. This is yet another important thing that sets ADRO apart; the adjustment and fitting of ADRO specifically addresses these subjective preferences, and settings are adjusted accordingly.

According to Peter Blamey, PhD who has been the prime mover behind the design and use of ADRO in cochlear implants and also in hearing aids, these three main tenets or platforms define ADRO as it is applied in a clinical setting: (1) an audibility rule, (2) a comfort rule, and (3) a unique, subjectively based fitting method whereby to arrive at the objectives of both of these rules for individual clients. We can now explain *how* these three elements are applied together to maximize the intelligibility of aided speech to the listener.

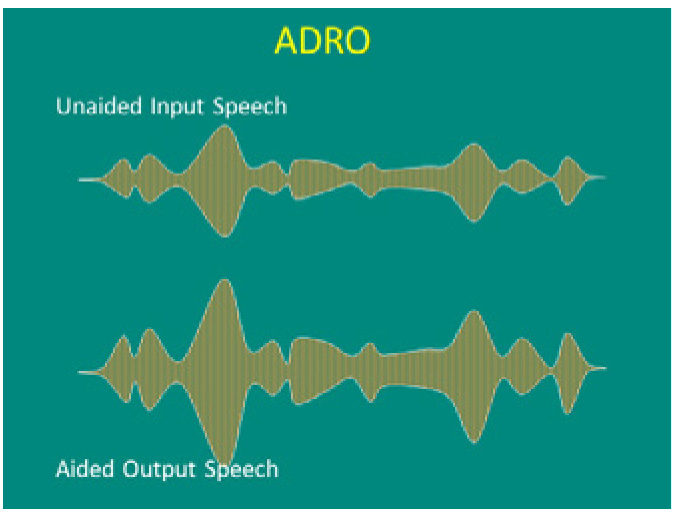

Figure 3. The same input sound wave is shown at the top as in Figure 4. Note here however, that with ADRO, the peak-to-valley contrast of the aided output sound wave (bottom) is kept intact. This is because ADRO uses linear gain, which provides similar amounts of gain for both the soft elements (valleys) and louder elements (peaks) of speech.

We have said that WDRC distorts the input speech signal. One might ask then if linear gain was so good in the hearing aids of yesterday, then why was it abandoned in favor of WDRC which first appeared in the KAmpTM in 1989? The reason is because those linear hearing aids weren't really all that good. The fundamental problem was that they remained fixed in their amounts of prescribed gain until the listener voluntarily and manually adjusted the volume control (VC). In fact, this was a visual give-away of a listener with an old-fashioned linear hearing aid. For soft speech the VC was rotated to increase the gain; for loud speech the VC would suddenly be decreased to escape the distortion caused by the peak clipping (which used to limit the maximum power output).

Here is what ADRO does differently with its linear gain: It automatically increases and decreases linear gain over time. The input intensity of the sound environment changes over time. Straight linear gain applied to increasing and decreasing input intensity would increase and decrease the output accordingly. In order to keep the clear and undistorted amplified speech situated nicely within the listener's dynamic range, ADRO uses internal built-in rules that tell it when to increase and decrease its linear gain!

INPUT/OUTPUT (I/O) FUNCTIONS AND LINEAR GAIN CHANGES

To understand ADRO the "language" of ADRO, it is very important to know how to interpret I/O functions, and to know how to read them. Figure 4 shows that on I/O functions, changes in linear gain result in left-right changes in the position of the 450 line or function on the graph. The length of the 450 line means nothing in terms of amount of gain; a long line simply means the same linear gain was given over a wider range of inputs. Also, contrary to what one might think, moving the line to the right means the linear gain went down, not up.

