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Short Term Plasticity and Hearing Aid Use: Do We Have Internal Volume Control?

Noise-Reduction Headphone Effect on Portible Audio Device Users

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This issue of the *Canadian Hearing Report* touches on some topics where we don't know all of the answers. For me that usually means the realm of vestibular disorders and neurological phenomena. I, like most audiologists, feel more comfortable in the realm of objective testing and verification. In this issue the Spotlight on Science delves in to the area of prostheses for vestibular loss, and as the name suggests offers up insight and possible therapies for our clients who present with vestibular dysfunction.

And not to end there, Sean Lennox and Uta Stewart will be tackling the area of balance disorders and aging. Balance disorders are not a necessary side effect of being 80 years old and it is not something that we can just dismiss in our clients because of their age.

And, for the younger folk, Iman Ibrahim, Rebecca Malcolmson-Cronin, Mary-Beth Jennings, and Meg Cheesman, from Western University examine the noise-reduction headphone effect on localization abilities of portable audio device users. This is not only an area of significant psychoacoustic and acoustic interest, but there are ramifications regarding safely while wearing headphones out in a busy urban street. Turning one's head to the right when a truck is coming from the left side, is not a desired response! (Does anyone know what Meg's real name is – what does Meg stand for?)

And, this next article is one of my favourites. Jessica Merrett and Kevin Munro from over the pond in England have written on short term plasticity and hearing aids use. Do we have an internal volume control neurologically and what does neuroplasticity have to do with where we end up setting the volume on our hearing aids?

Although it is not customary to editorialize about a new book, I do want to mention a most delightful book that I reviewed for this issue of the *Canadian Hearing Report* in the From the Library section. This is *Roeser's Audiology Desk Reference* …. by Ross Roeser. I was asked to review this book and dreaded having to do the task. The book sat on my desk and throughout the week I found myself actually using it. It is one of the few books that stays on my desk rather than filed away on a bookcase. This book is accessible, easy to use (even for me), and is a necessary addition to anyone's library (or desktop).

I hope you all had a wonderful fall season – my favourite of all seasons. And for those of you who attended the CAA annual conference in St. John's, Labrador and Newfoundland, I hope you had a great time. There is nothing like maritime hospitality.

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Ce numéro de la *Revue canadienne d'audition* porte sur certains sujets et nous n'avons pas toutes les réponses. En ce qui me concerne, c'est souvent le domaine des troubles vestibulaires et des phénomènes neurologiques. A l'instar de la plupart des audiologistes, je suis plus à l'aise avec la réalité des tests objectifs et des vérifications. Dans ce numéro, la rubrique Spotlight on Science plonge dans le domaine des prothèses pour la perte vestibulaire, et comme le nom le suggère, offre une vue de profondeur des thérapies possibles pour nos clients qui présentent des dysfonctionnements vestibulaires.

Et pour ne pas s'en tenir juste là, Sean Lennox et Uta Stewart vont s'attaquer aux domaines des troubles d'équilibre et du vieillissement. Les troubles d'équilibre ne sont pas nécessairement un effet secondaire parce qu'on a 80 ans et on ne peut pas les négliger chez nos clients seulement à cause de l'âge.

Et, pour les jeunes, Iman Ibrahim, Rebecca Malcolmson-Cronin, Mary-Beth Jennings, et Meg Cheesman, de Western University examinent les casques téléphoniques qui réduisent le bruit et leurs effets sur les capacités de localisation des utilisateurs des appareils auditifs portatifs. Ce n'est pas seulement un domaine d'intérêt acoustique et psycho acoustique significatif, mais il a ses ramifications en ce qui a trait à la sécurité quand on porte des écouteurs dans une rue urbaine peuplée. Tourner la tête à droite quand le camion arrive par la gauche, n'est pas la réponse souhaitée! (y-a-t-il quelqu'un qui connait le vrai nom de Meg- Que signifie Meg?)

L'article suivant est un de mes préférés. Jessica Merrett et Kevin Munro de over the pond en Angleterre, touchent le sujet de la plasticité de courte durée et l'utilisation des appareils auditifs. Aurions-nous un contrôle neurologique interne du son et que vient faire la plasticité synaptique dans la détermination du volume du son de nos appareils auditifs ?

Il y'a très longtemps, je venais juste de commencer dans ce domaine, on m'a demandé de gérer un stand à une foire sur la santé. Dans ce cas-ci, des citoyens âgés venaient et en 3 minutes, je leur disais tous ce qu'ils devaient savoir sur l'ouïe, la perte auditive et leurs remédiations. Bon, quand j'ai commencé dans ce domaine, j'avais besoin juste de 3 minutes pour dire à quelqu'un tout ce que je savais. La personne dans le stand voisin était de the Diabetes Association of Canada, et quand on n'avait pas de visiteurs, on bavardait. Je me souviens que je lui avais posé la question sur la relation entre le diabète sucré et la perte auditive et elle m'avait immédiatement répondu "No! Il n'y a pas de relation!" J'ai pensé que c'était étrange étant donné que toute perturbation du flux sanguin, spécialement si cette perturbation est dans l'approvisionnement du sang dans la cochlée, devrait affecter l'intégrité neurosensorielle de l'oreille. Ca date de plus de 30 ans, mais au fil des années plusieurs articles semblent certifier l'existence de cette relation, mais tous ne concluent pas la même chose. Nous avons dans ce numéro un article par Eirini Mihanatzidou et Rhonda Kerlew qui traite de ce même enjeu – "The link between diabetes mellitus and sensorineural hearing loss: A summary of the evidence..

Bien que ce ne soit pas coutumier de faire la rubrique de nouveau livre, je veux mentionner un livre très enchanteur que j'ai révisé pour ce numéro de la Revue canadienne d'audition et que vous trouverez dans la section From the library. C'est Roeser's Audiology Desk Reference …. de Ross Roeser. On m'a demandé de réviser le livre et j'étais épouvanté par la tâche. Le livre sur mon bureau, au fil de la semaine, je me suis rendu compte que j'en faisais usage moi-même. C'est un de rares livres qui restent sur mon bureau et non pas classé dans une étagère de bibliothèque. Ce livre est accessible, convivial (même pour moi) et une addition nécessaire à la bibliothèque de toutes et tous (ou poste de travail).

J'espère que vous avez eu toutes et tous une merveilleuse saison d'automne– ma saison préférée de toutes. Et pour celles et ceux d'entre vous qui avez assisté à la conférence annuelle de l'ACA à St. John's, à Terre neuve et Labrador, j'espère que vous avez eu des moments formidables. Il n'y a rien de mieux que l'hospitalité des gens de la région atlantique.

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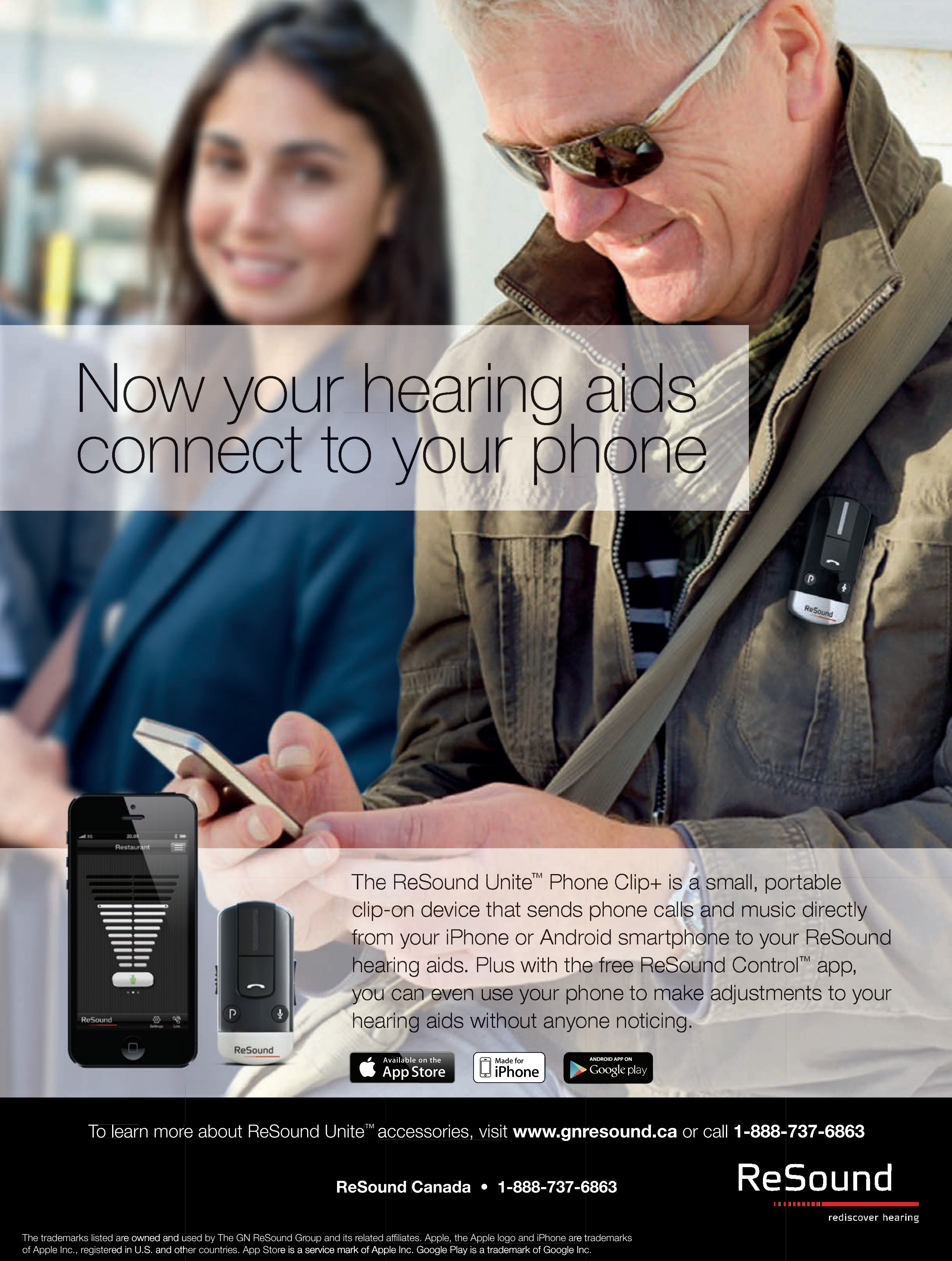
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By Calvin Staples, MSc
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"Those that can't, teach." Until I began to work clinically again, the preceding statement felt like my life, and at times still does. However, time in the clinic truly determines what you know and most definitely what you do not. I have been fortunate enough to be able to marry both academic and clinical work quite well and find myself trying to merge more and more of the literature into my practice regularly. As recent as last week, I was trying to figure out the guidelines for sudden sensorineural hearing loss (SSHL) and reached out to some of my colleagues for additional input. However, I could have easily turned to hearinghealthmatters.org as I was able to start to answer my question in a few short minutes. The blogs here are a wonderful resource for all of us in hearing health care.

