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Attawapiskat: An Audiology Northern Initiative

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I recall sitting in class more than 30 years ago and listening to a professor try to explain the difference between sound pressure and sound intensity. Finally, he just threw up his hands and said, "Don't worry about it – as far as audiologists are concerned its really irrelevant in any event." Well, he was right, but I suspect that he was wrong as well. There are significant differences between the two even though audiologists use the two interchangeably. Well, Alberto Behar in his new column, Noise about Noise, discusses the differences. Alberto and I have written books and chapters together over the years. I typically take the first stab at the chapter, send it off to Alberto, and then I get the phone call – "Let's meet for a beer. I need to teach you something." Many beers later, I think that I finally understand the difference between the two concepts.

That's one of the most interesting things about being the editor of the *Canadian Hearing Report* – I get to learn new things in spite of myself. And, this issue is full of things I can learn. It's interesting that after more than 30 years in the field one would suspect that he has it all figured out. I must admit to knowing less today than I did in the 1980s. Mind you, in the 1980s, pi only had 2 decimal places, the English language only had 21 letters, and we hadn't invented any numbers higher than 735. Simple clinical issues such as, "Should a child remain on medication while they are being assessed for central auditory processing disorders?" still elude me. However, in this issue's All Things Central, Dr. Kim Tillery addresses just this issue.

Clinical issues in a large metropolitan centre can be different than clinical issues in a remote community where hearing aid re-evaluations are done by snow mobile or through some form of telehealth. Jack Scott shares with us how audiology is delivered in Attawapiskat, where good hearing health strategies are not as straightforward as it would be in Calgary or Halifax. If you recall in the news, Attawapiskat is where there is a recent concern regarding adequate housing. I've always found stories of the north to be rather romantic and pioneering, but then again, I don't have to live there and deal with many of the difficult realities. How long will a #10 battery last when exposed to -20 degree weather? What are the operating parameters of a class D output stage when the humidity is very low? And what about intermittent eustachian tube dysfunction and the educational implications of a chronic 20-30 dB conductive hearing loss?

And speaking of romantic, the *Canadian Hearing Report* is pleased to be able to reprint, courtesy of *Hearing Review,* an article I wrote several years ago that talks about many of the acoustic principles that we use in every-day life, but in a form that is appropriate for a bed time story. I have been told that this whimsical story is required reading in some hearing aid and acoustics classes in several American universities. Try explaining why a flared piece of tubing enhances the higher frequencies or how acoustic resistance may alter the frequency response, to a five-year-old kid. It's a cute "bedtime story" but still is based on sound acoustic and axiomatic principles.

Returning to the technical side of life, Thom Fiegle provides a nice overview of in-ear monitors. Driving loud music through small diaphragm receivers is not an easy task, and some of the tricks of the trade and technology are clearly provided – great for late night reading.

Hope you all have a pleasant winter and let's hope for warmer weather to come.

Marshall Chasin, AuD
Editor in Chief
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Canadian Hearing Report 2012;7(1):3.

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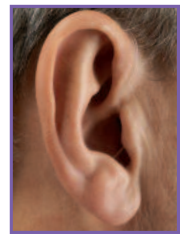

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Je me rappelle, assis en classe plus de 30 ans déjà, à écouter un professeur qui essayait d'expliquer la différence entre la pression du son et l'intensité du son. Finalement, il a juste levé les bras et dit, " ne vous en faites pas – pour les audiologistes, ce n'est vraiment pas pertinent de toute façon. " Bon, il avait raison mais je crois qu'il avait tort aussi. Des différences significatives existent entre les deux, même si les audiologistes utilisent les deux de façon interchangeable. Bon, Alberto Behar dans sa nouvelle colonne, Noise about Noise, traite ces différences. Alberto et moi avons écrit des livres et des chapitres ensemble à travers les années. Typiquement, je commence le premier chapitre, je l'envoie à Alberto, et je reçois le coup de fil – "Allons prendre une bière. J'ai besoin de t'enseigner quelque chose." Plusieurs bières après, je pense qu'enfin je saisis la différence entre les deux concepts.

Un des aspects les plus intéressants de mon titre d'éditeur en chef de la *Revue Canadienne d`Audition* est que je suis mis au courant des nouveautés bien malgré moi. Ce numéro en a plusieurs. Il est intéressant de sentir qu'après plus de 30 ans dans le domaine, on a l'impression de tout savoir. Je dois reconnaitre que j'en sais moins aujourd'hui que dans les années 80. Remarquez, dans les années quatre-vingts, pi avait deux décimales, la langue anglaise seulement 21 lettres, et nous n'avions pas encore inventé de chiffres supérieurs à 375. Des problèmes aussi simples que, " un enfant devrait-il rester sous médicament tant qu'il est évalué pour troubles des processus auditifs centraux ? " continuent de me dépasser. Toutefois, dans ce numéro, tout ce qui est central est traité par Dr. Kim Tillery.

Les enjeux cliniques dans un grand centre métropolitain peuvent être différents des enjeux cliniques dans une communauté éloignée où les réévaluations des appareils auditifs sont faites par motoneige ou certaines formes de télésanté. Jack Scott nous raconte comment l'audiologie est livrée à Attawapiskat, où les bonnes stratégies de santé auditive ne sont pas aussi directes que celles de Calgary ou Halifax. Si vous vous rappelez les nouvelles, Attawapiskat est le lieu où des préoccupations récentes quant au logement approprié se sont manifestées. J'ai toujours trouvé que les histoires du nord sont plutôt romantiques et pionnières, mais là encore, je ne vis pas là-bas et je n'ai pas à faire face aux réalités difficiles. Combien de temps est ce qu'une batterie #10 va durer quand exposée à des températures de -20 degrés ? Quels sont les paramètres operateurs d'un étage de sortie de classe D quand l'humidité est très basse ? Et les répercussions du disfonctionnement intermittent de la trompe d'eustache et les implications de formation d`une perte auditive chronique de conduction de 20-30 dB?

Et parlant de romantisme, la *Revue Canadienne d'audition* a le plaisir de pouvoir réimprimer, courtoisie de hearing review, un article j'ai écrit plusieurs années auparavant, article qui touche aux plusieurs principes acoustiques que nous utilisons dans la vie de tous les jours, mais en un format plus adéquat pour une comptine. On m'a dit que cette note de fantaisie d'histoire est une lecture exigée dans certaines classes de formation sur les appareils auditifs et acoustiques dans plusieurs universités américaines. Essayer d'expliquer à un enfant de cinq ans qu'une pièce évasée de tube rehausse les fréquences supérieures ou que la résistance acoustique puisse altérer la fréquence de la réponse. C'est une "comptine" mignonne mais toujours est-il qu'elle est basée sur l'acoustique de son et les principes axiomatiques.

Retournons au volet technique de la vie, Thom Fiegle fournit un bel aperçu sur les écouteurs intra-auriculaires. Pousser une musique forte à travers des récepteurs de petits diaphragmes n'est pas tâche facile, et certains tours de chapeau du commerce et de la technologie sont clairement fournit, superbe pour une lecture de fin de soirée.

J'espère que vous aurez un hiver plaisant et espérons avoir des températures plus clémentes à venir.

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2012: A Year of Growing Potential

Dear CAA Members and Colleagues,

The last year and a half marked some remarkable changes for me personally and professionally. About four months after I took up my role as president-elect of CAA at the end of 2010, my husband and I happily yet surprisingly became expectant parents.

I remember the day when I announced the news to my fellow executive and board members, fully prepared to step down so I wouldn't burden them, and they immediately and generously offered their full support – from much needed practical help in chairing and attending meetings on my behalf, to their kind words of encouragement when I was put on bed-rest at the start of my third trimester. These are the amazing colleagues and talented team of volunteers from all sectors of audiology who work tirelessly and enthusiastically for the betterment of our profession, and I am privileged and so thankful to work alongside them.

Volunteer opportunities are highlighted in this issue of *CHR* – they are great chances to network and tackle issues that are important to you. I can vouch that problem-solving with like-minded colleagues will lift up your spirits – after all, no one understands the professional frustrations and triumphs we face better than a fellow audiologist!

This year, with the vital and dynamic expertise of our executive director and equally indispensable administrative assistant's support, we are focusing our resources on a number of key priorities:

- Continuing to provide top audiology educational opportunities through the upcoming spring symposium and through offering the most comprehensive national audiology conference every fall;
- Maintaining our commitment to promote audiology to consumers and students by developing professional press kits and presentations for your use;
- Furthering excellence in hearing healthcare by working in partnership with key government and research stakeholders;
- Improving the organizational and financial efficiencies of our non-profit association;
- Augmenting our membership base via the creation of new members-only benefits;
- Representing and advocating for your interests in government, regulatory and related issues including inter-organizational collaborations; and
- Keeping you updated on the latest news in audiology and CAA through a re-launch of our monthly newsletter and the continued growth of our website.

As you can see, there is plenty of work to tackle and fun to be had in 2012.

Amidst the torrent of diaper changes, spit-ups and mop-ups, and round-the-clock feedings (not to mention, pecking out e-mail responses a few words at a time or changing fresh diapers and clothes consecutively for reasons that I shall leave to your collective imagination), I couldn't feel happier or more grateful as I look forward to all the challenges and rewards that lie ahead for my family and for CAA.

Here's wishing you and yours good health, happiness, and prosperity in 2012!

Best regards and looking forward to collaborating with you this year,

Victoria Lee, AuD, FAAA, CCC-A
President of the Canadian Academy of Audiology

Canadian Hearing Report 2012;7(1):8.

Provincial/Territorial Initiatives Network

In order to keep our members up to date on what is going in audiology across Canada, CAA is looking for volunteers for its Provincial/Territorial Initiatives Network (PIN). The PIN's mandate is to inform and update audiologists, employers of audiologists, purchasers of audiology services, and the public about provincial initiatives related to audiology services in each province and territory.

The role of the members of this committee is to raise or highlight important issues in each province/territory related to regulatory bodies, third-party insurers, local association business, educational opportunities, local accomplishments, etc. The PIN members will accomplish this by providing information/updates to PIN coordinator to post information on the website so that all members will know what is going on across the country as well as acting as a resource for CAA members about issues in a given province/territory, and as a resource to the local area about CAA and its initiatives.

If you are interested in applying to be a part of the PIN or if you have any further questions please contact Carri Johnson at PIN@canadianaudiology.ca.

Third Party Funding News

NON-INSURED HEALTH BENEFITS (NIHB) PROGRAM

As of January 1, 2012, audiologists are now recognized as valid prescribers of audiology equipment and supplies. Referral prescriptions from physicians or nurse practitioners are no longer required.

Hearing aid specialists such as hearing aid practitioners, hearing instrument practitioners, and audio-prosthetics still require referral prescriptions.

Audiologists in PEI and Nova Scotia are not regulated. Therefore, to qualify as a prescriber under the NIHB program, audiologists from these provinces must be a member of either CAA or CASLPA.

DEPARTMENT OF NATIONAL DEFENSE (DND)

As part of the DND members' overall health check there will be an addition of screening audiometers (air only) on each base. The procedure for the screenings will be a true threshold search. In addition, part of the screening process will include a case history questionnaire and the information collected will be used to start accumulating data and statistics on members.

Our other Federal Healthcare Partners are working on some exciting developments.

See the link *FHP Meeting Oct 2011 Minutes at www.canadianaudiology.ca/advocacy-and-funding/federal-health-partners.html.*

Questions and ideas are always welcome at caa@canadianaudiology.ca

CALENDAR OF EVENTS

FEBRUARY 2012

February 18
Mayo Clinic 22nd Audiology Conference - Rochester, MN
http://www.mayo.edu/webcasts/audiology.html

February 25–29
35th MidWinter Meeting of the Association for Research in Otolaryngology (ARO), San Diego, CA, USA

MARCH 2012

March 3
27th annual Seminars on Audition
Dr. Nina Kraus will be talking about the brain and how speech in noise and music perception are intimately related. Steve Armstrong will be discussing some of the nuances and issues surrounding DSP technology.
www.chasin.ca/seminarsonaudition

March 8-10
American Auditory Society
Annual Meeting, Scottsdale, AZ | www.amauditorysoc.org

March 28–31
24th Annual Convention of the American Academy of Audiology - Audiology Now! 2012, American Academy of Audiology (AAA)
Boston MA, USA • http://www.audiologynow.org/

APRIL 2012

April 29 – May 3
World Congress of Audiology
Moscow, Russia • http://www.wca2012.ru/

JUNE 2012

June 13–16
The 6th Annual TRI Conference
Bruges, Belgium • http://www.tri2012.org

June 21–24
Hearing Loss Association of America (HLAA)
Providence, Rhode Island
http://www.hearingloss.org/content/convention

June 29–July 12
Alexander Graham Bell Association for the Deaf and Hard of Hearing
Scottsdale, Arizona
http://nc.agbell.org//Page.aspx?pid=1338

AUGUST 2012

August 15–18
SayWhatClub (SWC) - Internet support group for adults with hearing loss: August
Salt Lake City, Utah
http://www.saywhatclub.com/events/SLC-con/SLC-con.html

August 19–22
INTER-NOISE 2012
The theme of the congress is Quieting the World's Cities
New York City, NY • http://www.internoise2012.com/.