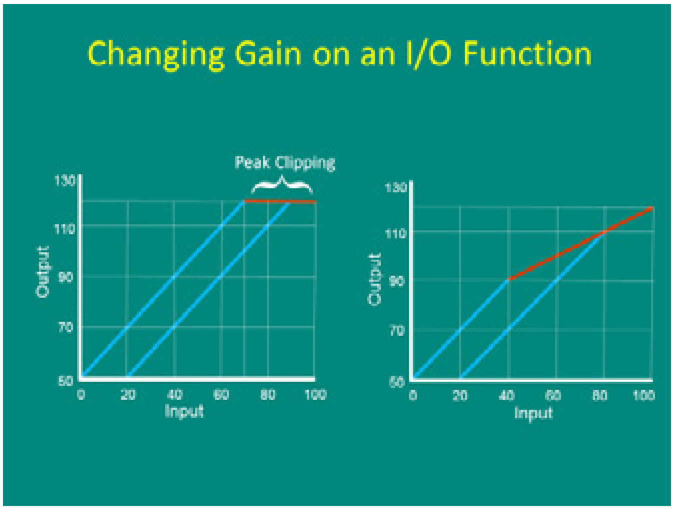

Figure 4. The left panel shows linear gain with its old method of limiting the maximum power output (peak clipping). The right panel shows typical WDRC. Changes of linear gain in either case, are shown as left-right movement of the 450° line or function. Note that for both, the left-most function shows that a 20 dB SPL input results in an output of 70 dB SPL; this is a gain of 50 dB. The right-most function shows that a 40 dB SPL input results in an output of 70 dB SPL; this is a gain of only 30 dB. As the gain function moves to the right, the gain decreases; as it moves to the left the gain increases.

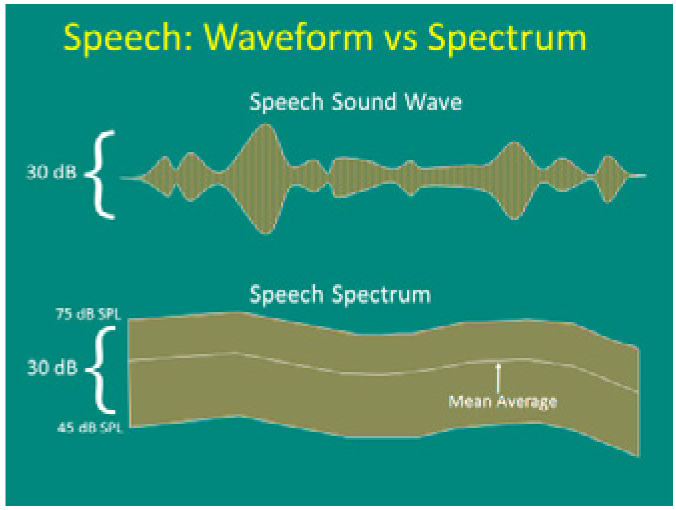

Figure 5. The top panel shows a sound wave for a fictitious spoken sentence of speech. The bottom panel illustrates a corresponding frequency spectrum for the same speech sentence. The challenge for optimal speech intelligibility is to: (1) preserve the peak-to-valley contrast of the speech sound wave, and (2) ensure that the roughly 30 dB dynamic range of the speech spectrum is maintained. Both of these should be amplified in such a way as to be: (1) audible and (2) comfortable to the client.

DYNAMIC RANGE OF INPUT SPEECH

In changing its linear gain over time, ADRO not only considers the reduced *dynamic range that occurs with SNHL, but it also keeps in mind the dynamic range of the input; whether it is speech, music, or any other sound*. There are two common and complementary ways to display the frequency, intensity, and time dimensions of sound: (1) sounds waves and (2) frequency spectra. Figure 5 shows a fictitious sentence of speech spoken at a conversational listening level as a sound wave (top) and a spectrum (bottom). When looking at the sound wave, it can be seen that WDRC would give more gain to the soft-intensity valleys of the sound wave than to the louder peaks of the sound wave. On the other hand, linear gain would preserve the peak-to-valley contrast of the speech sound wave and thus, preserve all the acoustical speech cues that are so necessary for optimal speech understanding. SNHL results from loss of cochlear hair cell function which tends to decrease one's ability to discriminate speech; it thus behooves of us to deteriorate the wave forms of speech as little as possible.

The frequency spectrum of average conversational speech is shown at the bottom of Figure 2. In contrast to a sound wave which shows time horizontally and amplitude vertically, a spectrum shows frequency horizontally and amplitude vertically (unlike sound waves then, a frequency spectrum does not show time, it averages over time instead). Here we can see that speech is a broadband sound comprised of many different frequencies. The typical spectrum for average intensity speech spans an intensity from about 45 to 75 dB SPL; thus it has a dynamic range of 30 dB. In other words, the loudest elements are about 30 dB louder than the softest parts. *With ADRO, linear gain is applied so that the most important parts – mean average – of the speech spectrum are amplified into the listener's dynamic range of hearing.*

As an aside, one interesting thing to note about the speech spectrum is that the mean or average intensity does *not* lie at the centre of the dynamic range; the mean or average intensity of average conversational speech is about 65 dB SPL or about 55–60 dB HL. This is due to the fact that the intensity of spoken speech (vowels-to-consonants-to vowels, etc) fluctuates rapidly in intensity over time. In contrast, the intensity of ongoing noise, such as that from a fan, air conditioner, or even background speech babble is much steadier in its intensity over time. As a result, the mean or average intensity of such noise would lie more toward the center of its overall dynamic range of intensity. By the way, this is how most digital noise reduction works: staccato-like sounds are interpreted as speech and are given most gain across the channels of the hearing aid, while sounds of more constant intensity over time are given a reduced amount of gain.