REACTION TIME AND SUDDEN DECREASE IN HEARING

By, Jennifer Lamfers, AuD

We all know that turning the volume up too high or standing too close to speakers is going to permanently damage our hearing and once ringing occurs or we experience a sudden decrease in hearing, there is permanent damage. That is true. But what if that reaction is also partly protective?

A study in Australia shows that in mice, those who were able to have a sudden hearing decrease reaction had a lower degree of permanent loss than those mice whose genes were alerted to deter that reaction. The researchers uncovered this by breeding mice to lack a specific gene thought to protect the inner ear. The mice in the control group and the specifically bred mice were then exposed to a moderately loud noise for a sustained time of 12 hours. Those mice whose genes were altered experienced less temporary effects but suffered more permanent damage. The results showed that although a sudden decrease in hearing and sudden increase in ringing (tinnitus) means that there is damage, it could have been worse.

People who are experiencing sudden sensorineural hearing loss (SSHL) should consult their physician right away. SSHL can also be linked to side effects to certain prescription medications and they should discuss discontinuing possible casual medications or if warranted, seeking a steroid treatment with their physician if medically appropriate. Some patients recover completely without medical intervention, often within the first three days, and others get better slowly over a one to two week period. David Kirkwood had published the Otolaryngology Foundation's guidelines for SSHL last year.

The general rule to use is this: if the sudden sensorineural hearing loss from loud noise has been present for more than two weeks it will likely not recover on its own and it is time to seek a comprehensive audiological evaluation and consultation regarding amplification.

http://hearinghealthmatters.org/hearin privatepractice/2013/reaction-time-sudden-decrease-in-hearing/

OTOLARYNGOLOGY FOUNDATION PUBLISHES GUIDELINES ON SUDDEN HEARING LOSS

By David Kirkwood

If you or a loved one experiences sudden hearing loss (SSHL) in one or both ears, getting a prompt and accurate diagnosis – and treatment, if necessary – is important in reducing the chance that the loss will become permanent.

So says the American Academy of Otolaryngology-Head and Neck Surgery Foundation (AAO-HSNF) in its new Clinical Practice Guideline on Sudden Hearing Loss (SHL) published March 1 as a supplement to *Otolaryngology-Head and Neck Surgery.*

SSHL is a frightening condition that may result from a variety of causes and that most often prompts urgent medical care. The foundation's guideline provides evidence-based recommendations for the diagnosis, management, and follow-up of adults who present with SHL. According to the foundation, prompt, accurate recognition and management of sudden sensorineural hearing loss (SSHL), a subset of SHL, may improve hearing recovery and patient quality of life. SSHL affects 5 to 20 per 100,000 people, with about 4000 new cases a year in the United States.

The guideline is intended to help any clinician who may encounter patients with SSHL. By focusing on opportunities for quality improvement, the guideline seeks to improve diagnostic accuracy, facilitate prompt intervention, decrease variations in management, reduce unnecessary tests and imaging procedures, and improve hearing and rehabilitative outcomes for affected patients.

KEY POINTS IN THE GUIDELINE

Among the main recommendations in the guideline are:

(1) Prompt and accurate diagnosis is important: (A) Sensorineural (nerve) hearing loss should be distinguished clinically from conductive (mechanical) hearing loss. (B) The diagnosis of idiopathic sudden sensorineural hearing loss (SSHL) is made when audiometry confirms a 30-dB hearing loss at three consecutive frequencies and no underlying condition can be identified by history or physical exam.

(2) Unnecessary tests and treatments should be avoided: (A) Routine head/brain CT scans, often ordered in the ER setting, are not helpful and expose the patient to ionizing radiation.

(B) Routine, non-targeted, laboratory testing is not recommended.
(3) Initial therapy for SSHL may include corticosteroids.

(4) Follow-up and counseling is important: (A) Physicians should educate patients with ISSNHL about the natural history of the condition, the benefits and risks of medical interventions, and the limitations of existing evidence regarding efficacy. (B) Physicians should obtain follow-up audiometry within six months of diagnosis for patients with SSHL. (C) Physicians should counsel patients with incomplete hearing recovery about the possible benefits of amplification and hearing assistive technology and other supportive measures.

http://hearinghealthmatters.org/hearingnewswatch/2012/otolaryngology-foundation-offers-advice-on-sudden-hearing-loss/

NEUROMA OR SCHWANNOMA – EITHER WAY IT'S A TUMOUR

By Judy Huch

As an audiologist I was taught about the hearing test early on. Though I do have to keep my eye out for many disorders, there is one condition that always seems to be on the top of my mind, acoustic neuroma, or vestibular schwannoma. This is a slow-growing, (1.5 mm a year) benign tumor (non-spreading, non-malignant) found on the acoustic nerve from the cells making the myelin sheath.

The VIII cranial nerve, the acoustic nerve, controls hearing and balance and lies very close to the VII cranial nerve, the facial nerve, which supplies the neural pathway for motion to the muscles for facial expression. In fact, both cranial nerves pass through a bony canal, which is named the internal auditory canal. Early symptoms are hearing loss, which is worse on one side (in most cases if the tumour is on only one side, type 1) as well as tinnitus on the affected side. Later, as the tumour grows, balance and facial muscle symptoms can develop. Alan Desmond has discussed audiometric testing in detail in a 2011 post.

When I look at the numbers, I see that only a very small number of individuals develop this condition, yet it seems that this is the top worry whenever I test. A study in Denmark, published in 2004, had a very large sampling showing 2 people out of 100,000 will have an acoustic tumour. Some argue that the incidence is rising, but this is most likely due to better diagnostics, including the advancements of MRI scanning and better referrals for those experiencing symptoms. The general consensus is that both sexes are affected equally and is usually diagnosed between the ages of 30 and 60. There is usually only one side affected by the tumour. David Kirkwood reported last year how an ENT was sued over missing an acoustic tumour, which is most likely why it is on my mind during diagnostic testing. I would not want to be the provider to miss this.

How does a tumour form? It is not entirely understood, but some suggest genetically there is a breakdown in tumour suppression genes that allows the tumour to grow. There is no concrete proof that an external factor such as cell phones create these tumours. There is a condition, neurofibromatosis (NF2), which is a genetic disorder affecting 1 in 50,000 births. With this condition, tumors grow in both sides of the head on the acoustic nerve. If this occurs there is a chance of losing the hearing on both sides leading to complete deafness.

Treatment consists of three areas – observation, radiation, and surgical removal. Since the tumour surrounds the nerve, a specialist should be used for consultation. Neurosurgeons and/or neurotologists are surgeons who specialize in the ear area and perform delicate surgeries. They depend on a team of other providers to cover other areas that may be affected. No one treatment is right for every patient. If the tumour is very slow growing and the patient is not in good health, the best option might be to watch and wait.

Surgical removal may be an option in the case of NF2 with a smaller tumor or faster growing tumors in young healthy persons.

The last option is radiation. There are

two techniques – one delivered as a single dose, stereotactic radiosurgery (SRS), and the other is multi-session fractionated stereotactic radiotherapy (FSR). Each is targeted to stop growth and kill the tumor (necrosis). With radiation there is a chance for some hearing to be retained in the treated ear, which must be monitored during and after treatment.

The Acoustic Neuroma Association provides education and support to those faced with this type of condition. The ANA also has a Facebook page.

http://hearinghealthmatters.org/hearinprivatepractice/2013/neuroma-schwannoma-either-way-it-is-a-tumor/

Where are the Hearing Loss Heroes?

By Gael Hannan
gdhannan@rogers.com

In Canada, we don't do heroes very well. Not in the way that other countries put people, deserving or not, up on pedestals to be lauded and adored.

In Canada, we have countless citizens just as deserving of heroic adjectives – but we just don't *celebrate* them very well. We're not a splashy lot, reluctant to go overboard in extended public displays of affection. American-style hero worship makes us uncomfortable; we wouldn't be caught dead in adoring mobs, punching sticks in the air with *pictures* of the objects of our affection. No, we're more likely – from the comfort of our seat in front of the television or computer screen – to give a heartfelt but reserved, *Way to go, eh!*

When we do recognize incredible feats of courage and citizenship, in quiet ceremonies at city hall or on Parliament Hill. But maybe we need to change a bit, shake things up.

We need to strike up the band more often, because we need heroes to inspire us, to give us a chance to celebrate what is wonderful in life.

We need some *hearing loss heroes*. The hearing health care industry needs to recognize and applaud not just its own members, but also the people it serves. Some hearing aid manufacturers in the US recognize outstanding people with hearing loss who have made a difference in their community or on the national scene. One company uses the online nomination-and-voting process that brings them a huge consumer response and some good publicity.

Could we not do that here in Canada?

Canadians with hearing loss are fighting for increased awareness of our disability. We are struggling to articulate that our needs go beyond hearing aids and cochlear implants; we need public recognition, accessibility, laws, and opportunities. We are finding ways to identify our accessibility needs and demanding access from governments and businesses. We are bringing hearing loss out of the closet and while we're at it we're asking questions, not all of them comfortable, of our hearing healthcare and technology providers. We are holding meetings and conferences, teaching speechreading, and connecting on online forums where we share questions and ideas.

We're doing this not only to help ourselves but to make life with hearing loss *easier* for everyone who has it – and those who are *going* to have it. And, quite frankly, we do all of this with little recognition from the professional players.

Many consumer organizations such as the Canadian Hard of Hearing Association celebrate our luminous members through annual awards and scholarships. We *also* celebrate outstanding professionals.

So, how about returning the favour, national hearing-related organizations, retailers, and manufacturers? Why not celebrate your "consumers" through awards, scholarships – or even simple recognition on your websites?