Doremi's CaptiView Closed Caption Viewing System for Deaf and Hard of Hearing Movie Audiences

Now Playing at Cineplex Entertainment Theatres Across Canada

By Elizabeth Manley
Manager of Trademarks and Marketing Law
CINEPLEX ENTERTAINMENT LP

The global film industry is embarking on a tremendous and exciting change to the way in which movies are exhibited. Analogue film prints (or 35 mm films) have been the mainstay of the industry for almost 100 years. However, with the development of digital projection systems, 35 mm films will become obsolete as motion picture exhibitors around the world begin transitioning to new digital technology. The benefit to movie goers is the pristine quality of digital images on the screen. With film, the image quality diminishes with every pass through the projector however with digital; the image quality remains pristine whether it is the first or the 500th pass through the projector. Digital projection also enables the opportunity to add 3-D, which has become very popular in the past few years. Another added benefit is the ability to expand the content shown beyond movies to include other forms of entertainment such as live concerts, operas, ballet and Broadway plays to name a few.

In 2001, the Society of Motion Picture and Television Engineers (SMPTE) began work on developing an inter-national set of guidelines to standardize practices for the digital distribution and exhibition of television and motion pictures (the Standards). The Standards were finalized in the spring of 2010. Special effort was made to ensure that features were addressed, including captioning for deaf, deafened, and hard of hearing viewers as well as narrative audio for blind and low vision audiences. SMPTE standardized the communication of closed captioning content between the digital cinema servers and third party closed captioning systems. As a result, new closed caption systems for digital cinema began to emerge.

Before the development of digital projection systems and the introduction of the Standards, the only widely available captioning system for the motion picture exhibition industry was Rear Window Captioning (RWC). The RWC system consists of a display unit which is mounted on the rear wall of the auditorium and displays the captions in mirror image. The backwards image is emitted from the display unit onto a reflector panel, which is mounted into the cup holder situated next to the guest.

In order to provide a better overall experience for our guests who are deaf, deafened or hard of hearing, senior executives at Cineplex Entertainment worked with numerous organizations to ensure that we could provide the highest quality captioning technology that is compatible with digital projection systems. While it has taken several years

and a significant amount of work, these efforts have paid off.

Cineplex Entertainment is pleased to offer its guests CaptiView, a digitally compatible closed captioning viewing system, created by Doremi Cinema. The CaptiView system consists of a small captioning display unit with a flexible support arm that fits into the theatre seat's cup holder. The high contrast onscreen display is easy to read and comes with a privacy visor so it can be positioned directly in front of the theatre guest with minimal impact or distraction to neighbouring guests.

Once the CaptiView system is in place, it will provide guests who are deaf, deafened, or have hearing loss, with more viewing options, including the ability to sit in any seat in an auditorium, receive captioning in up to four different languages (provided that such captioning is made available by the movie distributor or studio) and the ability to watch movies in 3-D with captioning. As the captioning display unit operates using a wireless system, there is no interruption in the display of the captions if a guest stands up behind the viewer. More importantly, the new digital technology will allow Cineplex Entertainment to provide captioning in any auditorium in the theatre, giving theatre-goers a greater selection in the movies they wish to see.

As Cineplex Entertainment replaces its existing 35 mm film projection systems with Christie digital projectors supported by Doremi servers, new CaptiView systems will be installed in most of our 130 theatres. This process is currently underway and we anticipate that conversion will be completed in approximately 24 months. A list of movies and showtimes near you can be found at Cineplex.com. Movies offering this service are displayed with the "CC" designation in the film's title.

Reprinted from Vibes Fall, 2011 with permssion from The Canadian Hearing Society

| FROM THE BLOGS@HEARINGHEALTHMATTERS.ORG

By Calvin Staples, MSc
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This issue I thought I would return to my roots and think like a clinician. In reviewing the hearing-healthmatters.org blogs there was a nice theme surrounding solid, everyday clinical decision making required to manage the ears we treat. Over the past several years I have waffled back and forth between being an academic and being an in the trenches clinician; in doing so I have routinely found myself investigating in a greater degree the "ho-hum" everyday occurrences in the clinic. The results of my investigations have been quite humbling as I continue to learn how much I didn't know. The latest blog entries have been a great jumping off point for further investigation and in some cases even provided me an "ah ha" moment.

Hope you enjoy the blogs as much as I. Happy reading!

EARDRUM RUPTURE: AT WHAT PRESSURE?

By Wayne Staab

Ruptured eardrums are not uncommon, but when they occur, they are traumatic to the person involved. However, there seems to be little knowledge among professionals working with the hearing impaired as to the actual pressure levels required to rupture the eardrum (tympanic membrane) even though they know that this can happen.

There are many causes of eardrum rupture. They include, but are not limited to pressures from: middle ear problems, blasts, constant loud noises, and pressure from deep-water swimming. A typical overpressure required to guarantee a rupture to an eardrum would be about 100,000 pascals, or 100 kPa, but rupture could occur at lower pressure levels as well.

BRIEF ANATOMICAL DESCRIPTION OF THE EARDRUM, AND EUSTACHIAN TUBE

A brief anatomical description of the eardrum is warranted in order to describe why an eardrum can rupture. The eardrum (tympanic membrane) consists of three thin layers, with the outer and inner layers continuous with the tissues of the outer ear canal and the middle ear respectively. The middle layer is fibrous, containing both radial and concentric features. The tympanic membrane (TM) provides some protection to the middle and inner ears, but also receives sound vibrations from the outer ear and transmits them to the middle ear.

Biologically, the Eustachian tube must be considered in discussions of eardrum rupture. This tube has elastic properties and extends from the nasopharynx (back of the throat) to the middle ear cavity. It is normally closed, but opens to equalize air pressure on both sides of the TM, and also to provide an oxygen supply to the middle ear to help "dry up" some of the mucous that is generated in the middle ear by its mucous membrane lining, the same mucous membrane that lines the oral cavity. It also allows for drainage of normal and diseased middle ear secretions from the middle ear cavity into the nasopharynx. It normally dilates during yawning, swallowing, shouting loudly, chewing, etc. However, when it does not dilate naturally (blocked by an infection, cold, allergy, or scarring), air can no longer enter or leave the middle ear cavity. As a result, either positive or negative middle ear pressure can result from no pressure equalization or to a buildup of fluids in the middle ear, the latter of which, when great enough, can lead to ruptured and bleeding TMs.

HOW MUCH PRESSURE TO RUPTURE?

Because the TM is so thin, it can be ruptured or punctured. One of the ways in which it can be ruptured from the outside is by excessive pressure occurring so rapidly that the Eustachian tube cannot manage the pressure equalization.

Pressure: Force per unit area applied on a surface in the perpendicular direction. The pressure equation is:

$P = F/A$ P = *pressure*
F = *force*
A = *area*

Pressure is measured in pascals (Pa). A pascal is equal to a newton per square meter [$\text{Pa} = \text{N/m}^2$]. To relate this to something most people would understand, this would translate to

0.00014 psi (pounds per square inch), a very small pressure – too small for reasonable use. As a result, the pascal is used, where 100 pascals equals 0.01 psi – still a very low value, but something that one can somewhat get a handle on, especially if one can relate this to tire pressures. And, because numbers related to the pressures in pascals become so large, it is convenient to relate the pressures in kPa, where 100 pascals is equal to 0.1 kPa.

The tympanic membrane can actually tolerate fairly high pressures, but do reach a level where the amount of pressure can no longer be tolerated. The eardrum may rupture at pressures above 35,000 pascals (35 kPa, or 5.08 psi) but is normally at higher levels, closer to 100,000 pascals (100 kPa or 14.5 psi).

EAR DRUM RUPTURE EXPECTATIONS

Water

- 17 kPa (120 mmHg) in about 1.7 to 5.3 ft. of water[1]

Differential Pressure

- 20 kPa (2.9 psi) – overpressure required to produce minor, moderate, and major eardrum ruptures[2]
- 35 kPa (5.1 psi) – May rupture[3–5]
- 35–69 kPa (5.1–10.0 psi) – General rupture expectation range[6]
- 100 kPa (14.5 psi) – Almost all will rupture[3,5]

Injuries from Blast Waves

Caused by exposure to high pressures with very short rise times.
Examples:

- 6.9 kPa – TTS – Could result with an overpressure (1.0 psi) [4]
- 35 kPa – injuries from blast waves to high pressure exposure could occur (5.1 psi)[7,8]

Used widely as rupture *threshold* in blast criteria:

- 100 kPa – psi rupture rate increases to 50% (14.5 kPa)2
- Almost all rupture at 100 kPa (14.5 psi)
- 50% rupture probability – 6.3 psi[9]
- 90% rupture probability – 12.2 psi[9]
- 100 kPa – 50% probability – 14.5 psi[4,8]
- 103 kPa – median overpressure – 14.9 psi[10]

TABLE RELATING PRESSURE VALUES IN THIS BLOG TO OTHER PRESSURE SCALES

Pa	kPa	psi	Bar	mmHg	
100	0	0.0	0.00	0.0	
1,000	1	0.2	0.001	7.5	
10,000	10	1.5	0.10	75.0	
20,000	20	2.9	0.20	150.0	
30,000	30	4.4	0.30	225.0	
35,000	35	5.1	0.35	262.5	Potential Rupture
75,000	75	10.9	0.75	562.5	
100,000	100	14.5	1.00	750.0	Rupture Guaranteed
250,000	250	36.3	2.50	1,875.2	

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http://hearinghealthmatters.org/waynesworld/2012/eardrum-rupture-at-what-pressure/

DIRECTIONAL MICROPHONE HEARING AIDS – DO THEY CHANGE?

Wayne Staab

SITUATION

Directional microphone hearing aids are a preferred embodiment in many of today's hearing aids, being used advantageously for listening in noise. When used in this fashion, the directional performance is employed in either a fixed, or more commonly, in an adaptive mode, and normally commands a premium price from the consumer. Conventional wisdom suggests that directional performance should be highly desirable, especially for improving the signal-to-noise ratio.

An unanswered question related to directional microphone performance, especially when two different microphones are used to create directionality, is whether they retain directional properties after they had been in the field for longer than one year. (In a previous blog, I reported the results of hearing aids that had been programmed with directional performance and the differences between the programmed and measured polar plots that resulted, showing that the programmed and actual polar plots were quite variable from each other. Also, some of the hearing aids that no longer showed directional properties, were unable to be reprogrammed to show directional performance.)

It was therefore decided to investigate the ability of directional microphone hearing aids to be programmed for directional performance after they had been in the field for longer than one year.

PROCEDURE

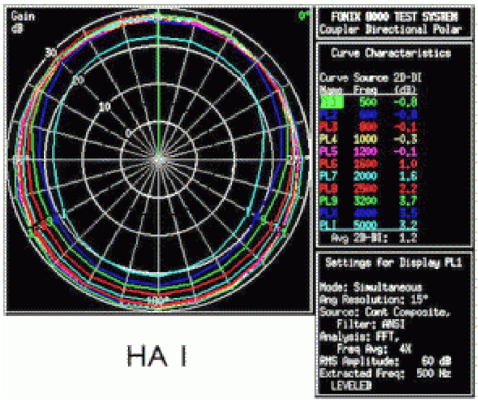
Six RIC hearing aids that use dual microphones to achieve directional performance, and had been in the field more than one year, were measured. The hearing aids were all of a single make and model obtained from a local dispenser, and were programmed exactly the same – in all cases to render the instrument with maximum linear amplification to emphasize the aid's directional properties. All compression, equalization, and noise reduction was removed from the instruments, along with other parameters that were likely to have an adaptive impact on the hearing aids. The hearing aids were programmed for maximum cardioid polar pattern, and were all closed coupler fitted. As a control, each of the hearing aids was checked prior to and following polar plot testing to ensure that that hearing aid was programmed as identified. All measurements were made using a Frye Electronics 8000 Hearing System.

RESULTS

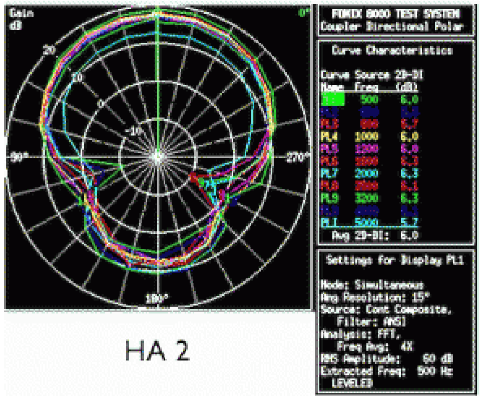
As can be seen from the following graphs, only two of the hearing aids showed directional polar plots, and even of the two that did, neither showed a cardioid polar pattern, as was programmed. Instead, they showed greater gain at 180° (where a cardioid pattern should have least gain) than at 120 and 240°. It is also significant to note, as should be realized, that when viewing the 60-dB response gain curves of these six instruments, that those without directional properties had significantly greater gain (15 to 20 dB) than those recording directional polar plots.