ADRO'S SUBJECTIVE IN-SITU FITTING METHOD

ADRO customizes the fitting for each client in a subjective way, and it *does this with the hearing aid in-situ (in place)!* This means the listener is making loudness judgements while the hearing aid is producing the noises from its own receiver. The beauty of this method is that it eliminates all kinds of transforms. For example, if the noises were to be produced from headphones, one would have to then figure out how to transform these loudness values into equivalent ones that would be produced from the hearing aid in the client's ear. In-situ measures circumvent all of this because the measurements to establish the client's loudness judgements are made with the hearing aid situated in place in the client's ear. After all, this is the way the client will hopefully be listening to speech!

The client's loudness judgements can be estimated on the basis of his/her audiogram. Experienced ADRO fitters have learned however, that it is best by far, to actually *measure* a client's comfortable loudness levels. Progressively increased frequencies of multi-tone tone complexes or "chimes" are presented to the client, and the client is asked to report if any of these are heard louder or softer than the adjacent noises. The main idea is to determine if the chimes are a bit too soft or a bit too loud, or as in the story of Goldilocks, if they are "just right." In other words, could the client listen to this loudness level for a long time? Once all frequencies are matched in loudness for one ear, they are then compared and are adjusted to match in loudness between right and left ears.

ADRO USES TARGETS AND RULES

In order to place the most important parts of the speech dynamic range into the client's reduced dynamic range, ADRO uses *targets* and *rules*. The targets are derived from the client's audiogram and loudness judgements. Rules are then applied to keep the output from straying from these targets. When the rules are applied, the linear gain changes. The whole idea is to keep the output within the targets.

The very first step is to establish the client's comfort level with the narrow bands of noise, an intensity level that the client indicates he/she could listen to for a long time. This information is then used to predict what is known as the comfort target (CT). An audibility target (AT) and a maximum output level (MOL) are predicted from the CT that has been established. A maximum gain (MG) for the hearing aid is also predicted from the audiometric thresholds of the client.

An Audibility rule and a Comfort rule are applied to make sure that the amplified speech stays both audible and comfortable. There are two more rules that also serve to manage how linear gain is applied with ADRO: a *Hearing Protection* rule and a *Background Noise* rule. These four rules operate together *in each channel* of an ADRO hearing aid. We now have four rules (Comfort, Audibility, Hearing Protection, and Background Noise) that can be respectively applied to four targets (CT, AT, MOL, and MG). So, in any channel of the hearing aid:

- If the output exceeds the CT more than 10% of the time, the Comfort rule serves to decrease the linear gain
- If the output falls below the AT more than 30% of the time, the Audibility rule serves to increase the linear gain
- If a sudden, transient intense input would cause excessively intense outputs past a specific maximum value that could further damage hearing, the Hearing Protection rule instantaneously applies output limiting compression
- If in quiet listening situations, the gain increases enough to make background noise annoyingly audible to the client, the Background Noise rule serves to limit the MG that is appropriate for the client's hearing loss

APPLYING THE COMFORT AND AUDIBILITY RULES

ADRO assumes that for any particular client, the most important acoustic information required to understand speech will lie between the listener's AT and CT. Figure 6 shows how the rules are applied in order to keep the most important parts of the speech dynamic range within the client's reduced dynamic range. The bump in the middle is known as a "distribution." Think of a bell curve showing grades in a class. The grades A, B, C, and D would be shown horizontally along the bottom. The number of students who got those grades would be shown vertically. The distribution here in Figure 3 indicates the output intensities horizontally, and the amount of times those outputs occurred vertically. Hearing aid outputs constantly change over time and ADRO uses statistics in order to constantly apply its Comfort and Audibility rules *in each channel* over time. While the outputs are constantly increasing and decreasing in each channel of the hearing aid, the rules ADRO applies remain constant. If the outputs exceed the CT more than 10% of the time, the linear gain decreases. If the outputs fall below the AT more than 30% of the time, the linear gain increases. If neither of these rules is violated, the linear gain stays the same.

In general, the focus is to keep the most important part of the input speech dynamic range both audibly and comfortably situated within the listener's reduced dynamic range of hearing. The tiny amount that is above the CT (10%) is not the focus, nor is the 30% below the AT.