And it can happen at the local level, too. Individual clinics could recognize a Client of the Month in newsletters that go to your client base. Why not an article about what that person has done to live more successfully with hearing loss – or what he or she is doing to help others? Or go completely *out there* and put their picture up in your clinic as a shining example of success. For many, simply breaking through the taboo of hearing aids or admitting a hearing loss is a monumental act of courage.

As consumers with hearing loss, we value and depend on the expertise and comfort we get from our hearing health care providers. You are our partners in hearing health. So let's work together to inspire thousands, millions, of Canadians to finally accept their hearing loss – and to not accept the discriminatory practices that still exist in our society.

Let's celebrate our hearing loss heroes – because we have many.

Canadian Hearing Report 2013;8(5):13.

Prostheses for Vestibular Loss

By Christopher Phillips and Jay T. Rubinstein
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Vestibular disorders are both common and debilitating. According to the National Institutes of Health, dizziness and vertigo are among the top 25 reasons that patients seek medical care in the United States, accounting for more than 5 million visits to a doctor each year. 36% of the U.S. population will see their doctor with a complaint of dizziness at least once in their lifetime.[1] For most patients, the dizziness is either short lived or can be treated effectively by their primary care physician. In some cases, however, an acute attack of dizziness can lead to a permanent and debilitating condition of chronic disequilibrium. Typically, this is due to a loss of the hair cell receptors or vestibular afferent neurons of the inner ear. This condition cannot be effectively reversed by current therapies. Patients can, in most cases, adapt to this loss of function, a process that can be aided by vestibular rehabilitation specialists, who work to assure that the final compensation state is appropriate for a range of activities and environmental conditions. However, for many other patients, the compensation is not adequate to allow a return to a normal life.

Meniere's disease is an example of a condition where recurring acute attacks of vertigo, over time, leads to a permanent loss of vestibular function. Patients with Meniere's disease are commonly young to middle age adults, many of whom lead active lives. Typically, these patients present with episodic low frequency hearing loss, tinnitus, aural fullness and profound attacks of vertigo. Frequently, such patients experience nausea and vomiting with their attacks, which can last for several hours, after which the patients slowly recover function and can return to low levels of activity. Between attacks, most patients with early Meniere's disease are essentially normal. Although the exact pathophysiology of Meniere's disease is not known, it is thought that the disorder arises from endolymphatic hydrops, an accumulation of fluid in the inner ear, resulting in distention and then rupture of the membranes that provide the electrical potentials that drive the sensory processes. When the rupture occurs, the afferent fibers, which constantly convey information centrally from the vestibular end organs, may suddenly decrease their firing rate. If this occurs unilaterally, as it usually does, the brain interprets the difference between a robust signal from the non-affected ear and an abnormal signal from the affected ear as arising from a continuous rotation away from the affected ear. As the ear heals from the rupture and the potentials are reestablished, the normal activity is restored, and the vestibular system functions normally. After repeated attacks, however, this process takes its toll on the function of the inner ear. This means that late Meniere's patients can experience an increasing sense of disequilibrium between their attacks, as the end organs of the inner ear slowly lose the ability to transduce motion.

While the natural history of Meniere's disease leads to a chronic loss of vestibular function, the many medical treatments for Meniere's disease themselves may also intentionally hasten this process. To eliminate the debilitating fluctuation in function, neurotologists often offer a destructive therapy to reduce or eliminate function in the affected ear. The physician may perform a labyrinthectomy of the affected ear, which permanently eliminates hearing and balance information from that ear. They may propose a nerve section of the vestibular branch of the 8th nerve, which spares hearing but eliminates vestibular function in the affected ear. Finally, they may inject an ototoxic aminoglycoside antibiotic into the affected ear, which progressively reduces vestibular function in that ear, and may spare hearing. All of these interventions reduce and eventually eliminate vestibular function. Optimally, the patient is now free of attacks, but must deal with the chronic loss of vestibular function for which, if symptomatic, there is no current solution.

For these reasons, there is a great need for new, rehabilitative treatment strategies, which restore vestibular function for patients with vestibular loss. Cochlear implants have proven to be a remarkably successful technology for restoring hearing in patients with sensorineural hearing loss. Peripheral vestibular loss is a comparable problem: when the transduction mechanisms in the vestibular labyrinth cease to function normally either through the course of disease or following a destructive medical intervention, the afferent fibers themselves may remain intact and remain capable of conveying information centrally. Encouraged by this, some research groups have begun investigating chronically implantable vestibular neurostimulators, similar to cochlear implants, which act as vestibular prosthetics by directly stimulating these afferent fibers.[2]

Some particular aspects of the vestibular anatomy and physiology are encouraging for the development of such a device. First, afferents innervating the vestibular end organs are sensitive to galvanic stimulation, similar to those located in the cochlea. These afferents encode head linear acceleration or rotational velocity information by modulating their firing rate around a baseline resting rate: rotation of the head towards the ear is excitatory and increases the firing rate of the afferent, while rotations in the opposite direction have the opposite effect. Early experiments in vestibular neurophysiology have shown that localized galvanic stimulation can be used to directly modulate the firing rate of vestibular afferents. Furthermore, this same stimulation drives behavior mediated by vestibular reflexes.[3–4]

Second, while the afferents innervating the cochlea are arranged tonotopically, those innervating the vestibular end organs are arranged based on their specific directional sensitivity. Within the three semicircular canals (SCCs), which are the sensory organs for rotational motion, all of the hair cells in each ampulla are plane polarized, such that they have a uniform directional sensitivity that is maximally sensitive to rotations in the plane of their canal. In contrast, the hair cells located in the maculae of the otolith organs, the saccule and utricle, which sense linear motion, are oriented around a central line that divides the tissue. As a result, each area of the macula is sensitive to motion in a unique direction. Because electrical stimulation techniques are not capable of directing current to specific regions of these tissues, much work on the development of vestibular prostheses has excluded the otolith organs and instead focused on the three SCCs, where stimulation of an entire ampulla encodes motion in a single direction.

Finally, the vestibular nerve branches innervating a given SCC are anatomically distinct, such that localized electrical stimulation of a single canal without unwanted activation of afferents with different directional sensitivity is possible. Taken together, a multichannel vestibular prosthesis that can selectively deliver localized stimulation within the ampullae of individual SCCs, in conjunction with a head mounted rotational sensor, could serve as a functional vestibular prosthesis.

Results in the laboratory have been encouraging for this line of reasoning. Implantable single channel (i.e., with a single stimulating site) and multi channel neurostimulators have been developed and tested in animal models. One such device, developed by our group at the University of Washington, is a modified Nucleus Freedom cochlear implant (Cochlear, Ltd., Sydney). This device contains three separate leads, each of which contains multiple stimulation sites at the distal end of each lead. During surgical implantation, the tips of each lead are inserted into the vestibular labyrinth adjacent to the ampulla of each SCC through small fenestrations in the bony labyrinth. In animal models, implantation is well tolerated and the devices remain functional over long periods of time.[5]

Similar to the results of early neurophysiology experiments, these chronically implanted devices are capable of driving afferent neurons and eliciting behavioral responses through electrical stimulation. The UW/Cochlear vestibular prosthesis employs trains of biphasic stimulation pulses, which can be modulated in frequency or current amplitude, effectively modulating the rate at which afferent neurons are driven to fire or the size of the afferent population affected by stimulation, respectively. Recordings made in the vestibular nuclei during stimulation trains show that secondary vestibular neurons – those receiving information from the vestibular end organs – are driven similarly to the afferent neurons. This suggests that the artificially induced signal produced by the neurostimulator is propagated within the central vestibular system. The behaviors most readily used to study the vestibular system are the eye movements from the vestibulo-ocular reflex (VOR). VOR assists in stabilizing the visual field on the retina by compulsory movements of the eyes opposite to movements of the head. In the clinic, VOR responses to passive rotation can be a powerful tool for identifying vestibular deficits. Electrical stimulation from these devices also elicits eye movements comparable to those from VOR during natural rotation.

Electrical stimulation drives eye movements parametrically. Stimulation delivered to the lateral SCC alone will elicit eye movements directed in the horizontal plane, as would mechanical manipulation of a healthy lateral canal (similar to the effects of warm water calorics, as conducted in the clinic) or a yaw rotation of the body or head. In contrast, stimulation of either of the two vertical canals yields eye movements with vertical and torsional components. Modulation of the pulse rate or the current amplitude modulates the velocity of the eye movements, such that increasing either will result in a faster slow phase eye movement. Together, these findings in animal models show that selective stimulation of individual canals does result in controlled eye movements that are identical to those produced naturally during rotation.[6]

VOR is a well studied and understood aspect of the vestibular system and for that reason is an ideal system to evaluate the efficacy of vestibular neuro-stimulators. However, the vestibular system is multimodal and clinical manifestations of dysfunctional VOR, such as oscillopsia – the sensation of world movement during self-motion due to a lack of the stabilizing eye movements arising from VOR – are often not the sole or even the most debilitating aspect of vestibular loss. The effects of vestibular stimulation on balance and perception of motion must be studied carefully in order to develop a vestibular prosthetic that addresses patient needs. Some experiments have been conducted in animal models that suggest that these other modalities of the vestibular system are similarly affected by stimulation.[7] However, it is more difficult to assess postural or perceptual responses in animal models. In addition, it is difficult to translate those results to those that we might expect from human subjects.

To date, our group has implanted four human subjects suffering from severe unilateral Meniere's disease with the UW/Cochlear vestibular prosthesis. These patients had previously failed conservative treatment of their Meniere's disease. As a treatment for Meniere's, the neurostimulator is not connected to a rotational sensor, nor is the device delivering constant stimulation, as you would want to provide for a complete vestibular prosthetic. Instead, the device is intended to act as a vestibular pacemaker. When the patients experience a Meniere's episode, they can activate the device to stimulate at a constant rate and current to drive the vestibular afferents. This stimulation can remain on until the episode subsides and the vestibular system can resume a baseline level of activity without the aid of the device. These patients, followed by another group of patients in Maastricht and Geneva using a different device,[8] are the first to receive a therapy of this type as a treatment for vestibular loss.

