OFFICIAL PUBLICATION OF THE CANADIAN ACADEMY OF AUDIOLOGY
PUBLICATION OFFICIELLE DE L'ACADÉMIE CANADIENNE D'AUDIOLOGIE

Canadian Hearing Report

Revue canadienne d'audition

CAA Canadian Academy of Audiology Heard. Understood.
ACA Académie canadienne d'audiologie Entendus. Compris.
www.canadianaudiology.ca

Vol. 8 No. 3
2013

Articles from the Final Seminars on Audition

Noise Reduction to Achieve Quailty ABR Measurement

Publications Agreement Number 40025049 | ISSN 1718 1860

Peer Reviewed

Published by ANDREW JOHN PUBLISHING INC.
www.andrewjohnpublishing.com

For the past 28 years, Seminars on Audition has been one of my favourite hobbies. Joanne DeLuzio and I began co-ordinating this one-day conference back in 1986 and we just had our final one earlier this spring – the 28th Annual Seminars on Audition. The purpose of this seminar was to get clinicians, hearing aid design engineers, and researchers together in one room and provide a speaker or speakers that will set the milieu for discussion. In many ways, much of what was learned was during coffee breaks and from the person sitting next to you. Although there are a number of other continuing education opportunities now such as on-line CEUs, there was something special about a face-to-face meeting with people who may not normally cross your paths. All proceeds went to scholarships either at the University of Western Ontario (Seminars on Audition scholarship) or the Institute of Biomaterials and Biomedical Engineering at the University of Toronto (Poul B. Madsen Scholarship). The Seminars on Audition scholarship allowed a student in their final year of their master's degree to attend an "extra-ordinary" facility anywhere in North America. Recipients over the years have gone to the Canadian arctic to see how hearing aid evaluations and follow-up was performed over a 3000 km distance by dog sled, and also to world class pediatric facilities such as Boys Town in Nebraska.

This issue of the *Canadian Hearing Report* has a selection of three summaries of the some speakers from this last Seminars on Audition entitled "Hearing Though the Ages" with contributions from Dr. Susan Scollie, Dr. Jo DeLuzio, and Marilyn Reed. As you can probably guess from the areas of specialty of these people, the seminar started with young children and end with senior citizens and their unique communication requirements.

Also found in this issue of the *Canadian Hearing Report* is a transcript from the panel/discussion section of the fourth Seminars on Audition between Harry Levitt and Edgar Villchur who were the speakers for that meeting. Harry Levitt is a retired professor from CUNY in New York and is well known for his pioneering work on digital hearing aids. Edgar Villchur invented multi-band compression and is the father of the air suspended loudspeaker. Previous issues of the *Canadian Hearing Report* have had Founders of Our Profession interviews with both of these pioneers.

At the 2012 Canadian Academy of Audiology convention in Ottawa I attended a wonderfully clear and thoughtful presentation by Andre Marcoux (who was the first editor of the *Canadian Hearing Report*). He spoke about some new technologies and new approaches in ABR measurements. I thought it was so clear that even I could understand it, so he was asked to write something for us.

And talk about clarity, Dr. Jim Jerger wrote a wonderful article for the *International Journal of Audiology (IJA)* called "Why the audiogram is upside-down." I saw it in draft form and immediately called him up (and Ross Roesser, the editor of the *IJA*) to get permission to reprint it. They graciously agreed but I was second in line. *The Hearing Review* was before me and so you may have seen this before, however, it certainly is well worth the read and the triple exposure.

Marlene Begatto and her colleagues at Western University (the new name of the University of Western Ontario) has written a delightful article on audiological outcomes for children who wear hearing aids, and it's pretty obvious from the title, what that article is about. Alberto Behar, who recently received a major award from the Canadian Standards Association (see last issue of the *Canadian Hearing Report*) has co-written an article with one of the graduate students at Ryerson University in Toronto and examine whether headsets with a dual function of hearing protection and electronic communication can be damaging to one's hearing.

And of course we have our regular columnists, Calvin Staples (From the Blogs), Gael Hannan (The Happy HoH), and Dr. Vincent Lin from the Sunnybrook Health Sciences Centre and his colleagues have contributed under the banner of the E in ENT column Oral vs. transtympanic injection of steroids as treatment options for sudden sensori-neural hearing loss.

To round things out Dr. Brian Fligor from Boston has agreed to write this issue's Clinical Questions column, but you will have to read further to see what he said.

I wish you all a pleasant warm season, wear a hat, use sunscreen, and don't forget to register for the next annual conference of the Canadian Academy of Audiology this October in Newfoundland and Labrador.

Marshall Chasin, AuD, M.Sc., Aud(C), Reg. CASLPO, Editor-in-Chief
marshall.chasin@rogers.com

Canadian Hearing Report 2013;8(3):3.

Canadian
Hearing Report

Revue canadienne d'audition

Vol. 8 No 3 • 2013

Official publication of the
Canadian Academy of Audiology

Publication officielle de l'académie
canadienne d'audiologie
www.canadianaudiology.ca

Canadian Hearing Report is published six times annually by Andrew John Publishing Inc. with offices at 115 King Street West, Dundas, On, Canada L9H 1V1.

We welcome editorial submissions but cannot assume responsibility or commitment for unsolicited material. Any editorial material, including photographs that are accepted from an unsolicited contributor, will become the property of Andrew John Publishing Inc.

FEEDBACK

We welcome your views and comments. Please send them to Andrew John Publishing Inc., 115 King Street West, Dundas, ON, Canada L9H 1V1.

INDIVIDUAL COPIES

Individual copies may be purchased for a price of $19.95 Canadian. Bulk orders may be purchased at a discounted price with a minimum order of 25 copies. Please contact Ms. Brenda Robinson at (905) 628-4309 or brobinson@andrewjohnpublishing.com for more information and specific pricing.

contents

Follow us on Twitter @chr_infor

Publications Agreement Number 40025049 • ISSN 1718 1860

Return undeliverable Canadian Addresses to:
Andrew John Publishing Inc. 115 King Street West,
Dundas, ON, Canada L9H 1V1

Pendant 28 ans, les séminaires en ouïe ont été parmi mes passe-temps favoris. Joanne DeLuzio et moi-même avons commencé à coordonner cette conférence d'une journée en 1986 et nous venons d'avoir notre toute dernière plutôt ce printemps – le 28ieme séminaire annuel en ouïe. L'objectif de ce séminaire était de réunir ensemble dans une même salle cliniciens, ingénieurs concepteurs des appareils auditifs, et chercheurs et de proposer un conférencier ou des conférenciers qui établira le milieu de la discussion. A bien des égards, l'apprentissage se passait durant les pauses cafés et de la personne assise à côté. Même maintenant, avec des opportunités de formation continue comme les CEU en ligne, c'est tout à fait spécial que de rencontrer des gens face à face, des gens qui peut-être vous n'auriez pas rencontré autrement. Toutes les recettes ont été versées sous forme de bourses soit à the University of Western Ontario (Bourse des séminaires en ouïe) ou à the Institute of Biomaterials and Biomedical Engineering de l'Université de Toronto (La bourse de Poul B. Madsen). Les bourses des séminaires en ouïe ont permis à une ou un étudiant en dernière année de maitrise de fréquenter un établissement "extraordinaire" n'importe où en Amérique du nord. Sur plusieurs années, les récipiendaires sont allés dans l'arctique canadien pour voir comment les évaluations des appareils auditifs et les suivis sont exécutés sur 3000km de distance à l'aide de traineaux à chiens, et aussi dans des établissements de pédiatrie de renommée internationale tel que le Boys Town dans le Nebraska.

Ce numéro de *la Revue Canadienne d'audition* affiche une sélection de trois résumés de certains conférenciers au dernier séminaire en ouïe intitulé " l'ouïe à travers les âges" avec des contributions de Dr. Susan Scollie, Dr. Jo DeLuzio, et Marilyn Reed. Comme vous devez certainement le deviner par le domaine de spécialité des conférencières, le séminaire a commencé avec des jeunes enfants et a fini avec des personnes du troisième âge et leurs exigences uniques en communications.

On trouvera aussi dans ce numéro de la Revue Canadienne d'audition, une transcription de la section du panel de discussion du quatrième séminaire en ouïe entre Harry Levitt et Edgar Villchur qui étaient les conférenciers à cette réunion. Harry Levitt est professeur à la retraite du CUNY à New York et bien célèbre pour son travail pionnier sur les appareils auditifs numériques. Edgar Villchur a inventé la compression multi bande et est le père du haut-parleur à air suspendu. Des numéros antécédents de la Revue Canadienne d'audition ont affiché des entrevues avec ces deux pionniers dans la rubrique Les fondateurs de Notre Profession.

Au congrès de l'académie canadienne d'audiologie à Ottawa de 2012, J'ai assisté à une présentation admirablement claire et réfléchie par André Marcoux (qui était le premier rédacteur en chef de *la Revue Canadienne d'audition*). Il a évoqué certaines technologies et approches nouvelles dans les mesures des réponses évoquées auditives du tronc cérébral. J'ai pensé que c'était tellement clair que même moi je pouvais comprendre, alors il a été sommé de nous écrire quelque chose.

En parlant de clarté, Dr Jim Jerger a rédigé un merveilleux article pour the *International Journal of Audiology (IJA)* intitulé "Pourquoi l'audiogramme est inversé." Je l'ai vu sous forme d'ébauche d'article et je l'ai immédiatement appelé (et Ross Roesser, le rédacteur en chef de IJA) pour demander la permission de le réimprimer. Ils ont bien voulu mais j'étais le deuxième sur la liste. The Hearing Review était avant moi alors vous l'auriez peut-être déjà vu avant, mais certainement, il vaut bien la peine d'être relu et trois fois.

Marlene Begatto et ses collègues à l'Université Western (le nouveau nom de the University of Western Ontario) a rédigé un article enchanteur sur les résultats audiologiques pour les enfants qui portent des appareils auditifs, et évidemment le titre est explicite. Alberto Behar, qui a récemment reçu un prix majeur de l'association canadienne de normalisation (voyez le dernier numéro de *la Revue Canadienne d'audition*) a coécrit un article avec un des étudiants diplômés de l'Université Ryerson de Toronto et y examine les écouteurs double fonction de protection de l'ouïe et de communication électronique et s'ils sont nuisibles pour l'ouïe.

Bien entendu, nous avons nos chroniqueurs réguliers, Calvin Staples (From the blogs), Gael Hannan (The Happy HoH), et Dr. Vincent Lin du centre des sciences de santé de Sunnybrook et ses collègues qui ont contribué sous la bannière de la chronique the E in ENT, au sujet des injections de stéroïdes par voir orale versus tympanique comme options de traitement pour la perte auditive neurosensorielle soudaine.

Pour fermer la boucle, Dr Briam Fligor de Boston a bien voulu rédiger la chronique Questions Cliniques de ce numéro, mais il faudra lire plus en avant pour en savoir plus.

Je vous souhaite à toutes et à tous une belle saison chaude, utilisez l'écran solaire, portez un chapeau, et n'oubliez pas de vous inscrire à la prochaine conférence annuelle de l'Académie Canadienne d'Audiologie qui aura lieu le mois d'octobre prochain à Terre Neuve et Labrador.

Marshall Chasin, AuD, M.Sc., Aud(C), Reg. CASLPO
Éditeur en chef
marshall.chasin@rogers.com

Canadian Hearing Report 2013;8(3):7.

www.gnresound.ca/control

ReSound Control™

The first hearing aid app you can't afford to miss

Available on the App Store

ANDROID APP ON Google play

Get ready to offer your customers an industry first that truly improves their quality of life – and keeps them coming back for more.

Smart control anywhere
The new ReSound Control™ app turns any smartphone into a remote control. When used with the ReSound Unite™ Phone Clip+, the app gives your customers cutting-edge control of their wireless hearing instruments, phone conversations and streaming accessories – straight from the device they already carry with them.

It's connectivity options like these that take the experience of hearing to a whole new level. Market-leading. Empowering. Hassle-free.

Give them the control they deserve.

Made for iPhone

Made for Android™

ReSound Unite™ Phone Clip+
gnresound.ca/phoneclipplus

ReSound Unite™ Phone Clip+ is required for operation.

ReSound
rediscover hearing

ReSound Canada • 1-888-737-6863

With Brian J. Fligor, ScD Board Certified in Audiology with a Specialty Certification in Pediatric Audiology, Director of Diagnostic Audiology, Boston Children's Hospital; Instructor in Otology and Laryngology, Harvard Medical School.

Q: We are trying to relate sound pressure levels (SPL) in the ear canal to damage risk criteria for hearing loss ... it seems most of the standards use dBA not dB SPL. Are there any standards based on SPL in humans or of a way to convert SPL to dBA?

A: The SPL in the ear canal versus Damage Risk Criteria (DRC) came up immediately in the early 2000s when I was doing my dissertation on headphones and risk for hearing loss. Several authors before and since have forgotten that the DRC were developed with microphones in the diffuse field, and not in a coupler (e.g., a 2 cc coupler, or in an ear canal – which is of course also a coupler). Coupler-to-diffuse-field transfer functions are even more variable than dB SPL (flat) to A-weighted dB SPL – unless all your energy is above 1000 Hz where there are minimal SPL-dBA differences.

One of the problems in this area is terminology. Some researchers use the phrase "Transfer Function of the Open Ear" (TFOE) and others (especially audiologists) use "Real Ear Unaided Gain" (REUG). For the purposes of this question, the two acronyms are equivalent.

For broadband noise, the TFOE essentially gives about 7 dB higher level at the eardrum/ear canal than you get at the shoulder/diffuse field. This means a DRC that is 85-dBA for 8-hr TWA with 3 dB exchange rate would be 92-dBA for 8-hr TWA with 3 dB exchange rate if the location of measurement was the ear canal rather than diffuse field. A "correction factor" can then be subtracted from the ear canal (probe tube microphone) measure to change the results to equivalent diffuse field results for a valid estimation of DRC. The real ear to diffuse correction factor can be used but only if the exact nature of the spectrum is known.

Canadian Hearing Report 2013;8(3):9.

By Calvin Staples, MSc
Hearing Instrument Specialist
Faculty/Coordinator, Conestoga College
CStaples@conestogac.on.ca

As April showers have brought May snow in most of Ontario and throughout many parts of Canada, most of us have just finished up spring conference season. Conferences often provide clinicians the opportunity to view the latest and greatest products from hearing aid manufacturers. The blogs in this series will focus on the new developments in the hearing and hearing aid industry. I frequently visit the blogs at hearinghealthmatters.org as a springboard to further topic investigation, I hope our readers find the topics below insightful and useful clinically. As you will see from the submissions below, numerous achievements have occurred that will help shape our industry into the future. Happy Reading!

SCIENTISTS DEVELOP A "BIONIC EAR" WITH SUPER-HUMAN POWER

By David Kirkwood

Blending electronics and biology, scientists at Princeton University have used readily available 3-D printing tools to create a functioning "bionic ear" that can detect radio frequencies far beyond the range of normal human capability.

In a May 1 news release, John Sullivan of the Office of Engineering Communication at Princeton reported that the primary purpose of the researchers was to develop an effective means of merging electronics with biological tissue. The scientists used 3-D printing of cells and nanoparticles followed by cell culture to combine a small coil antenna with cartilage, creating what they termed a bionic ear.

The lead researcher is Michael McAlpine, an assistant professor of mechanical and aerospace engineering at Princeton. He told Sullivan, "There are mechanical and thermal challenges with interfacing electronic materials with biological materials. However, our work suggests a new approach – to build and grow the biology up with the electronics synergistically and in a 3-D interwoven format."

The Princeton team has been doing research in cybernetics for several years. This promising field seeks to design bionic organs and devices to enhance human abilities. The bionic ear project was the first effort by McAlpine and colleagues to create a fully functional organ: one that replicates a human ability and then uses embedded electronics to extend it.

Writing in the journal *Nano Letters*, the scientists said that cybernetics, "has the potential to generate customized replacement parts for the human body, or even create organs containing capabilities beyond what human biology ordinarily provides."

In order to replicate complex three-dimensional biological structures, the researchers turned to 3-D printing. A 3-D printer uses computer-assisted design to conceive of objects as arrays of thin slices. It then deposits layers of materials to build up a finished product.

One example of this approach is CAMISHA (computer-aided-manufacturing-for-individual-shells-for-hearing-aids), which was invented by Soren Westermann at Widex, and is now used to build 95% of custom hearing aids.

According to Princeton, the bionic ear project marked the first time that researchers have demonstrated that 3-D printing is a convenient strategy to interweave tissue with electronics. The researchers used an ordinary 3D printer to combine a matrix of hydrogel and calf cells with silver nanoparticles that form an antenna. The calf cells later develop into cartilage.

The initial device developed by McAlpine and colleagues detects radio waves, but the team plans to incorporate other materials that would enable it to hear acoustic sounds. While it will take much more work to develop a bionic ear that could restore or enhance human hearing, McAlpine said that in principle it should be possible to do so.

The team that developed the bionic ear consists of six Princeton faculty members, two graduate students from Princeton and Johns Hopkins University, and Ziwen Jiang, a high school student at the Peddie School in Hightstown, NJ. McAlpine said of the precocious teenager, "We would not have been able to complete this project without him, particularly in his skill at mastering CAD designs of the bionic ears."

http://hearinghealthmatters.org/hearingnewswatch/2013/scientists-develop-a-bionic-ear-with-super-human-power/

THREE BEST IDEAS TO RAISE AWARENESS OF HEARING LOSS ARE HONORED

By David Kirkwood

ANAHEIM, CA–An international public art initiative, a "Three Wise Monkeys" campaign to encourage regular hearing health checks, and a pocket-sized electronic hearing testing device captured top honors in the Ida Institute's competition, *Ideas, Speak up – Action and Awareness for Hearing Loss*. The winning entries were celebrated at a reception held here April 3 at the start of the American Academy of Audiology's annual convention, AudiologyNOW! 2013.

The purpose of the international contest was to stimulate ideas with the potential to create public awareness of hearing loss, put hearing loss on the public agenda, and encourage people to take action to address hearing loss.

The Ida Institute, a Danish-based independent non-profit foundation funded by the Oticon Foundation, launched the ideas competition at AudiologyNOW! 2012 held in Boston. Over the following months it generated more than 400 submissions from all over the world.

THREE TOP PRIZES

From these, first prizes were awarded in three categories. The winning entry in the Public Awareness Campaign category was submitted by Curtis Alcott, from the United Kingdom. Entitled "Three Monkeys: Eyes Checked. Teeth Checked. Hearing Checked," his idea was to link a simple message to the iconic three wise monkeys ("See no evil, hear no evil, speak no evil") to raise awareness of regular hearing health checks. The monkeys encourage making hearing checks part of a health routine that also includes getting one's eyes and teeth checked on a regular basis. The three monkeys image can be used in many media, including print and broadcast advertising, web sites, billboards, bus posters, and cinema trailers.

Khalid Islam of Bangladesh invented the winning idea in the Best Event category. He devised "Look Who's Hearing," an international public art initiative that would involve "fitting" hearing aids on statues in major cities around the world. The artist-designed hearing aids could be mounted as sculptures and then auctioned off to support hearing health charities. An Internet campaign would enable people to follow this initiative, track the next statue, and spread awareness.

In the Best Gadget category, Kasper Rubin, a Dane, won the blue ribbon for his Hearing Tone Test Card, an inexpensive electronic card that would serve as a practical hearing checker. The pocket-sized card uses simple electronic technology like that used in singing greeting cards. However, instead of making music, the technology is used to test hearing.