HEARING AID FITTING AND COUNSELING IMPLICATIONS

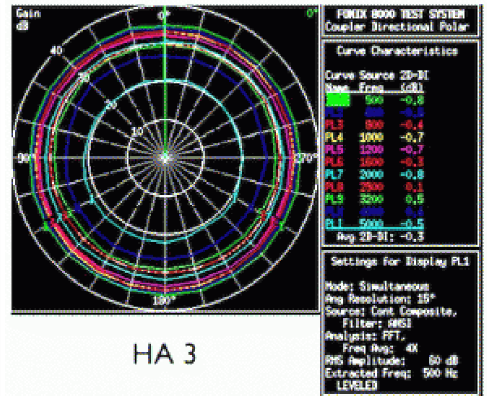
Some dual microphone directional hearing aids do not maintain their directionality over time, even if they were programmed as directional microphone hearing aids when fitted.



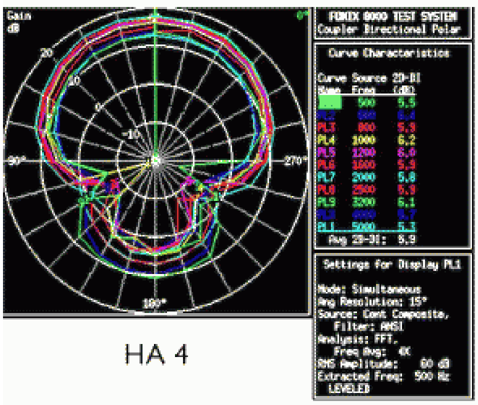
Hearing Aid #1. Not directional.



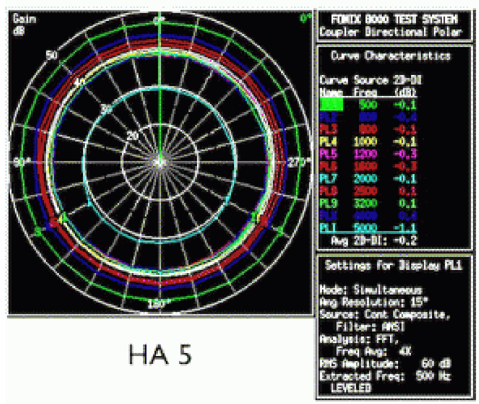
Hearing Aid #2. Directional.



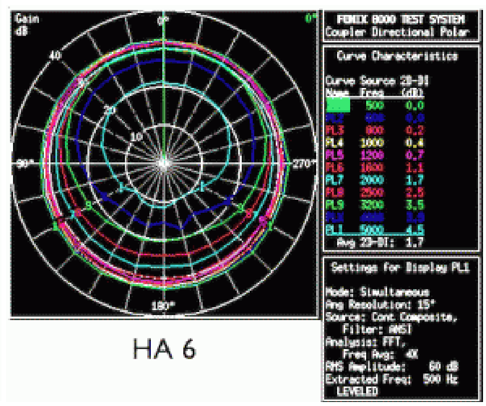
Hearing Aid #3. Not directional.



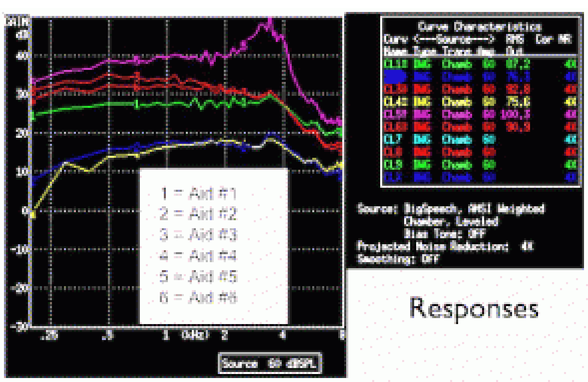
Hearing Aid #4. Directional.



Hearing Aid #5. Not directional.



Hearing Aid #6. Not directional.



60 dB SPL input gain responses for the six hearing aids.

Whether they were actually directional when programmed as such during the initial fitting is something to be investigated. Knowing this information is especially important because essentially no dispenser has the proper equipment to make this check, and manufacturers do not run polar plots on assembly line instruments.

Some of the hearing aids in this investigation could not be measured as having directional polar plots, even though the programming software indicated that they were so programmed.

As reported in my earlier blog on this topic, the failure of some hearing aids to hold their directional properties appears to show up in instruments from all manufacturers, based on other measurements that I have made.

The fact that the hearing aids that did not program properly for directional performance had greater gain suggests that the gain levels programmed for some patients may provide significantly more amplification than the patient requires. This may be a cause of some of the reprogramming following fitting, with the dispenser wondering why the user is asking for reductions in gain.

All of this puts dispensers in a difficult situation, and one that many most likely do not recognize – that is of telling patients that their hearing aid(s) has directional properties, when it may not be true. Or, of reprogramming the aid to be directional, and not knowing that it actually is. It also suggests that dispensers need to check hearing aids often, and reprogram when necessary. The problem is, however, when, and how do they really know whether directional properties have been installed into the instrument? One could ask the patient to respond to differences they can detect. However, it has been my experience than many patients cannot tell if their directional hearing aid is directional or not, even when it is.

There will be more to come on this topic in a future blog.

http://hearinghealthmatters.org/waynesworld/2011/directional-microphone-hearing-aids-do-they-change/

THE ROLE OF AUDIOMETRY IN VESTIBULAR TESTING

By Alan Desmond

"Why are you doing a hearing test? My hearing is just fine."

I've heard this frequently enough over the years that I know to take a minute to explain to every vestibular patient, before we get started, why we require an audiogram. I keep it pretty straightforward and simple:

"We do a quick hearing test on every patient complaining of dizziness because we have to be sure there is no infection or inflammation behind your eardrum, and we need to make sure there isn't any unexplained difference in hearing between the two ears. Some inner ear problems affect hearing as well. Some do not. Knowing your hearing levels will help us rule out some causes."

Audiometric evaluation is a necessary starting point for a number of reasons, but it primarily provides information about auditory asymmetry, possible retrocochlear pathologies, and the health and integrity of the ear canal and tympanic membrane before caloric irrigation.

Audiometric evaluation consists of pure-tone air and bone-conduction thresholds; speech audiometry, including speech reception threshold (SRT) and speech recognition tests; tympanometry; acoustic reflex threshold and decay tests; speech rollover tests; and, when indicated, otoacoustic emissions (OAEs)

AUDITORY ASYMMETRY

Auditory asymmetry refers to a significant difference in threshold hearing levels between the ears and indicates the possibility of peripheral vestibular or auditory nerve pathology. The Mayo Clinic[1] uses a criterion of a *"difference of 15 dB or greater averaged across 500, 1000, 2000, 3000 Hz or differences of 15 dB or greater in speech recognition thresholds"* to determine significant asymmetry.

Although there are numerous causes for asymmetric auditory sensitivity, including middle ear pathologies, various patterns have been linked with specific vestibular disease. Endolymphatic hydrops (Meniere's disease) is frequently accompanied by unilateral, fluctuating, low-frequency sensorineural hearing loss. Acoustic neuroma is often characterized by an asymmetry in the higher frequencies. Perilymph fistula and labyrinthitis are usually accompanied by unilateral sensorineural hearing loss with no specific pattern or configuration of loss.

RETROCOCHLEAR PATHOLOGY

Retrocochlear pathology refers to site of lesion at the cranial nerve (CN) VIII, cerebellopontine angle, or root entry zone of the CN VIII into the brain stem. A number of audiometric findings are suggestive of retrocochlear site of lesion and may be found in acoustic neuroma, multiple sclerosis, and a variety of brain stem lesions. Audiometric signs consistent with possible retrocochlear pathology include the following:

1. Asymmetric, typically high-frequency, sensorineural hearing loss
2. Speech recognition scores poorer than would be expected based on audiometric configuration and severity
3. Rollover (decreased speech recognition scores with higher intensity speech presentation levels)
4. Absent or elevated acoustic reflex thresholds or abnormal acoustic reflex decay

THE EAR CANAL AND TYMPANIC MEMBRANE

The health and integrity of the ear canal and tympanic membrane must be ascertained before beginning vestibular evaluation. Many patients with middle ear pathology will complain of dizziness as well as other auditory symptoms. It is prudent to treat the middle ear problem first to determine whether there is an improvement in the complaint of "dizziness." Also, treatment might remove confounding factors affecting sensitive evaluation, such as aural fullness, tinnitus, and otalgia, which are common to both middle ear and peripheral vestibular disorders. Conditions such as tympanic membrane perforation, cerumen impaction, external otitis, or discharge may contraindicate caloric irrigation of the external auditory canal.

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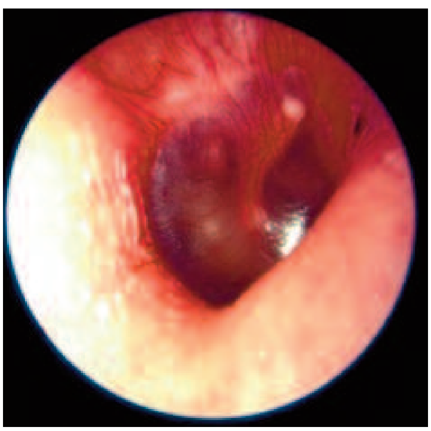
http://hearinghealthmatters.org/dizzinessdepot/2011/the-role-of-audiometry-in-vestibular-testing/

RED IS MORE THAN A COLOUR OF THE SEASON!

By Judy Huch

NAME THAT DISORDER

The first is an "attack" of burning pain and redness of the pinna of one ear and is made worse by a variety of common things: touch, neck movement, lying on affected ear, contact with hot or cold water (drinking or touch) or straining. Depending on the person, it can go on from 15 min to a couple of days. However, a few hours is the most typical length of time. The redness is at the pinna only but the pain can be above/behind the ear and possibly the upper neck, cheek or temple on the affected side. This syndrome has been around for many years but research has been more prevalent since the 1990s. There have also been studies of this particular disorder with having a higher incidence in children with migraines or other primary headaches. It may also be linked to irritation of the third cervical root, temporomandibular joint dysfunction, or thalamic syndrome. Do you know? Red Ear Syndrome. If you know of someone who suffers from RES there is also a Facebook page for peer support.



HOW ABOUT THIS PICTURE?

There is no particular disorder to this picture, but a red reflex when light hits the tympanic membrane. The red usually starts at the umbo and radiates out. It is usually a triangular shape radiating up (anterior inferior) along the TM and canal wall. Other terms to describe this are Politzer's luminous cone, Wilde's triangle, light reflex and cone of light.

http://hearinghealthmatters.org/hearinprivatepractice/2011/red-is-more-than-a-color-of-the-season/

Canadian Hearing Report 2012;7(1):12-17

Attention and Auditory Processing Disorders

By Kim L. Tillery, PhD, CCC-A
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About the Author

Dr. Kim L. Tillery, professor and chairperson of the Department of Communication Disorders and Sciences at the State University of New York at Fredonia also has a private practice in diagnosing and treating individuals with (C)APD. She has been honoured to present 90 workshops or presentations at national, international, and regional conferences, and authored and co-authored several chapters and journal articles on (C)APD.

Parents often inquire if their child with diagnosed attention disorders should receive his or her routine regimen of stimulant medication when being evaluated for auditory processing disorders (APD). In fact, I was asked this question at the 1994 ASHA consensus meeting that resulted in the first formal definition of APD.[1] While there is some research assisting with this answer there are common sense practices, also, that audiologists routinely employ to control for attention.

Should the adult or child with anxiety arrive to the evaluation with or without taking medication prior to being evaluated? Such clients are receiving a medical treatment to assist with a medical diagnosis. This is the same for clients with attention disorders who have been found to have less impulsivity and increased attention when receiving a central nervous stimulant (CNS) medication. If the medication assists in improving attention then it makes sense to test the client while medicated.