ADRO ON AN I/O FUNCTION

We can now look at how the Audibility and Comfort rules of ADRO can be seen on an I/O function (Figure 7). This shows how ADRO applies its changing linear gain in any one channel over time. For listening environments with soft inputs, the linear gain will provide some specified output, depending of course, on the client's hearing levels and established CT.

As the soft inputs increase, the outputs will increase at a 1:1 ratio along with them. This is simply linear gain at the MG gain value. Once the outputs exceed the CT 10% of the time however, the comfort rule is applied, and the linear gain is reduced in order to keep the output at the set CT. If input levels decrease from this point, the output will drop linearly, at a 1:1 ratio along with the input. This is simply linear gain again, although it is now at a reduced amount compared to our beginning amount of MG linear gain. With continuing decreases to inputs, however, the outputs will fall to the AT. Here, the Audibility rule is applied, and the gain will be increased in order to keep the output audible. In keeping with the Background Noise rule however, this gain increase will continue only up until the MG level. From here, the outputs will drop once again at a 1:1 ratio with the inputs. We have just done a clockwise loop.

ADRO PROCESSING IS THUS, TO BE SHARPLY CONTRASTED WITH THAT OF WDRC

ADRO uses linear gain until one of its rules is violated. This results in linear gain being applied to a fairly wide dynamic range of input sound intensities. WDRC uses compression with a fixed knee-point and fixed compression ratio. The static compression is applied to a wide dynamic range of sound inputs, while linear gain is applied only to very soft input intensities. ***The results can easily be visualized in Figure 8, 9, 10 and 11***.

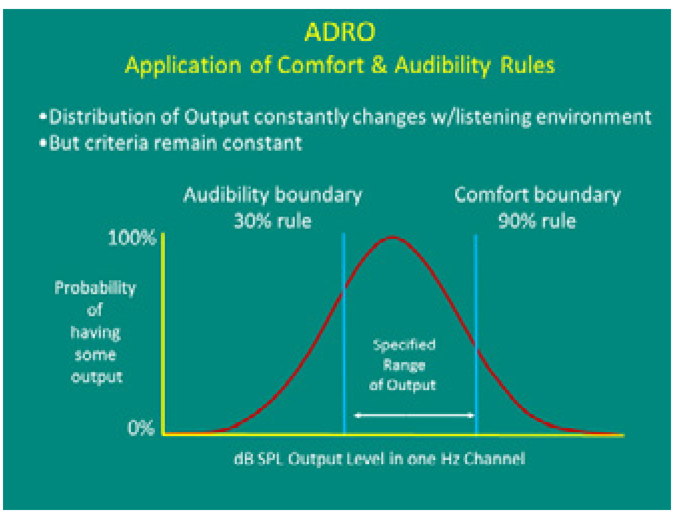

Figure 6. A fictitious output distribution is shown over a short period of time. The outputs change constantly over time but the rules for audibility and comfort remain constant. Linear gain is increased if the outputs fall below the audibility boundary more than 30% of the time. The linear gain is decreased of the outputs exceed the Comfort boundary more than 10% of the time.

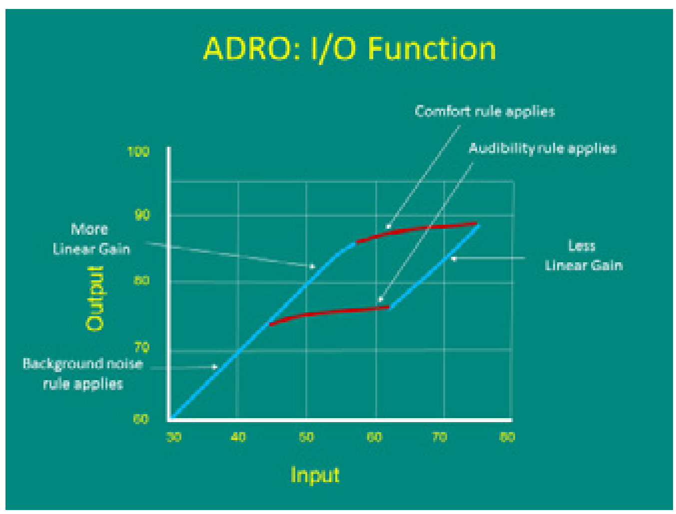

Figure 7. This figure shows the ADRO I/O function that would be traced out for a sound that increased slowly from 30 dB to 75 dB and then slowly decreased back to 30 dB at the input. The blue 450 lines show greater and lesser amounts of linear gain. The red flatter lines show outputs where the audibility and comfort rules apply. Here, the outputs no longer increase or decrease with a 1:1 (linear) ratio with inputs, and with increasing inputs, there is progressively less and less gain.