At the reception in Anaheim where the contest winners were announced, Niels Boserup, chairman of the Oticon Foundation, said, "We recognize that to continue the good work of this project and to achieve increased public awareness of hearing loss worldwide will require a strategic, dedicated initiative." He added that the Oticon Foundation "will investigate ways to develop and implement the worthy ideas."
Lise Lotte Bundesen, managing director of the Ida Institute, said, "The Ideas Campaign sparked the creativity and passion of people around the world."

IDEAS WORTH HEARING

The prize-winning ideas were selected by a panel of judges including Brenda Battat, executive director of the Hearing Loss Association of America; Tom Healy, a writer, poet and chairman of the Fulbright Foreign Scholarship Board; Bob Isherwood, former worldwide creative director of Saatchi & Saatchi, the Ideas Agency; Sergei Kochkin, PhD, former executive director of the Better Hearing Institute; and Helle Østergaard, executive director of the Crown Princess Mary Foundation.

These and some of the other best ideas submitted can be viewed online at *Ideas Worth Hearing*. The Ideas Catalog is designed to inspire and to help people around the world take action and start raising awareness of hearing loss in their communities.

http://hearinghealthmatters.org/hearingnewswatch/2013/three-best-ideas-to-raise-awareness-of-hearing-loss-are-honored-at-aaa-convention/

THE MORNING AFTER PILL

By Robert Traynor

Most audiologists realize that noise-induced hearing loss (NIHL) refers to a gradual, cumulative and preventable decline in auditory function that follows repeated exposure to loud noise. It is, of course, the leading cause of preventable hearing loss. It is also estimated that 10% (30 million) of Americans are encountering hazardous levels of noise, that 25% of those working in the construction, mining, agriculture, manufacturing, transportation, and military industries routinely encounter noise levels above 90 dB (A), and that such noise exposure has already generated a sizeable population of workers who meet the Occupational Safety and Health Administration's (OSHA) definition for material impairment of hearing" (over 25 dB threshold at 1000, 2000, and 3000 Hz). This number is probably much greater among workers and participants in high noise activities in countries where regulations are not as stringent as those in developed countries. Since workers and those with recreational hearing losses can have significant effects on their employment, social interactions, family interactions, protecting hearing health in the workplace and while having fun has become very important. Programs and regulations for occupational exposure (e.g. maximum allowed daily noise doses) have been designed, but no matter where you live there are virtually no standards for recreational noise, an emerging contributor to noise-induced hearing loss. There are numerous sources of non-occupational noise exposure. Clark and Bohne have compiled a partial list of significant sources of leisure noise, and music figures prominently in their construct.

Music, in addition, transcends the recreational setting to pose an occupational risk of NIHL for groups such as music venue workers and music performers, even the audiences……

THINK BACK

Most of us (yes, even audiologists) have "been there" at one time or another. You are a fan! A BIG FAN LL Cool J, Beyonce, Madonna, maybe even the Stones and your favorite musical artist is in town for a greatest hits concert! You have a babysitter, a designated driver. Look out, you are out on the town! As Rick Nelson said, "Sang them all the old songs, thought that is why they came" and that **IS** why they came…and a super time was had by all! The Next Day: You wake up with horrible tinnitus, probably a hangover as well and wonder why it was so important to get close to the speakers during the rock concert the night before. As the day goes on you begin to feel better, but the tinnitus lingers on reminding you of a major noise exposure the night before. Over the next day or so, the tinnitus will usually subside and we end up OK, but as audiologists we know that there has been some hair cell destruction.Typically, the noise exposure causes levels of toxic chemicals called "free radicals" inside the hair cell to rise beyond manageable levels, and the cell dies. We also know that if we continue to attend too many of these concerts the exposure to the intense sound levels will ultimately lead to a number of hair cell deaths and, subsequently, a permanent hearing impairment. ***BUT***….What if we could reverse the process, make it like we had never been exposed at all….a **Morning After Pill**…..Now it probably will not do too much for the hangover, but there may be a method to minimized or eliminate the effects of the noise exposure due to taking a pill that actually works.

THE MORNING AFTER

Studies in this area have been ongoing for a number of years. Based upon their studies, researchers at the University of Michigan, Kresge Hearing Research Institute have developed AuraQuell (pill) which is a combination of Vitamins A, C and E, plus magnesium, taken before a person is exposed to loud noises. The funding for the Michigan project was provided by General Motors and the United Auto Workers that led to the 2007 study of the mechanism attributed to induce hearing loss and the pre-clinical research that contributed to the development of AuraQuell. During clinical studies, guinea pigs who had been administered AuraQuell experienced about eighty percent preventative blockage of noise-induced hearing impairment ("The treatment one hour before a five hour exposure to 120 decibel (dB) sound pressure level noise, and continued once daily for five days." Josef M. Lynn, Ph. D., the Lynn and Ruth Townsend Professor of Communication Disorders, Director of the Center for Hearing Disorders at the University of Michigan Department of Otolaryngology's Kresge Hearing Research Institute and co-leader of the research expects AuraQuell could effectively block 50% of noise induced hearing loss in humans. A trademark for AuraQuell was granted in June 2009. Clinical human testing of AuraQuell is being evaluated in four multinational trials: "Military trials in Sweden and Spain, an industrial trial in Spain, and trial involving students at the University of Florida who listen to music at high volumes on their iPods and other PDAs." The human clinical trials for AuraQuell maybe in the form of a tablet or snack bar. These trials studies are funded by National Institute of Health (NIH)."This is the first NIH – funded clinical trial involving the prevention of noise-induced hearing loss." AuraQuell may prove to limit induced hearing loss of military personal exposed to improvised explosive devices (IEDs) and other noises. It appears that AuraQuell is still in clinical field trials, but if these trials are successful, Dr. Joseph Miller, the noise-induced hearing loss prevention concoction could be available within two years.

http://hearinghealthmatters.org/hearinginternational/2013/the-morning-after-pil/

Canadian Hearing Report 2012;8(3):10-12.

Hearing Loss – A Family Affair

By Gael Hannan
gdhannan@rogers.com

Yo – hearing care professionals! Can anybody tell us where a family can sign up for a communication course? (And I'm not talking about a mandatory program involving a psychologist or the police.) It's tough enough for a hard of hearing person to find access to effective aural rehabilitation, let alone a program that includes communication partners like spouses and children past the spit-up stage.

The need is great. In many families, hearing loss is the elephant in the room, the monkey wrench thrown into family communication. Attending even a single facilitated session on communication strategies can make a big difference in the quality of family life. I know what you might be thinking – and to keep this animal analogy going – you can lead a horse to water but you can't make it drink. People may not break down your door to sign up for the session or course, but the ones that do will benefit greatly.

It can be a bit lonely as the only HoH in the house. Just because a family is well-versed in effective communication strategies, doesn't mean it actually *practices* them. This is not because of pettiness, negligence or a lack of caring, but simply because family members, in the moment, can forget the basics of good communication. A turned-away face or a question bellowed from upstairs can suck the pleasant air out of a room in two seconds flat, kick-starting a familiar scenario of rising irritation and heated words.

Me: *Why did you do that?*
Him: *(sigh) Do what?*
Me: *You started talking to me as you walked away. You KNOW I can't understand when you do that.*
Him: *Sorry, hon, I forgot.*
Me: *You forgot, you forgot! How many times will it take before you remember?*
Him: *Until death do us part, OK? I will always forget sometimes, I can't help it. Now, do you wanna know what I said, or not?*

Hearing loss is a family affair. Its impact reaches beyond the personal to anyone within communicating distance. In my house, even after living together for years, simply mis-communications can still spark reactions that range from a laugh to mild irritation to full-on frustration. This is part of our more-or-less accepted family dynamic and, when the bad moment passes, we move on – time after time.

But the family affair has recently become more complicated. One change involves the 17 year-old son who has already moved beyond our sphere of influence. The little boy who was raised to respect the gift of hearing and understand the consequences of hearing damage, now enjoys his music at dangerous levels. There's not much I can do beyond offering a good supply of earplugs (which I can no longer stuff in his ears for him) and reminding (nagging) him that if he continues to abuse his hearing, we'll be comparing hearing aids at some point in the future.

The other change involves his parents. Up until now, Mommy has been the only one playing in the hearing loss sandbox. But now Daddy, who has been sitting on the fence between the two worlds of hearing (his) and hearing loss (mine), may have stuck a toe in the sandbox, too. When it's noisy, he doesn't hear me as well as he used to. Recently, at a hearing health fair I was involved with, my husband signed up for free hearing test. Although the testing environment was less than ideal, his hearing was "normal" until 4000 Hz – and then kaboom, the famous NIHL notch!

The day may have arrived that the former Hearing Husband and I must practice two-way communication strategies. I now need to practice what I preach, making sure, for example, that he can see my face in order to understand what I'm saying.

But my husband and I have grown into this situation – I was already hard of hearing when we got married. What about the couples or families who experience hearing loss after years of being together? The emotional impact is often immeasurable. Internet resources such as personal blogs and consumer/professional hearing loss sites offer a great deal of helpful information, but don't match the effectiveness of learning and practicing good communication strategies with real people.

As hearing care professionals, you can help ensure your clients' success by helping their families deal with the emotional barriers of hearing loss, clearing the way to better communication with real-life strategies that work.

The time is ripe to introduce family communication sessions. If a hearing professional in my area cares to offer one, I'll sign up me and my boys. A good family dynamic is dependent on many things, and handling hearing loss is definitely one of them.

Be sure to visit Gael's blog, "The Better Hearing Consumer" at: http://hearinghealthmatters.org/.

Canadian Hearing Report 2012;8(3):13-14.

By Popular Demand!

Outstanding CAA Pre-conference Workshops October 16, 2013

PRE-CONFERENCE A: VESTIBULAR EVALUATION AND REHABILITATION: ALL THE BASICS YOU NEED TO KNOW

Take a tour of the vestibular system; learn about available vestibular tests and how to recognize vestibular disorders. Rehabilitation techniques will be introduced and you will have the opportunity to "ask the experts" who deliver services in an active hospital-based centre. This workshop will appeal to audiologists with novice and experienced knowledge levels in vestibular function.

Maxine Armstrong provides vestibular training to medical students, otolaryngology residents, neurotology fellows, audiology students, and SLP students. She manages the Toronto General Hospital's Centre for Advanced Hearing and Balance Testing and The Munk Hearing Centre. Carolyn Falls assists Maxine in overseeing the centres and both participate in University of Toronto based research activities.

PRE-CONFERENCE B: HEARING AND COGNITIVE DECLINE IN AGING: NEW DIRECTIONS FOR AUDIOLOGICAL PRACTICE

We have assembled a world-class team of researchers and clinicians to bring you up to the minute evidence based knowledge and how to apply it clinically.

Mounting research points to the connection between hearing loss and dementia; however, the mechanisms underlying the connection remain unknown. Possible connections will be described. Recently published diagnostic guidelines regarding mild cognitive impairment (MCI) and dementia will be reviewed. The need to include hearing testing in protocols for screening and assessing MCI and dementia will be discussed. Ongoing research on the possible advantages of including cognitive measures in audiology protocols will be presented. Importantly, there is great interest in finding ways to stave off or slow down the onset of dementia. Whether hearing loss prevention and/or hearing rehabilitation could reduce the risk of dementia is an important question for researchers and clinicians. The issues to be covered will consider questions such as: Can individuals with dementia benefit from hearing aids and/or other forms of audiologic rehabilitation? How could audiologists offer help to caregivers for individuals with dual hearing and cognitive impairments? The workshop will include some hands-on exercises, interactive discussions and presentations by international researchers as well as clinical experts in otolaryngology, audiology and psychology who are trying to develop new approaches to care for people that bridges age-related declines in hearing and cognition.

Part 1 Research evidence of the connection between hearing and cognitive decline in aging

Ulrike Lemke – Scientist Phonak AG Switzerland – Diagnostic continuum from healthy aging to dementia

Dr. Frank Lin – Johns Hopkins University – Epidemiological evidence of the connection of hearing loss and cognitive decline in aging

Dr. Kathy Pichora Fuller – University of Toronto – Experimental research evidence of the link between hearing loss and cognitive decline in aging

Part 2 Determining what older adults with hearing loss and cognitive decline want and need

Mary Oberg – Audiologist Sweden – Views of 80 year olds about hearing aid and rehabilitation options.

Marilyn Reed – Baycrest – Rehabilitative options for older adults with hearing loss and dementia

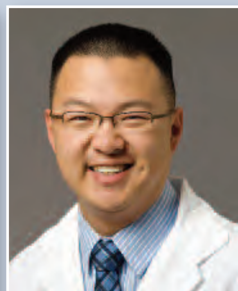
Kate Dupuis – University of Toronto – Screening for cognitive loss by audiologists and screening for hearing loss by psychologists

Conference details:
www.canadianaudiology.ca/conference2013

Oral vs. Transtympanic Injection of Steroids as Treatment Options for Idiopathic Sudden Sensorineural Hearing Loss

By Mary Edgar, BKin, David Clinkard, MS, and Vincent Lin, MD, FRCSC
edgarmary01@hotmail.com





About the Authors
Mary Edgar (left) has a bachelor's degree in kinesiology and has just been accepted into the MSc physiotherapy program at UBC. She has worked as an audiometric technician at the Vernon Health Unit for the past five years. David Clinkard (middle), and Vincent Lin (left) are with the Otolaryngology Department at Sunnybrook Health Sciences Centre, Toronto, Ontario.

ABSTRACT

There is a myriad of treatment options for sudden sensorineural hearing loss. However clinical evidence supporting the efficacy of these treatments are generally limited to case series and a few clinical trials. Due to the paucity of good clinical evidence, the treatment of sudden sensorineural hearing loss continues to challenging for otolaryngologists. Although controversial, corticosteroids are considered the standard of care. A typical treatment regiment is a tapering course of high dose oral corticosteroids. Recently, transtympanic corticosteroids have been administered as salvage therapy, primary therapy or in addition to oral corticosteroid treatments. The role of oral versus transtympanic corticosteroid therapy remains poorly understood.

Sudden sensorineural hearing loss (SSNHL) is a relatively common complaint in audiology and otolaryngology practices. SSNHL is the acute onset of hearing loss of at least 30 dB in at least three different frequencies over a 72-hour period.[1] While usually unilateral in origin, bilateral occurance is possible, though rare (1–2%).

The overall incidence of diagnosed ISSNHL ranges from 5 to 20 per 100,000 persons per year, with some estimates as high as 160 per 100,000.[2] Given the high spontaneous recovery rates (32–65%), the actual incidence of ISSNHL may be higher.[3] ISSNHL typically occurs between the ages of 50 and 60, with no gender predominance.[4,5] Etiology is often unknown, with the majority (85%) of patients having no identifiable cause.[5,6] However, viral, vascular and immunologic contributions have been suggested as possible etiologies.[2,3]

DIAGNOSIS AND TREATMENT

Aural fullness and muffled hearing are the most common presenting symptoms of SSNHL and may be mistaken for less serious conditions such as cerumen impaction or nasal congestion leading to eustachian tube dysfunction[7]. These can be ruled out with a complete history, physical exam, and audiologic evaluation.[2] A rapid diagnosis of SSNHL is vital because a delay in diagnosis may reduce the efficacy of treatments thought to restore hearing.[3,4]

Given the multifactorial and ultimately unknown nature of ISSNHL multiple therapy options have been proposed. These include steroids, vasodilators, anticoagulants, plasma expanders, vitamins, and hypobaric oxygen.[3,5,8]

Current standard of care is a tapering dose of systemic steroids, either oral or intravenous. The treatment should be started as soon after diagnosis in order to obtain the best outcome. Prednisone (1 mg/kg/day up to 60 mg max), as a single dose for 10–14 days is currently recommended by the American Academy of Otolaryngology.

Other commonly used steroids include methylprednisolone, prednisolone, and dexamethasone, depending on physician preference. Steroids were first shown to have beneficial effects by Wilson et al., who demonstrated that patients receiving oral steroids experienced a significantly greater return of spontaneous hearing (61%), as compared to those receiving placebo (32%). This is believed to have benefit due to research showing steroids blunt a cellular inflammatory cascade that occurs ISSNHL.[4,8,9]

The initial use of transtympanic injections of glucosteroids were recommended as salvage therapy if patients do not experience an increase in hearing recovery within 10 days of the initial treatment. However, there is limited research to support dosing regiments for salvage therapy.[10]

PROGNOSIS

The prognosis of ISSNHL is dependent on a variety of risk factors including demographics, duration of hearing loss, severity of hearing loss, speech discrimination scores, age, presence of vertigo, associated symptoms, and audiogram characteristics.[11] Of all demographic factors studied, advanced age (>60 years in most studies) has been universally correlated with decreased rates of hearing recovery and lower absolute threshold gains.[5] The greatest spontaneous improvement in hearing occurs during the first two weeks and late recovery has been reported but is rare. Treatment with corticosteroids appears to offer the greatest recovery in the first two weeks, with little benefit after four to six weeks.[2]

CHANGES TO TREATMENT OPTIONS

Despite their widespread use, there is little consensus on the effectiveness of oral steroids in ISSNHL. High-dose administration of systemic steroids can raise risks of adverse effects, such as avascular necrosis of the femur head, immune suppression, endocrine problems, osteoporosis, glucose intolerance, or weight gain.[3] To avoid these side effects, recent studies have proposed transtympanic treatment be used as the sole initial treatment for ISSNHL, with studies showing this protocol to be non-inferior to conventional oral steroids.[4,12] However, there are numerous downsides to this approach; transtympanic steroids can cause patient discomfort, are more expensive, inconvenient to inject and carry a risk of otomycosis.[3]

Preliminary work has suggested that administration of glucosteroids by perfusion through a round window catheter can deliver a higher concentration of steroid to the inner ear and improve hearing when compared to tympanic membrane injection. This delivery method can avoid the side effects caused by systemic steroid use and avoid tympanum perforation.[13,14]

Currently, the Sunnybrook approach involves an audiogram to confirm hearing loss, followed by blood work to rule out infectious processes if clinically indicated. If the hearing loss is unilateral, magnetic resonance imaging (MRI) is ordered to rule out retrocochlear causes such as an acoustic schwannoma. If these investigations fail to a reveal cause of hearing loss, then prednisone at 1 mg/kg/day for the first six days and then tapering for eight days, for a 14-day total course is prescribed. Patients are also offered intratympanic dexamethasone injections (1 cc of 10 mg/mL) for at least three daily injections until hearing improvement plateaus. If hearing improvement continues, then the injections continue until audiologic testing reveals no further improvement. One major issue which has still not be fully addressed is the window of opportunity in which either oral or intratympanic corticosteroid treatment will continue to have any effect. Our centre uses the 14–21 day window-patients presenting after that period are not typically offered any treatment.

CONCLUSION

Although controversial, the use of oral steroids in the initial treatment of ISSNHL has been considered by many to be the gold standard of care. Current research suggests that transtympanic corticosteroid treatment increases concentration in the cochlear fluids. Therefore in the philosophy of maximizing corticosteroid concentration in the inner ear to minimize permanent damage, we advocate a combined oral and intratympanic corticosteroid treatment paradigm in patients diagnosed with SSNHL.