The device implanted in the human Meniere's patients is identical in design to those used in previous studies in non-human primates. The effects of vestibular stimulation in human subjects are in many ways similar to those observed in animal models.[9] Electrical stimulation is well tolerated by human subjects. Eye movements elicited by stimulation are not accompanied by auditory sensations, facial nerve activation, or pain. This suggests that the vestibular nerve can be activated without activating the adjacent facial or cochlear nerve. As in animal models, the direction and velocity of the elicited eye movements could be controlled by selectively stimulating individual SCC ampullae at different frequencies or current amplitudes. However, the velocities elicited in human subjects typically were lower than those elicited in non-human primates at comparable stimulation levels. This may be a product of the larger anatomy of the human inner ear, which could be compensated for by redesigning the neurostimulator to include larger stimulation sites. Despite the lower velocities, that the eye movement responses of humans are roughly comparable to those from non-human primates is an encouraging result for the development of a vestibular prosthesis.

Results from human subjects show that electrical stimulation affects multiple vestibular modalities concurrently. While seated, electrical stimulation elicits a perception of self motion typically opposite in direction to the elicited eye movement. While standing upright in quiet stance, the same stimulation elicits a postural response in the form of whole body sway.[10] Both the postural and perceptual responses, like eye movement responses, can be controlled in direction and magnitude by selecting the location of stimulation and the current or frequency of the stimulus. However, early results from these experiments suggest that different vestibular subsystems may be driven unequally by the electrical stimulation employed by current devices. Stimulation at a given current may elicit a sensation of turning 180 degrees while the concurrent eye movement response would be much smaller in amplitude. Nevertheless, these early results are encouraging for a vestibular prosthesis as a restorative treatment for vestibular loss, where VOR, postural, and perceptual deficits can all be handicaps.

There are many challenges remaining for the full development and imple-mentation of a vestibular prosthesis, which represent future directions for research. Vestibular prostheses need to be extensively studied in humans. It is important that we study processes such as perception of motion and postural performance during daily activity as well. These may be difficult or impossible to assess adequately in animal models, and there may be significant differences between human and animal vestibular responses to stimulation with these devices. We must extensively study these behaviours and the systems that produce them in human subjects in order to optimize stimulation parameters across modalities and behavioral contexts. Our early results suggest that electrical stimulation may produce a mismatch in the motion commands to the various subsystems that utilize vestibular information, producing poorly aligned sensation, posture, and eye movement. This challenge may be overcome by the adaptive capability of the central nervous system, but it is likely that we will discover new and better ways of driving vestibular sensation through continued experimentation, which will facilitate this adaptation and produce a better therapeutic result.

Second, we must develop strategies for and evaluate the effects of, long-term continuous electrical stimulation of the vestibular system with a prosthesis. This work can and should proceed in human subjects and in animal models. Our results in humans and animals with intermittent stimulation suggest that there is both preservation of effective stimulation for months to years, and also high variability in the longevity of stimulation to different electrodes, different end organs, and different subjects. This variability suggests that strategies may need to be developed for the continuous tuning of stimulation maps to compensate for the changes in efficacy that result over time.

Finally, we really have very little data on the effect of electrical stimulation with a vestibular prosthesis on the central nervous system. We empirically understand the short-term behaviours that such stimulation evokes, but the underlying mechanism is largely unexplored. Neurophysiological experiments need to be undertaken to study the central processes that allow for integration of the abnormally synchronous neural inputs from vestibular prostheses, and then combine these signals with the information from other sensory modalities. Only a thorough understanding of these processes will allow future engineers to design devices that maximize benefit to the patient while minimizing the other effects of what is essentially a new sensory system, combining the pathways and surviving elements of a damaged vestibular system with a novel technology for signaling motion to the brain.

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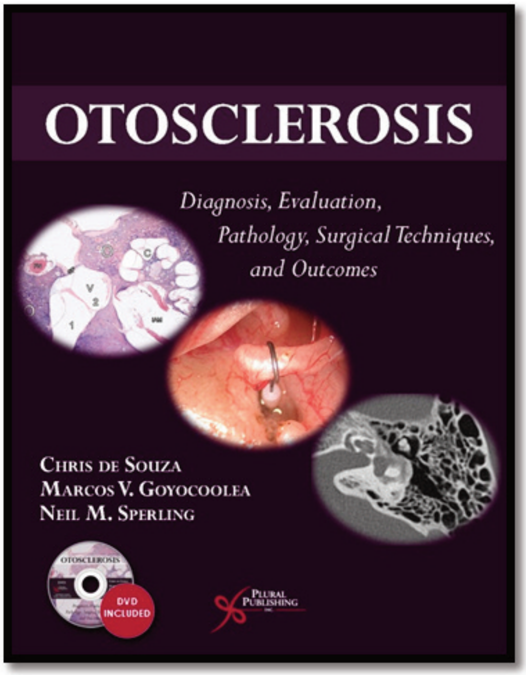
Editor's note: For those who are interested in becoming involved in a new CAA interest group on vestibular issues, please contact either Maxine Armstrong (Maxime.Armstrong@uhn.ca) or Janine Verge (Janine.Verge@cdha.nshealth.ca).

Canadian Hearing Report 2013;8(5):14-17.



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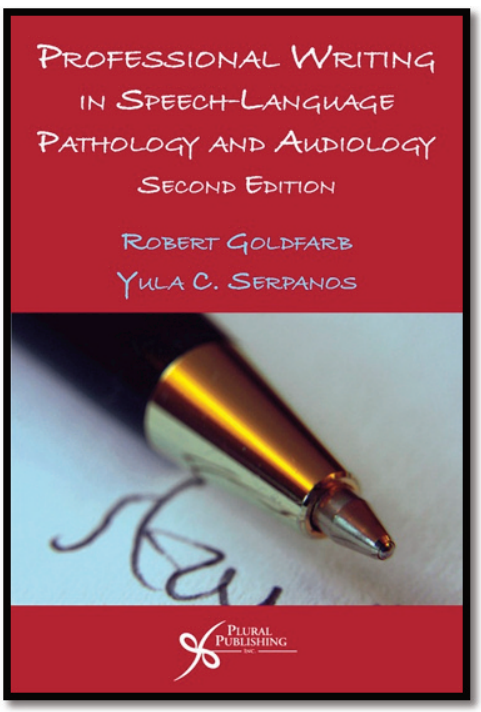

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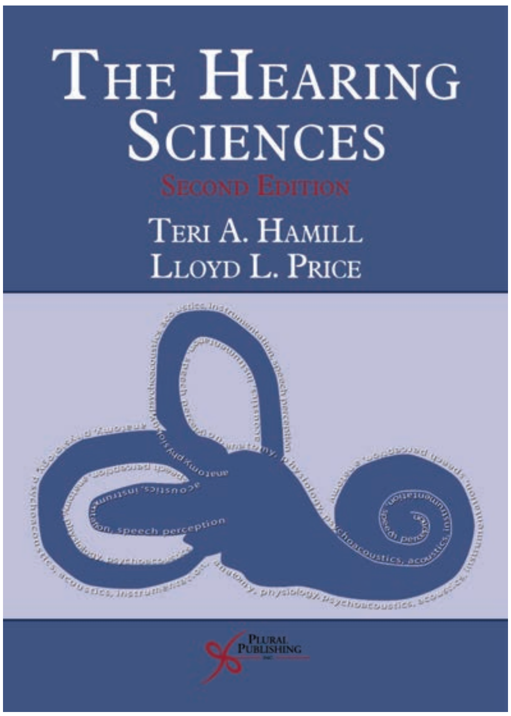

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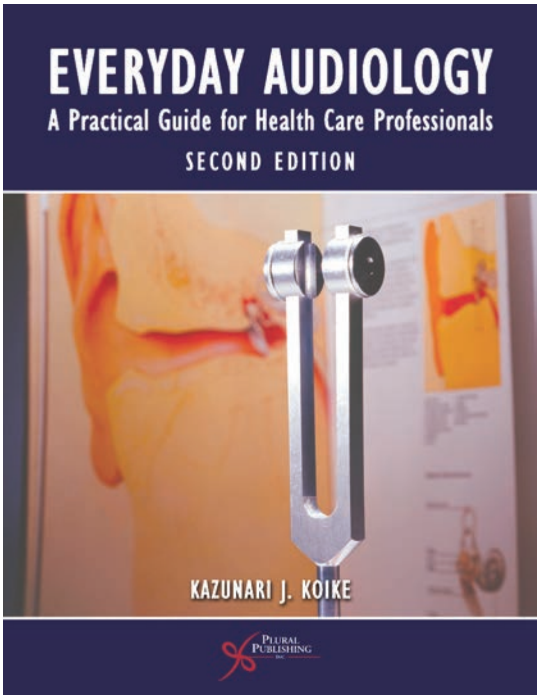

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EVERYDAY AUDIOLOGY
A PRACTICAL GUIDE FOR HEALTH CARE PROFESSIONALS, SECOND EDITION

Kazunari Koike, PhD

ABOUT THE BOOK

Everyday Audiology, Second Edition is an invaluable guide for clinicians involved in the care of patients with hearing impairment or balance disorders. Originally written for ENT residents, it has also become a useful resource for other health care professionals who need to synthesize audiologic test results and come up with one cohesive clinical diagnosis. This includes otolaryngologists, family medicine physicians, pediatricians, medical students, audiologists, audiology students, teachers of the hearing impaired, hearing instrument specialists, speech-language pathologists who work with hearing- impaired children, and even physical therapists who provide rehabilitation to patients with balance disorders.

The book contains clinically relevant norms and values that are extremely useful for clinical interpretation. Drawn from lectures given to otolaryngology-head and neck surgery residents and case reports conducted by clinical audiologists at West Virginia University School of Medicine, the book is designed for easy consumption of essential information. Key concepts are presented on left-hand pages and supporting and tabular material on the right.

The book is divided into five parts:

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- Part II: Evaluation of Balance Disorders
- Part III: Rehabilitation of Hearing Disorders
- Part IV: Otologic/Audiologic Differential Diagnosis
- Part V: References and Notes

For the second edition, there is an addition of an entirely new section. Otologic/audiologic diagnoses that are commonly seen in otology and audiology clinics are presented with a battery of associated audiologic examinations . In this new section (Part IV), the diagnostic code, commonly known as International Classification of Diseases 9th Revision Clinical Modification (ICD-9-CM), is conveniently provided under each case as a reference.

Frequently used audiology terminology and significant clinical criteria are printed in bold. The Current Procedural Terminology (CPT) code, if available, is listed under each test procedure. This book has been found to be helpful in preparation for periodic in-service exams for ENT residents, the ASHA praxis exam for AuD students, and the Step 2 clinical exam for medical students.