SUMMARY

1. The normal loudness relationship between the low-frequency vowels and high-frequency consonants is changed with WDRC, but not with ADRO
2. ADRO therefore provides for the listener a bright and clear sound, untainted by the squeezing (read "distorted") effects of compression
3. ADRO's three "calling cards" are its: Audibility rule, Comfort rule, and client-centered fitting method which asks for subjective loudness judgements
4. ADRO uses in-situ loudness measurements
5. Fitting methods used today (e.g., NAL-NL2) espouse Audibility & Comfort, but really they focus on Audibility alone; they hope for resultant Comfort to follow along as a logical end-point or conclusion. *ADRO actually measures comfort*.
6. ADRO takes dynamic range of:
   a. Input
   b. client's audiometric data
7. ADRO has a circular I/O function, enabling it to utilize linear gain for a maximal amount of inputs. WDRC on the other hand uses linear gain for very soft inputs

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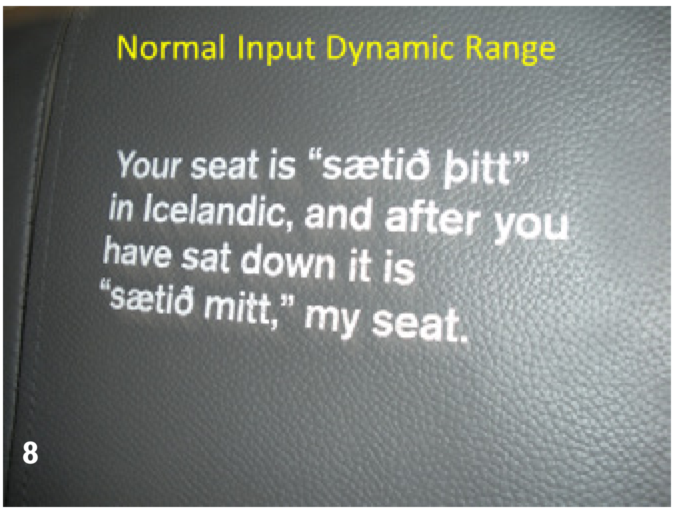
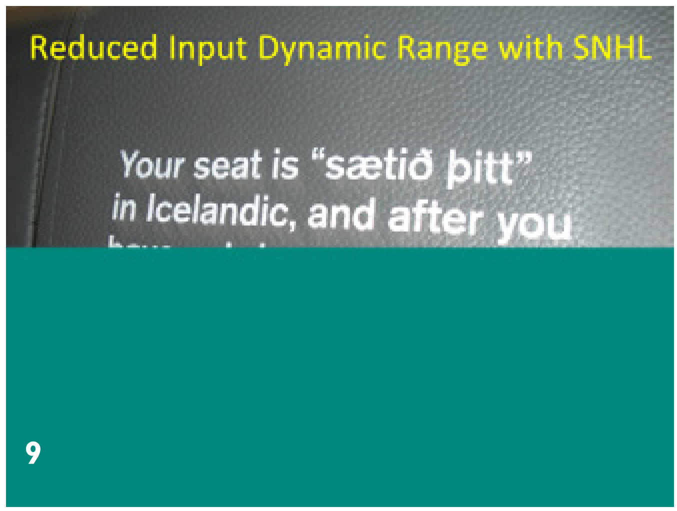
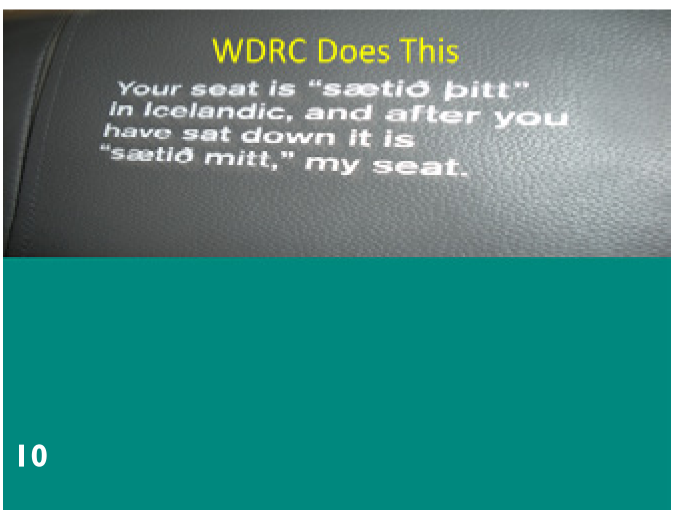
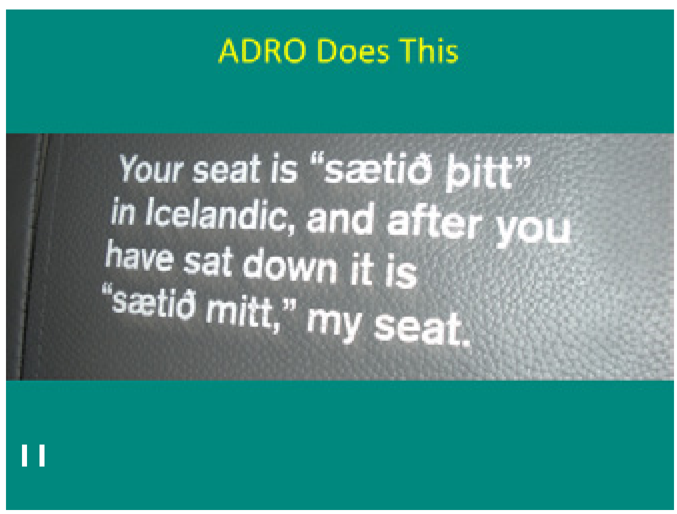