REFERENCES

1. National Institute of Deafness and Other Communication Disorders (NIDCD). Sudden deafness. 2003. http://www.nidcd.nih.gov/health/hearing/pages/sudden.aspx. Accessed October 26, 2012.
2. Stachler RJ, Chandrasekhar SS, Archer SM, et al. Clinical practice guideline: sudden hearing loss. Otolaryngol Head and Neck Surg 2012;146(3):S1–S35.

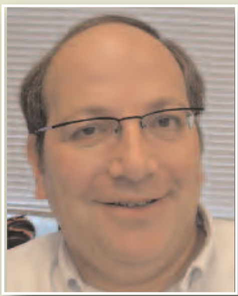
3. Lim HJ, Kim YT, Choi SJ. Efficacy of 3 different steroid treatments for sudden sensorineural hearing loss: a prospective, randomized trial. Otolaryngol Head and Neck Surg 2013; 148(1):121–7.
4. Rauch SD. Clinical practice. Idiopathic sudden sensorineural hearing loss. N Engl J Med 2008; 359(8):833–40.
5. Kuhn M, Heman-Ackah SE, Shaikh JA, et al. Sudden sensorineural hearing loss: a review of diagnosis, treatment, and prognosis. Trends in Amplification 2011;15(3):91–105.
6. Neely JG, Ortmann AJ. Sudden sensorineural hearing loss and delayed complete spontaneous recovery. J Am Aca Audiol 2012; 23(4):249–55.
7. Rauch SD, Halpin CF, Antonelii PJ, et al. Oral vs intratympanic corticosteroid therapy for idiopathic sudden sensorineural hearing loss. JAMA 2011;305(20):2071–79.
8. Conlin AE, Parnes LS. Treatment of sudden sensorineural hearing loss, I: a systematic review. Arch Otolaryngol Head Neck Surg. 2007;133(6):573–81.
9. Roebuck J, Chang CY. Efficacy of steroid injection on idiopathic sensorineural hearing loss. Otolaryngol Head and Neck Surg 2006;135(2):276–79.
10. Shemirani NL, Schmidt M, Friedland DR. Sudden sensorineural hearing loss: an evaluation of treatment and management approaches by referring physicians. Otolaryngol Head and Neck Surg 2009;140(1):86–91.
11. Kara E, Cetik F, Tarkan O, et al. Modified intratympanic treatment for idiopathic sudden sensorineural hearing loss. Eur Arch Otorhinolaryngol 2010;267(5):701–7.
12. Piccirillo JF. Steroids for idiopathic sudden sensorineural hearing loss. JAMA 2011;305(20):2114–15.
13. Wang Y, Ren J, Lu Y, et al. Evaluation of intratympanic dexamethasone for treatment of refractory sudden sensorineural hearing loss. J Zhejiang Univ Sci B 2012;13(3):203–8.
14. Spear SA, Schwartz SR. Intratympanic steroids for sudden sensorineural hearing loss: a systematic review. Otolaryngol Head and Neck Surg 2011;145(4):534–43.

Canadian Hearing Report 2012;8(3):15-17.




Noise Reduction to Achieve Quality ABR Measurement

By André Marcoux, PhD and Isaac Kurtz, MHSc, PEng
amarcoux@uottawa.ca



About the Authors
André Marcoux, PhD, adjunct professor, Department of Audiology and SLP, University of Ottawa; chief audiologist and president, The Sound Room Hearing Centres; www.thesoundroom.ca.
Isaac Kurtz, MHSc, PEng, vice-president of research and technology, Vivosonic Inc.; www.vivosonic.com.

ABSTRACT

Canada is a leader in the development of auditory brainstem response (ABR) technologies that enhance response detection. In this article, we examine the clinical challenges associated with ABR measurements and uncover advanced technologies developed by Canadian researchers and engineers that offer noise reduction capabilities essential for achieving quality ABR measurements. These advanced technologies are transforming hearing health care around the world.

Most audiologists would agree that noise is the foremost frustration with clinical auditory brainstem response (ABR) measurements. In this context, noise refers to interference from electromagnetic and myogenic sources which make it challenging to recognize and detect the true response in ABR waveforms. Whether employing ABR for neurodiagnostics, for estimating hearing ability, or for screening, noise is a common and persistent issue.

As an electrophysiological measurement which requires information be collected "far field," at a distance, ABR is extremely susceptible to contamination. With electrodes placed on the patient's scalp, minute responses of 0.05 to 0.5 microvolts are acquired from the auditory nerve and brainstem pathways. These minute responses travel to a recording device to be processed. From the point of data acquisition to processing of the signal, there is ample opportunity for the ABR to be contaminated by physiological artifacts from the patient, and extraneous artifacts and interferences in the environment. When the amplitude of the recorded response shows more than 20 microvolts, it is certain that what is shown is not ABR, but noise.

COMMON SOURCES OF NOISE (INTERFERENCE)

Noise is everywhere. ABR recordings are particularly vulnerable to interference from sources with frequencies of 20 to 30 Hz up to 2500 Hz – the frequency range of a typical ABR signal. Thus, it is helpful to recognize potential sources of noise and understand how they might be introduced into an ABR waveform.

Physiological Artifacts

There are numerous sources of physiological noise generated voluntarily or involuntarily by the adult or child being assessed. Muscular activity or movement, even from a fragile newborn, can produce significant artifact that interferes with the much smaller ABR. A patient who is relaxed and motionless still has small EMG activity in the area of the electrode sites such as the forehead, mastoids and scalp, as well as EOG arising from the eyes, ECG from the heart, and EEG from the brain. All of these sources lead to unwanted noise in the recordings. It is impossible to eliminate their effects entirely, but it is possible to significantly reduce them through good clinical practice and advanced ABR technologies.

Motion Artifacts

Artifacts due to motion are the result of electrode leads moving during data acquisition. Often this is caused by patient movement or when adjustments to the leads are made.

Recording Environment

Sources of extraneous noises in our environment are typically the most difficult to identify and mitigate. Frequently the presence of electromagnetic noise from nearby equipment, conducted power line noise, and radio frequency interference, all serve to contaminate the ABR recording. Without proper shielding of wires and/or the recording environment, electrode leads are prone to field artifacts. Inadequate grounding invites unwelcome electrical pickup from circuitries in the room and the influence of 50/60 Hz noise and harmonics can appear in the waveform.

CONSEQUENCES OF (TOO MUCH) NOISE

Too much noise in ABR recordings has a number of consequences. Here are the major ones.

Misinterpretation of ABR

Artifact and interference make it difficult to interpret waveforms and can result in reduced accuracy of wave recognition and latency measurement. When estimating hearing ability or hearing loss, specifically at lower stimulus intensity levels, the amplitude of the waveform may be similar to that of the noise making it difficult to interpret. Stapells[1] cautions that ABR recordings of insufficient quality may mean that an ABR wave V is identified as "present" when its amplitude is not significantly greater than the background noise. Or, a common mistake is to indicate a "no response" when the recording is too noisy and the residual EEG noise is greater than a typical threshold response.

Lengthy Measurement Period

In noisy environments, when conventional averaging of waveforms is used, measurement must continue for excessively long periods of time in order to accurately detect the response. This is problematic when assessing infants, children, or other patients who may be uncooperative. Only partial data may be collected and a follow on appointment must be arranged to complete the assessment adding to costs and inconvenience for all concerned.

Sedation of Infants and Young Children

Sedation or anesthesia is often used to minimize contamination of the ABR recording from myogenic artifacts present when infants and young children are awake and alert. There is an entire body of literature that examines the effects of sedation. For the most part it is safe, yet there remains a certain amount of risk related with its use. "Sedated ABR procedures are costly, time-consuming and require constant patient monitoring during the procedure."[2] In a recent report by the Pediatric Sedation Research Consortium,[3] auditory brainstem response was identified as one of the procedures for which sedation was commonly used. Data from 114,855 pediatric sedations indicated that monitoring guidelines published by the American Academy of Pediatrics (AAP) were followed in only 52% of cases.

Time Spent Reducing Noise

"Electrical interference from feeding pumps, monitors, etc. is our #1 problem. Much more time is spent trying to solve electrical interference issues than in actual test time."[2] When the source of noise cannot be identified or eliminated, the patient may need to be moved to a less noisy environment, or assessed in a shielded room or Faraday cage.

Cannot Complete Assessment

In some cases, it is simply not possible to reduce noise to acceptable levels to obtain quality recordings. This is a frequent occurrence in environments with high electromagnetic interference, such as the neonatal intensive care unit (NICU) or operating room (OR). Even when potential sources of interference have been removed and non-essential equipment powered off, noise may remain so high that testing must be abandoned.

CONVENTIONAL MEANS OF REDUCING NOISE

How is noise extracted from the response that we are trying to measure? Following good clinical practice, along with built-in noise reduction features of the ABR measurement instrument, it is possible to reduce noise in the ABR. Conventional methods for reducing noise are mentioned here.

Shielding

When noise and interference cannot be mitigated further by moving or powering off equipment in the test environment, shielding is sometimes the only means to ensure adequate immunity. This can be an effective, but costly solution to the problem of extraneous noise.

Natural Sleep and Sedation

Natural sleep and sedation are common approaches used with infants and young children to manage muscular activity. In general, it is preferable to assess an infant in natural sleep over the risks of sedation. Natural sleep often requires that an infant be deprived of sleep before the appointment, and still it may be necessary to wait for the infant to fall asleep before testing can proceed. Particularly in the case of older infants and young children, natural sleep is frequently not an option. Rather than manage the myogenic artifact arising from an active or uncooperative child, many clinics proceed directly to sedation, providing that sedation is not contraindicated and caregivers consent to this procedure.

Patient Posture and Positioning

To reduce muscular activity and provide support for the neck, adult patients are typically asked to lie supine on a bed, close their eyes, and relax as much as possible. In most cases, this is sufficient to minimize muscular noise. However, when patients are aware that the assessment seeks evidence of a tumour, they are understandably agitated and as a consequence generate undue levels of muscular artifact which is not easily extracted from the signal.

Electrode Impedance

To obtain cleaner recordings, it is common practice to scrub and exfoliate the skin of the patient with a mild abrasive before applying electrodes to the site. This serves to reduce electrode impedance which can significantly impact EEG quality. "The impedance does not affect the ABR itself, but the larger the impedance, the larger the amount of pickup of external electromagnetic interference and of artifacts from movement of the electrode leads."[4] A low electrode impedance of 3 or 4 kOhm is often recommended, with impedance difference between electrode pairs not more than 1 kOhm. Acceptable ABR recordings can be obtained with higher impedances providing the impedance difference is balanced and symmetrical. This is needed for common-mode rejection, otherwise there is difficulty obtaining an acceptably low level of EEG noise when recording ABR.

Averaging

Signal averaging is possible because ABR is time-locked to the stimulus, with each repeated stimulation eliciting the same response. Noise, on the other hand, is very random and has no regular pattern. By presenting the same stimulation over and over again, and averaging the responses together, the ABR waveform should emerge from the noise. Increasing the number of stimulus presentations, or sweeps, improves waveform morphology. Averaging can be terminated as soon as a clear ABR waveform is visualized. Repeatability of the waveform is required to confirm the presence or absence of a response. If the measurement instrument has two recording buffers, repeatability is easily determined by visually comparing the averaged waveforms in each buffer. Statistical tools can further provide an objective validation.

Conventional averaging techniques typically weight all sweeps equally so that sweeps with higher amplitudes (high noise) have the same impact on the waveform morphology as sweeps with lower amplitudes (less noise and closer to an ABR). Note that more advanced "weighted" averaging techniques, such as Kalman Weighted Averaging, weight sweeps according to noise content so that noisy responses have less of an impact on the waveform morphology.

Artifact Rejection

When conventional averaging is used, it is typical to set an artifact rejection level of a certain voltage such as 20 microvolts. Sweeps with amplitudes greater than the rejection level are deemed to have too much noise and are not included in the averaging. While this reduces the impact of noisy responses on ABR morphology, too many rejected sweeps can prolong recording time. As sweeps are rejected, more data must be collected for sufficient averaging to occur.

Pause Equipment

Signal processing and noise cancellation techniques are usually inadequate to overcome the effects of myogenic artifact such as a baby stirring or a child squirming. When patient movement causes too much noise, it may be more practical to simply pause data acquisition until the movement subsides.

ADVANCED ABR TECHNOLOGIES THAT REDUCE NOISE

Noise in ABR measurements can be significantly reduced through innovative technologies developed by researchers and engineers in Canada. The three technologies described here have been developed by Vivosonic Inc., a leader in technologies that enhance ABR detection.

The combination of these technologies effectively minimizes the need to sedate infants and young children for ABR assessment,[5] is effective in managing electrical and artifacts in places with high electromagnetic interference such as the NICU6–8 and OR,[2] permit ABR measurement via tele-audiology,[9,10] help to identify false indications of noise-induced hearing loss,[11] and provide more accurate ABR under non-ideal conditions compared to conventional methods.[6,7,12,13]

"We were able to get valid passing newborn hearing screenings on infants that were awake and in electrically complex locations (running isolette and being held by a parent/nurse)." And,

Figure 1. Amplitrode with built-in pre-filtering and amplification at the recording site.

Figure 2. VivoLink wireless technology provides convenient testing.

"Accurate recordings were obtained regardless of whether or not the baby was awake, asleep, in a crib or running isolette."[7]

"There is much less, if any, interference from monitors and other OR equipment. Test time is easily cut in half."[2]

AMPLITRODE

This patented technology provides two distinct innovations: filtering of the ABR before amplification, along with amplification of the signal directly at the recording electrode site (Figure 1). By prefiltering the signal, the effects of EOG, ECG, motion artifact, and RF are almost completely eliminated. Gain adjustments are no longer needed, and the risk of signal saturation is reduced. Furthermore, by amplifying the signal "in situ" (at the recording site), sources of noise from the recording environment are reduced. Instead of an unamplified signal travelling along the electrode leads picking up electromagnetic noise and other contamination, the result is the recording of a more robust ABR signal.[14]

In contrast, the of lack in-situ amplification in conventional systems means that amplification occurs after the signal has had to travel from the electrode, along a cable, all the way to a preamplifier. With the cables acting as an antenna, there is a great deal of opportunity for noise to be introduced from sources present in the recording environment. Line noise and additional wires also contribute to contamination of the signal. Now, when the signal reaches the preamplifier, it is contaminated with all sorts of noise which is subsequently amplified.

The patented Amplitrode eliminates many of the problems related to extraneous noise by prefiltering and amplifying immediately at the site of data acquisition, before the signal has had a chance to pick up undesirable noise.

WIRELESS TECHNOLOGY

Technology that can provide complete wireless communication between the recording platform and the electrodes has valuable benefits. As a battery-powered unit, the VivoLink is immune to line noise. Furthermore, elimination of wires reduces susceptibility to electromagnetic interference in the recording environment. Overall, this means there is less noise to manage which translates to very clean waveforms in very little time.

Wireless recording also makes it possible to collect data while a baby is held, strolled, or nursed – untethered to equipment. In the case of high-risk babies in the NICU, the VivoLink enables babies to be tested inside an incubator while the recording platform remains outside. The incubator may even be closed shut while testing is in

Figure 3. SOAP Adaptive Processing enables ABR without risks of sedation.

progress, with the recording platform up to 10 metres (30 feet) away. This technology also permits children and adults the freedom to move and be tested in comfort (Figure 2).

SOAP ADAPTIVE PROCESSING (AN EVOLUTION OF KALMAN WEIGHTED AVERAGING)

This is perhaps the most innovative technology for noise reduction in evoked potential responses. SOAP Adaptive Processing is a combination of patented and proprietary technologies that adaptively reduce the myogenic and electromagnetic noise in ABR. It is an evolution of signal processing algorithms that use Kalman Weighted Averaging. Together with the Amplitrode and VivoLink wireless technology, SOAP provides superior response detection under non-ideal conditions and facilitates non-sedated ABR measurement (Figure 3).

As with Kalman Weighted Averaging techniques, there is no artifact rejection. Instead, sweeps are included in the recording and assigned a weighting based on its noise content. Groups of sweeps with less noise are assigned a much greater weighting than sweeps with higher amplitude noise. Thus, noisy responses have less of an impact on the waveform morphology. By including all sweeps, and by weighting them according to the noise content, we can actually obtain a much clearer ABR waveform in less time.

In addition to averaging, adaptive processing methods are used throughout the measurement. The system recalculates all weightings according to the noise content and the relationship between sweeps (covariance). This very active and unique dynamic weighting system provides much cleaner waveforms in much less time.

FINAL THOUGHTS

Mastering ABR measurement is a worthwhile undertaking in order to provide a comprehensive diagnostic picture of auditory function. Good clinical practice combined with technological advancements can help to overcome frustrations with noise in data acquisition and interpretation, and ultimately aid in obtaining quality ABR measurements.

REFERENCES

1. Stapells DR. Frequency-Specific ABR and ASSR Threshold Assessment in Young Infants. Phonak Sound Foundations 2010 manuscript (pp. 67-105). An updated version of Frequency-specific threshold assessment in young infants using the transient ABR and the brainstem ASSR. In R.C. Seewald and A.M. Tharpe (eds.), Comprehensive handbook of pediatric audiology (pp.409-448). San Diego: Plural Publishing, Inc.
2. Horsch M. Newborn Hearing Screening: Utilization of Non-Sedated ABR to Assist with Loss to Follow-up. Presentation at AudiologyNOW! 2011, Chicago, IL, April 6-9, 2011.
3. Langhan ML, Mallory M, Hertzog J, Lowrie L, Cravero J for the Pediatric Sedation Research Consortium. Physiological Monitoring Practices During Pediatric Procedural Sedation: A Report from the Pediatric Sedation Research Consortium. Arch Pediatr Adolesc Med. 2012;166(11):990–98.
4. BC Early Hearing Program (revised by Hatton J, Hyde M, Stapells DR). Audiology Assessment Protocol, Version 4.1, November 2012.
5. Hall JW III, Sauter T. Clinical Experience with New Technology For Recording Un-Sedated ABRs. Poster presentation at AudiologyNOW! 2010, San Diego, CA, April 14-17, 2010.
6. Brown DK, Hunter LL, Baroch K, Eads E. Comparison of Auditory Brainstem Response Systems in the NICU Population. Poster presentation at AudiologyNOW! 2011, Chicago, IL, April 6-9, 2011.
7. Johnson K. Universal Newborn Hearing Screening in the NICU Population Using New Features of the Vivosonic Integrity ABR Unit: Assessing the Correlation Coefficient as a Function of the Number of Sweeps Collected. Proceedings of University of Kansas Intercampus Program in Communicative Disorders. Au.D. Research Day, April 27, 2012.
8. Walker B. Clinical Significance of Advanced ABR Technology for Newborn Hearing Screening Programs. Hearing Review Products, March 2012.
9. McVicar S, Randall K, Wnek S, Bleazard C, Ladner D. Tele-Audiology in Utah: Our Efforts to Reduce Newborn Hearing Screening Loss to Follow-up. AMCHP 2013 Annual Conference, Washington, DC, February 9-12, 2013.
10. See C. and Seeliger E. TeleAudiology: The Key to Serving Rural Populations. EHDI 2012 Conference, St. Louis, MO, March 5-6, 2012.
11. Steinman A. Use of the Vivosonic Integrity V500 System to Identify False Indications of Noise Induced Hearing Loss (unpublished document). Based on an instructional document by Holdstein Y. Definitive auditory evaluation of workers exposed to excessive noise at work. Prepared for Labour Ministry, Israel, 10/12/2009.
12. Meyer D, Moskop J, Winston A, Schupback J. ABR Results in Quiet and Active Subjects. Poster presentation at AudiologyNOW! 2011, Chicago, IL, April 6-9, 2011.
13. Gerhart MJ, Hall JW III, Black AL. Evaluation of the Vivosonic Integrity Device for Auditory Brainstem Response Measurement. Poster presentation at AudiologyNOW! 2010, San Diego, CA, April 14-17, 2010.
14. Kurtz I and Sokolov Y. Reducing the effect of electric and magnetic fields on auditory evoked potentials. Presented at 28th Annual Midwinter Meeting of Association for Research in Otolaryngology, New Orleans, LA, February 19-24, 2005.