ROESER'S AUDIOLOGY DESK REFERENCE, ROSS ROESER, 2ND EDITION, THIEME MEDICAL PUBLISHERS, INC., 2013, 434 PAGES

Reviewed by Marshall Chasin, AuD,
Doctor of Audiology
August 2013

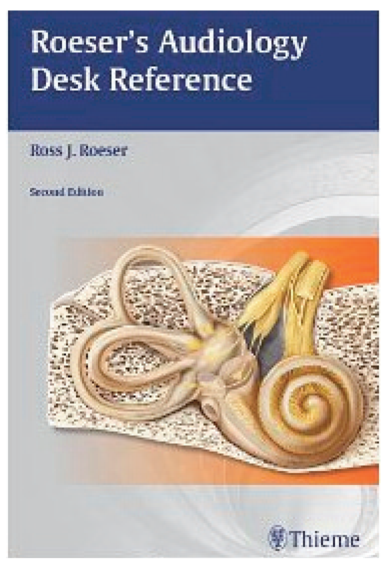
Whenever one sits down to review a book a review of the chapters, strengths and weaknesses, of the text are typically done. This is a second edition of this text and typically one would dwell on the sometimes subtle differences between the first and second editions. However, the first edition was in 1996 – well over a decade has passed. Despite the title of this book, it really is a first edition. In 1996 we were still just learning to turn to the Internet for information – today, it is typically the first thing. Nevertheless, as pointed out by Dr. Roeser in the preface, there is still something special about being able to hold an actual book in your hand and thumb through the pages to see related and relevant information.

I do admit to a bit of trepidation about reviewing this book since it's unlike many other audiology text books where neatly crafted chapters can be written on one topic. I dreaded looking at it sitting on my desk and fearing that it would be unreadable. However, before I had a chance to perform the task to reviewing the book, I found a use for it. I needed some information about the units of "intensity" versus that of "sound pressure." And there is was on page 119. Over the two or three weeks since I received it in the mail for review, I have referred to it about 10 times. Each time the desired information was sitting right there in front of me in a clear table or figure format.

Before I even begin to review the book, I can guarantee that it will stay on my desk and not be filed away on my book shelf – to date I have not been disappointed by the accessibility of the book and the clarity (and well referenced) information.

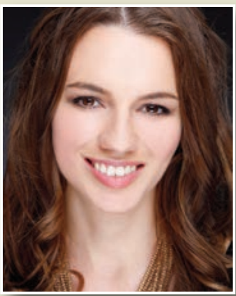
The *Roeser's Audiology Desk Reference* has 10 sections – each replete with figures or tables. Very little text clutters up the space in between. Section one, which comprises almost a third of the entire book, is about anatomy and physiology. This has been co-compiled with Dr. Gary Wright. The use of red as a highlighted colour makes for easy access for the illustrations in the text. Section two is on physical acoustics and reviews virtually any question that a practicing audiologist would ever need. Section three is on audiometric standards, and it is quite up to date. Section four (co-compiled with Doctors Jackie Clark and De Wet Swanepoel) is about 150 pages long and deals with all aspects of audiological procedures and materials. Section five is about tinnitus and provides the reader with an unbiased overview of the salient elements of many approaches and assessments. Section six has been co-compiled with Deanna Meinke – a world authority in hearing loss prevention, and no surprise, is entitled hearing loss prevention. Section seven covers the various aspects of Vestibular assessment and rehabilitation. Section eight is a very nice overview of the salient aspects of modern hearing instruments. Section nine, co-compiled with Dr. Jackie Clark is on the psychosocial aspects and rehabilitation of hearing loss. Section ten is on deafness and provides an overview of some of the modes of communication that deaf people utilize. Section 11 provides us with a large listing of organizations and publications, replete with fully functional URL addresses. And, finally I would be remiss if I did not mention the wonderfully complete index section at the end. To date, it has never failed me.

This is a text that I will not give away – it will stay on my desk waiting for the next question that I don't have an answer for off the top of my head. I would strongly recommend that all practicing audiologists and many other hearing health care professionals obtain this book. I'm not going to be lending out my copy!



Short Term Plasticity and Hearing Aid Use: Do We Have an Internal Volume Control?

By Jessica F. Merrett and Kevin J. Munro
jfmerrett@gmail.com



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Jessica Merrett completed her MSc in audiology at the University of Manchester in 2010-2011. Currently, she is working as a trainee clinical scientist at Bradford Royal Infirmary, UK. Kevin Munro is a professor with the School of Psychological Sciences, University of Manchester, Manchester, United Kingdom.

The auditory system is far from being a hard-wired processing machine. It boasts a dynamically connected map of ipsilateral and contralateral pathways that retain a great deal of plasticity throughout adulthood. "Auditory plasticity" is a term used to describe changes in the anatomical and physiological properties of neurons in the brain, following a change in auditory input or experience.[1] Such experience related physiological reorganisation is often accompanied by perceptual changes which may, or may not, be helpful to the individual.

The main cause of auditory plasticity in humans results from a reduction in auditory input to the central auditory system due to a sensorineural or conductive hearing loss. Reintroducing auditory input through hearing aid use or cochlear implantation has been shown to induce secondary plasticity.[2] The implications of long term deprivation and stimulation have been found to affect a range of physiological and perceptual measures including loudness perception, intensity discrimination, the auditory brainstem response and the acoustic reflex threshold (ART).[3] Some of these changes are thought to result from a "central gain mechanism."

The central gain mechanism can be likened to an internal volume control. Recent neurophysiologic research has proposed that high levels of neural gain are implicated in the disorders of tinnitus and hyperacusis.[4,5] It has been suggested that a central homeostatic mechanism causes an abnormal increase in central gain in response to auditory deprivation or trauma.[6] Consequently, a possible solution is to find ways to decrease central gain.

Previous research suggests that it is possible to manipulate central gain. Perceptual and physiological changes have been found to occur following short term auditory deprivation. Munro and Blout fitted 11 normal hearing adults with monaural ear plugs.[7] They found that after seven days of regular use the level required to elicit the acoustic reflex in the treatment ear (i.e., the ear with the earplug) decreased by 5–7 dB, relative to pre-treatment levels. Measurements made seven days post-treatment showed that the ART had returned to baseline values. It was hypothesised that because the plugged ear is deprived of input, neural processes increase the gain in order to restore average neural activity and this is revealed by a lower sound level required to elicit an acoustic reflex. When the earplug is removed, gain reverts back to pre-treatment levels and this is accompanied by an increase in the level required to elicit an acoustic reflex.

In addition to physiological changes, previous research has shown that it is possible to induce perceptual changes following short term auditory deprivation and stimulation. Formby and colleagues reported on 10 normal-hearing listeners who wore bilateral

Figure 1. Starkey S series, non-occluding, receiver in the canal (RIC) hearing instrument.

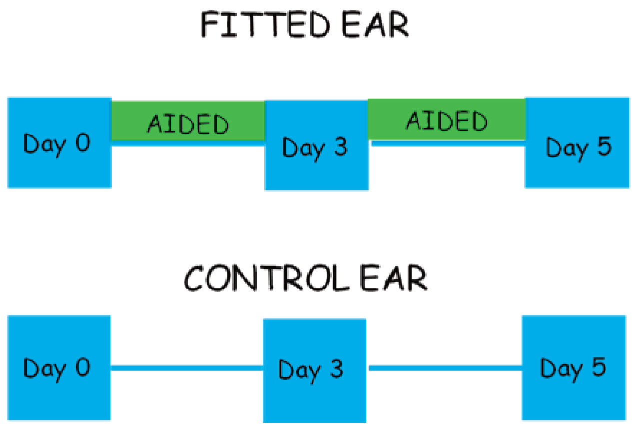

Figure 2. Timeline of test sessions. Blue boxes represent the test sessions for the fitted and the control ear. Baseline measurements were made on Day 0.

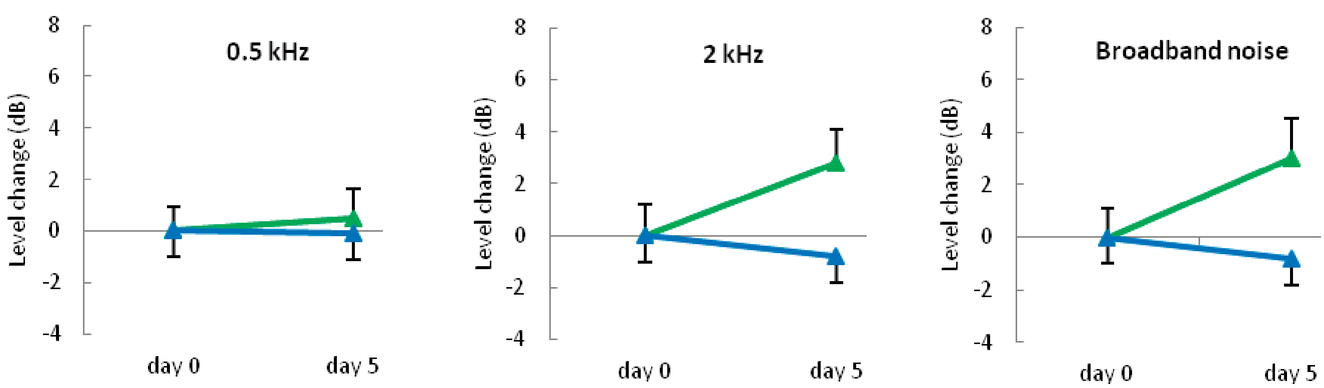

Figure 3. Mean change in acoustic reflex threshold for fitted ear (green symbols) and control ear (blue symbols). Error bars show ± standard error. Modified from Figure 2. in Munro and Merrett.[10]

earplugs (deprivation) or noise generators (stimulation) for 2–4 weeks.[8] After earplug experience, listeners required a decrease in level of around 6–8 dB to match pre-treatment loudness for moderate and high stimulus presentation levels. Conversely, listeners required an increase in level of around 6–8 dB after noise generator experience.

In summary, previous work suggests that short-term auditory deprivation results in a decrease in the ART, an increase in loudness of sounds and thus an increase in central gain. These findings were the motivation for our recent study; is it possible to induce plasticity in response to short term auditory stimulation?