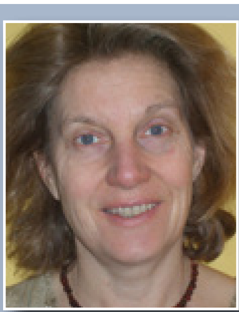






Cholesteatoma: A Family's Journey

By Sarah Orlowski



About the Author
Sarah Orlowski is a graduate of Ontario College of Art & Design. She went on to become a Master Herbalist, graduating from the Wild Rose College of Natural Healing. Sarah has been fortunate to have also trained in First Nations herbal traditions and also has her Permaculture Design Certificate. She enjoys music and as such, highly values hearing. Sarah has taught for many education institutions, including Simon Fraser University, Boucher Institute of Naturopathic Medicine, Canadian College of Traditional Chinese Medicine, Vancouver School Board, Van Dusen Gardens, Squamish First Nations, Capilano College and Douglas College. Currently, Sarah and her husband run an organic fruit & nut orchard/medicinal herb farm in Grand Forks, BC, where she makes her herbal products & trains student apprentices.

Our son Rowan has had hearing problems since a very young age, although this was not always all that noticeable, especially since I tend to use a loud voice a lot of the time. We first found out when he was about 2 ½ years old. We had recently moved into a rural area of BC, and the next-door neighbour kindly looked after him upon occasion. Fortuitously, she was the audiologist technician in the nearby town. After a while, she suggested that we bring him in for a hearing test because she suspected that he had hearing trouble. Sure enough, his hearing was below normal, especially for his left ear. This was the beginning of a long journey of ear escapades in which our son was the central character.

Rowan had regular ear exams, but his hearing at best never got above the low end of normal on hearing tests, and testing also consistently showed bilateral middle ear dysfunction. Eventually, my husband John and I took him to see Dr. Riding, an ear, nose and throat (ENT) physician at Children's Hospital in Vancouver. Rowan had PE tubes inserted during a bilateral myringotomy. Our caring audiologist technician then fit him with custom-made earplugs so that he would not have to give up swimming, which we both loved.

CHOLESTEATOMA #1

By grade 5, a noticeable mass was building up in his left ear. Dr. Riding said that he would book a tentative surgery date but prescribed him eardrops first just to see if the condition would clear up. The eardrops clearly did not work (as the doctor was predicting); our son had a benign cholesteatoma tumour, and so we made plans to proceed with the surgery. Dr. Riding explained that the name "cholesteatoma" was actually a misnomer because originally it was thought that these tumours were due to cholesterol build-up, but we now know that this is not the case (Figure 1).