Canadian Hearing Report 2012;8(3):19-23.

Audiological Outcomes for Children Who Wear Hearing Aids

By Marlene Bagatto, Sheila Moodie, Christine Brown, April Malandrino, Frances Richert, Debbie Clench, Doreen Bartlett, Richard Seewald, and Susan Scollie
bagatto@nca.uwo.ca

About the Authors
Marlene Bagatto (pictured), Sheila Moodie, Richard Seewald, and Susan Scollie are with the Child Amplification Laboratory, Western University, London, Ontario. Christine Brown and Frances Richert are with the Speech & Hearing Clinic, Western University. April Malandrino and Debbie Clench are with theHumber River Regional Hospital, Toronto, Ontario. Doreen Bartlett is with the School of Physical Therapy, Western University.

(Adapted from a poster presented at the International Hearing Aid Research Conference, Lake Tahoe, California, August 2012)

BACKGROUND

The primary goal of Early Hearing Detection and Intervention (EHDI) programs is to provide effective intervention by six months of age to maximize the infant's natural potential to develop language and literacy skills. Intervention with hearing aids is a common choice among families of infants identified as having permanent childhood hearing impairment (PCHI). Audiologists have access to scientifically based strategies and clinical tools to ensure the hearing aids are fitted appropriately to the infant.[1]

PEDIATRIC OUTCOME EVALUATION

Outcome evaluation is a key component of the pediatric hearing aid fitting process; however, there has been little consensus on best practices for functional outcome measurement in EHDI programs. A lack of well-normed clinical tools that are valid and feasible may have been a barrier to outcome evaluation in children with hearing aids.

The University of Western Ontario Pediatric Audiological Monitoring Protocol Version 1.0 (UWO PedAMP)[2] consists of a battery of outcome evaluation tools and related support materials. This protocol aims to support clinical, systematic evaluation of auditory-related outcomes for infants, toddlers, and preschool children with PCHI who wear hearing aids. This includes both clinical process measures and functional outcome measures in a two-stage process by developmental level. The functional outcome measures included in the protocol are the LittlEARS Auditory Questionnaire[3] and the Parents' Evaluation of Aural/Oral Performance of Children (PEACH).[4] The PEACH is used in its rating scale format,[4] and applied in the second developmental stage.

PURPOSE

This study examines how children with aided PCHI perform on the functional outcome measures within the UWO PedAMP. The LittlEARS is a 35-item questionnaire that assesses the auditory development of infants during the first two years of hearing. The PEACH Rating Scale is a 13-item questionnaire that assesses auditory performance in quiet and noisy situations for toddlers and preschool children. Normative values exist for normal hearing children for both questionnaires.[5,6] However, few data for children who are followed within an EHDI program are available. This work characterizes LittlEARS and PEACH scores for children with PCHI who (a) are enrolled within an EHDI program; and

TABLE 1. DESCRIPTION OF INFANTS, TODDLERS AND PRESCHOOL CHILDREN WITH AIDED PCHI INVOLVED IN THIS STUDY

Number of Participants	Pure Tone Average (range in dB HL)	Mean Age (months)*	Age Range (months)*	Typically Developing (%)	Comorbidities (%)	Complex Factors (%)
116	21.2–117.5	35.6	3.6–107.1	36.2	23.5	40.9

*Chronological age.

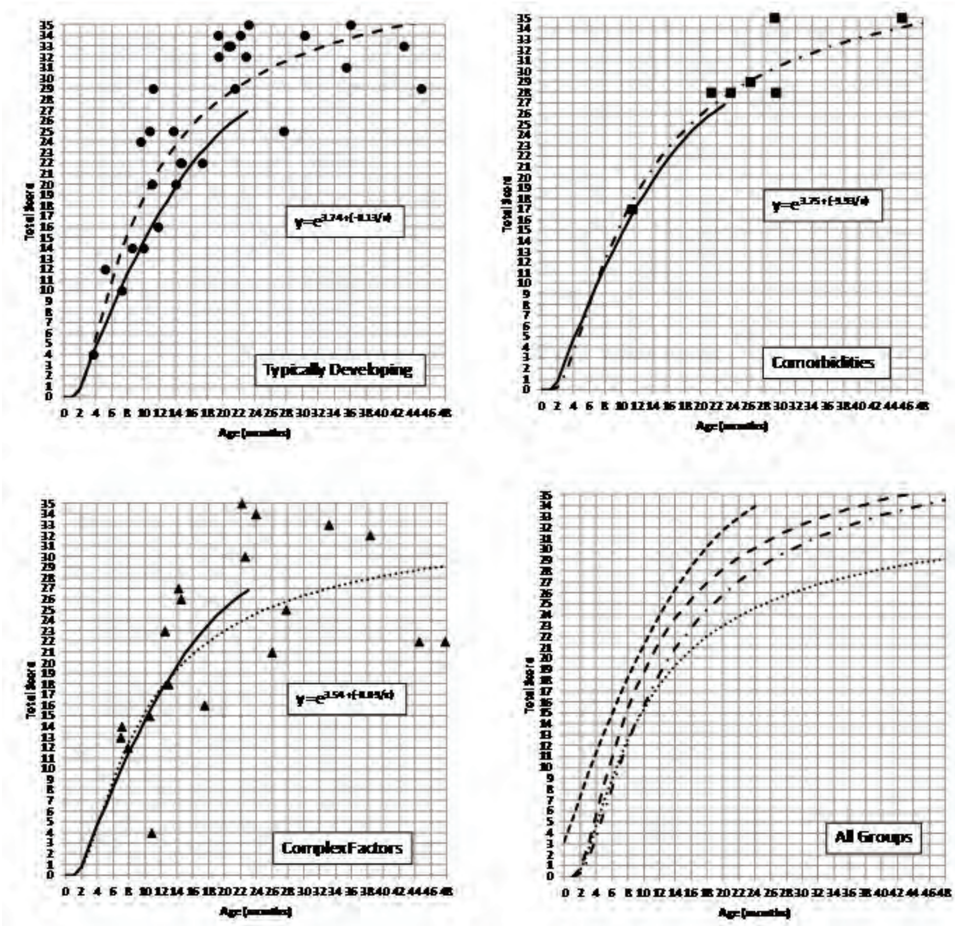


Figure 1: LittlEARS scores (y-axis) by age (x-axis) and regression lines from typically developing children (circles), children with comorbidities (squares) and complex factors (triangles). The solid line represents the minimum normative values. Various dashed lines indicate the regression for each data set.

(b) reflect the general population of children typically followed in a pediatric audiology outpatient clinic.

METHOD

Data were obtained as part of a longitudinal observational study in which outcomes were logged for all patients at participating sites. Pediatric audiologists at four clinical sites administered the LittlEARS and PEACH to caregivers of infants, toddlers, and preschool children with aided PCHI. The patients were seen during routine clinical care through Ontario's Infant Hearing Program (OIHP) over a period of 18 months. The OIHP follows children from birth to age six years and uses provincial protocols for the provision of hearing aids,[1] which include fitting the hearing aids to the Desired Sensation Level (DSL) version 5.0a prescriptive algorithm.[7] Audiometric and medical profiles of the children varied, along with follow-up details.

PARTICIPANTS

Table 1 provides the number of participants involved in this study in one of three groups: (1) typically developing; (2) comorbidities; and (3) complex factors. Children with comorbidities were born prematurely and/or had other identified medical issues besides hearing loss. Complex factors were logged to track non-medical issues that may impact overall outcome with intervention (i.e., late identification, late fitting, inconsistent hearing aid use).

RESULTS: AUDITORY DEVELOPMENT AND AUDITORY PERFORMANCE

Regression analyses were conducted on each group separately to determine **the effect of age** on the overall PEACH score. For all children who were **typically developing**, scores varied significantly with age (R^2=0.19; F=5.60, df=25, p<0.05; Figure 1). This is consistent with published data.[5] In a second analysis, only typically developing children **older than 24 months** were included, and the effect of age was not significant (R^2=0.09; F=1.57, df=16, p=0.23; Figure 2). Comparing the curves indicates that there is no significant age effect on overall PEACH scores after 24 months of age. This may support the use of raw (rather than age-

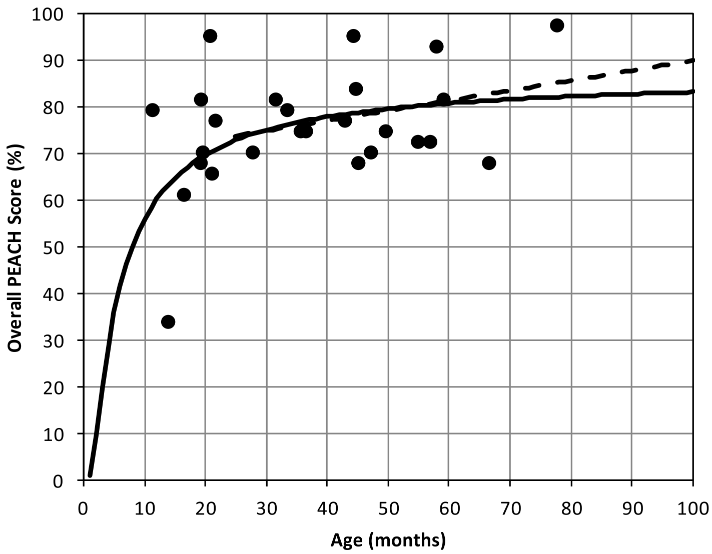


Figure 2. PEACH scores by age (filled circles) and regression lines from typically developing children with aided PCHI. The solid line is an s-shaped regression for children of all ages and the dashed line is a linear regression for children older than 24 months.

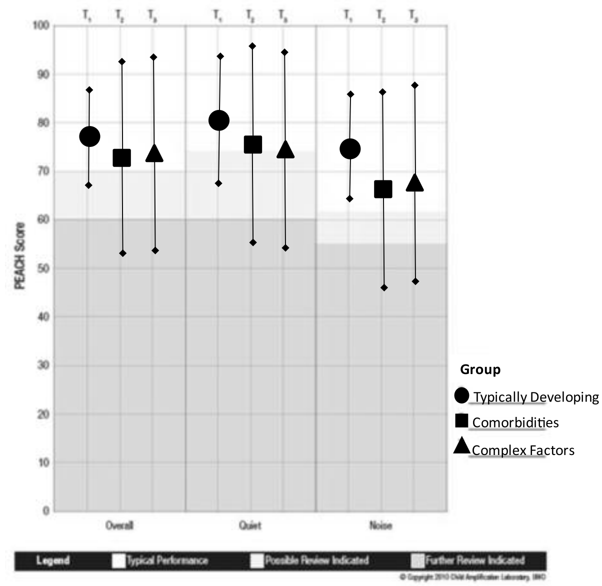


Figure 3. PEACH scores by age from the three subgroups: typically developing (circles), comorbidities (squares) and complex factors (triangles). Symbols represent average percentage scores for each subscale and vertical bars represent the standard deviation around the mean.

corrected) scores for children older than 24 months of age and typical development.

Overall PEACH scores for all children in the study ranged from 13.64 to 100% (mean=74.47%; *SD*=16.87). Descriptive statistics are reported for 17 typically developing children, 16 children with comorbidities and 32 children with complex factors related to hearing aid use (Figure 3). These scores differ markedly from published normative ranges[5] for this scale for typically developing children.

A multivariate analysis of covariance (MANCOVA) was conducted to determine the impact of degree of hearing loss and complexity (three-level independent variable) on the scores for the PEACH Quiet and Noise subscales. Results indicated that the multivariate effect of degree of hearing loss was significant (F [2,70] = 7.43, $p < 0.05$, η^2=0.179) but presence of complexity was not (F [2,70] = 0.37, $p > 0.05$, η^2 = 0.011). Univariate effects confirmed that children who are typically developing or have complexities did not differ on their PEACH scores for either the Quiet (F [2,73] = 0.39, $p > 0.05$) or Noise (F[2,73] = 0.53, p >0.05) subscales. However, the degree of hearing loss had a significant impact on PEACH scores for the Quiet (F [1,73] = 9.59, p <0.05) but not the Noise (F [1,73] = 1.03, p >0.05) subscales. Regression analysis of the entire sample revealed a decrease in overall PEACH scores with increasing hearing loss (R^2 = 0.07; F = 4.99, df = 72, p = 0.03).

SUMMARY AND CLINICAL IMPLICATIONS

In summary, typically developing children who were identified and fitted early with high quality amplification reach age-appropriate auditory development milestones (LittlEARS) and display typical auditory performance (PEACH). Children with comorbidities and complex factors display different auditory development trajectories on the LittEARS compared to their typically developing peers. PEACH scores for typically developing children in this sample are approaching the score achieved by normal hearing children (90%) by age three years.[5] Regression analyses indicated there is no age-related effect on overall PEACH score for children who are typically developing and older than 24 months: this may simplify clinical use of the tool as it obviates age-corrected scoring. Further analysis indicated that the degree of hearing loss impacts scores on the PEACH but complexity does not.

This study contributes to a better understanding of functional outcomes for children within an EHDI program using a systematic approach to outcome evaluation.

ACKNOWLEDGEMENTS

This work was supported by The Canadian Institutes of Health Research (M. Bagatto 220811CGV-204713-174463) and the Ontario Research Fund, Early Researcher Award (S. Scollie).

REFERENCES

1. Bagatto M, Scollie S, Hyde M, and Seewald R. Protocol for the provision of amplification within the Ontario Infant Hearing Program. Int J Audiol 2010:49:S70–79.
2. Bagatto M, Moodie ST, Malandrino A, Richert F, Clench D, and Scollie S. The University of Western Ontario Pediatric Audiological Monitoring Protocol (UWO PedAMP), Trend Amplif 2011;15(1):34–56.
3. Tsiakpini L, Weichbold V, Kuehn-Inacker H, Coninx F, D'Haese P, and Almadin S. LittlEARS Auditory Questionnaire, MED-EL, Innsbruck: Austria; 2004.
4. Ching T and Hill M. The Parents' Evaluation of Aural/Oral Performance of Children (PEACH) Rating Scale, Australian Hearing, Chatswood, New South Wales, Australia; 2—5. http://www.outcomes.nal.gov.au/LOCHI %20assessments.html.
5. Ching T and Hill M. The parents' evaluation of aural/oral performance of children (PEACH) scale: Normative data, J Am Acad Audiol 2007;18:220–235.
6. Weichbold V, Tsiakpini L, Coninx F, and D'Haese P. Development of a parent questionnaire for assessment of auditory behaviour of infants up to two years of age, Laryngo-Rhino-Otol 2005;84:328–34.
7. Scollie S, Seewald R, Cornelisse L, et al. 2005. The Desired Sensation Level multistage input/output algorithm. Trends Amplif 2005;9(4):159–97.

Canadian Hearing Report 2012;8(3):24-27.

Headsets – Are They Damaging Your Hearing?

By Alberto Behar, PEng and Gabe Nespoli, BSc, MA Ryerson University
albehar31@gmail.com

About the Authors

Alberto Behar is a professional engineer and certified industrial hygienist. He holds a diploma in acoustics from the Imperial College and has been the recipient of several fellowships, including one from the Fulbright Commission (USA) and the Hugh Nelson Award of Excellence in Industrial Hygiene (OHAO, Canada).

He is lecturer at Dalla Lana School of Public Health, University of Toronto and a board certified member of the Institute of Noise Control Engineering. Alberto is a chairman and member of CSA and ANSI committees and working groups and is also the Canadian representative at two ISO Working Groups.

Gabe Nespoli is research operations coordinator at Ryerson University and lab manager (SMART Lab) at Ryerson University

Headsets are headphones with an attached microphone that allows the user to communicate.

We see them all the time in fast food take-outs (sometimes with one cup only) so that the worker can take your order while walking around. On a noisy shop floor they are used to attenuate background noise while enabling communication with fellow workers or supervisors. Some truck drivers wear headsets to listen to the radio or communicate with the dispatch centre, freeing their hands for driving. They are also used in call centres, airport control towers, and construction sites. We even use them at home when we want to listen to TV without disturbing others, or when trying to block out environmental noise while working or playing on the computer. Different headsets provide different amounts of attenuation for different applications. High attenuation headsets may also act as hearing protectors.

When wearing a headset, there are two sources of sound involved: enviro-nmental (background) noise and an audio signal (that can be speech or music).

The headset's cups attenuate environ-mental noise, while the signal is routed directly into the ears of the listener through the loudspeakers situated in the

Figure 1. Example of headset.

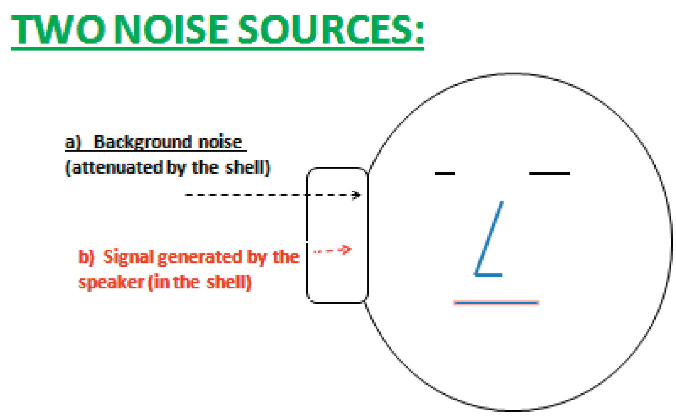


Figure 2. The noise level inside the headset.

Figure 3. Set-up for the experiment.

cups. Usually, the user adjusts the signal to a comfortable listening level for speech or music.

CAN THE USE OF HEADSETS DAMAGE OUR EARS?

How much does the level of the signal have to be raised above the background noise to ensure comfortable intelligibility? At Ryerson University, 22 students were individually presented with a speech signal (non-related sentences) through a headset. They were asked to adjust the level to be able to understand it properly. Three different types of background noise – babbling speech, industrial noise and construction noise – were introduced in a sound-treated room where the tests were performed. Two headsets were used: one with high attenuation and one with low attenuation.

For the low attenuation headset (average measured attenuation 0.7 dBA), our results show that the addition of the speech signal increased the sound level by as much as 5 dBA. For example, if the background noise level is 85 dBA, the level inside the headset could be as high as 90 dBA (background noise + speech signal).

The high attenuation headset used in our experiment reduced the background noise level by an average of 13.5 dBA. Therefore, a background noise level of 85 dBA would be reduced to 71.5 dBA. Including the speech signal the total sound level inside the headset would be 76.5 dBA (that is, the background noise attenuated by the headset, plus the 5 dBA increase due to speech).

It was found that the resulting sound levels in the headset are strongly dependant on the type of background noise, since different noise spectra mask speech differently.