There is an abundant amount of research, over 250 studies, totalling 6,000 children and adults across all ages, analyzing the safety and effectiveness of stimulant medication used as a treatment for attention deficit hyperactivity disorder (ADHD).[2] The most researched CNS medication is methylpehnidate (Ritalin)[3] with other medications responding in the same manner as methylphenidate.[4] Such medications are Adderall, Cylert, Dexedrine, Concerta, Focalin, Ritalin LA, Metadate, and Adderall XR.[5] Overall, the stimulant medication enhances the dopamine (DA) and norepinepherine (NE) effect, thereby assisting with the low cortical activity seen in motivation and reinforcement response[6] and improved inattention and impulsivity.[7]

Obviously, attention and fatigue are behaviours that can impact the reliability of evaluations.[8,9] The audiologist routinely provides ways to enhance attention by scheduling appointments early in the day, giving breaks and positive reinforcement, and providing a novel situation of having the child sit in a sound booth. In addition, testing individuals with ADHD should be done when they are medicated if there is evidence that the prescribed medication assists with their inattention and/or impulsivity.[5,10]

To date, there are four studies that investigated the effect of CNS medication on auditory processing (AP) abilities.[11–13] Only one of these studies[14] used a double-blind, placebo-controlled study employing three AP tests and an auditory attention vigilance measure, the Auditory Continuous Performance Test (ACPT).[15] (The ACPT is described below.) The tests were counterbalanced and administered to 32 children previously diagnosed with APD and ADHD, and with clinical evidence that their prescribed Ritalin dosage improves their ADHD behaviours. Sixteen children received the Ritalin test condition first while the other 16 children received the placebo condition first. Findings revealed a significant medication effect (p = .004) for the ACPT measure when comparing the test scores in the medicated and non-medicated conditions, and no medication effect on the AP measures. Ritalin enhanced the participants' sustained attention and impulsivity, but did not have an effect on the AP dysfunction.

Another conclusion in the Tillery, Katz and Keller[14] study was that the ACPT may be an efficient tool to measure the effect of CNS medication. The ACPT assesses auditory attention and impulsivity by delivering 96 monosyllabic words six times. The client is instructed to raise his or her thumb to the target word, "*dog.*" There are 20 target words in each list. The administration of all 576 words takes about 15 minutes. The score for the first set of words presented is compared to the score of the final set of words presented. (Clients with ADHD perform better on the first part of a vigilance task verses the final part of the task.)

Because of the usefulness of the ACPT there are school professionals (e.g., psychologists, speech-language pathologists) who administer the ACPT to measure for attention/impulsivity and the SCAN-C[16] to screen for APD. Those students who fail the SCAN-C are referred to the audiologist for a comprehensive audiological evaluation to ascertain of a possible APD. Those students who fail the ACPT are referred for a comprehensive psychological evaluation to investigate of a possible attention disorder or a learning disability which results in behaviours of inattention or impulsivity. In fact, psychologists in Western New York routinely administer the ACPT to assist in titrating CNS medication (once when medicated and once when non-medicated) or to measure attention and impulsivity.

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Canadian Hearing Report 2012;7(1):18-19.

Can the Web Replace My Audiologist?

By Gael Hannan
gdhannan@rogers.com

It was a simple e-mail question. What did I think about direct-to-consumer online hearing testing and hearing aid sales? My fingers hovered over the keyboard to reply, but then I lowered my hands. What *did* I really think about this?

Not too long ago I would have answered, without hesitation, that a web service could *not* meet the needs of a person with hearing loss. How could anonymous staff on an arms-length website provide the necessary supports – technical, practical, *and* emotional – that are crucial for successful hearing aid use? Hearing loss has a powerful impact on quality of life, and hearing health care must go beyond hearing aids to include counselling, technology, and other communication strategies.

But what about the person who cannot access those supports, which can carry a hefty price tag? Or those who have difficulty getting out to the audiologist's office? It's estimated that only about 25% of people who could benefit from hearing aids actually use them, which means that millions of people with hearing loss are living without communication supports that could boost their quality of life. (Please see the article by Dr. Wayne Staab on page 22 for further information.)

AARP and the American Speech-Language-Hearing Association (ASHA) recently polled Americans, 50 years and older, on their attitudes around hearing loss. Nearly two-thirds of respondents said concerns about cost and lack of health insurance prevented them from pursuing treatment for hearing difficulties. But a similar number said that their hearing loss didn't require any further attention, and that their problem was "easy to hide." On the other hand, 70% said they would do something about their hearing loss *if* they felt it was affecting their relationships.

It's clear that a great deal of confusion and stigma clings to hearing loss, along with a pervasive reticence to discuss a private issue. It was only a matter of time before innovators stepped forward with web solutions for the masses. One direct-to-consumer online hearing aid company claims to offer a more convenient, private, and affordable system for people considering hearing aids. The traditional hearing health care world is in an uproar and I'm twisted into an opinion pretzel.

There are benefits and drawbacks to both service options. The need for hearing health services has exploded and service providers, regardless of their delivery model, will succeed only if their goal is a satisfied client who communicates well.

EDUCATION AND INFORMATION

If you're selling hearing aids, give us the back story and the front story. Yes, we need to know the *signs* of hearing loss, but most people already *get* that, otherwise they wouldn't be on the web looking for information. We need to understand the big picture, including the fundamentals of hearing loss and the scope of assistive technology.

COMPREHENSIVE HEARING TESTING

My son took the web service's 5-minute hearing test. It was very basic and didn't include speech discrimination testing. He was asked how he felt about his hearing and ability to communicate. *Can you understand speech in a noisy environment?* Not particularly well, but who can? Apparently he has a slight hearing loss and was advised to follow up with a hearing health professional (HHCP). The kid can hear a pin drop on the other side of the city.

As a veteran of the torture chamber (hearing booth), I admit to trying to memorize the hearing test words *(Say the word "baseball!" say the word "keep!")*. Is that any sillier than an incomplete hearing test? With visions of bank-breaking $4,000 hearing aids dancing before my eyes, I want a comprehensive test, thank you very much.

HEARING AID AFFORDABILITY

Although many professionals and consumer advocates agree that much of today's technology is overkill – most of us don't need all the super-aid bells and whistles – a good hearing aid is still the first and most important step in reclaiming good communication. The new online service offers lower-priced hearing aids and, if their promise holds, who can argue against that? Hearing aid service providers need to step up and find a way to make hearing aids and other assistive devices more affordable; otherwise, the 75–80% of people with hearing loss who are not darkening their doors, will remain un-aided, poorly-aided, or using someone else's service.

PROFESSIONAL SERVICES

I'm nervous about any service option that bypasses the valuable exchange of information between a hearing health care provider (HHCP) and client. Nearly 75% of the AARP-ASHA poll respondents said that if they were to seek hearing help, it was critically important to them to use a highly trained HHCP, but that the Internet is a key source of information.

Can we truly choose a hearing aid online in the same way that we buy clothing? Buying a dress doesn't require counselling or a user manual. I see a cute, affordable dress, and I click in my credit card number and mailing address. If it doesn't fit, or the colour makes me look bad, I return it. How in blazes is someone shopping online for their first hearing aid supposed to make an informed decision on which hearing aid model is best, or to effectively evaluate how well it's working?

COUNSELLING, FITTING, AND FOLLOW-UP CARE

I've never read a how-to manual that's better than a knowledgeable HHCP who not only answers my questions, but anticipates them. A proper fit and properly programmed hearing aid takes time, although the process now is a marvel of modern technology. All I really need, though, is an HHCP with patience.

HHCP: There, it's in. How does my voice sound to you?
Client: Do you always breathe so loudly?
HHCP: Yes I do. But my voice?
Client: Somewhere between Donald Duck and a vampire.
HHCP: (adjusting program) Ok how's that?
Client: You're better, but my voice is Niagara Falls.
HHCP: We'll adjust the venting…
Client: How many adjustments before things sound good?
HHCP: As many as you want, or when your brain gets used to it, whichever comes first.
Client: Thank you, I love you.

Could I ever love a web-based hearing help program? Maybe, if it gave me good service. But coming soon, I hope, is a *fusion* of personal and online hearing health services that will encourage more people to adopt hearing aids for a fully engaged, communication-rich life.

Canadian Hearing Report 2012;7(1):20-21.

By Wayne J. Staab, PhD

This issue's For the Consumer column is in the form of a question that has been kindly fielded by Dr. Wayne Staab. Dr. Wayne Staab is well known in the hearing health care field and has worked in clinical, academic, and the manufacturing sector for over 40 years. As well as having written and contributed to many textbooks, many of the innovations in the field of audiology that we now take for granted have had input from Dr. Staab. Dr. Staab is also one of the editors of the weekly blog www.hearinghealthmatters.org.

Question: I have often read and heard statistics regarding the numbers of people who require hearing aids but don't actually obtain them. The numbers are typically that only one in five or one in six actually get hearing aids. Is this an accurate statistic and what do you feel may be the reason(s) for so few people obtaining hearing aids?

I think the numbers are very gross estimates and often reflect the bias of the person(s) and what message they are conveying.

We have to ask who makes the decision as to when hearing aids are needed? Keep in mind that hearing aids, and their need, are never fitted based on the degree of hearing loss, but only on the degree of "hurt." If the hurt is not great enough psychologically, emotionally, economically, or socially, there is no hearing loss and hence, no justification for hearing aid use. As a result, I know, and have fitted, some people with "normal" hearing thresholds, but at other times do not consider some people with 40-dB hearing thresholds as hearing aid candidates.

As an example, I come from farming and ranching country. Many farmers have a hearing loss as can be defined by audiometric thresholds, but many live with their spouses (the children are gone), speak with them from fairly close distances, and use their television volume controls as their hearing aids.

And, there is a problem with using pure-tone thresholds as found on an audiogram to make this decision as to what a loss is, and then using this information to determine hearing aid need. We make measurements in 5-dB increments, meaning that at any frequency we can be off 10 dB. So, if 25 dB is used as a "low fence," to help determine if a person has a hearing loss, it could be that the person's hearing levels may actually be 15 dB, or could be 35 dB. In one case the person would be considered to have a "mild" hearing impairment and in the other case hearing within the normal range.

So the question shouldn't be what proportion of people that require hearing aids actually get them, but that we should really be doing a better job in the field of educating our clients so that they can be better prepared to make an educated decision whether they require some amplification in their lives. An "exact" number will always be misleading.

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Canadian Hearing Report 2012;7(1):22.

27th Annual Seminars on Audition:

Speech In Noise, Music Perception & Some Nuances of DSP

Saturday March 3, 2012

Novotel Toronto Mississauga

3670 Hurontario Street, Mississauga, ON
(Toronto area) 905-896-1000

Pre-registration Only by Feb. 27, 2012:
Registration rate is $200.00 and $100.00
(full time student)
CHEQUES PAYABLE TO: "SEMINARS ON AUDITION" MAIL TO: 34 Banstock Drive, Toronto, Ontario, M2K 2H6.

Seminars on Audition is a one day conference relevant to Audiologists, Hearing Instrument Practitioners, researchers and Engineers interested in hearing loss, its prevention, assessment and remediation. For almost a quarter of a century, experts from all over North America have shared their knowledge and insight with us. A forum will be provided where participants can exchange experiences, information and philosophies.

All proceeds from Seminars on Audition go to sponsor two scholarships. One enables a University of Western Ontario Audiology student in their final year of study to visit an extra-ordinary facility anywhere in North America. Previous recipients have attended world class clinical and research facilities. The other scholarship goes to support the Poul B. Madsen Award through the University of Toronto Institute of Biomaterials and Biomedical Engineering. This is for a graduate student who demonstrates excellence in applied Biomedical Engineering.

What do the perception of speech in noise and the appreciation of music have in common? The brain comes to mind. Cognitive processes are intimately linked with the nature of the input signal and environment. Nina Kraus's work on how the brain is configured to handle music provides insight into how it allows us to pick up speech in a noisy environment- the two areas of research are intimately intertwined. And what are some of the engineering challenges and issues to be resolved- this is where Steve Armstrong comes along with some of the limitations and issues with DSP technology.

8:45–9:15 Registration
(complimentary coffee, tea and muffins available)

9:15–12 noon: Speech in Noise and Music Perception

Nina Kraus,Ph.D.
Sensory processing of speech and music is tightly coupled with the cognitive abilities that underlie language and musical expertise; this knowledge can be used to advantage in the consideration of educational and remediation strategies for hard of hearing children and for improvement of an adult's ability to hear speech in a noisy environment.

10:45–11:00	Coffee Break
11:00–12:00	Speech in Noise and Music Perception... continued
12:00–1:15	Lunch Break (provided)
1:15–2:45	Speech in Noise and Music Perception... continued
2:45–3:00	Coffee break

3:00–5:00: Bits, Bytes and Other Things That Can Drive You Nuts!

Steve Armstrong
Given its many advantages, Digital Signal Processing (DSP) is not without its challenges. Hearing Aid designers and software developers routinely make trade-offs during the development process. This talk responds to questions frequently raised by the clinical community. Comments like "We were told once everything went digital there wouldn't be any circuit noise or distortion", and "Why do we now have to worry about time delay issues". Likewise the fitting process is heavily dependent on software which places high reliance on the mathematical models of the product and the patient. So what does the "On Screen" display really represent? Factors such as the RECD have an impact and will be used to illustrate potential issues.

Contributors
Nina Kraus, Ph.D., Hugh Knowles Professor, (Communication Sciences; Neurobiology & Physiology; Otolaryngology) at Northwestern University, directs the Auditory Neuroscience Laboratory. Dr. Kraus investigates biological bases of speech and music. In addition to being a pioneering thinker who bridges multiple disciplines (aging, development, literacy, music, and learning), Dr. Kraus is a technological innovator who roots her research in translational science.