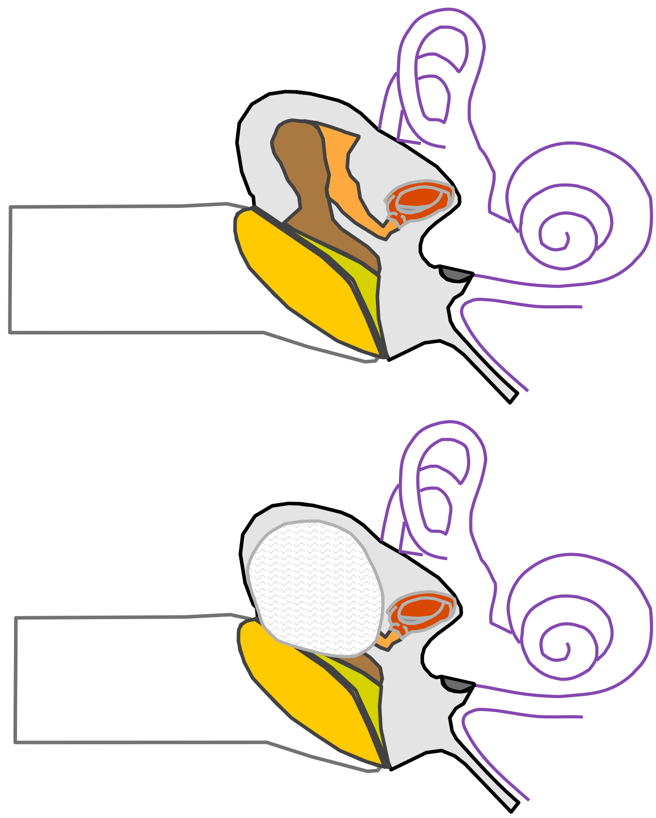


Figure 1. Normal (top), Abnormal (bottom). A cholesteatoma often begins with a perforated eardrum. The tumour then can grow quite rapidly. The base of the brain is quite close to the roof of the middle ear space. Surgery is done quickly to prevent the spread of growth.

We had never seen the little PE tubes after they were self-ejected, as they are supposed to, and at one point, Dr. Riding suggested that there was the possibility that one had not ejected, and that the mass of cholesteatoma had formed around it. He stressed the urgency for the tumour removal because of its fast growth rate and close proximity to the brain. It was strange seeing my little guy going into a giant magnetic resonance imaging machine, but he stayed very still as requested.

After that first surgery, life went on as usual. Sometimes he had some inflammation or infection, but very rarely did he ever have any pain. He has always had occasional, inexplicable headaches, sometimes quite severe, so I have wondered if there is any connection between them and his ears or the tumour. He still gets these headaches periodically.

Dr. Riding performed Rowan's first surgery to remove the cholesteotoma in spring of grade 5. This required three months without swimming, so it was unfortunate timing, as the summer was quite hot. Come September when the three months were finally up, he played in the ocean waves all day and barely ever came out.

Dr. Riding was a superlative doctor, who really took time with patients. He had an excellent bedside manner, with respect and humility in spite of his high standing. Upon completing Rowan's surgery, he came to see me in the waiting room. He drew a sketch of the procedure for me and explained that the cholesteotoma was so large that they had to abandon the idea of going in through the ear canal. Instead, they cut through the bone behind the ear. They discovered that there was so much erosion of the anvil, due to the tumour, that the ossicle was no longer of any use. ***The tumour itself was providing the conductive hearing in Rowan's left ear!*** So once the tumour was removed his hearing level actually went down.

Dr. Riding recommended that once Rowan had completed his physical growth, he should get a prosthetic ossicle. He also advised that we keep a close eye on Rowan's ear, as the cholesteatoma was fuelled by growth hormone and were known to grow somewhat aggressively. Rowan appears to have abundant growth hormone as he has always been large for his age: his 12-year molars were in place by age 10, which his dentist said he had never seen before, and he wore size 15 shoes by the time he was 13 years old.

Life carried on as usual although Rowan's hearing was always an issue, as well as his periodic headaches. He did very well at school, nonetheless, and for the most part people did not know that he had a hearing problem. I made sure to tell his new teacher each year. When he reached grade 7, he had a teacher who was not much of a disciplinarian, so the average noise level of the classroom was quite loud and Rowan was having a hard time in class. Without his conductive hearing loss, he had difficulty locating the teacher's voice out of the general milieu. It was also harder for him to concentrate on his work due to the noisy classroom and she suggested that he sit out in the hall to do it, which I thought was a rather poor solution. Halfway through that school year; however, we moved to a new town in the BC Interior. Dr. Riding had by then retired and each of our follow-up appointments at Vancouver Children's Hospital had been with different doctors. So we travelled to Trail to see Dr. Cook, an ENT specialist who was then doing Rowan's ear exams. After a few visits, he noticed the cholesteatoma beginning to grow back. Grateful to Dr. Cook for spotting it, we looked for an experienced ear surgeon and ended up with Dr. Kramer, an ENT in Kelowna, who had been trained by Dr. Riding.