The results clearly show that if a person has to wear a headset in the presence of noise, he has to make use of a high attenuation headset to avoid high noise levels. This way, the associated risk of hearing loss is greatly reduced.

The three main conclusions of the study are:

1. In high noise environments, headsets must be of the high attenuation type.
2. The increase in noise exposure due to the signal is on the order of 5 dBA on top of the background noise attenuated by the headset.
3. This increase is highly dependent of the type of noise in the environment (speech, industrial, construction, etc.).

Canadian Hearing Report 2012;8(3):28-29.

Foreword by Ross Roeser, PhD: Is Higher Really Better and Lower Worse?

In the following article, originally published in the March 2013 edition of the *International Journal of Audiology,*[1] Jim Jerger, PhD, provides us with an historical perspective on one of the most often used and valued diagnostic tools in audiology: the audiogram. In his article, Dr. Jerger describes the beginnings of the development of the audiogram and, based on traditional scientific graphics, how it became backwards or upside-down. Before reading this article, I personally never questioned the way the data on the audiogram appears, because this is the way it was presented to me when I was first introduced to audiometry and the audiogram – it never occurred to me to think that it was backwards. But, based on conventional logic, Dr. Jerger makes the point clear that the audiogram truly can be considered upside-down.

Along these lines, one thing that has always been confusing is the terms used to describe results from pure-tone threshold audiometry. Some use "higher" and "lower" to represent the symbols that appear on the audiogram form, so that higher means poorer hearing and lower means better hearing. However, psycho-acousticians tend to use the term "lower" to mean better hearing and "higher" to mean poorer hearing. As a result, one can totally miss the meaning of information that uses higher or lower when describing audiometric thresholds.

When such terms are used, it is always best to ask for clarification. Otherwise, the audiologist who is pleased to know that a patient's thresholds are higher will be disappointed to learn that hearing has worsened, rather than improved. Better yet, to prevent confusion on these terms, the convention should be to avoid using them, and refer to either better or poorer hearing or thresholds. That way, there is no confusion about the intended meaning.

No matter how we view the audiogram, even with its known limitations, it is considered the "gold standard" for audiological diagnosis. Virtually every patient undergoing diagnostic audiological testing has pure-tone threshold audiometry, and data are displayed on the audiogram. Dr. Jerger's article now gives us a clear historical understanding of how the audiogram is the way it is, and makes us think more carefully about how it is displayed.

—Ross J. Roeser, PhD, Editor-in-Chief, IJA

Reprinted with permission from the International Journal of Audiology

Why the Audiogram Is Upside-Down

By James Jerger, PhD

Figure 1. Edmund Prince Fowler (1872-1966) was a giant in otology during the first half of the 20th century and is perhaps best known for his discovery of loudness recruitment.

Figure 2. Harvey Fletcher (1884-1981) was a physicist who joined Bell Laboratories and became a pioneer in speech and hearing sciences.

In every new generation of audiology students and otolaryngology residents, at least one or two inquisitive individuals invariably ask why the audiogram is upside-down.

Students spend years studying science textbooks in which two-dimensional graphs are virtually always portrayed such that the numbers on the vertical scale increase as they move from the bottom to the top of the page; then they encounter audiograms and wonder why the "HL in dB" numbers increase in a downward rather than an upward direction. Basically, the audiogram is upside down; the values on the vertical axis become smaller, rather than larger, as they move from the bottom to the top of the graph.

How this anomaly came about is the story of an interesting collaboration among three remarkable individuals: Edmund Prince Fowler, Harvey Fletcher, and R.L. Wegel.

Edmund Prince Fowler (Figure 1) was an otolaryngologist who practiced in New York City. He received his MD degree from the College of Physicians and Surgeons of Columbia University in 1900, then became a member of the Manhattan Eye, Ear, & Throat Hospital staff and, ultimately, Professor at the College of Physicians & Surgeons. Fowler was one of the giants of otology during the first half of the 20th century. He is perhaps best known to audiologists for his discovery of loudness recruitment, but his investigative nature took him into many other aspects of hearing and hearing loss.

Harvey Fletcher (Figure 2) was a physicist who earned his PhD degree from the University of Chicago in 1911, and then taught physics at Brigham Young University in Utah for 5 years. In 1916, he moved to the New York City area to join the Bell Telephone Laboratories. Fletcher was an early pioneer in the speech and hearing sciences, and his 1953 book, *Speech and Hearing in Communication*,[2] was a virtual bible for serious researchers throughout the second half of the 20th century.

R.L. Wegel (whose photo we were not able to locate) was a physicist who earned his AB degree from Ripon College in 1910. From 1912 to 1913, he worked as a physicist in the laboratory of Thomas A. Edison. In 1914, he joined the Engineering Department of the Western Electric Company in New York City. He worked mainly in the area of telephone transmitters and receivers, but developed an interest in hearing and hearing disorders as a result of his own intractable tinnitus.[3] Wegel is perhaps best known to auditory scientists for his collaboration with C.E. Lane on an early study of tone-on-tone masking.[4]

GENESIS OF THE AUDIOGRAM FORM

The trio – Fowler, Fletcher, and Wegel – came together in the New York City area in the years immediately following World War I. Their common interest was the development and evaluation of the first commercially available audiometer in the USA, the Western Electric Model 1-A, designed jointly by Fletcher and Wegel for the American Telephone and Telegraph Company (AT&T) and employed clinically in the otologic practice of Dr. Fowler.

Throughout World War I, the research resources of AT&T were focused on underwater sound transmission and detection, but when the war ended, interest returned to the basic study of the hearing and speech processes, and, tangentially, hearing loss, all important to telephone communication. AT&T

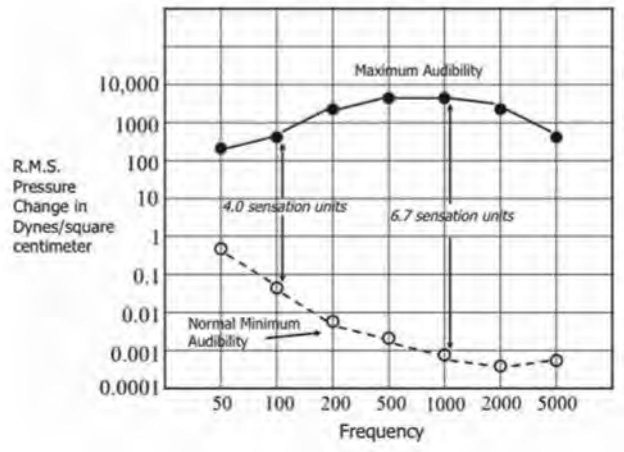


Figure 3. Wegel's graphic scheme: A recreated graph of the auditory area, including threshold of audibility (Normal Minimum Audibility) and threshold of "feeling" (Maximum Audibility), as described in Wegel's 1922 paper.[11] His original terminology is purposely preserved on the figure for the sake of historical accuracy. At each frequency, the area between these two boundaries was divided into "sensation units" by Fowler. Each sensation unit was defined by a sound pressure ratio of 10:1. [Based on Wegel 1922,[11] Figure 1, p 156]

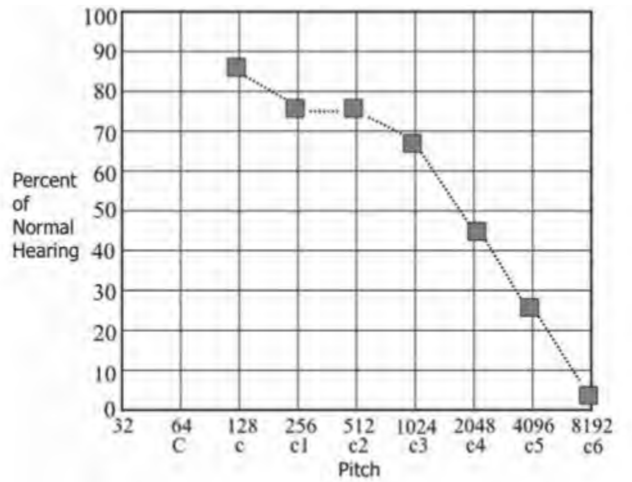


Figure 4. Fowler's graphic scheme: Method for recording audiometric results suggested by Fowler & Wegel in 1922.[10] At each frequency, patient's threshold is converted to "percent of normal hearing" by counting the number of sensation units from normal threshold of audibility to patient's threshold of audibility, dividing by number of sensation units from normal threshold of audibility to threshold of feeling, multiplying by 100, and subtracting this value from 100%. The filled squares plot percent-of-normal-hearing results for a person with a hypothetical high-frequency loss. *Note that the "percent-of-normal-hearing" scale conforms to the conventional scientific scheme for reporting data on a two-dimensional graph.* Note also that, for the first time, the 100% line – which subsequently became the zero line of the audiogram – was linked to the variation in SPL across frequencies at the threshold of audibility. [Based on Fowler & Wegel 1922,[10] Figure 3, p 110]

turned, therefore, to its engineering wing, the Western Electric Company, and to its research wing, the Bell Telephone Laboratories, for the development of an instrument to measure hearing loss. R.L. Wegel of Western Electric and Harvey Fletcher of Bell Labs took responsibility for the task. When the 1-A audiometer was ready for clinical evaluation, Wegel and Fletcher found a willing collaborator in Edmund Prince Fowler. (Fowler had previously worked with Fletcher and Alexander Nicholson of Western Electric in the development of a group phonograph audiometer for screening the hearing of schoolchildren.[5])

THE SAGA OF THE VERTICAL SCALE

It is difficult to imagine from our present-day vantage point the *terra incognita* in which this trio worked. Prior to the invention of the vacuum tube by Lee De Forest in 1906, there was really no satisfactory way of controlling and calibrating the amplitude of a pure tone. Tuning forks could produce a range of frequencies, but their use in measuring degree of hearing loss was restricted either to a temporal measure (ie, how long could the patient hear the fork in relation to how long the examiner could hear it), or to a distance measure (ie, how far away from the examiner could the patient still hear him).[8] Thus, tuning forks interjected a truly mind-boggling number of uncontrolled variables.

Use of the intensity dimension – the faintest intensity at which the patient can just hear the tone – had never been successfully exploited until the electric audiometer became available to clinicians. (As Alberto Behar[9] has emphasized, the exact definition of "intensity" in physical acoustics is a complex issue; the term is used here mostly in the popular general sense of "strength of sound.") Now it was possible via a telephone receiver to produce a pure tone of known sound pressure level, which could be systematically varied to facilitate a threshold search separately for each ear.

As the Western Electric 1-A audiometer came into clinical use, our trio of Fowler, Fletcher, and Wegel began to wrestle with the issue of how to standardize the reporting of audiometric thresholds. Fowler and Wegel's first attempt was presented to otologists in 1922 at the 25th annual meeting of the American Laryngological, Rhinological and Otological Society in Washington, DC.[10] It was concerned primarily with how to represent thresholds graphically.

There was never a serious issue concerning representation of the frequency scale; the well-established musical scale, in which octave intervals are equally spaced, was readily adopted for the horizontal dimension of the graph. But the vertical dimension, the representation of threshold intensity, underwent a number of iterations.

In a 1922 publication, Wegel[11] had

published a graph of the "auditory area" – the area between threshold audibility and the sensation of "feeling" across the audible frequency range. I have recreated this historic graph in Figure 3. Frequency was represented horizontally at approximately equally spaced octave intervals; intensity was represented vertically on a logarithmic scale of sound pressure level change, ranging from 0.0001 to 10,000 dynes/cm^2. A logarithmic scale of sound intensity was already widely accepted in the 1920s, based on the earlier studies of the great German psychologists, Ernst Weber and Gustave Fechner.[8] It was well agreed, among students of audition, that the "strength of sensation" dimension should be represented logarithmically. From the standpoint of scientists like Fletcher and Wegel, the sound pressure level, expressed in dynes/cm^2, and increasing logarithmically from small numbers at the bottom to large numbers at the top of the graph, was consistent with scientific tradition.

But the story does not end here. Indeed, it has hardly begun. After studying graphs like Figure 3, Fowler noted that when sound intensity was represented logarithmically, in which each successive step represented a pressure change ratio of 10:1, slightly less than 7 such steps separated the threshold of audibility from the threshold of feeling in the mid-frequency (1000 to 3000 Hz) region. Fowler described this as the range of "sensations" characterizing the human auditory system and arbitrarily defined each step as a "sensation unit."

From here, it was only a short jump to the concept that the hearing loss of a hearing-impaired person could be represented as a loss in sensation units; if the normal sensation range, from just-heard to just-felt, was 6.7 sensation units, and the patient's threshold of audibility was 2.1 units above the normal threshold of audibility, then one could say that the patient had a loss in sensation units of 31% (2.1/6.7). In other words, one could convert any patient's threshold of audibility to a "percentage loss" by this arithmetic maneuver.

It was possible to take this one step further, reasoned Fowler, by subtracting the percentage loss from 100 to achieve "percent of normal hearing"(100% –31% = 69%). Figure 4 is based on Figure 3 of the Fowler and Wegel (1922) paper.[10] The filled squares show the hypothetical audiometric contour of a person with a high-frequency hearing loss. This chart, thought Fowler, gave you the numbers you needed to counsel patients. In his own words:

"This chart gives, perhaps, the most practical and logical answer to the question so often asked by the patient. 'How much hearing have I left?' This can be read for single frequencies from the chart. The physician, as well as the patient, is usually interested in the loss, or amount retained, of sensory capacity." [p 110][10]

Interestingly, a similar graphic representation was advanced in 1885 by the German otologist A. Hartmann of Berlin.[8] He displayed duration of hearing at each tuning fork frequency as a percentage of normal duration. The percentages on the vertical scale ranged from 100% at the top of the graph to 0% at the bottom.

ALEA JACTA EST!

The die is cast! Julius Caesar uttered this famous phrase to indicate that crossing the Rubicon was an irrevocable act. However, Edmund Prince Fowler could not have known that placing the 100%-of-normal-hearing line at the *top of the audiogram* form was a similar irrevocable act.

Fowler's influence in the otologic community in the decade of the 1920s was so pervasive that no one ventured to challenge it; indeed, his colleagues seemed to applaud the concept. The vertical scale satisfied the notion that the numbers ought to increase from bottom to top of the graph.

We can see in Figure 4 that, if Fowler's original concept had been followed, the graph of audiometric results, which came to be called the "audiogram," would have followed standard scientific usage; the values on the vertical scale (percent of normal hearing) would, indeed, have moved upward from the lowest to the highest numbers. At this point, the die had been cast. The line that came to be called "zero HL in dB" was fixed at the top of the graph and would never change thereafter.

But Harvey Fletcher, a physicist, not a clinician, clearly did *not* agree with the percent-loss approach. In a lecture and demonstration given before the American Academy of Ophthalmology and Otolaryngology in Chicago in 1925,[13] he made the following argument:

"In a paper presented before the American Triological Society by Fowler and Wegel (Audiometric Methods and Their Applications, May 1922), a hearing scale was proposed which has been objected to by some otologists because it is dependent on the threshold of feeling as well as the threshold of hearing. On this scale the percent hearing loss is the number of sensation units from the normal to the patient divided by the number of sensation units from the normal to the feeling point for a person of normal hearing. It is undoubtedly the best answer to the practical question as to what is the percent hearing loss, and is very useful in expressing general results. It is particularly useful for describing to the patient his degree of hearing. However, for an accurate expression of the degree of hearing loss, it seems desirable to express results in terms of sensation units rather than percent hearing loss."[p 167][13]

In 1923, Fletcher presented audeograms [sic] of patients with typical deafness in which the intensity dimension was

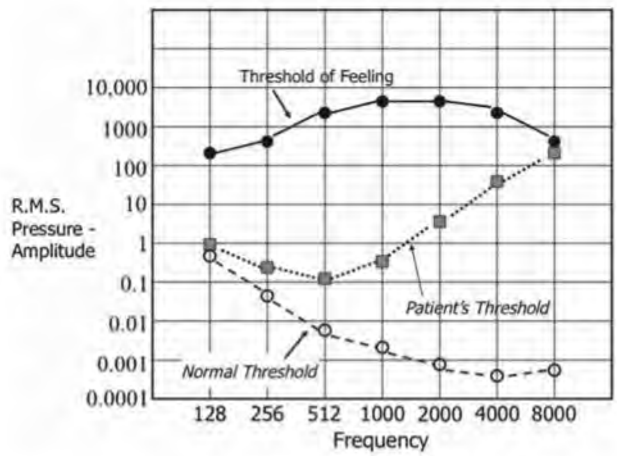


Figure 5. Fletcher's graphic scheme: Example of the same hypothetical audiometric contour of a person with a high-frequency loss as shown in Figure 4, but here plotted in the scheme originally advocated by Harvey Fletcher. Open circles represent "Normal Threshold of Audibility," filled circles represent "Threshold of Feeling," filled squares represent "Audibility thresholds" of the same patient whose percent-of-normal-hearing results are shown in Figure 4. [Based on Fletcher 1923,[12] Figure 2, p 493]

presented in just exactly that fashion. An example is shown in Figure 5. The filled squares reflect the data of the same hypothetical contour shown in Figure 4. Audiologists who deal with the frequency-response data of amplification devices will recognize how much more easily the response of the impaired ear and the response of the hearing aid could have been compared over the past half-century if this representation of audiograms had been retained.

Clearly, physicist Fletcher was more comfortable with a purely physical scale of sound intensity than with the percentage concept based on the range between "just audible" and "just felt." But when he had convinced Fowler to abandon the "percent-of-normal-hearing" concept, he failed to follow through on the approach illustrated in Figure 5. Instead, he renamed Fowler's vertical scale "sensation units" in which each unit represented not a percentage change but a 10:1 change in sound pressure, but left the zero line at the top rather than moving it to the bottom of the graph. He simply changed the 100% line at the top of the graph to 0 sensation loss and renumbered so that increasing loss moved downward on the vertical scale. The audiogram was now *doomed to be upside-down forever.*

Implicit in Fowler's original concept of "sensation units" was the principle that intensity, or hearing loss, was plotted relative to average normal hearing rather than relative to a physical baseline; at each frequency, the straight line at 100% on Figure 4 was simply the threshold of audibility straightened out to eliminate the fact that the sound pressure level corresponding to that 100% level varies with frequency. This concept quickly took hold, leading to the terminology "Hearing Loss in Sensation units."

By 1926, Fletcher was publishing audiograms in which the vertical scale was "Hearing Loss–Sensation Units." By 1928, Fowler had abandoned his "Percent of Normal Hearing" measure and now plotted audiograms with intensity progressing downward from 0 to 120, and labeled "Sensation Loss."

INTRODUCTION OF THE DECIBEL NOTATION

In the original conception of the sensation unit, slightly less than 7 units covered the range from audibility to feeling in the most sensitive portion of the auditory area. Fletcher13 thought this range too small for making meaningful distinctions among different degrees of hearing loss. In the Western Electric 1-A audiometer, he and Wegel redefined hearing loss as:

$HL = 10 \log I/I_o = 20 \log P/P_o$, *where...*

I is the patient's threshold power level, I_o is the threshold power level of the average normal ear, *P* is the patient's threshold pressure level, and P_o is the pressure level of the average normal ear.

They adopted what we now know as the *decibel notation*, thereby increasing the range on the vertical dimension from slightly less than 7 sensation units to about 120 decibel (dB) units. As a result of Fletcher's influence, over the next decade, "sensation units" and "sensation loss" slowly gave way to "Loss in Decibels." In a 1943 publication[14] by Fowler's son, Edmund Prince Fowler Jr, the vertical scale in one of his figures [Figure 1a, p 393] is clearly labeled "Hearing Loss in Decibels."