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Neurotrophin Gene Expression – A Potential Treatment for Hearing Loss

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The most common form of hearing loss is due to the loss or damage of hair cells in the organ of Corti and is called sensorineural hearing loss (SNHL). In severe-to-profound SNHL, cochlear implantation has proven to be a successful method of treatment. The loss of hair cells, however, leads to the secondary degeneration of spiral ganglion neurons due to the removal of trophic or nutritional support normally provided by the hair cells. This degeneration of neurons results in a reduced population of neurons available for electrical stimulation. Abnormal sprouting of the peripheral fibers could in turn negatively affect electrical stimulation. Because the pitch coding of the cochlear implant relies on stimulation of spatially distinct populations of spiral ganglion neurons, extensive and disorganized fiber resprouting may reduce the spatial precision with which electrical stimulation can be delivered. This neural overlap may cause a spread in electrical activation and deterioration of implant performance. Thus, strategies that not only provide spiral ganglion neuron protection but also control fiber resprouting may lead to an improved electrode-neural interface and improved implant performance. Recently, studies examining the administration of exogenous neurotrophins (proteins that signal cells to survive, differentiate, or grow) have been completed where increasing neuron survival and redirecting fiber sprouting have been achieved via gene therapy following SNHL.[1] Although the overall safety and long-term effectiveness of the technique in achieving spiral ganglion neuron survival and targeted fiber regrowth still need to be determined, the Wise et al. study reveals that this is indeed a possible future option for treating hearing loss.

Neurotrophin-3 (NT3) and brain-derived neurotrophic factor (BDNF) are two neurotrophins that have been shown to play an important role in the development and maintenance of spiral ganglion cells. Spiral ganglion neurons express receptors for NT3 and BDNF, and these two neurotrophins are known to be released by hair cells in the organ of Corti.[2–5] After aminoglycoside-induced SNHL and loss of this endogenous source of neurotrophins, intracochlear administration of exogenous BDNF and/or NT3 proteins in guinea-pigs has been shown to promote survival of spiral ganglion neurons and resprouting of their peripheral fibers, although the resprouting is abnormal.[6–9] Recently, cellular expression of the BDNF gene has been obtained by injection into the scala tympani, but the gene expression also did not directionally guide the resprouting peripheral fibers.[10–12]

Some study results have shown that there is potential to localize gene expression by injecting into the scala media.[13,14] Therefore, in the Wise et al (2010) study,[1] it was hypothesized that (i) injection of neurotrophins into the scala media would result in more localized gene expression compared to scala tympani injections; and (ii) localized neurotrophin expression in the organ of Corti would protect SGNs from degeneration and limit the disorganized peripheral fiber resprouting after hearing loss.

Ototoxically deafened guinea pigs were unilaterally injected with a viral vector containing green fluorescent protein, with or without NT3 or BDNF genes. Viral vectors are viruses which efficiently transport genes or specific genetic material into cells. The vectors were injected into either the scala tympani or scala media. Cochleae were examined 3 weeks after the injections. Normal-hearing guinea pigs were included in the study to determine the extent of hearing loss associated with the delivery of these vectors into the scala tympani and scala media, and to examine in detail gene transduction in the normal organ of Corti.

Results demonstrate that injection of the vectors into the scala media resulted in more localized gene expression in the organ of Corti compared to scala tympani injections. Furthermore, these localized sources of neurotrophins protected spiral ganglion neurons from degeneration after hearing loss resulting in greater neuron survival. A well, the localized neurotrophin gene expression could redirect the regrowth of their peripheral fibers.

This work provides a strong basis for establishing the effectiveness of neurotrophin gene transfer to the deafened cochlea and improving our understanding of how cochlear cells respond to neurotrophin treatment. This study also suggests that gene therapies that target cells of the organ of Corti utilizing the scala media approach are likely to be more effective in providing protective or regenerative factors to the cochlear nerves. Although there is a long way to go before it is possible to achieve targeted fiber regrowth in humans, this study presents a first step in a new approach toward improving outcomes after hearing loss.

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Sound Intensity and Sound Level

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Here are two terms that are frequently misused: sound pressure and sound intensity.

What? Are they not the same thing? Don't we talk about the intensity of a musical passage written by Beethoven? Besides, pressure sounds a bit pedestrian, like someone pushing you, while intensity appears more ethereal, sentimental, etc. Yes, that is so in colloquial speech, but not when we are dealing with physical quantities that have to be well defined.

Let's start from the beginning. What is sound? High school physics teaches us that sound is vibration of the air molecules, that when they impinge on our ear drum elicit the sensation of hearing. So far, so good! When both arms of the tuning fork are vibrating, they are pushing the molecules that are touching them. Once set in vibration, they push the molecules in their vicinity and so on and the sound is traveling through the air creating the phenomenon called "propagation."

Now, what happens to the molecules that are touching our tympanic membrane? Well, they cannot move further, because the membrane, as a wall, does not budge. (Well that is not exactly true, since the vibration of the molecule is transmitted with much smaller amplitude to the membrane). So, the molecules are pushing against a surface, in the same way as our hand pushes against a wall. The result is pressure. In the case of the little molecules, it is **sound pressure** we are talking about. It has units and these are "force per unit of surface" (N/m^2).

But what about sound intensity? Imagine this time a balloon that vibrates. In other words, its surface increases and decreases periodically. Here, again, we have molecules pushing each other and the sound is traveling from the balloon outwards. It is easy to understand that the further the sound travels its energy is spread over a larger surface (see Figure 1). Therefore the energy per unit of surface becomes smaller. Now, there is a simple relation between energy and pressure- since the energy is decreasing, the pressure is decreasing too. This is why the further we are located from a sound source, the weaker is the sound that we perceive. So, now we can define another sound magnitude: the sound intensity, as the "energy per unit of surface" (W/m^2).

(Here we are getting away from the mathematical formulas and concentrating only on the physical aspects of the phenomenon).
So, in summary, we have:

Sound pressure: force per unit of surface, and
Sound intensity: flow of energy per unit of surface.

One more difference (maybe the main one from the practical point of view): what we measure using a sound level meter is precisely the sound pressure. Measuring intensity is an entirely different ball game that requires

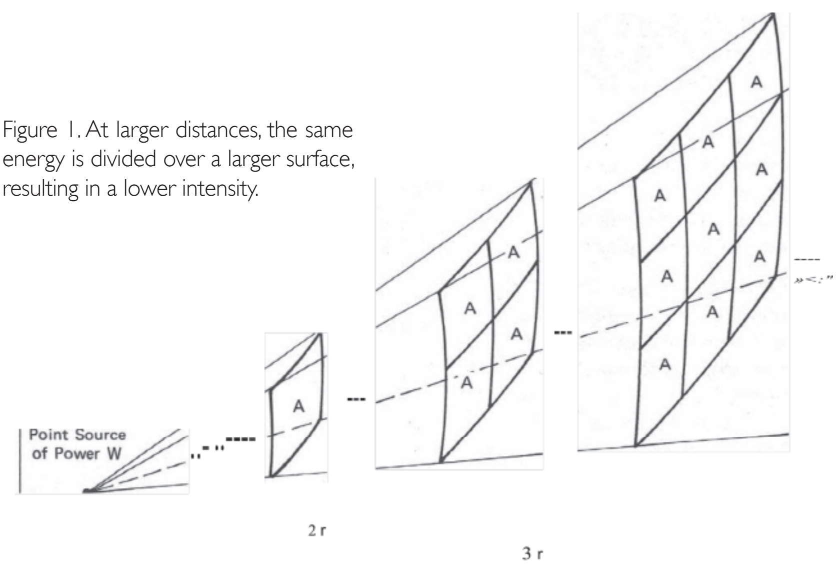

Figure 1. At larger distances, the same energy is divided over a larger surface, resulting in a lower intensity.

sophisticated (and expensive) instruments that not everybody knows how to operate. And this includes not knowing what to do with the results of the measurement…

WHAT ABOUT LEVELS?

You have probably noticed that sound pressure and sound intensity are usually expressed as sound pressure level (SPL) and sound intensity level (SIL). While SPL is found everywhere, SIL is very seldom mentioned.

So, what about "levels"? To start with, the term "level" implies a mathematical procedure that reduces the span between the weakest sound pressure that we can hear and the one that can destroy our sense of hearing. This relation is almost 1:1,000,000. By using SPL it is reduced to only 120 units, called decibels (dB). Decibels are easier to measured and use.

Although the decibels are obtained using logarithms, the dB scale is linear. An increase of 3 dB is equivalent to a doubling of the sound energy. A 10 dB increment sounds like doubling the loudness and that is the same whether its 20 to 23 dB or 80 to 83 dB.

BOTTOM LINE

When in doubt, use the terms "pressure," "sound pressure level" and "SPL" and you will be right 99% of the time.

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Attawapiskat: An Audiology Northern Initiative

By Jack Scott, PhD
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The first thing you notice when flying in is the isolation: it is difficult to shake the sensation that you are seeing territory that has been viewed by less than .1% of 1% of the world's population. Below the plane stretches snow-covered fields and forests, and frozen rivers as far as the eye can see. It is beautiful country from 15,000 feet up, but one can only imagine the true sense of loneliness and desperation if left there on the icy tundra. All of this fosters a feeling of respect for the northern communities of Ontario, and their ability to persevere in a terrain and climate where many others would have failed. They would have failed in part due to the lack of resources and services that the northern reserves deal with on a daily basis. As the small plane struggles against the wind, a collection of houses finally appears on the edge of the horizon, it is the First Nation reserve of Attawapiskat.

ATTAWAPISKAT, ONTARIO

Attawapiskat is a Mushkego Cree community located in northern Ontario at the mouth of the Attawapiskat River on the west coast of James Bay. If you find Akimiski Island on a map, Attawapiskat would be almost immediately to the left. In 2001, Statistics Canada reported the total population to be approximately 1,293. The reserve has an airport, an elementary school, a secondary school, a Northern Store, and a 16-bed wing of the Weeneebayko General Hospital. Ninety kilometers west of Attawapiskat is the De Beers' Victor Diamond Mine. And, starting in 2010, it began to receive audiological services from The University of Western Ontario.

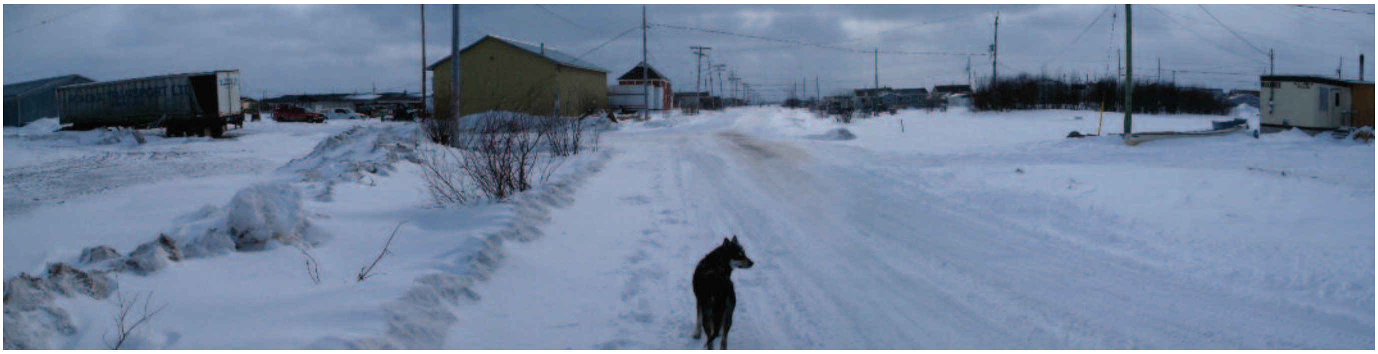
Flying in to Attawapiskat

NORTHERN INITIATIVE

The University of Western Ontario has a number of initiatives in place to provide their graduate students in communication sciences and disorders with a variety of unique and exciting clinical settings. For example, the speech pathology program for the past several years has provided student clinical experiences in Peru and northern Ontario, specifically the First Nation communities of Moose Factory, Kashechewan, and Attawapiskat. Following their first excursion to the north, the speech pathology supervisors realized the need to add an audiology component to provide hearing screenings to the school-aged children. Two years ago, the first audiology supervisor and student accompanied the speech pathologists to the north.

As one can imagine, the implementation

Edge of Attawapiskat



of audiological testing in one remote community – let alone three – can lead to logistical issues given the necessary equipment inherent with any audiological endeavour. Therefore, a single community had to be selected for the initial implementation of the audiology northern initiative. The Attawapiskat community was chosen given its need and the timing of the first visit.

EQUIPMENT

Because Attawapiskat did not have any of the necessary items for providing audiological screenings in place, the initial part of the preparation process was deciding on and procuring all relevant equipment. The University of Western Ontario generously provided an audiometer, TDH headphones, ER-3A insert receivers, a bone oscillator, and screening tympanometer; otoscopes were borrowed from the university teaching labs. In addition, UWO provided funding for foam eartips, earphone covers, otoscope speculum, and impedance eartips.