CHOLESTEATOMA #2

I believe it was 2011 when Dr. Kramer performed surgery on Rowan's left ear to remove another benign cholesteatoma. Perhaps more accurately, it was the same one growing back. Again, he went in behind the outer ear. The surgery took longer than predicted. Rowan had three feet of gauze tubing inserted inside to keep the area open for the future surgery of replacing the ossicles, which I now learned was not just one, but all three of them; they had all been eroded by the cholesteatoma! The gauze tubing caused Rowan considerable pain, which did not resolve until the tubing was removed about three weeks later.

Most of Rowan's teachers did not detect Rowan's hearing loss, as he was adept at positioning himself to his best hearing advantage. At one point, however, one of his teachers, who had been with him since grade 8, remarked to me that he had finally noticed our son's hearing loss because Rowan had responded to a question with a non sequitur, and he realized that sometimes Rowan was guessing at what had been said. Walking down the road with Rowan, he will always place himself on the left side of companions so that his right ear is closest to them; otherwise, he will not be able to hear the conversation.

CHOLESTEATOMA #3

By grade 12, Rowan's cholesteotoma was growing back yet again. This time, Dr. Kramer recommended that another ENT, Dr. Mick do the surgery. They now shared a practice in Kelowna. Having had a fellowship from U of T, Dr. Mick was young and experienced in the new techniques. So in March of this year, Rowan underwent surgery for his third cholesteatoma removal. Like the previous surgeries, Dr. Mick went in behind the ear, although by now there was a lot of scar tissue from the previous surgeries, so he had to cut the old scar out and add new skin to the region, resulting in a slightly raised scar. Because it's behind the ear; however, it does not show. After removing the latest cholesteotoma tumour, Dr. Mick inserted a *Total Ossicular* Replacement Prosthesis (Figure 2). This is a titanium ossicular chain and Rowan now has a wallet-sized card declaring that he has titanium in his head. Like the previous time, this was a very long surgery and Rowan once again had the dreaded gauze tubing inserted to keep the cavity from collapsing. Pain was immediately relieved upon its subsequent removal.

I am happy to say that Rowan has recovered well from all these surgeries, and we feel that we were in good hands at all times with some of the best ear surgeons in Canada working on our son. He has graduated with scholarships and honours from high school and will be attending UBCO in Kelowna, so he will be able to attend his ear appointments on his own from now on. Rowan, however, has told us that in spite of all the work done, his hearing levels have not really changed and he has not noticed an increase in hearing ability, even with the new ossicular prosthesis in place. At first we thought that this might change once the inflammation was gone and the post-surgical healing had taken place. But the surgery was five months ago now and he has still not noticed an improvement in hearing. I don't know why, but nonetheless, I am glad that the cholesteotomas are gone. I am aware that there is a chance that it could grow back yet again, as it is possible that Rowan may still grow some more and that the growth hormone might fuel some more tumour growth (you know what they say about puppies with big paws). In any case, I am grateful to live in Canada with universal health care and excellent doctors. I hope that this is something upon which we can always rely.

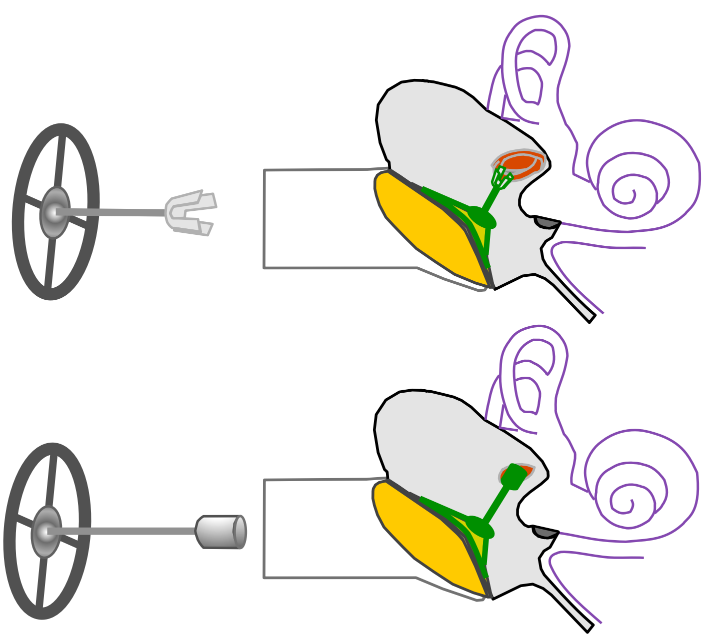


Figure 2. Top: Partial Ossicular Replacement prosthesis. Bottom: Total Ossicular Replacement prosthesis.

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