Some years later, in a move toward terminological purity, Hallowell Davis, at Central Institute for the Deaf in St Louis, pointed out that "loss" can only be expressed relative to a known previous status of the patient rather than relative to average normal hearing. The term "Hearing Level in dB" (dB HL) was deemed more appropriate for the vertical scale. This brings us to contemporary usage.

And *that* is the interesting story of how the audiogram came to be upside down.

REFLECTIONS

What lessons might we derive from this saga? First, it seems clear that relating a patient's degree of hearing loss to the physical characteristics of amplification devices would have been greatly simplified if Fletcher's scheme for the format of the audiogram (see Figure 5) had ultimately survived. Both sets of data would have been based on the same physical reference at all frequencies rather than the present situation in which one is based on sound pressure levels that vary across the frequency range according to the variation in "average normal hearing" (the audiogram), while the other is based on the same reference sound pressure level (0.0002 dynes/cm^2 or 20 μPa) at all frequencies (amplification characteristics).

Second, Fowler's notion of "…amount of retained sensory capacity" as quantified by "percent of normal hearing" may not have been such a bad idea. It had the virtue that it yielded a number, at each test frequency, easily understandable as a percentage rather than a decibel value. It also had the property that the numbers on the vertical scale increased, rather than decreased, from the bottom to the top of the recording form.

Fletcher's discomfort with the threshold of feeling as a point of reference may have stemmed from the perception that "feeling" must be quite variable across individuals with and without hearing loss. In fact, however, the variability of the threshold of feeling in young adults with normal hearing is less than the variability of the threshold of audibility.[16] It has the additional property that it is the same in persons with varying degrees of hearing loss, both conductive and sensorineural, and in persons with total deafness.[17,18]

Additionally, a measure of loss based on the range of useful hearing at each frequency (range from just audible to felt), rather than the range of all possible sound pressure levels above the audibility threshold, has a certain face validity. The fact that the usable range of hearing varies across the frequency range is a fundamental property of the auditory system but is not evident from the contemporary audiometric display.

In any event, two quite sensible ways of recording audiometric threshold data emerged in the early 1920s, Edmund Prince Fowler's scheme, illustrated in Figure 4, and Harvey Fletcher's scheme, illustrated in Figure 5. Either would probably have been better than the present system, and would have preserved scientific tradition relative to the ordinates of graphs.

ACKNOWLEDGMENTS

The author is grateful for the many helpful suggestions of Susan Jerger, Michael Stewart, and Richard Wilson.

This article originally appeared in the March 2013 edition of *The International Journal of Audiology*,[1] and is adapted and reprinted here with permission from the publisher. CHR thanks *IJA* Editor-in-chief Ross Roeser and Managing Editor Jackie Clark for their help in the preparation and republishing of this article.

REFERENCES

1. Jerger J. Why the audiogram is upside-down. Int J Audiol 2013;52:146–150.
2. Fletcher H. Speech & Hearing in Communication. 2nd ed. New York: Van Nostrand; 1953.
3. Wegel R. A study of tinnitus. Arch Otolaryngol 1931;14:158–165.
4. Wegel R, Lane C. The auditory masking of one pure tone by another and its probable relation to the dynamics of the inner ear. Phys Rev 1924;23:266–285.
5. Fagen M. A History of Engineering and Science in the Bell System. Vol II, National Service in War and Peace (1925-1975). Murray Hill, NJ: Bell Telephone Laboratories Inc; 1975.
6. Dean L, Bunch C. The use of the pitch range audiometer in otology. Laryngoscope 1919;29:453.
7. Bunch C. Auditory acuity after removal of the entire right cerebral hemisphere. J Am Med Assn 1928;90:2102.
8. Feldmann H. A History of Audiology. Vol 22: Translations of the Beltone Institute for Hearing Research. Chicago: The Beltone Institute for Hearing Research; 1970.
9. Behar A. Sound intensity and sound level. Canadian Hearing Report 2012;7:26–27.
10. Fowler E, Wegel R. Audiometric methods and their applications. In: 28th Annual Meeting of the American Laryngological, Rhinological, and Otological Society, Washington, DC, May 4-6, 1922. Omaha, Neb: American Laryngological, Rhinological, and Otological Society [now Triological Society]; 1922:98–132.
11. Wegel R. Physical examination of hearing and binaural aids for the deaf. Proc Nat Acad Sci 1922;Wash 8:155–160.
12. Fletcher H. Audiometric measurements and their uses. Transactions of the College of Physicians of Philadelphia 1923;45:489–501.
13. Fletcher H. New methods and apparatus for testing hearing. Ann Otol, Rhinol & Laryngol 1926;35:165–180.
14. Fowler E Jr. Audiogram interpretation and the fitting of hearing aids. Proc Royal Soc Med 1943;36:391–402.
15. Martin M. Decibel—the new name for the Transmission Unit. The Bell System Technical Journal 1929;8:1–2.
16. Durrant J, Lovrinic J. Bases of Hearing Science. Baltimore: Williams & Wilkins; 1977.
17. Reger S. The threshold of feeling in the ear in relation to artificial hearing aids. Psych Monographs 1933;44:74–94.
18. Lierle D, Reger S. Threshold of feeling in the ear in relation to sound pressure. Arch Otolaryngol 1936;23:653–664.

Canadian Hearing Report 2012;8(3):31-35.

Articles from the Final Seminars on Audition

By Marshall Chasin, Editor-in-Chief

For the past 28 years, Seminars on Audition has been one of my favourite hobbies. Joanne Deluzio and I began coordinating this one day conference back in 1986 and we just had our final one earlier this spring – the 28th annual Seminars on Audition. The purpose of this seminar was to get clinicians, hearing aid design engineers, and researchers together in one room and provide a speaker or speakers that will set the milieu for discussion. In many ways, much of what was learned was during coffee breaks and from the person sitting next to you. Although there are a number of other continuing education opportunities now such as on-line CEUs, there was something special about a face-to-face meeting with people who would not normally cross your paths. All proceeds went to scholarships either at the University of Western Ontario (Seminars on Audition scholarship) or the Institute of Biomaterials and Biomedical Engineering at the University of Toronto (Poul B. Madsen Scholarship). The Seminars on Audition scholarship allowed a student in their final year of their master's degree to attend an "extra-ordinary" facility anywhere in North America. Recipients over the years have gone to the Canadian arctic to see how hearing aid evaluations and follow-up was performed over a 3000 km distance by dog sled, and also to world class pediatric facilities such as Boys Town in Nebraska.

Previous speakers included EAG Shaw, Edgar Villchur, Mahlon Burkhart, Lu Beck, Ruth Bentler, Ken Berger, Elliott Berger, Rich Tyler, Mead Killion, William A. Cole, Richard Seewald, Susan Scollie, Steve Armstrong, Michael Valente, and Catherine Palmer, to just name a few.

This last one was the final Seminars on Audition. We did something a little bit different this time around. Instead of participants paying a registration fee, I sought assistance from the hearing aid manufacturers in Canada to cover all costs. Funds were graciously provided by:

GOLD SPONSORS
Bernafon Canada
GN Resound
Oticon Canada

SILVER SPONSORS
Phonak Canada
Siemens Canada
Widex Canada
Unitron Canada

Registration was therefore offered free of charge to the first 100 people who registered. The registrants were asked, however, to make a voluntary contribution to one of two scholarships at Western University's School of Communication Sciences and Disorders – the William A. Cole Scholarship or the Richard C. Seewald Scholarship. Contributions can still be given to these scholarships by contacting Catherine Dorais-Plesko at cdoraisp@uwo.ca.

Below are three of the summaries from this last Seminars on Audition entitled "Hearing Though the Ages" with contributions from Dr. Susan Scollie, Dr. Jo DeLuzio, and Marilyn Reed. As you can probably guess from the areas of specialty of these people, the seminar started with young children and ended with senior citizens and their unique communication requirements.

Also found, following the above three articles is a transcript from the panel/discussion section from the fourth Seminars On Audition between Harry Levitt and Edgar Villchur from 1989, who were the speakers for that meeting. Harry Levitt is a retired professor from CUNY in New York and is well known for his pioneering work on digital hearing aids. Edgar Villchur invented multi-band compression and is the father of the air suspended loudspeaker. Previous issues of the *Canadian Hearing Report* have had Founders of Our Profession columns on both of these pioneers.

Early Intervention for Children with Hearing Loss: An Update for 2013

By Susan Scollie
scollie@nca.uwo.ca

About the Author
Dr. Susan Scollie is an associate professor and faculty scholar at the National Centre for Audiology at Western University. Together with colleagues, she develops and supports the DSL Method for hearing aid fitting in adult and children. Her current research focuses on the evaluation of digital signal processing for hearing aids, and early intervention for children with hearing loss. In her classroom teaching, Dr. Scollie focuses on calibration, pediatric audiology, and advanced procedures in amplification

Many Canadian provinces are now initiating universal newborn hearing screening programs (UNHS), while others have not yet begun. This pattern significantly lags the progress made in the United States, where 100% of states have universal newborn hearing screening programs in place. Why the difference? Over the course of my career, I have witnessed the transformation of this area of our scope of practice, from high-risk registry screening to present day practices. Interactions with colleagues involved in this rapidly changing area has allowed me to observe the impacts of what I feel have been major factors in the near-universal implementation of UNHS south of the border. These include the recommendations of the interdisciplinary Joint Committee on Infant Hearing (JCIH), which recommended UNHS in 1996. This impactful group includes not only those from our profession, but also our colleagues from medicine (especially pediatrics), speaking with one evidence-based voice for the good of the children whom we serve. They have continued to do so, with re-jigging of important UNHS details as recommendation updates in 2007.[1] Recommendations, however, do not result in successful UNHS practices on the ground, nor do they ensure that legislative support for programs is achieved. These changes have been largely mediated by the National Centre for Hearing Assessment and Management (NCHAM), which has worked diligently to provide nation-wide clinician training and legislation development for many years, among other initiatives. Remarkably, NCHAM provided proposed bill "templates" that could be downloaded at no cost, and used as a starting place for discussions with legislators, keeping track on a national map with colours indicating states with versus without legislation. With most of the legwork done, advocates for UNHS could provide a bill to their elected representatives that was 99% complete. This single act is likely responsible for the widespread legislation supporting UNHS in the United States, most recently culminating in The Early Hearing Detection and Intervention Act (EHDI: 2010) which added an EHDI requirement to the Public Health Services Act at the federal level. NCHAM continues their important work, with current efforts aimed at promoting legislation for improved hearing aid coverage in health care plans.

Do we have parallel efforts in Canada? Although we can lean upon standards development (such as ANSI) and evidence from audiology science from south of the border, leaning upon their efforts in health care legislation is less likely to be helpful. Our health care systems are just too different. It's encouraging that we seem to have a recent parallel to JCIH. The Canadian Pediatric Society recently issued a report on Canadian public policy and child and youth health entitled "Are We Doing Enough?"[2] Listed third among eleven key areas for improvement is "Newborn hearing screening" alongside such mainstream issues as youth smoking, child and youth mental health, and bicycle helmet legislation. Powerful messages supporting the cost-benefit of early detection of infant hearing loss are provided in this important document, as well as 2011 summary table of the current status of screening programs with recommended next actions. This type of position statement sets the stage for follow up action and lends support to provincial initiatives to initiate legislative support for new programs.

In discussion of these issues, we can and should remember that UNHS does not imply that intervention and follow up services are available or equitable. We have some provinces that provide fully funded, interdisciplinary services that halt in early childhood due to coverage based on age and others that carry on to age 18. We have others that provide government-funded or low-cost hearing aids to all children, and others that rely upon the limited means of families to purchase full-cost hearing aids for thousands of dollars. A national initiative to improve access to equitable health care for infant and childhood hearing impairment could call not only for UNHS, but also equitable and evidence-based intervention services that take cost burdens into consideration.

Evidence-based intervention with hearing aids is possibly a more comfortable topic. New evidence and developments in hearing aid fitting techniques for children offer several messages: (1) the electroacoustic "success" of the fitting seems to matter, with new studies of outcome revealing that children whose hearing aids are grossly underfit have significantly poorer outcomes than do their well-fitted peers; (2) new technologies in hearing aids may have different uses for kids, and new tools for verifying these may be helpful in making clinical selection decisions; (3) monitoring of outcomes in children who use hearing aids has been a major area of change in pediatric practice in recent years. New tools are available. The sections below will review these three areas.

ELECTROACOUSTIC SUCCESS AND OUTCOMES

Recent studies in Canada have looked at the nature of fit to prescribed DSL targets for kids on a normal pediatric audiology caseload. This work has been led by the Network of Pediatric Audiologists of Canada.[3] The group includes a large number of clinicians from British Columbia, Alberta, Manitoba, Ontario, Quebec, and Nova Scotia. Their documented fit to targets across hundreds of ears is within 5 dB to the limits of the gain of the device. These data have been used to develop a normative range of Speech Intelligibility Index (SII) values for well-fitted hearing aids. In contrast, two recent U.S. studies have examined children whose hearing aid fittings are "off the street" to see how they fare. Both studies,[4,5] found that although many children were fitted well, a subset of children were not. Stiles et al. found that low versus high SII values were predictive of poor word recognition, phoneme repetition, and word learning. These results reinforce the importance of consistent hearing aid practices, with routine electroacoustic verification and use of a validated prescriptive method. The basics still matter.

NEW TECHNOLOGIES: EVIDENCE, FITTING, AND VERIFICATION

Over the past decade, advances in digital signal process have allowed us to have feedback controls (leading to open fitting more often than ever before), noise reduction, and frequency lowering. These three technologies can be considered from a pediatric perspective.

First, effective feedback control is of obvious interest for any pediatric fitting, but does it partner well with open fitting for pediatrics? The issue of open fits for kids is trickier than for adults, mainly because of ear canal size and hearing loss magnitude. Kids often pair ears that are too small for vents with losses that are challenging for highly vented (a.k.a. "open") fittings. Does this take consideration of venting and open fitting off of our mental radar screens? Recent data from Johnstone et al. may push us a little to put it back on the considerations list, at least for kids with certain types of losses.[6] Consistent with older adult data form,[7] Johnstone reports better sound localization with open versus closed molds for children, and shares particularly interesting cases of children with unilateral hearing losses. Children who were provided with an open fit in their aided ear were able to localize sound better: is there a sensitive period for spatial hearing development? Recall that the primary cue for horizontal sound localization is low frequency timing difference between ears.[8] The best way to preserve and deliver this timing cue is through a large vent, if appropriate for the degree of loss. We can verify the acoustic transparency of open fittings by comparing the open ear response to the occluded ear response with the aid worn but turned off. This can tell us how much vent-transmitted sound is making its way into the ear canal. These protocols for verification have not changed over the years (it's just the classic "REOG" approach9) – what's different is that it's now relevant to more of our fittings.

Other enhancements in signal processing include noise reduction and frequency lowering. We are motivated to pursue options for use in noise because children spend a lot of their day in noise.[10] We are motivated to pursue options for frequency lowering for fittings where extended bandwidth can't give us access to the important fricative cues in speech.[11] Management of loudness in noisy situations can take the form of simply using less gain in those situations.[12] This strategy is implemented in DSL v5 as a DSL-Noise prescription,[12] and has been shown effective in maintaining audibility of speech cues while reducing loudness for high-level inputs.[13] A variety of other noise-focused signal processors exist, and new verification techniques are available to probe their function effectively (For a review of these, see Smriga, 2004.[14]). Frequency lowering signal processing is now available in many different forms: we use the term "frequency lowering" as an umbrella which covers frequency transposition, compression, and translation. Each of these provides a different type of frequency lowering effect. Outcomes research on the use of frequency lowering for children has provided data on efficacy, effectiveness, and candidacy,[15] acclimatization,[16] sound quality, and changes in brain activity arising from changes in audibility from frequency lowering.[17] Case studies reveal the importance of fine tuning to an appropriate setting for each individual, in order to achieve actual benefit in speech sound detection and recognition.[18] Obtaining these outcomes in clinical practice is supported by the use of systematic verification and fine tuning protocols.[17,18] We can monitor the outcomes for individual children with targeted tests of speech sound detection aimed at bandwidth and/or frequency lowering effects,[18,19] as well as more generic outcomes monitoring through caregiver reports or tests of sentence-level speech recognition.[20,21]

SUMMARY

The practice area of pediatric audiology is challenging, important, and has experienced dramatic and rapid changes both from the fronts of policy and product. This update article highlights some of these areas, with a discussion of their impacts on change in clinical practice. We have wonderful tools for hearing aid signal processing, verification, and fitting. We need better resources for universally available early detection and cost-effective intervention for permanent childhood hearing loss.

REFERENCES

1. Joint Committee on Infant Hearing. Year 2007 position statement: Principles and guidelines for early hearing detection and intervention programs. Pediatrics 2007;120:898–921. doi: 10.1542/peds.2007-2333
2. Canadian Pediatric Society. Are we doing enough? A status report on Canadian public policy and child and youth health. ISSN 1913-5645. Accessed from: http://www.cps.ca/advocacy-defense/status-report. 2012.
3. Moodie S, Bagatto M, Miller L, et al. An Integrated Knowledge Translation Experience: Use of the Network of Pediatric Audiologists of Canada to Facilitate the Development of the University of Western Ontario Pediatric Audiological Monitoring Protocol (UWO PedAMP v1.0), Trends in Amplification 2011;15:34–56.
4. McCreery R, Bentler R, and Roush P. The characteristics of hearing aid fittings in infants and young children. Ear and Hearing 2012; in press.
5. Stiles D, Bentler R, and Mcgregor K. The speech intelligibility index and the pure-tone average as predictors of lexical ability in children fit with hearing aids. Journal of Speech, Language, and Hearing Research, first published online on January 5, 2012 as doi:10.1044/1092-4388(2011/10-0264); 2012.
6. Johnstone PM, Náb lek AK, and Robertson VS. Sound localization acuity in children with unilateral hearing loss who wear a hearing aid in the impaired ear. Journal of the American Academy of Audiology 2012;21:522–34.
7. Noble W, Sinclair S, Byrne D. Improvement in aided sound localization with open earmolds: observations in people with highfrequency hearing loss. Journal of American Academy of Audiology 1998;9:25–34.
8. Macpherson E and Middlebrooks J. Listener weighting of cues for lateral angle: The duplex theory of sound localization revisited. Journal of the Acoustical Society of America 2002;111(5):2219–2236.
9. Mueller HG. Probe microphone measurements: 20 years of progress. Trends in Amplification 2001;5(2): 35–68.
10. Crukley J, Scollie S, and Parsa, V. An exploration of school-age listening landscapes: Implications for pediatric hearing aid fittings. Journal of Educational Audiology 2011;17:23–35.
11. Stelmachowicz P, Pittman A, Hoover B, et al. The importance of high-frequency audibility in the speech and language development of children with hearing loss. Archives of Otolaryngology -- Head & Neck Surgery 2004;130(5):556–62.
12. Scollie S, Ching T, Seewald R, et al. Evaluation of the NAL-NL1 and DSL v4.1 prescriptions for children: preference in real world use. International Journal of Audiology 2010;49: S49–S63.
13. Crukley J, and Scollie S. Children's speech recognition and loudness perception with the Desired Sensation Level v5 Quiet and Noise Prescriptions. American Journal of Audiology 2012; Doi: 10.1044/1059-0889(2012/12-002).
14. Smriga DJ. How to measure and demonstrate four key digital hearing aid performance features. Hearing Review 2004;11(11).
15. Glista D and Scollie S. Modified verification approaches for frequency lowering devices. AudiologyOnline 2009; http://www.audiology-online.com/articles/article_detail.asp?article_id=2301.
16. Glista D, Easwar V, Purcell D, and Scollie S. (2012). A Pilot Study on Cortical Auditory Evoked Potentials (CAEPs) in children: Aided CAEPs change with frequency compression hearing aid technology, International Journal of Otolaryngology 2012; Article ID 982894, doi:10.1155/2012/982894.
17. Glista D, Scollie S, and Sulkers J. Perceptual acclimatization post nonlinear frequency compression hearing aid fitting in older children. Journal of Speech, Language, and Hearing Research 2012; Doi:10.1044/1092-4388(2012/11-0163).
18. Scollie S and Glista D. (2011). Digital signal processing for access to high frequency sounds: implications for children who use hearing aids. ENT and Audiology News 2011;20(5):83–87.
19. Glista D and Scollie S. (2012). Development and evaluation of an english language measure of detection of word-final plurality markers: The University of Western Ontario Plurals Test. American Journal of Audiology 2012;21:76–81.
20. Ng S, Meston C, Scollie S, and Seewald R. Adaptation of the BKB-SIN test for use as a pediatric aided outcome measure. Journal of the American Academy of Audiology 2011;22:375–86.
21. Bagatto M. 20Q: Baby steps following verification - outcome evaluation in pediatric hearing aid fitting. AudiologyOnline 2012; http://www.audiologyonline.com/articles/article_detail.asp?article_id=2414).