Additional assistance was sought from two manufacturers. Starkey Canada contributed to the initiative by calibrating and shipping the audiometer and tympanometer to Attawapiskat, and providing tools for cerumen management, while Bernafon Canada donated items for hearing aid troubleshooting and repair. The contributions of these three entities assisted in the overall success of Year 1.

YEAR 1

Audiology and speech pathology travelled to the north together in April 2010. As it was the third trip for the speech pathology clinical faculty, they were instrumental in initiating contact with the local representatives from the school and hospital, and arranging accommodations and flights. Travelling to the north is not as simple as navigating from Point A to Point B. In total, it takes six flights to reach Attawapiskat from London, Ontario. The last portion of the trip, from Moosenee to Attawapiskat, was provided by Weeneebayko Health Authority's chartered flights. For obvious reasons, patients and physicians had priority on available seats, but by allowing access to the service, overall travel costs for the initiative were greatly reduced. However, this did result in an overnight stay in Moosenee while waiting for an available charter flight, instead of making the entire trip in one day.

J.R NAKOGEE ELEMENTARY SCHOOL

Every institution has their go-to person: one individual that wears many hats and can solve almost any problem with MacGyver-like skill and ingenuity. At J.R. Nakogee Elementary School, that person is Casey Enright. Casey has been the special education coordinator at the elementary school for almost 10 years. Ten years is a lifetime for a non-native living and working in a northern community. If you need anything done at the elementary school, ask Casey. He was an important asset on the ground in Attawapiskat. He arranged with Air Creebec to have the equipment shipped the final leg from Timmons to Attawapiskat, and he was instrumental in organizing the screening schedule prior to the arrival. During the run-up to the trip, Casey received hearing screening referrals from the teachers, and ensured consent forms and all other relevant paperwork were appropriately signed.

In 2000, the original building that was J.R. Nakogee Elementary School was closed by the Attawapiskat First Nation Education Authority due to

Casey Enright, Special Education Coordinator, J.R. Nakogee Elementary School.

"Temporary" portables that make up the J.R. Nakogee Elementary School.

The two hearing screening rooms.

contamination from an underground diesel leak, after the school was classified as unsafe. The school was demolished in 2009, and the contaminated debris was transported away from Attawapiskat. To this day, the original location of the elementary school stands empty – an open wound in the community reminding it of what was and what may never be again. Following the closure of the original J.R. Nakogee Elementary School, portables were constructed near the site as "temporary" classrooms. Unfortunately, temporary eventually became permanent.

HEARING SCREENINGS

The hearing screenings took place in a portable building that housed the resource teacher and a "soon-to-be-completed" library. Two rooms, side-by-side, were made available: one room was for otoscopy and immittance testing and the other room was for audiological screenings.

Prior to testing, biological evaluations were performed on the equipment to check for issues due to shipping. Evaluations took place over three days. Casey brought 5 children at a time to the library as a temporary waiting room. One by one the children were evaluated by the 2nd year audiology student, Alaina Baker, and the clinical supervisor. In total, 56 children had their hearing screened or evaluated. A majority of the children were in senior kindergarten; however, 22 of the children were from various grades and referred for screenings by either their teachers, parents/guardians, or the speech pathology supervisors. In addition, 5 teachers were evaluated and 5 hospital referrals were made.

Many of the children were successfully screened using conditioned play audiometry. Although several of the children did not interact verbally, they all were conditioned to the task and performed with fair-to-good reliability.

RESULTS

Based on the results, the children were grouped into 5 recommendation categories: (1) normal hearing sensitivity, no follow-up required (26 children); (2) refer for cerumen removal at the Attawapiskat General Hospital (8 children); (3) refer for rescreening of middle ear function and hearing in 2–3 weeks (8 children); (4) refer for cerumen removal plus rescreen of middle ear function and hearing in 2–3 weeks (8 children); and (5) complete hearing evaluation by Paul Stevenson, audiologist at Hotel Dieu Hospital in Kingston, Ontario (6 children).

SUMMARY

In total, the supervisor and student were in clinic three and a half days. The evenings were used to organize paperwork and complete summary reports. Following the trip, reports were written for those children that were directly referred to Paul Stevenson and for the hospital referrals and teacher evaluations. Overall, the trip resulted in a large number of children being screened and a handful of adults and hospital referrals receiving full audiological evaluations. It was a wonderful opportunity for the student clinician and the supervisor alike.

YEAR 2

Following the success of the first year, it was agreed that the UWO Audiology Northern Initiative should again return to Attawapiskat. However, in 2011, speech pathology decided to travel to the north in February to coincide with the University's Reading Week. After consultation with Casey Enright and the speech pathology supervisors, it was determined that audiology should return in April 2011. The trip was scheduled for the end of the university's winter term and a few weeks prior to goose season in the north. Having the two groups travel at different times would allow for flexibility with flights and accommodations in Attawapiskat. In addition, this allowed Casey to focus his attention on each initiative individually in preparation for and during the visits.

Unfortunately, in late 2010, Weeneebayko Health Authority reported that they would no longer provide seats on their chartered flights due to administrative changes and budget considerations. While this revelation did result in the initiative being fully responsible for the cost of the flights, it meant that the trips would not have an overnight layover, which would mean more time in Attawapiskat, and more time seeing patients/clients.

J.R NAKOGEE ELEMENTARY SCHOOL AND WEENEEBAYKO HEALTH AUTHORITY (ATTAWAPISKAT BRANCH)

Again, Casey Enright was a valuable asset in organizing the hearing screening schedule for the visit and obtaining the essential paperwork for the trip. As it was the second year, there was a better flow to the process – Casey had a better understanding of how long it took for each screening. Because there was more time in Attawapiskat, and given the total number of children that needed cerumen management in 2010 (8 children), an afternoon was set aside to attempt ear wax removal. In addition, a greater effort was made to incorporate more interaction with the local hospital. Unfortunately, this was not possible prior to arriving in Attawapiskat, but the flexibility of the schedule did allow for hearing evaluations to occur at the hospital.

The local hospital in Attawapiskat is a 16-bed facility. Of those 16 beds, about 10 are continuously used by the same chronic care patients. In essence, because of the lack of services on the reserve, the hospital functions as a type of assisted living centre. During a visit to the hospital, the nursing staff reported that several of the chronic care patients had difficulty hearing, but never had their hearing evaluated. Due to the limited mobility of the patients, it was decided to transport the audiological equipment from the school to the hospital for the testing. Casey arranged for one of the school custodians to assist with the transportation, and the hospital allowed for the use of an evaluation room for testing.

Hospital exam room converted for hearing testing.

HEARING TESTING

The hearing screenings at the school occurred similar to the year before. That is, Casey brought 4–5 children to a waiting area and the children were screened individually; however, this year, the screenings occurred at a

Casey Enright and Heather Jessome (UWO audiology graduate student) standing in front of the new Attawapiskat audiology suite.

different location. As a show of commitment to the audiology initiative, Casey had the school administration convert part of his classroom into a testing room that housed all the audiological equipment. The new renovation improved the security of the equipment between visits and eased the transition from immittance testing to hearing screening.

As mentioned, several of the hospital's chronic care patients had significant mobility issues. Therefore, prior to being transported to the hearing evaluation area, they were triaged in their rooms; informed consent was obtained with the assistance of a Cree translator and otoscopy was performed to determine if they had excessive cerumen. If a patient presented with excessive cerumen, they were still evaluated but if tympanometry revealed non-compliant eardrum mobility and reduced ear canal volume, masked bone-conduction testing was also attempted.

RESULTS

Based on the results obtained from the 58 hearing screenings, the following recommendation categories were created: (1) no follow-up required (26 children); cerumen removal (16 children); cerumen removal with rescreen of eardrum movement and hearing (5 children); rescreen of eardrum movement and hearing in 2–3 weeks (6 children); medical evaluation for outer ear infection at local hospital and rescreen (2 children); complete audiological evaluation by Paul Stevenson (3 children). In addition, two children and five school staff received complete hearing evaluations.

Of the 16 children that required cerumen management, it was attempted on eight of them at the school using irrigation and a curette. Unfortunately, due to the dry granular nature of the cerumen and the stenotic ear canals, cerumen management was only successful on three of the eight. The remaining children were referred to the nurse's station at the hospital for follow-up.

Six of the 10 patients at the local hospital received hearing evaluations. They were transported to the evaluation room and provided instructions in their first language. All of the patients presented with some type of reduced hearing sensitivity, with the losses ranging from moderate-to-profound. It should be noted, however, that even with receiving the instructions in their first language, most of the patients presented with fair-to-poor response reliability. In an attempt to gain more reliable results, more time will be scheduled for evaluations at the hospital during the following year.

SUMMARY

Due to the changes in the travel arrangements, the supervisor and student were in Attawapiskat a total of four and a half days. Because of the additional day, cerumen management was attempted, hospital patients were evaluated, and an observation of the classroom noise levels was performed. In addition, due to the additional day, a majority of the reports could be written while in Attawapiskat to help facilitate the referral process. With each year, the audiology initiative is able to include additional services, which, in turn, provides a more diverse placement for the student and assists more members in the community.

YEAR 3: FUTURE PLANS

A third trip to Attawapiskat is planned for April 2012. The visit will again include hearing screenings at the school, cerumen management, and audiological evaluations at the hospital. However, from the 2011 trip, it was apparent that additional assistance is needed. For example, the incorporation of soundfield FM systems in the portable classrooms, some type of amplification devices for the chronic care patients and education on the hazards of noise exposure in general and during hunting season. The funding for the equipment and potential additional trips to Attawapiskat for training and orientation exceeds the dollars available or permissible from the university; therefore, outside funding opportunities are being pursued as a supplement to the assistance provided by the university.

CONCLUSION

It has always been the goal of the school director and the CSD faculty that the Northern Initiative placement be an ongoing commitment. That through the annual trips, the community will continue to realize the vested interest the university has in providing the services and assisting the individuals of Attawapiskat. Hopefully, as more placements occur through the years, the impact the CSD faculty and students make on the reserve will be seen in the smiling faces of the children of Attawapiskat.

ACKNOWLEDGEMENT

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What Your Mother Never Told You About Earmold Acoustic Formulae… or "Acoustic bedtime stories based on the work of Mead Killion"

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Some people are born to audiology, others have audiology thrust upon them...

Was she too embarrassed, or did she simply gamble that you'd find out for yourself? Here's what your mother never told you about earmold acoustic formulae—a breathless tale of venting, acoustic resistance, and flared earmold tubing, all based on the work of Mead Killion.

When I was quite young, as my mother (below) was putting me to sleep, like all mothers, she would tell me about all of the interesting statistical and physical formulae that she thought I would need to know in life. I recall my mother saying that, if there were statistically significant interaction effects, one could not trust the main effects in an ANOVA (and to always check for homogeneity of the variance). I lost plenty of sleep over that one. I also remember an interesting story about the specific impedance of a tube and how the world was saved by a judicious use of 1500 ohms of acoustic resistance. I am sure that your mother told you similar stories, which is why, of course, we all went into audiology and hearing health care (or developed a sleeping disorder).


Marshall's mother.

The following are some of the things that my mother told me about when it comes to earmold acoustics, as well as some things she *didn't let me know* at such a tender age. Some are quite familiar, whereas others may be more obscure. Nevertheless, all can be used to help select the appropriate characteristics of earmold plumbing when we prescribe and fit hearing aids. This will be covered under the three main categories: venting, acoustic resistance, and flaring of the earmold tubing.

VENTING

Venting was one of the first stories I recall my mother telling me about. You have to realize that I was told these stories in the late 1950s when active feedback management control was decades off. My mother would always tell me that, clinically, I needed to provide my clients with the largest vent that I could get away with. Being only 4 years old at the time, I had yet to take my first course in acoustics and algebra, so I found what she had to say a bit hard to believe.

She said that vents reduce gain for the lower frequency sounds and have their greatest effect below 1000 Hz. She also told me that the mass of air that was trapped in the vent acted as *acoustic inertance* – and I must admit that I found comfort with this. The mass of air oscillates as a single unit and provides a resonance at about 400 to 500 Hz, and this would slightly offset the effect of the vent by enhancing sounds in this region.

Being 4 years old, I had trouble recalling this information, so she gave me this important formula, which she had stolen from a young Australian schoolgirl named Robyn Cox:

$$\mathbf{F = 5500\ Hz\ (\pi r^2 / loVe)^{1/2}}$$

We are all quite familiar with this formula, and I recall playing with the square root calculations until my father came home from work the next day. This is simply 5500 Hz times the square root of the cross-sectional area of the vent in cm^2 (πr^2) divided by the length (lo) and the volume of air (Ve). I believe that the original formula didn't have the subscripts, but my mother thought that she would put them in since it spelled something that a 4-year-old might like. If you ignore the 5500 Hz term (as most children do), the resonant frequency of the air trapped in the vent is simply proportional to the area and inversely proportional to the length. In other words, a long, narrow vent will have a relatively low frequency resonance, whereas a short, wide vent will have a higher resonant frequency. The way I remembered this was that Boris Karloff was tall, thin, and a bass, while Mickey Rooney was short, pudgy, and an alto.