The main aim of the study was to investigate the effect of short-term use of low-gain hearing aids on ARTs and loudness. We recruited 21 normal hearing adults for the study. The participants were fitted monaurally with a Starkey S series, non-occluding, receiver in the canal (RIC) hearing instrument (Figure 1.) The hearing aid settings were adjusted so that real-ear insertion gain such as the difference in response between the aided and unaided conditions, was 0 dB at 0.5 kHz and 15–20 dB at 2–4 kHz. Amplification was given at 2–4 kHz only, so that we could assess whether the treatment could induce frequency specific changes. The participants were asked to wear the device continuously for five days, except while in bed.

ARTs and loudness ratings for the fitted ear and the control ear were made on three occasions over a five day period: immediately before hearing aid fitting (day zero), after three days of hearing aid

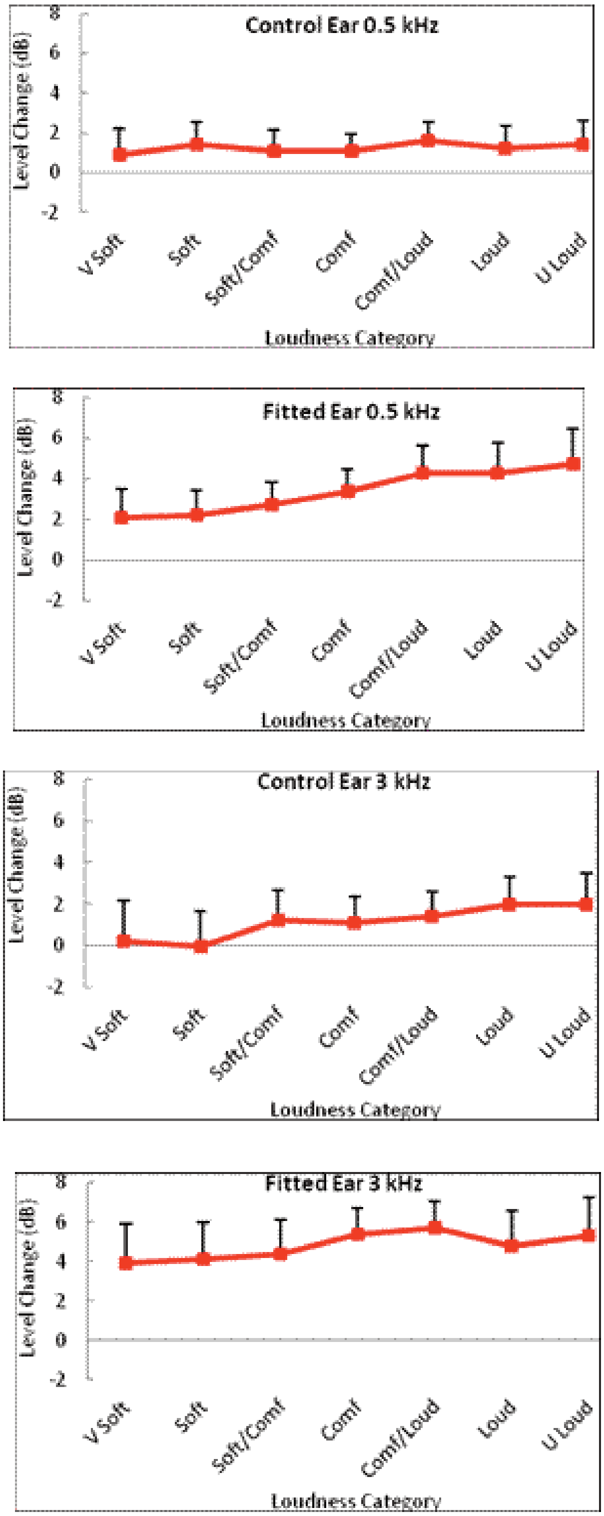

Figure 4. Mean change in loudness at day five. Error bars show ± standard error. Modified from Figure 3 in Munro and Merrett.[10]

use and after five days of hearing aid use (Figure 2.). Ipsilateral ARTs were measured using a 0.5 kHz, 2 kHz and broadband noise (BBN) stimulus. Loudness judgements were obtained with a 0.5 kHz and 3 kHz tone using the Contour Test of Loudness Perception.[9] Listeners used a response pad to assign one of seven loudness categories to a train of pulsed warble tones. The loudness categories ranged from "very soft" to "uncomfortably loud."

The mean change in ART at day five, relative to baseline, is shown in Figure 3. The data presented in this article compares the change at day five only. However, all the findings have been reported in Munro and Merrett.10 For the 0.5 kHz tone, the change was less than 2 dB in the fitted ear. For the 2 kHz tone, the change was greatest at day five, where the mean difference between ears was around 3 dB, primarily due to an increase in ART in the fitted ear. For BBN, there was a mean difference between ears of around 3–4 dB at day five.

The mean level change at each loudness category is shown in Figure. 4. For the fitted ear, listeners generally needed more intense stimuli (+3 to +5 dB) after wearing the hearing aid in order to give the same loudness judgements. In contrast, changes for the control ear were small and generally <1 dB.

The effect of amplification-induced stimulation is opposite to the effect of earplug-induced deprivation. Our results show an increase in the ART and an increase in loudness tolerance in the fitted ear following short term amplification. The change in ARTs provides support for a gain control mechanism. Because the fitted ear is provided with an 'enhanced' input, the gain is reduced and this is revealed by a higher sound level required to elicit the acoustic reflex.

In comparison to the loudness judgement changes, the changes in the ARTs appear to be relatively frequency specific. This may reflect different characteristics of the gain mechanism at different levels within the auditory system.

The findings in the present study may have implications for patients with tinnitus and/or sound tolerance problems. It is possible that ear plug use may increase neural gain and exacerbate perceptions such as tinnitus and hyperacusis. Computational models have illustrated how auditory deprivation may result in an increase in neural gain as homeostatic plasticity attempts to restore average neuronal activity.[11]

However, it would be important to replicate the study with a larger sample size, a longer treatment period and to make a comparison between solely high and low frequency stimulation.

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Noise-Reduction Headphone Effect on Localization Abilities of Portable Audio Device

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ABSTRACT
Noise reduction headphones and earphones are available for use with portable audio devices. These head- and earphones may result in a reduction of music-induced hearing loss. By blocking some external background noise, noise reduction phones may result in lower preferred listening levels (PLLs). However, as a result of attenuating environmental warning sounds and modifying localization cues, the localization abilities of wearers may be diminished, posing another risk of physical harm. To test this, sound localization abilities of thirty-nine normally hearing participants (age 21 to 30) who owned and regularly used portable audio devices were measured when wearing an audio device. Real-ear PLLs and localization abilities in a hemi-anechoic chamber were measured under two background noise conditions (ambient room noise and traffic noise) with

Portable audio devices (PADs) have flooded the markets in recent years. These devices store and play audio files and include smart phones and devices such as iPods and MP3 players. Such devices are increasing in popularity, especially among young adults, and their sales are increasing yearly as demonstrated by the National Product Development (NDP) group reports.[1,2]

PADs are frequently used in noisy backgrounds such as during commuting by bus or walking in the street. In such environments, users typically tend to increase the volume setting to maintain a comfortable music-to-noise ratio.[3–5] The National Institute for Occupational Safety and Health guidelines[6] recommends an exposure limit of 85 dBA for an eight hour time-weighted average in order to minimize the risk of noise-induced hearing loss. Portnuff et al. measured the output of five different PADs and found them to have similar output levels especially at the highest volume control settings.[7] Based on their measurements, and the NIOSH guidelines, they calculated guidelines for the recommended daily use of these devices: with the volume set at 70%, listeners should be able to listen to PADs for up to 4.6 hours/day without exceeding the NIOSH guidelines. However, when the volume is increased to 100%, listeners should restrict device use to no more than five minutes/day.

By increasing the volume control setting to overcome some of the masking produced by external noises, wearers may be increasing their risk of music-induced hearing loss.[4,8,9] Consumers are purchasing headphones and insert earphones that reduce the noise levels in the ear canal to reduce the masking effect of environmental sounds. These headphones may attenuate the external noise by fitting tightly in or around the ear, in the manner of earplugs or earmuffs. Alternatively some ear- and headphones use active noise cancellation circuitry to reduce the output for frequencies below 1000 Hz, while providing a boost to frequencies above 1000 Hz.[5] By blocking or attenuating environmental noises, noise-reduction headphones can help reduce the risk of music-induced hearing loss by obviating the need to increase the level of the music.[10]

While PLLs may decrease when noise-reduction headphones are worn, the attenuation of environmental sounds poses another safety issue. It is known that hearing protective devices degrade sound localization.[11,12] Not only do hearing protection devices reduce the intensity of environmental sounds, but they also may degrade the interaural loudness cues for sound localization. As a result, they may pose a risk of physical harm by degrading the user's ability to spatially locate important environmental sounds, such as approaching vehicles, sirens, and car horns. News reports of pedestrians and bicyclists who are wearing portable music devices being involved in vehicle-pedestrian collisions are so frequent that one New York City senator proposed legislation to ban the use of portable electronic devices, including PADs, for pedestrians while crossing the street.[13] Such pedestrian-vehicle collisions may be caused, at least in part, by three factors: (1) PAD wearers may be unable to detect the oncoming vehicle because of the environmental sound attenuation caused by the phones and the masking caused by the PAD music; (2) if the oncoming vehicle is detected, the wearer may not be able to localize the source of the hazard which makes the wearer unable to react quickly to the hazard; and (3) the music may provide social isolation that reduces the wearer's attention to environmental sounds.

In order to investigate the effects of headphones and music on the localization of warning sound perception, the effects of several headphone types on PLLs and horizontal sound localization in both quiet and traffic noise were examined.

STUDY DESIGN

The 39 participants had normal hearing, owned and used PADs for the purpose of listening to music, and ranged from 21–30 years of age (mean = 25.3 ± 2.8). Two tasks were conducted while the participants were wearing a Samsung (YP-T9JBQP) PAD and listening to a 60-second music selection: (1) real-ear measurement of the listener's preferred listening level (PLL) and (2) sound localization.

All testing was completed in a hemianechoic chamber. Participants were seated 1.5 meters from all speakers in the center of a 64-speaker array. All sounds were presented via a subset of eight speakers spaced 45° apart at the height of the listener's ear.