Canadian Hearing Report 2012;8(3):37-39.

My Horsie Has a Cochlear Implant: The Importance of Child-Centred Outcomes for Children with Hearing Loss

By Joanne DeLuzio, PhD
jo.deluzio@utoronto.ca

About the Author
Joanne DeLuzio PhD, Audiologist, Reg. CASLPO, is adjunct professor with the Department of Speech-Language Pathology at the University of Toronto.

The "gold standard" for outcomes in the field of childhood hearing loss is language development and academic achievement commensurate with age and cognitive ability. However, achieving age-appropriate levels in these areas will not necessarily ensure that the children have good social-emotional development (i.e., the ability to form close, confident relationships and to experience, regulate, and express emotions within these relationships). Even with good auditory language measures, the social development of many children with hearing loss continues to lag behind their typically hearing peers[1,2]

Communication training with young children with hearing loss relies primarily on adult-child interactions, as the children are usually involved in therapy with one or more adult service providers. Adult-child interactions are important because language learning occurs during conversations with adults, and the adults serve as language models for the children. During adult-child interactions, adults are typically the initiator and they modify their language and communication to accommodate both the linguistic and social needs of the children.

Peer interactions on the other hand are also imperative, and may be the primary context in which young children can practice assertiveness, aggressiveness, and conflict management because there is not the power imbalance that occurs when interacting with adults.[3] It is during peer interactions that children have the opportunity to function as equal and autonomous communication partners. It may not be sufficient to place children with hearing loss into integrated classrooms and assume that positive peer interactions will flourish. The typically hearing children may not be responsive to them.[1]

Given the importance of social skills development and positive peer interactions, assessment of children with hearing loss should include measures of social-emotional maturity and peer interaction skills. As well, the literature has "reduction of loneliness" as an outcome with children who have chronic illness, and these types of measures may also be beneficial for children with hearing loss.[4] Additionally, education for parents needs to include milestones for social-emotional maturity and social skills development in addition to speech and language milestones.

Professionals in the field of childhood hearing loss need to move towards more child-centered outcomes. This means considering outcomes that: are identified by the child, support the child's physical social and psychological development, consider the child's developmental needs, and measure the child's perceptions of the impact of the treatments they are receiving. To that end, measures of pediatric quality of life should be used routinely in the assessment protocol. The pediatric quality of life inventory[5] (PedsQL) is one tool that may be applicable. It addresses dimensions of health that are of universal concern to children across age groups and has data on 35,000 healthy children.

The platinum standard in the field of childhood hearing loss should be commensurate achievement in all developmental areas including: social-emotional development, communication, language, and academic success. The ultimate goal is for these children to be healthy and well adjusted and to experience positive self-esteem, peer acceptance and the ability to form close relationships throughout their life.

REFERENCES:

1. DeLuzio J and Girolametto L. (2011). Peer interactions of preschool children with and without hearing loss. Journal of Speech, Language, and Hearing Research 2011;54:1197–10.
2. Martin D, Bat-Chava Y, Lalwani A, Waltzman SB. Peer relationships of deaf children with cochlear implants: predictors of peer entry and peer interaction success. Journal of Deaf Studies and Deaf Education 2011;16(1):108–20.
3. Ladd GW. Children's peer relations and social competence. New Haven, CT: Yale University Press; 2005.
4. Ladd GW, Kochenderfer BJ, and Coleman CC. Friendship quality as a predictor of young children's early school adjustment. Child Development 1996;67:1103–18.
5. Varni J. The PedsQLTM (Pediatric Quality of Life Inventory). http://www.pedsql.org/; (2008-2013).

Canadian Hearing Report 2012;8(3):40-41.

Third Party Funding: Frequently Asked Questions

Carri Johnson, AuD
Canadian Academy of Audiology
Chair, Third Party Committee

Over the years many of you have sent in questions for the federal health partners. Many of these questions are repeated each year so, I thought I would take this opportunity to clarify a few things.

DID YOU KNOW……

VAC will pay for the manufacturer's invoice cost for earmolds as long as the invoice is submitted with the billing. They will also pay impression fees for replacement molds. For ear molds fit with the hearing aid originally the cost of the impression fee is included in the dispensing fee.

As of June 1, 2013, audiologists are no longer required to complete NIHB's Hearing Aid Confirmation Form. We must now only fax the manufacturers invoice with a copy of the Pre-authorization Form (referencing their PA number) to their respective Health Canada regional office in order to finalize the approval process

DND, NIHB, RCMP, VAC have negotiated 2 year warranties on all hearing aids with all CAEA members. This is the standard warranty for all their clients regardless of what warranties you have negotiated for your private pay clients

If your patient is covered by one of the federal health partners and requires an item that is on their grid, a letter can be written to request an exception. These applications should include the medical reasons why this device is required for the clients day to day living. They are considered on a case by case basis.

If you have questions about any of the federal health partners please feel free to contact CAA at anytime of the year. We are here to help you and your patients.

CAA Canadian Academy of Audiology Heard. Understood.
ACA Academie canadienne d'audiologie Entendus. Compris.

When the Brain Gets Hard of Hearing: Paying Attention to Cognition in Hearing Rehabilitation

By Marilyn Reed, MSc
mreed@baycrest.org

About the Author
Marilyn Reed, MSc, is the practice advisor for audiology at Baycrest, a geriatric care and research center in Toronto, where she has worked since 1997. Marilyn graduated with a master's degree in audiology from the University of Southampton in England in 1976, and has since worked in clinical audiology in a variety of settings, always with a geriatric interest.

Alzheimer's disease, the most common form of dementia, has become the primary public health concern in Canada. It is the leading cause of disability among Canadians over the age of 65, already costs billions of dollars each year, and prevalence is predicted to double worldwide within 20 years.[1] Dementia cannot be prevented or cured, and there is an urgent need to find ways to delay the onset and progression of the disease and reduce the associated social and economic costs.

Since hearing loss and cognitive impairment are both highly prevalent in older adults, dual impairments are common. However, hearing loss is more prevalent in those with dementia than in matched control.[2] The link between age-related hearing loss and cognitive impairment has been well-established through over 30 years of research, but recent epidemiological findings show that older adults with hearing loss are more likely to develop dementia, and the more severe the hearing loss, the greater the risk.[3] Longitudinal studies have also shown a close correlation between central auditory processing (CAP) problems and cognitive impairment, with scores on dichotic speech tests being predictive of the likelihood of cognitive decline.[4,5]

The specific mechanisms underlying the association between audition and cognition are unknown; theories include the possibility of a common cause, due to age-related pathological changes in the brain, or a causal relationship, with hearing loss being a modifiable risk factor for cognitive decline. Possible causal pathways might involve the additional burden that hearing loss places on declining cognitive resources needed for information processing, or the lack of cognitively stimulating interaction and social isolation resulting from sensory deprivation.

Whatever the mechanism, the evidence strongly suggests that hearing loss may contribute to or accelerate the progression of symptoms of cognitive decline in older adults. If management of hearing loss could reduce or delay the progression of dementia, the implications for the cognitive health of older adults and the costs of dementia to public health and society as a whole are huge.

Audiologists need to be aware of the role that cognition plays in the communication problems of our clients so that we can begin to apply recent research findings to improve both assessment and management. While it may be obvious which clients have more advanced dementia, milder cognitive impairment is difficult to recognize in only one or two visits, and yet can have a significant impact on the success of our interventions. A "snapshot" of the cognitive status of randomly selected Baycrest audiology patients over the age

TABLE 1. MODIFIED ASSESSMENTS FOR PATIENTS WITH DEMENTIA

Give short, simple instructions
Practice, to ensure instructions are understood
Provide prompting and encouragement
Accept a variety of responses
Get most valuable information first (i.e. minimize fatigue, agitation)
Speech testing (meaningful stimuli) more successful that PTs; SRTs more reliable than PTTs
Obtain SATs where SRTs unobtainable
Use any speech material that is effective; meaningful/familiar speech (simple questions or digits more successful than PBs or spondees)
Test at time of day when most alert (usually morning)
Presence of caregiver/family member may reduce agitation or anxiety
Assess over multiple sessions if needed
Include speech in noise and CAP test (s) appropriate to capability, if possible
Objective assessment; acoustic reflexes, ABR (OAEs unlikely)

of 68 years revealed that 16 out of 20 failed the Montreal Cognitive Assessment test, indicating that they had at least mild cognitive impairment and suggesting that cognitive screening is warranted. Many authors advise us that this is indeed the case.[6–8] Assessment of cognitive status through observation of behaviour, history taking, screening tools, or speech tests that address working memory and other aspects of auditory processing and cognitive function would be a valuable addition to the audiologic assessment battery. Similarly, assessment of hearing should be part of any assessment of cognitive function, especially since many cognitive tests are verbal and therefore impacted by hearing loss. Audiologists can play an important role in the education of other health care professionals in this area, and provide them with hearing screening tools and referral criteria.

There are currently no established best practice protocols for the audiologic assessment of patients with cognitive impairment. While those of us working with elderly clients have developed our own modifications to test procedures (see Table 1), it would be helpful to develop more standardized test protocols that address the impact of cognitive decline on patients' ability to provide information and the most effective ways for us to obtain it. We should also include new tests that provide information about higher auditory and cognitive processing; we need to do more than speech testing in quiet to get information about the entire auditory system that will assist with management decisions. Specialized speech tests can provide much information about functional communication ability, CAP and aspects of cognitive function, and are available in varying degrees of difficulty to suit the ability of the patient. Dichotic tests which target binaural integration skills, dual tasking and memory target both auditory and cognitive processing. The dichotic digit test[9] is recommended by many in the literature[10] as being the most appropriate and cost-effective for use with the elderly, and is currently under trial in our clinic at Baycrest.

How does knowledge of cognitive status change what we do? Baycrest audiologists are currently looking at whether we modify our services based on awareness of our patients' cognition, with a view to developing and integrating best practice procedures for those with both hearing loss and cognitive decline. We do know that there is a great need to provide and improve services for this population[11,12] for whom amplification in the form of hearing aids provides limited benefit and poses problems for management. Our current, technology focused approach is not very successful for older listeners and needs to be resituated in a broader context of audiologic rehabilitation (AR) because of the important role that training and therapy play in promoting compensatory cognitive function.[13]

Speech perception difficulties of the elderly result from a complex interaction of sensory and cognitive processes, and arise from peripheral, central and cognitive changes that occur with age. Listening, comprehending and communicating require more general cognitive operations such as attention, memory, and language representation.[14] In daily life, listeners constantly take in bottom-up information using their hearing, and combine it with "top-down" knowledge that's learned and stored in the brain. The more difficult the listening conditions, the more effort we have to make to hear and understand. This increased listening effort puts more demands on cognitive resources needed for other aspects of information processing such as deriving meaning and storing in memory. Cognitive decline makes it harder for older listeners to ignore, inhibit or suppress irrelevant acoustic stimuli like music or competing voices, and attend to the specific voice of interest. Poorer working memory (WM) makes it harder to fill in the gaps in conversation, and the effort of listening and paying attention means that older listeners are less likely to understand and remember what they're hearing, even if they hear it.[15] Focusing on the hearing aid as a "fix" for their communication problems misleads many clients with

TABLE 2. CONSIDERATIONS FOR FITTING FOR PERSONS WITH AGE-RELATED COGNITIVE AND PHYSICAL IMPAIRMENTS

Automated features, minimal manual controls
Verbal prompts
Manageable battery doors (marked if low vision)
Removal cords
Safety loops for attachment to clothing for advanced CI
For previous users:
do not change style (or manufacturer) of aid
do not change battery size or style of door
Facilitate phone use with hearing aid, so not removed
Establish routine for storage once removed
Remote controls intuitive/user friendly
Accessories to improve SNR (remote microphone, FM compatible)
Longer acclimatization period (6–12 months)
Written instructions (large print, pictures, supported communication)
Schedule prompt and more frequent return visits
Counseling and AR; group/social model
Involve/instruct caregivers in management and AR

TABLE 3. AR STRATEGIES TO IMPROVE COMMUNICATION IN OLDER ADULTS

Bottom-up Strategies
Management
Use of assistive technology
Requesting Clear Speech (slow rate, etc.)
Use of visual cues (speech reading and graphics)
Environmental modification and manipulation
Therapy
Auditory skills training such as difference between /ba/ and /da/
"Communication exercise": adaptive, repetitive, practice such as. Listening and Communication Enhancement (LACE21) using neuroplasticity to change neural responses to sound
Top-down Strategies
Management
Teaching communication partners (caregivers, etc) importance of clear language (plain, familiar language; short, simple sentences)
Use of context
Giving more time to process
Therapy
Teaching compensatory strategies (active listening; communication repair; self-efficacy; self-advocacy)
Stress reduction exercises (reduce anxiety and confusion)
Auditory and cognitive training to improve working memory
Include caregivers in communication training

age-related hearing loss into having unrealistic expectations and sets them up for failure. No matter how perfect our real-ear aided responses are, the speech signal provided at the periphery will be distorted by damaged central and cognitive processing.[8,16]

Hearing aids can both help and hinder success with communication; they can reduce listening effort by improving the quality of the signal reaching the auditory cortex through restoring audibility and improving the signal to noise ratio with directional microphones and noise reduction algorithms. However, complex signal processing may not necessarily be beneficial for everyone, as it may introduce distortions in ways that impede or cancel the intended benefits for some individuals. Studies show that those with cognitive impairment and lower WM are more susceptible to distortion from fast amplitude compression (WDRC) and frequency compression/lowering and that HA signal processing should be less aggressive for these patients.[16–18] Binaural aiding may not be the best strategy for some elderly persons for whom higher auditory processing factors such as decreased inter-hemispheric communication and binaural integration result in reduced ability to use binaural cues.[19,20] Aging and cognitive decline also appear to affect hemispheric asymmetry in linguistic processing, so that asymmetry favoring the left hemisphere reverses, resulting in significant right ear advantage in those with cognitive impairment.[10]

Of course we also have to pay attention to non-acoustic factors related to age-related cognitive and physical limitations (Table 2).

If our goal is to maximize our patients' ability to communicate, we must consider the role of cognitive processing in AR. It is impossible to disentangle sensory loss from cognitive processing in older listeners, and so effective intervention must include both amplification (bottom-up) and training (top-down) to improve auditory skills and teach compensatory behavioral strategies. Bottom-up strategies focus on access to a clear signal, while top-down strategies focus on functional communication (see Table 3, based on Ferre, J: Rehabilitation for Auditory Processing Difficulties in Adults, ASHA on-line seminar, 2012).

"There's more than one way to recognize a word"[13]; through AR techniques, we can teach compensatory behavioral communication strategies to patients and caregivers, to improve top down processing and help to compensate for sensory deficits.

Group AR programs not only help older adults become more effective communicators, they also foster their participation and social interaction.[22] A group gives an opportunity for repetitive practice of communication repair strategies in a meaningful context while addressing social participation needs. Social interaction is known to promote cognitive health and has been shown to have a protective effect against dementia.[5,23,24] The Hard of Hearing Club at Baycrest was designed for seniors with severe hearing loss at risk for social isolation and has successfully addressed both educational and social needs for many of its members over the 13 years that it has been running.[25]

There is a pressing need for audiologists to understand how cognitive impairment interacts with hearing loss so interventions can be tailored to better suit client needs. Dr. Lin is conducting another research project that will follow older adults over time to see if audiologic interventions will help delay the onset or slow the progression of cognitive decline. At Baycrest, audiologists will be working with psychologists to look at whether fitting HAs and providing AR will have a positive impact for patients with early dementia and their caregivers. If this is indeed the case, the implications are huge, and audiologists could play a critical role in providing solutions to this pressing public health concern.