My mother would patiently explain that a hearing aid (or a hearing protector) with a long narrow vent would have a 300–400 Hz resonance that caused a person's voice to be quite noticeable. I didn't understand that she was talking about the occlusion effect, but then again, I was only 4 years old. She told me that short, wide vents were probably better at minimizing the occlusion effect since the resonant frequency would be higher.

I recall a rather stern warning one night that I was not to forget that the resonant frequency varies as the "square root" so that I must make both changes (in diameter and length) for any real change to occur. She explained that changes inside a square root sign would result in smaller changes than outside. I commented that this was also true of logarithms; I understood perfectly and went to sleep.

The Physics of Compression: Eerie Prescience, Or Just An Upset Tummy?

I was, however, woken up near midnight when I overheard an argument between my mother and father. When the shouting and crying had stopped, both of my parents came into my room and told me that they had something important to tell me: I was never to forget that the venting would also have an effect on the real compression ratio that I was to set. I found this odd because hearing aids of the 1950s were linear, but I always listened to my parents.

They explained that, with large vents, low frequency sound would enter the ear canal directly bypassing the hearing aid, which would add up with the low intensity and low frequency output of the hearing aid, thereby altering the slope of the input-output [i/o] function of the hearing aid for low intensity inputs.

ACOUSTIC RESISTANCE

Whereas venting was mostly for altering the low frequency sound transmission, my mother was excited to introduce me to acoustic resistance, which had a mid- and high-frequency effect. She explained that what was so exciting in the study of acoustic resistance was that its effect would depend on *where* the resistance was placed in the hearing aid tubing and ear hook system. This gave my mother the perfect opportunity to explain standing waves to me – certainly an exciting period in my childhood!

She told me that an acoustic wave propagating in any tube depends on the boundary conditions, but it was primarily governed by the length of the tubing (and not the cross-sectional area). I found this hard to believe initially and this caused much family strife for years to come. However, like most things, we later come to realize your mother is always right. What made my childhood so easy was that my mother thought that it would be best if we dealt only with the "closed on one end" and "open on the other end" boundary condition. This introduced me to the wonderful world of quarter wavelength resonators, and the formula that she whispered to me as I fell into a deep and restful sleep was:

F = (2k-1) v/4L

I was initially cautioned by my father to ignore the (2k-1) term, and he was quite correct ...

Well, technically he was wrong but his caution was well meant. My father was always well-meaning. I concentrated on the v/4L factor and realized that hearing aid tubing resonances were governed by the speed of sound, or v (which really can't be altered too much), divided by 4 times the length (*L*) of the tube.

Being 4 years old, I knew my 4 times tables well and was quite capable of calculating the first resonance of a 75-mm-long acoustic system that was "closed" at the receiver and "open" at the end of the earmold bore. I assumed for ease of calculation (since I was doing this in my head while snuggling with my teddy bear) that the speed of sound was 340 m/sec (or 340,000 mm/s in Canadian) and therefore the first resonance in a 75-mm-long tube would be about 340,000 mm/sec / 300 mm = 1100 Hz. I was later to learn in life (by my 5th birthday) that this was called the "1000 Hz" resonance and was characteristic of all like tubes of this length. I just assumed that my calculations were off (since calculators were not yet available, and I was not allowed to play with pencils in bed for fear that I would poke my eye out when trying to sleep). My mother explained that people sometimes just approximate things and that my calculations were quite adequate for a 4-year-old.

For my 5th birthday, my father allowed me to add the (2k-1) term back into the equation and, to my great surprise (and great enjoyment), I realized that this 1000 Hz resonance had “friends” at odd numbered multiples of 3000 Hz and 5000 Hz. The 5000 Hz resonance that I calculated in the late 1950s was purely academic because my mother told me that modern 1950 hearing aids really only went up to 4000 Hz at most so I didn't need to worry my little head about this supersonic 5000 Hz resonance.

Just when I thought that I had learned it all, my mother introduced me to the specific impedance of a tube. I still recall, about 50 years later, she told me one morning (over a cup of hot chocolate) that the specific impedance of a tube was given by the following formula:

Specific impedance = 41 ohms/cross-sectional area (in cm^2)

She did caution me about those who erroneously called this the *characteristic impedance*, and I was not allowed to play with these children.

When I sat down to do my calculations after nap time, I found that this works out to be about 1300 ohms for #13 tubing, but can be as high as 5200 ohms for a 1 mm inner diameter thin tube. My mother explained that this would be the maximum amount of resistance that could be placed in the tubing to obliterate the tubing-related resonance. She explained that, if a 1300–1500 ohm resistor was placed in the hearing aid tubing or the ear hook nub, there would be a smoother etymotic response.

I didn't know what “etymotic” meant then since I had yet to start my ancient Greek lessons, but my mother told me that it was sometimes OK not to understand everything. That same night she told me that acoustic resistance was probably not needed with thin tubes since many were used in non-occluding hearing aid fittings. This was a time of great joy and excitement since I got to use the vent formula that my mother had told me about once again. I had never considered a non-occluding fitting as a maximal condition for a vent. This left me almost breathless; I barely slept that night!

FLARING OF THE EARMOLD TUBING

One fall evening, both of my parents came into my room and quite soberly explained to me in hushed voices that, if you consider all those frequencies in which one-half of their wavelength is less than the length of the tube, then those are enhanced by having a larger cross-sectional area. They both glanced at each other, then to me, and said that this was the *acoustic transformer effect*. They felt that I was old enough for this, now that I had just celebrated my 5th birthday.

Well, obviously I was shocked. I had grown up thinking that length (*L*) was the primary element in acoustics. There were some rumblings that cross-sectional area was important, such as with the specific impedance, but I thought that that was an aberration. After some tears, we settled down to do some calculations. My mother, wiping away tears from my eyes, explained that – when a tube is gradually flared and the flare is at least one-third the total length of the tubing – then this serves to enhance the intensity of the higher frequency components.

They both gave me this important formula to help me remember the acoustic transformer effect, so that I could one day pass it on to my children:

F = v/2L

I looked at them strangely because this looked very familiar – it was a one-half wavelength resonator model! I was told to calm down, and that this was merely a coincidence. (At this point I suspected for the first time in my life that my parents were lying to me.)

My mother said that this formula would help me find the frequency that a flared tube would start to have its effect. Placing *L* = 75 mm for a behind-the-ear (BTE) hearing aid in the equation, I calculated that F = 2200 Hz. My mother explained that a flared tube that gradually increases its inner diameter would have increased intensity for all frequencies above 2200 Hz.

Suddenly, a stern look came across her face and she commanded me to do the calculation for a 60-mm-long tube – such as those found with smaller headed people such as infants. My mother is so clever. The calculation now comes out as *F* = 2800 Hz. That is, an infant would not derive as much benefit from a flared tube as would an adult, and the effect would not occur until 2800 Hz and higher. I thought that this was unfair and up to this point had considered acoustics to be devoid of ageism. Acoustics seemed to prefer adults. This was a rude awakening.

My mother only let me stew in self-pity for about a minute until she asked if I would like to know how much the flare's effect was? I jumped at the chance. Mom explained that this was called the *amplification factor*, given by another exciting formula:

Amplification factor (dB) = 20log (diameter #2/diameter #1)

This was exciting since I got to use the log tables that I had just received for my 5th birthday. My mother asked me to calculate the amplification factor for flaring a 2 mm inner diameter #13 hearing aid tubing to a 4 mm one, as suggested by Uncle Cy Libby. I got to work and calculated all morning. After several hours, I found that I got a value of:

20log(4/2) = 20log2 = 6 dB

My mother said that I was correct and that 6 dB was the highest amount of high frequency amplification that could be obtained. I stupidly asked her why I couldn't just turn up the electrical gain by 6 dB in the higher frequencies. Mom said that I could, but that would decrease battery life; additionally, when done acoustically, it maintains the relationship between the gain and the OSPL90, whereas you might run out of headroom if you do it electrically. (Despite this being the late 1950s, my mother was ahead of her time!) She always told me that an acoustical modification was generally better than an electrical one.

I exclaimed, "Mom, let's do this for a thin tube that has an inner diameter of 1 mm and see what happens when it 'flares' to 2 mm, like #13 tubing!" We spent a glorious morning doing the calculations, and to my surprise, the amplification factor was still 20log2 = 6 dB. So it seems that, if the inner diameter is doubled, a 6 dB increase in the higher frequencies is obtained regardless of the initial tube used!

My head was spinning at this but I felt happy. It was time for bed, and I kissed my mother and father goodnight.

Editor's Note: This article was based on Mead Killion's 1981 JSHD article on "Earmold Options for Wideband Hearing Aids".

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In-Ear Monitors – States of the Art Update

Helping a Growing Community Make Wise Choices

By Thom Fiegle

About the Author

Thom Fiegle has spent his entire career in the pro audio industry. Since 1984, he has been the owner/operator of Figleaf Productions, a Chicago area sound company. He is constantly mixing live sound in Chicago area nightclubs, and is also partner and chief technician at Reelsounds Recording Studios.

With his extensive experience and expertise in both product development and hands-on live sound, in 2007, Thom Fiegle brought his unique combination of skills to Sensaphonics Hearing Conservation, Inc. where he works as Sound Engineering Consultant. His main role is to help new IEM users transition to the new technology and to help all Sensaphonics customers get the most from their investment in personal monitors.

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Personal monitoring for pro sound reinforcement began in the 1980s with the invention of the Sony Walkman. By employing FM transmitters, off-the-shelf radio receivers and cheap ear buds, pioneering monitor engineers were lured to the potential of conquering feedback generated by onstage loudspeakers in close proximity to the vocal microphones. Early adopters of the idea include Stevie Wonder, The Grateful Dead, Todd Rundgren, and the Steve Miller Band.

In the 1990s, further developments in the radio frequency (RF) link and earpiece technology allowed these eclectic, expensive systems to become readily available to any performing group. Today, the distinct benefits of in-ear monitors (IEM) have made them commonplace in the world of touring sound. Those benefits include the following outlined below.

FREEDOM OF MOVEMENT

With an earphone connected to a wireless device, no matter where performers go, they are always in the sonic center, or "sweet spot," of the performance area. The mix isn't altered when the performer moves as it does with a stationary loudspeaker on the floor.

IMPROVED SOUND QUALITY

With the risk of feedback squelched by the sound isolation between the microphones and the monitor speakers inside of an IEM, sounds can be heard at any volume level without affecting other performers or the main mix for the audience. Moreover, most IEM systems transmit in stereo. This allows for greater realism within a monitor mix by exploiting the localization abilities of the ear-brain mechanism from left to right.

CONSISTENCY FROM VENUE TO VENUE

By removing wedge loudspeakers from the floor space in front of performers, room acoustics become less of a variable. The 0.5 cc airspace in a custom-sealed ear canal yields the same "listening environment" every time for monitor mix consistency from show to show. Monitor engineers spend less time equalizing the floor wedges for best gain-before-feedback so that precious sound-check time is saved. Furthermore, every time a performer transitions to IEM and away from traditional loudspeakers, the performance area will immediately become quieter due to the simple fact that it means one less speaker adding to the sound level on stage. This has benefits for the listeners downstream as well.

REDUCED VOCAL FATIGUE

With feedback eliminated and the monitors moved up from their feet to their ear canals, vocalists no longer have to put undue strain on their vocal cords just to hear their own voice. Singers can hear themselves better than ever before, allowing for better intonation (pitch) and timing. Fewer shows get postponed, cancelled, or performed poorly because of excessive vocal fatigue.

REMOVAL OF TEMPORAL DISTORTIONS

From a performance perspective, no loudspeaker system can overcome the frustration associated with multiple time-arrival miscues. By placing microphones in close proximity to their intended sound sources and placing speakers very near the eardrum, all associated propagation delays can be minimized when employing IEM – with the center of the musical tempo arriving at all performers' ears at once.

REDUCED CARTAGE AND STORAGE

IEM systems take up a mere fraction of the space (and for that matter, weight) that wedge loudspeakers, their associated power amplifiers and processors, cabling and cases occupy on stage, in the truck and in the warehouse of the sound company.

REDUCED RISK OF HEARING LOSS IF USED PROPERLY

By isolating the musician's ear from the interfering sounds on a loud stage, the improved signal-to-noise ratio in the plugged ear allows for significantly lower listening levels. However, just because a musician wears an IEM system does not automatically result in hearing safety for that musician. In fact, most ear monitor systems can produce in excess of 120 dBA! Users should be advised on safe use by a hearing professional, since they won't experience safe sound if they turn their IEMs up too loud.