Each listener completed the tasks with four types of earphones. Group 1 (n = 20) was tested under the following phone conditions: (1) open ear canal (i.e., no headphone) – localization task only, (2) ear-bud (Samsung EP370 earbuds), (3) over-the-ear headphones (Sony MDR 210-LP), and (4) noise-reduction inserts (Skullcandy Smokin' Buds SCBUDP). Group 1 testing was completed both in quiet and in 83 dBA recorded stereo traffic noise. Group 2 (n = 19) was tested under the following phone conditions: (1) open ear canal – localization task only, (2) noise reduction inserts (Etymotic Research ER6i Isolator In-Ear Earphones), (3) noise-reduction over-the-ear (Sony MDR-NC6 Noise Cancelling), and (4) noise-reduction around-the-ear (Bose QuietComfort2 Acoustic Noise Cancelling). Group 2 testing was completed both in quiet and in 70 dBA recorded stereo traffic noise. Noise cancellation was activated during testing, where applicable. All headphones and/or earphones were adjusted by the experimenter to avoid changing the position of the probe tube microphone and to ensure proper insertion of ER6i inserts. The car horn level for both groups was 67 dBA. Because groups 1 and 2 completed the study at different times, with different headphone types and noise levels, separate repeated-measures ANOVAs were performed for the data in each group.

Task 1: Preferred Listening Levels

Following otoscopic examination of the canal, an ER-7C probe tube microphone system was placed in the left ear canal of each participant medial to the output of the earphone. The probe tube was inserted 28 mm for females and 30 mm for males from the intra-tragal notch. Otoscopy was performed a second time to verify that the tip of the probe tube was within 5 mm from the participant's tympanic membrane.[14] The probe tube was secured by tape to ensure the placement was maintained with each change of the headphone. SpectraPlus software was used to record and store the microphone data and compute the A-weighted sound levels in the ear canal.

Output levels of the PAD in the ear canal, as adjusted by each participant, were measured across all conditions. Beginning with the PAD player set to a volume level of 0 (mute), the participants were instructed to adjust the music volume to "where it sounds best to you." Participants were not able to see the numerical volume display on the PAD during this adjustment. Under each headphone condition, the sound levels in the ear canal were measured and the numeric volume setting of the device was documented and used to set the volume control for the sound localization task. No corrections were made to transform the PLLs to diffuse field equivalents.

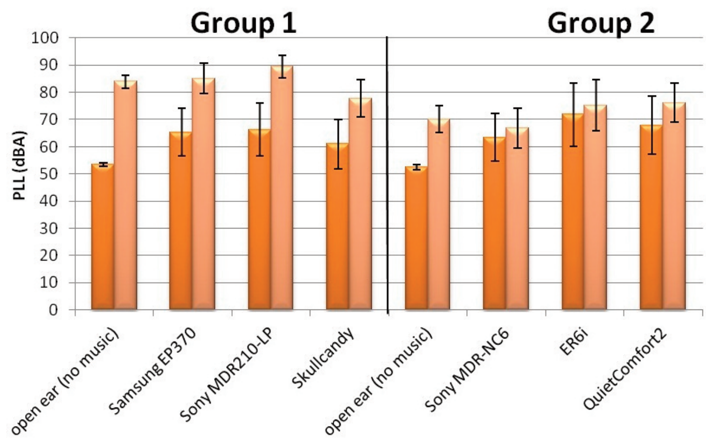

Figure 1. PLLs for different headphone types both in quiet and traffic noise. Dark bars – quiet; Light bars – traffic noise (83 dB A for Group 1 and 70 dB A for Group 2). Open ear conditions indicate the measured intensity of the noise background in the open ear canal. Error bars represent ± 1 standard deviation.

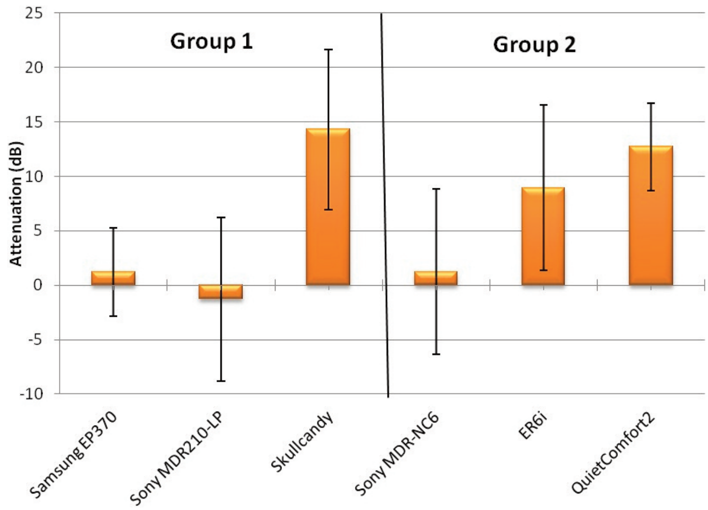

Figure 2. Estimated real ear attenuation of the background noise provided by the headphones. Error bars represent ± 1 standard deviation.

Task 2: Sound Localization

A sound localization task in quiet and background noise was conducted while music was simultaneously presented via ear/headphones at the PLL determined for the given headphone and noise condition. Following a training session using noise bursts only, participants were presented with a recording of a car horn from one of the eight speakers. The car horn was presented in a background of stereo traffic noise. Participants were instructed to orient their head towards the speaker that emitted the horn and register their response with a press of a button. An electromagnetic head tracking device determined their head position. Twenty-four presentations (3 from each of the 8 target speakers) were presented for each headphone and noise condition. There was a total of eight (2 noise conditions × 4 headphones) listening conditions per participant. Responses that were greater than 22.5° (i.e., midway between the target speakers) from the sound source speaker were scored as errors.

RESULTS

Participants reported using their PADs for 4.6 ± 1.6 days per week with a typical listening session, on average, of 1.1 ± 1.4 hours. This is consistent with Ahmed et al. who noted that half of the participants reported using their PADs for 5 to 7 days per week, for 2 hours/session[3] and Zogby et al.[15] None of our participants reported using their devices more than 4 hours/session. The self-reported duration of use appears to be related to the age of participants; Cheesman et al. revealed that high school students participate in noisy activities for longer periods (24.4 hours per week) than do university and college students (19.5 and 20.2 hours per week, respectively).[16]

Preferred Listening Levels (PLLs)

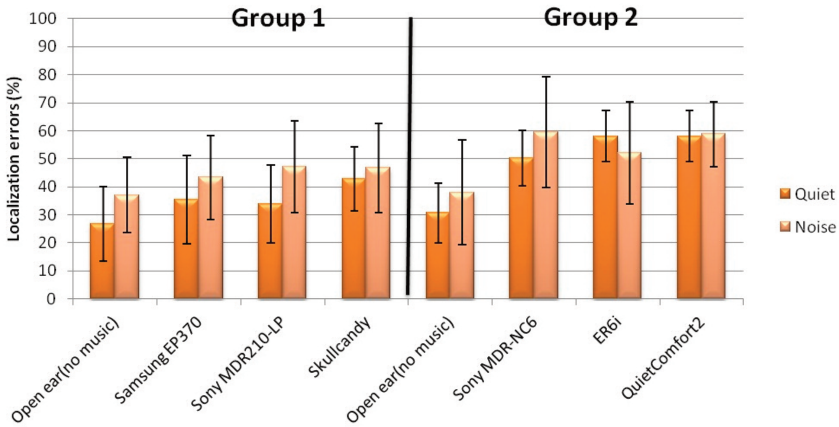

Figure 3. Localization errors for different headphone types both in quiet and traffic noise. Dark bars – quiet; Light bars – traffic noise (83dB A for Group 1 and 70 dB A for Group 2). Open ear conditions indicate localization performance without the PAD. Error bars represent ± 1 standard deviation.

Both groups had a significant main effect of headphone type (Group 1: [$F(2, 18) = 19.69$, $p < .001$]; Group 2 type [$F(2, 16) = 30.28$, $p < .001$), of background noise (Group 1: [$F(1, 19) = 124.65$, $p < .001$]; Group 2 [$F(1, 17) = 41.27$, $p < .001$]), and an interaction between headphone type and background noise (Group 1: [$F(2, 18) = 12.33$, $p < .001$]; Group 2: ([$F(2, 16) = 14.58$, $p < .001$]). Figure 1 illustrates the mean PLLs, as measured in the ear canal, for each headphone type.

Effect of the Listening Environment

The presence of traffic noise resulted in significantly higher PLLs for all headphone types (Group 1: [$F(1, 19) = 542.13$, $N = 20$, $p < .001$]; Group 2: [$F(1, 17) = 141.91$, $N = 19$, $p < .001$).

Effect of the Earphone Style

Headphone attenuation: An estimate of the amount of attenuation of environmental sounds provided by each headphone type was made by computing the difference of the sound level of the traffic noise in the open ear canal and when the headphone is worn without the music playing. Figure 2 shows the estimated attenuation for the six headphones.

Localization Errors

Participants in both groups generally made more errors in the traffic noise condition (Figure 3). Group 2 participants made significantly more localization errors than Group 1 despite the lower traffic noise intensity, where only one insert phone (Skullcandy) was of the noise-cancelling type. For Group 1, a repeated-measures ANOVA revealed a significant main effect of background noise ($F[1, 19] = 35.97$, $N = 20$, $p < .001$) and Headphone Type ($F[3, 57] = 10.99$, $N = 20$, $p < .001$). Localization errors increased in the Traffic Noise condition and with the use of the noise-cancelling insert phones in the Quiet condition. There was no significant interaction between Background Noise and Headphone Type. Repeated-measures ANOVA for the Group 2 data revealed no significant effect of background noise, headphone type, or any interactions between background noise and headphone type.