REFERENCES

1. Alzheimer's Society of Canada. Rising tide: the impact of dementia on Canadian society. Toronto: Author; 2010.
2. Uhlmann RF, Larson EB, Rees TS, et al. Koepsell. Relationship of hearing impairment to dementia and cognitive dysfunction in older adults. .Journal of the American Medical Association 1989;261:1916–19.
3. Lin FR. Hearing loss and cognition among older adults in the United States.Journals of Gerontology A: Biological Sciences and Medical Sciences 2011;66:1131–36.
4. Gates GA, Beiser A, Rees TS, et al. Central auditory dysfunction may precede the onset of clinical dementia in people with probable Alzheimer's disease. Journal of the American Geriatrics Society 2002;50:482–88.
5. Gates GA, Anderson ML, McCurry SM, et al. Central auditory dysfunction is a harbinger of Alzheimer's dementia. Archives of Otolaryngology-Head and Neck Surgery 2011;137:390–95.
6. Kricos P. Audiologic management of older adults with hearing loss and compromised cognitive/psychoacoustic auditory processing capabilities. Trends in Amplification 2006;10(1):1–28.
7. Pichora-Fuller MK. Effects of age on auditory and cognitive processing: implications for hearing aid fitting and audiologic rehabilitation, Trends in Amplification 2006;10(1) 29–59.
8. Lunner T. Memory systems in relation to hearing aid use. Cognition, Audition and Amplification, AAA Conference, Boston; 2012.
9. Musiek F. Assessment of central auditory dysfunction: The Dichotic Digit Test revisited. Ear and Hearing 1983;4:79–83.
10. Idrizbegovic E, Hederstierna C, Dahlquist M, et al.Central auditory function in early Alzheimer's disease and in mild cognitive impairment.Age and Ageing 2011;40:249–54.
11. Lin FR, Metter EJ, O'Brien RJ, et al. Hearing loss and incident dementia.Archives of Neurology 2011;68:214–20.
12. Kricos P. Providing hearing rehabilitation to people with dementia presents unique challenges. The Hearing Journal 2009;62(11):39–43.
13. Pichora-Fuller MK. Perceptual effort and apparent cognitive decline: Implications for audiologic rehabilitation. Seminars in Hearing 2006;27:4.
14. Kiessling J, Pichora-Fuller MK, Gatehouse S, et al. Candidature for and delivery of audiological services: Special needs of older people. International Journal of Audiology 2003;42(Suppl 2):2S92–101.
15. Pichora-Fuller MK. Audition and cognition: Where the lab meets clinic. ASHA Leader 2008;13(10):14–17.
16. Humes LE. Modeling and predicting hearing-aid outcome. Trends in Amplification 2003;7(2):41–75.
17. Gatehouse S, Naylor G, and Elberling C. Linear and non-linear hearing aid fittings – 2. Patterns of candidature. International Journal of Audiology 2006;45:153–71.
18. Lunner T and Sundewall-Thorén E. Interactions between cognition, compression, and listening conditions: Effects on speech-in-noise performance in a two-channel hearing aid. Journal of the American Academy of Audiology 2007;18:604–17.
19. Walden TC and Walden BE. Unilateral versus bilateral amplification for adults with impaired hearing. Journal of the American Academy of Audiology 2005;16(8):574–84.
20. Kobler S, Lindblad AC, Olofsson A, and Hagerman B. Successful and unsuccessful users of bilateral amplification: differences and similarities in binaural performance. International Journal of Audiology 2010;49(9):613–27.
21. Sweetow RW, Sabes JH. The need for and development of an adaptive Listening and Communication Enhancement (LACE) Program. Journal of the American Academy of Audiology 2006;17(8):538–58.
22. Worrall L and Hickson L. Communication disability in aging: From prevention to intervention. Clifton Park, NY: Delmar Learning; 2003.
23. Fratiglioni L, Paillard-Borg S, Winblad B. An active and socially integrated lifestyle in late life might protect against dementia. Lancet Neurol 2004;3(6):343–53.
24. Hultsch DF, Hertzog C, Small BJ, and Dixon RA. (1999). Use it or lose it: Engaged lifestyle as a buffer of cognitive decline in aging? Psychology and Aging 1999;14:245–63.
25. Reed M. The Hard of Hearing Club: A social framework for audiologic rehabilitation for seniors with severe hearing difficulties. In L. Hickson (Ed), Hearing care for adults: The challenge of aging. Phonak: Stäfa, Switzerland; 2009

Canadian Hearing Report 2012;8(3):42-45.

Signal Processing Techniques in Hearing Aids Fourth Annual Seminars on Audition

February 25, 1989 (Toronto)



Co-ordinator: Marshall Chasin, AuD., Reg. CASLPO (far left)
Speaker: Harry Levitt, PhD, City University of New York (middle)
Speaker: Edgar Villchur, MS Ed., Foundation for Hearing Aid Research (left)

Question: Could you please give some information on the redundancy of speech?

E. Villchur: The consonants are identified not only by their spectral makeup, but also by their temporal pattern. A [t] starts out with a sharp jump in amplitude and tapers off. Also, the consonant is affected by the vowel environment – it is preceded or followed by one sound or another. If interference destroys on or two of these cues, the third one may be enough to identify it. One of the cues that allows us to understand speech is the context or meaning of the speech. If I say "I fell out of the boak," we are going to change that [k] to a [t], because it doesn't make sense otherwise. But if I also miss the [b] or the [o], I won't have the additional cue.

H. Levitt: Another example of redundancy is to stress a syllable. In the word "confuse" – we change the stress pattern and the meaning is changed. There are cues that are correlated with stress, such as the lengthening of the stressed syllable, the intensity of the voiced syllable, and the increasing of the voice pitch of the stressed syllable. All of these cues depend on the stress, and that is a redundant situation. If only one of those cues is heard, such as may be the case with a hearing impaired person, then the redundancy is reduced so that the meaning may not be apparent.

Question: What are your experiences with frequency displacing hearing aids which transpose the high frequencies and impose them on the lower?

E. Villchur: Work by Johanssen, in Sweden, has tried to do this, and indeed they came out with a commercial product (under the name of Oticon in the 1970s). There was a modification of this which was published in an IEEE journal within the last decade, where instead of folding the entire high frequency band onto the low frequency band where they feared interference effects, he only folded the energy above 5000 Hz back down, in effect only affecting the fricatives. I don't know of any application of this in any hearing aid.

H. Levitt: There have been a number of experimental devices along these lines, but I'm not familiar with any one of them which has reached the marketplace other than the Johanssen device.

E. Villchur: One problem with these devices is that you have to learn a new language. You have to learn to recognize new sounds. The thing I liked about the synthetic fricatives, which followed surrogate fricatives (Levitt), is that you don't have to learn a new language.

H. Levitt: These transposition devices can be broken up into three groups (1) which transposes everything from the high frequencies to lower ones, (which have not been particularly successful), (2) the phonetic transposition devices which first decides whether it's a fricative or another sound, and only that sound is transposed down, (and that reduces the distortion and the transposition only occurs during fricatives. This has been more successful and the model was published around 1968), and (3) logic frequency transposition which is a device which reduces everything only slightly so that speech still sounds like speech. We get small improvements in intelligibility particularly with female and children's voices which have a higher pitched frequency spectrum. If you transpose about 20% down, you are likely to improve intelligibility.

Question: Dan Graupe who invented the Zeta Blocker chip, has stated that he has a system which can reduce speech down to an 800 Hz bandwidth and still be intelligible, because he was using a non-linear frequency transposition instead of a linear one.

H. Levitt: Non-linear transposition has been tried at MIT and they call it frequency warping. To my knowledge they have not gotten particularly exciting results. But, they also did a feasibility study which was quite interesting. One of the arguments against radical frequency transposition is that the resulting speech is not recognizable without training. You have to learn a new code. There is a fundamental question whether you can actually learn the new code. The group at MIT created artificial speech sounds which were all under 1000 Hz and that were as perceptually different from each other as possible. These were clicks and all sorts of strange sounds. They trained people to associate these sounds with speech sounds. They were able to demonstrate that it was possible to at least train a person to learn the consonant set. So in principle, people could learn a new code. Nobody has yet come up with a machine which does it automatically.

E. Villchur: I have no doubt that speech is intelligible in an 800 Hz band because unprocessed normal speech cut off above 800 Hz is intelligible. The question is whether intelligibility is improved with a hard of hearing person. When you compress the frequencies of speech down to 800 Hz, one of the things you do is bring the frequency components of speech much closer together. When a person cuts of at 800 Hz, that person is likely to be in the profoundly deaf group and is likely to suffer from problems in frequency resolution. It may be that bringing those formants together may do more harm than bringing the high frequency elements down to within the 800 Hz range.

Question: When you have a profound loss which requires a high amount of gain but at the same time you have recruitment, how do you make the compromise between the gain and the saturation level of the hearing aid?

E. Villchur: The best you can do is to amplify speech to within these limits but the first thing you need to do is to make these sounds audible by giving extra amplification to the weak sounds to bring them into the residual dynamic range of the subject, without over amplifying the intense sounds. This may not be enough but at least this is the first thing that must be done. If you decide that you are going to use some other type of processing, it's important not to drop that processing which at least made the sound audible.

Question: In all of the examples today, the hearing impaired person was described through the audiogram and the intensity dynamic range. Do you see any alternatives to describing the hearing impaired by other means?

E. Villchur: The presentation was based on an assumption which is that the two most prevalent distortions which affect the hearing impaired are (1) attenuated frequency response and (2) recruitment. If you make this assumption then data will be presented via the amplitude range. All that the dual channel compressors are, are two little men turning volume control wheels up or down – nothing more mysterious than that. Even if you solve the above mentioned two major distortions, you don't restore normal hearing, which implies that there are other aberrations, which either can or cannot be compensated. All I can do is discuss the ones we know about and they are in terms of amplitude.

Question: The kind of dimension that is missing is the temporal one. There are experimental data which go back quite some time which show that even if two people have identical amplitude audiograms, one may have very good speech understanding and the other, poor. The studies have tried to determine what other variables can explain the differences between these two individuals. Of all the variables looked at, temporal resolution was the most likely candidate. The one with better temporal resolution also has better speech understanding. This implies that we not only need to measure the amplitude/recruitment characteristics of an individual, but we need to measure the temporal resolution characteristics as well. It's not an easy thing to do but it can be done, and I think that we should pay more attention to it. Hopefully that will indicate what methods of signal processing will be required in the temporal domain to improve hearing.

E. Villchur: You can't have temporal resolution for sounds that you can't hear. Therefore, first bring the sound into the dynamic range of the hearing. It's a necessary, but possibly insufficient condition for achieving what we want.

Question: One of the problems with multi-band compression is that it seems to interfere with temporal characteristics. Do you have a comment?

E. Villchur: There is no question that compression reduces temporal resolution. It has to. For example, if you have two sounds, one following the other, and the first sound drops off and then there's silence, and then the next sound starts, the time where the first sound is dropping off will be changed by the compression – it will be lifted. The faint, trailing parts of the first sound will be increased by the compression. The compression will tend to fill in the gap between the two sounds. What it will do is to restore the temporal resolution to that of a normal listener. The person before compression hears a more precipitous drop off because of his recruitment, than the normal listener. But it may be that in some cases, the hard of hearing listener cannot take the restoration to normal temporal resolution. It may turn out that he needs an abnormally good temporal resolution. But, only to the extent that a properly adjusted compression system interferes with temporal resolution, and not by restoring normal temporal resolution.

Question: Some cases of profound hearing loss do not show any ability to function on cues that are below 800 Hz. I am questioning whether the transposition of cues to the low frequency band would be effective, and also whether we are using the same definition of profound loss.

E. Villchur: There are some profoundly deaf where there is no way to restore intelligibility. It has been shown that restoring some cues which are insufficient for intelligibility (accent, stress), gives them an advantage for lip reading. In some cases you just have to give up.

Question: When you map the high frequency information into the low frequency region, are you not destroying the temporal cues by doing this? In this case would you not be better to present both low and high frequency artificial cues rather than overloading the low frequency band?

E. Villchur: That has been done by using a vocoder system where a few individual bars of noise have been modulated to represent speech and from that way of thinking, I prefer to use my synthetic fricatives which only interferes at one point over a third of an octave at the top of the residual range, rather than folding over the entire frequency spectrum. As for the vocoder system, it's amazing how little you need to present before the system becomes intelligible. I have listened to a system with only three bars of noise going up and down and get an occasional word out of it. By the time you get to five bars of noise you understand it fairly well.

Question: Would it not be better to present the high frequency energy in the low frequency band only when it was important, and to present the low frequency energy in the low frequency band when that was important?

H. Levitt: That is indeed the philosophy underlying the technique of surrogate fricatives. If you had a voiceless fricative the low frequency energy is relatively unimportant. The only energy that counts is the high frequency energy. With the exception of these voiceless fricatives, the low frequency sounds are more important. That particular form of transformation worked quite well.

Question: Dr. Levitt mentioned that it was important to maintain the phase characteristics of the speech in the digital processing system. Would that be related to temporal information or something else?

H. Levitt: Basically phase information is temporal. There are some conflicting data in the literature, which I'll remind you of. A lot of data show that when you discard phase information in speech such as on the telephone, the speech remains intelligible and that you can hardly tell the difference. That is true for any monaural listening system. On the other hand, there are substantial data which show that if you have a binaural listening system, phase information is greatly important. So we have two rather extreme sets of data – monaural (phase unimportant) versus binaural (phase important). When people looked into noise reduction for monaural systems, since these systems used a single headphone, it was thought that phase was not important. However, the relative phase between the speech components and the noise components turns out to be important. The auditory system does not discard phase information. Although experiments show that phase information is not important for understanding speech, it does not mean that the auditory system discards phase information. What experiments do show is that as part of a noise reduction system, even monaurally, if phase information is retained, we get better results.

Question: In the two channel system discussed in your talk, where was the crossover between the low and the high frequency channels?

E. Villchur: In the tapes that I played, I used the average compensation characteristics required by the six subjects that I used in my 1973 study, which was 1500 Hz. But the last tape that I played through the Resound hearing aid has an adjustable crossover between 800 Hz to 2000 Hz. Among the six subjects there was a variation of no more than 1.5:1. The average falls in the area of 1500 Hz.

Question: it appears that the low frequency band in a two channel compression system requires a compression ratio of 2.3 whereas the higher frequency band requires a much higher ratio, perhaps even infinite. Is this indeed the case and what ratio characteristics would be required to cover the hearing impaired population?

E. Villchur: The compression ratios that I used were not a matter of guesswork or my own hypothesis, but were calculated on the basis of a formula which may not have been the correct one. The formula was this; I defined the normal dynamic range at any frequency as the distance between threshold and the equal loudness contour pegged to the maximum speech level of conversational speech. This is on the order of 65–70 dB across the spectrum. I then defined the residual dynamic range of a hearing impaired person as the distance between his threshold and the equal loudness contour pegged to his preferred listening level of conversational speech. When you do that, a typical person with moderately-severe to severe impairment, which my six subjects had, is likely to require a compression ratio of 2:1 in the low frequency band (which represents the ratio of the normal dynamic range and his residual dynamic range) and a ratio of 3:1 in the high frequency band. An infinite compression ratio may still be intelligible but it accomplishes something new. What I was trying to do was to place the speech band in the same position between his threshold and the equal loudness contour, as that for a normal hearing person. The average for the entire band was about 3:1 (frequency by frequency), and the subjects did not like it. They reported that speech was strident. I hypothesized that when the dynamic range was very severely reduced, that other things were going on which meant that they couldn't take the sound.

Question: So can we say that the highest ratio we need is 3:1?

E. Villchur: In my experience, below a profound or very severe loss, we would not need a ratio in excess of 3:1. A profoundly deaf person may need a 5:1 ratio. When you get to a compression ratio of 5:1, it doesn't make much difference. The result is the same as 10:1 and so on. With a ratio of 5:1, with an input increase of 10 dB, the change in output will only be 2 dB. If we double that to a 10:1 ratio the output change will only be 1 dB.

Question: With your dual channel system, when you go to a noisy party, the response in noise tends to become flat. This is in contrast to the Zeta Noise Blocker, or other ASP system which tries to achieve a relative high frequency emphasis. Would you comment on that?

E. Villchur: In fact, the frequency response which I adjusted it to was up 9 db at 4000 Hz so it wasn't flat. I was trying to see with my experience with compressed sound what would happen in a real life situation. It was not adjusted to an optimum setting to my hearing. It was purposefully exaggerated. But this highlights the last thing I was talking about. There are two things that you can do about the difficulty that hearing impaired people have in a noisy environment. One is to try to optimize the conditions which they listen in that environment so that the target signal has a better ratio to the background signal. The other thing is to ignore the signal to ratio and to concentrate on the clarity of the target signal. By increasing the number of redundancy cues, you make it possible for the hard of hearing person to operate better within the noisy environment, and that is what I have been trying to do.

Question: Was the recruitment simulator used in your experiments digital or analog?

E. Villchur: The one that I published about was done at MIT and I used their hybrid system but the one I have at home, which is the 16 channel one, built by Mead Killion about 15 years ago, is analog.

Question: Given the equipment which is out there, how does one go about evaluating level dependent type hearing aids?

E. Villchur: The first who wrote about level dependent hearing aids is Margo Skinner and she showed that the optimal frequency response of her subjects depended on level. The lower the level, the more high frequency emphasis she could take. In the higher level, the less high frequency emphasis was optimum for them or indeed that they would tolerate. She came to the conclusion that what was needed was a level dependent frequency response. I wrote her in agreement and said that a level dependent frequency response was the same as a frequency dependent amplitude response, which is what you get from a dual channel compression hearing aid with different compression ratios for the low and high frequency bands. I ran a series of curves with my 2 channel compressor using ratios of 2:1 and 3:1 showing that at low levels it had a contradiction between level dependent frequency response and frequency dependent amplitude response, but that they are indeed the same. On the other hand, a level dependent frequency response can be achieved in another way which Mead Killion is currently working on using a single channel compressor which he feels will be useful for mild to moderate deficits. Mead feels that a 2 channel approach is not needed for these more mild losses.

Question: The current calibration method for evaluating hearing aids uses a swept signal across the frequency range, but this would not be useful for dual channel systems.

H. Levitt: What is needed is a new standard which would specify the calibration and evaluation of these level dependent hearing aids. There are several methods being proposed. One method is to use a broadband signal and then analyze the resultant spectrum. The other is to have at least two tones – one to get the compressor working and the other to sweep across the frequency range. (Editor's note: A problem can occur if the first tone to get the compressor working is too low in frequency [e.g., 300 Hz], then difference tones can erroneously enter the frequency response).

E. Villchur: The most common is to use a family of curves – each one at a successively higher level. Instead of using one frequency response curve you will use a series, perhaps spaced every 10 dB from 50 to 80 dB input.

Comment: You can't characterize a non-linear system with a swept sinusold and there is a proposal before the ANSI committee which will allow you to use a complex stimulus and to define the characteristics of that spectrum as speech spectrum noise. The analysis means will be a swept spectral analysis at the output or a digital technique. There is some likelihood that that standard will come through in the next couple of years.

Question: In the cochlear implants mentioned today, what are the factors that limit the frequency of stimulation?

H. Levitt: You first have to characterize the implant. There is a single channel implant with a single electrode, and there are two multi-electrode cochlear implants. One multi-electrode system is like a vocoder where you have several contiguous frequency bands and each band drives a pair of electrodes. The second type has an array of 22 electrodes and each one electrode plus a round electrode is stimulated. You don't have much frequency resolution with the single channel cochlear implant, and that implant is on the way out. The multi-channel cochlear implant is the one that allows for coding of frequency information in various ways. There are two essential types of implants. One type of cochlear implant is a multi-channel system where there is a correspondence to different frequency bands. The design considerations are what frequency range bandwidths are required to encode speech. The other type of implant is where you extract the features of speech such as the voice fundamentals and encode that. This stimulates the electrodes in the cochlea. The question is which characteristics of speech ought to be encoded.

Question: For the benefit of those who do not fit hearing aids, could you comment on the relative effectiveness of hearing aids, including some of those discussed here.

E. Villchur: Neither Dr. Levitt nor I are clinicians. The models discussed here have not as yet been implemented in commercial hearing aids. 3M is just coming out. The Resound aid will be out in the spring of 1989, but I'm not quite sure.

H. Levitt: Regarding the Zeta Noise Blocker and similar hearing aids, there is generally not good clinical follow-up, so we only have information on those who are dissatisfied and that is not the best way to measure the degree of satisfaction. However, even using that crude measure, and by published return rates, there have been a fair amount of returns of the Zeta Nose Blocker. We should have more formal success/failure information on these systems.

E. Villchur: I would like to say a word about the ASP system. One of the two that Dr. Levitt described used a compressor in the low channel to reduce the noise and nothing in the high frequency channel. The compressor will reduce the noise only if the compression threshold is engaged by noise which is intense enough, so this would imply that it is not a compressor, but actually a compressor-limiter. With real compressors, weak sounds are not reduced but are increased in gain. Once you look at a compressor as increasing weak sounds out of the mud, and once you look at compressor-limiters as decreasing overly intense sounds, it becomes important to point out that I have been talking about compressors and not compressor-limiters. That is, a compressor increases gain, not decreases it. So the Zeta Noise Blocker is more of a compressor limiter.

Canadian Hearing Report 2012;8(3):46-50.