NOT A FAD

In-ear monitoring is here to stay. Ten years ago, the pro audio industry was a bit skeptical, but these days nearly 90% of the top 10 grossing tours consistently have at least one (if not all) performer(s) on IEMs. Performers, sound engineers, critics and audiences agree; today's stage and broadcast productions are sonically clearer than at any time in the electronic age of sound reproduction. Not being tied to a stationary loudspeaker has allowed performers like Peter Gabriel to make three-ring circus-like concert events incorporating elements of theatre into the presentation of rock and pop music. The Rolling Stones and U2 play concerts employing a "remote stage" out in the back-rows of the audience. Previously, such a performance area inside of a huge arena would be impossible to perform upon due to the PA being hundreds of feet away from the musicians' ears. But with IEMs, the problem is solved. Productions such as Cirque du Soleil and Blue Man Group could not acoustically take place without the use of IEM instead of traditional loudspeakers for the performers. These examples of state-of-the-art stagecraft are only possible when using custom molded earphones and stereo wireless systems. Today the personal monitor has become nearly as commonplace on a stage as an electric guitar or a wireless microphone.

Chances are good, if it hasn't happened already, a musician will be coming through your practice's doors and want ear impressions for an in-ear monitoring product of some sort. They may just want some ear impressions but may want to look to you for advice and consultation. Before prescribing just any old device, some comparisons between the myriad of product designs can be useful to help your musician-client choose the safest and most effective solution.

MONITORING THE MONITORS

Just like the loudspeakers they have supplanted, in-ear monitors can be used at dangerous levels. Vanderbilt University conducted a study[1] with 15 professional musicians to compare sound levels of floor wedges versus in-ear monitors by measuring sound levels at the performers' eardrums with probe microphone systems. The study surprisingly found that each musician would reliably and consistently set their own sound levels to within 1 dB over six performance trials, regardless of whether they were listening to loudspeakers at their feet or IEMs in their ears. The correlation coefficient was 0.98! This was considered the performers' Preferred Listening Level (PLL) in the study.

Then the same musicians were asked to turn the level down to the lowest level they would be able to perform at (the Minimum Acceptable Listening Level or MALL). With floor wedges the performers were only able to turn down by a maximum of 2 dB before they could no longer play well because of struggling to hear their monitor mix. However with IEMs, musicians could turn the monitor level down by as much as 6 dB averaged across all participants. Given that a reduction in sound level of 3 dB has one half the exposure, then a 6 dB reduction would have reduced the exposure to a quarter – the musicians can be exposed four times as long.

There is a particular device that measures the actual SPL an earphone user is experiencing while listening. When a user inquires how to use IEM products safely, without such a device, the answer becomes simply "don't turn 'em up too loud for too long." How loud is too loud? And if all musicians will potentially turn their IEMs up as loud as their wedge loudspeaker monitors (their PLL), what methods and techniques can be employed to make these performers aware that they are likely damaging their hearing?

TALKING THE TALK

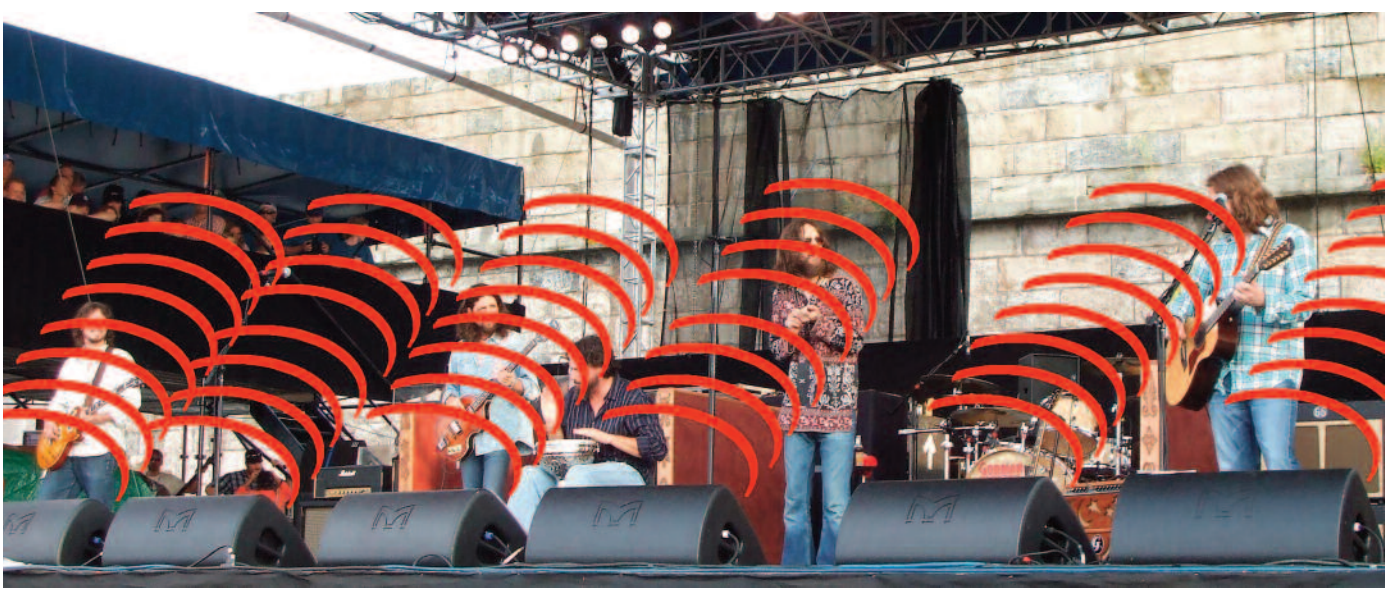
Most custom earphones are made of hard materials (acrylic, ABS plastic and rubberized vinyl), and most of them utilize a shallow earmold, stopping at, or well before the first bend of the canal – generally this is because the material is stiff and not very comfortable if it penetrates too deeply into the performer's ears. It's worth reminding the readers that these folks are expressing themselves while on stage and exercising most, if not all, of their facial muscles whether singing, blowing wind instruments or otherwise. Some of those loose-fitting, hard-shelled earphones contain as many as eight balanced armature drivers (speakers) inside of them to deliver "kick" and "punch," "presence" and "detail." The main reason these multi-band, super-sensitive earphones are designed is because they do not isolate the wearer's ears very well from ambient sound due to their shallow canal portions and hollow, hard, shells. When the acoustic seal of the ear canal is compromised, low frequency content is lost – never reaching the intended sound level because of the acoustic impedance added to the circuit by being attached to outside air pressure.

Another custom earphone-type uses a dynamic (moving-coil) speaker instead of balanced armatures. Most dynamic driver designs require air gaps outside of the earphone to regulate the air-mass on either side of the diaphragm in order to sound good, at the expense of losing ambient isolation (less than 10 dB of sound isolation with these "ported" systems). Unfortunately for the hearing health of the users of these kinds of devices, once it sounds good, the device is accepted by the artist and used rigorously. In many cases, no thought of hearing safety even transpires. No advice on safe usage is given. And almost all of those users will turn them up to an unsafe level.

Some of the world's finest musicians suffer from noise induced hearing loss. They are at very high risk and yet, unregulated in most countries. The maximum sound level capability of custom earphones recently has become a bit of a "mine's-bigger-than-yours" mentality, resulting in products that can pose a real threat to a musician's hearing heath cleverly disguised as a pursuit of sound quality.

WALKING THE WALK

It is up to an audiologist to explain how IEM devices can be used safely and more importantly, which devices aren't necessarily "safe." Sound levels versus exposure time still remain the guideline for safe monitoring level consultation. A band that plays a single, 45 minute show can safely monitor at a higher level than a wedding band that performs for three or four hours at a typical reception.



Rehearsal time as well as other loud hobbies and activities need to be taken into account when musicians complain of threshold shifts or tinnitus.

An audiologist consulting a musician should know that hearing protection is not necessarily the performing musician's first concern. Their primary (and sometimes only) concern is performing the best they possibly can. To get there, they need to hear what's going on in a very particular way.

In addition to high fidelity, hearing safety can be encouraged by offering high isolation earphone systems made of softer materials and with deeper seals that are comfortable to wear for long periods of time, look professional and sound fabulous. Softer materials and deeper seals have been shown to isolate ambient sounds from a wearer's ear by as much as 37 dB. A method of measuring the actual sound level in the wearer's ear is the only tool for advising on safe levels and exposure times. These kinds of devices in the hands (and ears) of professional musicians and technicians can yield extraordinary performance monitoring without the threats of excessive sound levels, even for prolonged time durations. This strategy not only extends the careers of these performers but can even improve their performances. Performers that can hear themselves can be themselves. Conquering the volume war onstage literally radiates confidence and professionalism. Today's audiences can benefit from the fact that, thanks to IEM, the stage area sound system is no longer so loud.

LESS IS MORE

Use of ear monitors onstage also makes the main audience mix more focused and in control. Even the best sound systems in the world are challenged by the presence of onstage loudspeakers and their resultant ambient sound level contributed to the event. Less sound bouncing around from the stage area (an interference source for the audience) allows the sound engineer more flexibility in tuning the main sound system for maximum coverage, dynamic range and frequency response. Monitor engineers have benefited as well, and now sport a new job description – IEM mixer.

ISOLATION AND AMBIENCE

For many performers, and for maximum hearing health care, ambient isolation is a wonderful blessing. For others, unfortunately, it is nothing short of a curse. Still others simply cannot bear wearing anything at all in their ears. Some users will complain of too much isolation or say they are "separated" or "disconnected" from the environment. After all, they are.

Understanding and communicating to your patients the main benefit of IEMs – greater potential for a usable signal (monitor mix) to noise (competitive sources: PA, stage and crowd noise) ratio – will result in new adopters of this technology.

Some musicians will choose to use only one earphone and leave the other ear open. This is a potentially dangerous and not very useful way to employ IEMs. Binaural summation accounts for the

perception of a 6 dB level increase in the brain. More importantly, once either ear is opened to a loud stage, the tendency to turn up the plugged ear's speaker is more likely due to masking effects from the stage noise's interference. This one-in/one-out phenomenon is not necessarily a reflection on an IEM product's inability to provide the performer what he is seeking. It is usually a desperate attempt to let the outside environment into the performer's head to regain "perspective" and a sense of "reality."

Some custom products build passive leaks (holes essentially) into their hard-shelled earphones to help performer's perceive outside sounds – another potentially dangerous technique that compromises acoustic isolation.

Some IEM mix engineers even position extra microphones around the stage area and pointed at the audience in order to blend them into the ear mixes so performers can hear the environment around them while their ears are plugged. Although this last method of isolation alleviation can be implemented safely compared to passive holes, the reproduction of the environment is a static representation and not very "realistic" for a performer that is moving about the stage area (and perhaps into the audience, as well).

BEST OF BOTH WORLDS

Recent advancements in transducer design and manufacturing in conjunction with further maturity of electronic component miniaturization and circuit design has enabled the development of a high isolation, soft construction, custom earphone system that employs microphones built into the outside of the earmold with a bodypack device to control them. When connected to a typical wireless device, the user becomes able to add or subtract room ambience in a calculated, measurable and repeatable manner. These purpose-built devices alleviate the last remaining obstacle to adoption (too much isolation) of the clearly superior monitoring technology that IEM has become. The binaural microphone system positions the microphones at the musicians' ears. The gain of the microphones is calibrated to only compensate for the insertion loss of the custom mold, with the maximum setting being unity gain. The user selectable settings attenuate the microphones in 4 dB steps for easy and repeatable ambient settings, specifically for hearing safety purposes.

Unlike ambient leaks, the microphones allow for six attenuation settings, plus unity (no attenuation) and an "off" setting for maximum isolation (~37 dB broadband). That is a 24 dB range of active attenuation, plus "off". These ambient microphones are actively combined with the monitor mix to add further depth and realism to the onstage experience, as well as real-time accurate head transfer functions allowing for exact, three-dimensional localization including behind, above and below the performer's head.

SERVING AND SAVING MUSICIANS

With the growing popularity of IEMs, it is increasingly important that audiologists become familiar with the different needs faced by the music community, including local venues and contemporary houses of worship. When someone asks for ear impressions for custom-fit in-ear monitors, rather than merely being a "goop-shooter," use the opportunity to raise awareness of their hearing health issues. The best way to do that is to encourage a hearing screening during that visit, if possible. It's also important to understand the differences among IEM product designs, especially regarding such issues as maximum sound level, isolation, and comfort. This allows the hearing health professional to recommend the most appropriate product and to educate in its proper insertion and usage.

We've learned that IEMs can be effective hearing protection devices, but only when used properly. They require a full seal and maximum isolation from outside sound to be effective for the wearer, who must be instructed in the specifics of proper fit and behaviour in order to achieve both the high fidelity and hearing protection that custom-fit IEM earphones can provide. By connecting with musicians, audiologists can help them have longer, more productive careers and better quality of life.

REFERENCE

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