DISCUSSION

The results of the current studies support the notion that using PADs in the presence of background noise results in an increase in PLLs. Hodgetts et al.[5] and Henry and Foots,[17] have demonstrated similar effects of background noise on PLLs. The results also demonstrate that the use of different types of ear/head phones can result in significantly different PLLs. Fligor and Cox measured the maximum outputs of portable music players measured through a Knowles Electronics Manikin for Acoustic Research (KEMAR) and converted to free-field equivalent values.[18] They found a general trend that PLLs increase as the headphones decrease in size. Following Fligor and Cox, Hodgetts et al.[5] and Henry and Foots[17] have demonstrated similar findings, where the use of earbuds resulted in higher PLLs than either the larger-sized headphones, or when earbuds were combined with earmuffs. It is worth noting that Henry and Foots corrected the PLLs measured at the ear canal to free field equivalent values, while Hodgetts et al., as well as the current study, reported uncorrected PLLs measured at the ear canal. These findings are consistent with the result for the ER6i inserts, which produced significantly higher PLLs than the other two (over-the-ear and around-the-ear) headphones in quiet worn by the same listeners. However, Group 1 did not show similar results, where the over-the-ear headphones had higher PLLs than the other two inserts, one of which is a noise reduction insert "Skullcandy," that provided 12.95 ± 2.5 dB of noise attenuation. More attenuation of the traffic noise was observed for the noise-reduction and noise-cancelling headphones and earphones (for example, the ER6i provided 9.2 ± 0.4 dB, and Bose provided 13.04 ± 1.7 dB of attenuation) indicating that these devices were, indeed, effective at reducing the environmental noise reaching the wearer's ear. Furthermore, the noise-reduction and noise-cancelling devices resulted in lower overall sound levels in the ear canals when the devices were set to the listeners' PLLs (Figure 1). However, the noise-reduction and noise-cancelling head/ear phones resulted in higher localization errors when compared with the regular head/ear phones, as revealed from the results of Group 1. The presence of background noise also resulted in an increase in the localization errors. ER6i inserts were expected to provide > 30 dB of attenuation; however, in the current study they produced only about 10 dB of attenuation. This could be attributed to the spectral differences between the stimuli in the current study and the stimuli used to measure the attenuation.

CONCLUSION

The noise-cancelling headphones and insert phones tested here provided variable amounts of attenuation for the traffic noise that resulted in lower overall sound levels in the ear canals. From this perspective they may contribute to a decreased risk of music-induced hearing loss. However, these phones also significantly degraded the spatial localization abilities of the users, as revealed by the increased localization errors, even with the relative large (45°) spatial separation of target sounds used in the present study. This lack of good spatial hearing may expose the wearer to other risks of physical harm such as inability to quickly locate environmental sounds or warning signals. It should be noted that PLLs reported here reflect levels in the ear canal, thus cannot be compared to current damage-risk criteria,[6] but are still valid in terms of relative risk. Attention is an important factor in localizing alerting sounds; however, it was not possible in the current studies' settings to separate the relative contribution of inattention due to listening to a favorite music from the contribution of attenuated environmental alerting sounds (the car horn) on the localization errors. Further research is required in this direction.

According to Shah et al.,[19] 85% of PAD users are aware of the possibility of acquiring a music-induced hearing loss. Although noise-reduction headphones or insert phones may be an effective way to decrease that risk, when considering the selection of a headphone type, the preservation of sound localization abilities and the risk of potential hearing damage may present a tradeoff. In light of these data and reports of vehicle-pedestrian collisions, where the pedestrians and/or bicyclists are wearing portable audio devices, users should be well-informed about both the benefits and the drawbacks of noise cancelling head/ear phones, and they should be cautious when using noise-cancelling headphones or insert phones where the risk of physical harm exists.

SUMMARY

- Noise-cancelling headphones and insert phones were introduced into the market with the aim of cancelling the environmental noise, reducing PLLs, and hence contribute to the prevention of music-induced hearing loss.
- The current study revealed that noise-reduction headphones and insert phones provided various amounts of attenuation for the environmental noise.
- The attenuation provided by the noise-cancelling head/insert phones allowed PAD users to listen to music at lower intensity levels and this may contribute to decreasing the risk of music-induced hearing loss.
- The current study also demonstrates that the localization abilities are degraded when noise-cancelling headphones or insert phones are used, increasing the potential risk of physical harm to the users due to reduced awareness of environmental sounds.
- Portable audio device users should be aware of both the benefits and drawbacks of the noise-cancelling phones and either avoid them or become cautious with using these phones when there is a potential for physical harm.

ACKNOWLEDGEMENTS AND NOTES

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Balance Disorders and Aging

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The trend in demographics that should lead to an overall concern for the health care systems of North America is the tremendous growth in the population of people over the age of 65 years. Konrad et al. reported that there would be almost 40 million adults over the age of 65 by 2010 in the United States alone.[1] Balance disorders and disorders that lead to instability become more prevalent with age.[2,3] The three sensory modalities responsible for normal balance and steadiness: vision, vestibular, and proprioception, can become compromised as a result of normal age related changes as well as age-related disease or pathology leading to increased risk of falls and fall related injury.[1,2,4,5]

The elderly fall more often and with greater consequence as a result of balance and instability issues, leading to huge personal costs as well as sky-rocketing health care costs.4 Over the age of 65, 1 in every 3 adults will suffer from a fall,[6] and given the explosion in the number people living today over 65 years of age, falls are a major healthcare crisis.[1] The US National Institutes of Health (Senior Health),[7] reported 1.6 million emergency room visits as a result of falls. The elderly are less likely to fully recover from a fall, and falls have been linked to increase the risk of death especially for individuals over 85.[5,7]

Authors have cautioned clinicians that gait and balance concerns should not be considered just a normal part of aging, as a large proportion of balance complaints occur in conjunction with some known disease process or a composition of different pathologies.[2,4] However, symmetric vestibular sensory hair cell loss, declining visual acuity, and declining muscular strength and mobility are some examples of known age-related changes to a human's balance system.[4] These normal age-related declines in function may cause worsening stability and sensory integration during locomotion.[3,6]

Many musculoskeletal, cardiovascular, and neurologic disorders are associated with advancing age while also having detrimental effects on gait and balance.[2,6] Some common age related pathologies that affect balance, postural stability and gait include: arthritis, orthostatic hypotension, vitamin B-12 deficiency, diabetes mellitus, vestibular disorders such as benign paroxysmal positional vertigo (BPPV) and vertebrobasilar insufficiency.[1] Cardiovascular disease such as atherosclerosis which is highly associated with increased age has a degenerative effect on vision structures, inner ear structures, and the peripheral musculature and nerve tissues which encompass the balance system, and can lead to hemorrhaging and stroke in the brain.[1] Orthostatic hypotension has been cited as a major cause of falls in the elderly.[3,5] The patient typically reports severe lightheadedness and presyncope upon rising from lying or sitting down.[8] Causes of hypotension include cardiovascular disease, poly-pharmacy, and dose related issues for medications to control hypertension.[2]

Arthritis, vitamin B-12 deficiency, and diabetes mellitus can lead to poor peripheral sensory control of limbs leading to poor gait and postural instability.[2] For arthritis, pain and inflammation of joints make quick movements needed to brace for falls more difficult and overall physical activity becomes difficult leading to physical muscular and skeletal attrition.[1] Joint pain has been cited as the most likely contributor to poor gait.[2]

Vitamin B-12 deficiency is a syndrome that forms as a result of a lack of essential vitamin B-12 absorption.[9] The deficiency of vitamin B-12 can cause significant degeneration of the peripheral and spinal nerves, causing poor postural stability and worsening gait because of poor tactile and proprioceptive sensitivity in the joints and extremities.[10]

Diabetes mellitus leads to sensory neuropathy for vision and peripheral sensory function in the extremities, leading to an increased risk for tripping over objects and loss of balance on moving, vibrating, or slippery surfaces.[1,2]

Benign paroxysmal positional vertigo (BPPV) is a vestibular impairment that is common as people age, and has been identified as another major cause of falls in the elderly.[1,5,6] The average age of onset for BPPV is between 51 and 57 years of age. BPPV is caused physiologically by misplaced otoconia in the semicircular canal (SCC), (commonly the posterior SCC) as a result of simple age related changes to the SCC, or head trauma.[5] The symptoms are usually precipitated by a change in head movement, so often people who have not been treated avoid that head movement or only sleep on a certain side in bed. The misplaced otoconia cause stimulation of the sensory structure of the SCC causing transient vertigo when the patient looks up, bends over, or turns in bed. This momentary vertigo can cause the patient to lose stability and fall. The dizziness/vertigo from this usually only lasts 30 seconds to a minute.

Vision is an essential sensory modality for balance as this sense allows a person to avoid obstacles and properly move around in space.[6] Physiologic deterioration to the eye and eye musculature, as well as vision disorders such as macular degeneration, cataracts, and glaucoma become more common with age, leading to poorer mobility, and identification of objects that could cause falls.6 Sturnieks et al., recommends the correction of visual deficits as part of falls prevention for the elderly.[6]

According to the American Academy of Audiology, an audiologist should be able to properly identify, assess, diagnose, manage, and help in the prevention of balance disorders for all patients. No other group will need these services more than those over 65 years.[8] The steps needed to prepare for this increased demand for balance services by the over 65 population include: improved diagnostic skills training, better inter-professional collaboration, proper and timely referral, improved falls prevention, and evidence based treatment strategies.

To increase proficiency in balance disorder and falls prevention diagnostics, university audiology programs will need to expand and improve balance disorders coursework and practicums to help future audiologists diagnose patients with balance complaints. As diagnostic protocols are developed for falls prevention clinics, audiologists will need to become active leaders in forming clinical test batteries. The next step is for Audiologists to become part of a team approach in diagnosing and treating balance disorders. Inter-professional communication and referral will need to be set-up between audiologists, ENT doctors, physiotherapists, neurologists, internal medicine physicians, and occupational therapists to provide the highest level of patient care in the falls clinic setting.[4,8]

Proper referral to other professionals will only be possible if audiologists become cognizant of the multitude of pathologies that may be associated with balance and dizziness symptoms which lead to falls, as well as normal age related changes to vision, muscular strength and mobility, and vestibular function.[2] An audiologist's caseload, even in a private practice hearing aid clinic, includes people predominantly over 65 years of age. As such, private practice "hearing focused" audiologists should have some idea of when a diagnostic balance assessment is necessary, and when there is a risk of falling present, so proper referral to a falls clinic can be made. Prevention of future falls as a result of balance disorders should be a high priority to all audiologists.[4,8] This means that any patient at risk for a fall based on balance disorder complaints, or patients who have reported a fall in the past should be referred to a falls prevention program and have a home safety assessment.[4,8]

In some circumstances, audiologists may also be needed to conduct vestibular rehabilitation therapies (VRT) or be able to recommend exercises to do at home. Audiologists can be involved in coordinating home-based VRT, group VRT, and simple exercise programs which have been shown to be effective for the elderly.[1,5,6] Canalith repositioning maneuvers are also within the scope of practice for audiologists for patients with BPPV.[2]

CASE STUDY BILATERAL WEAKNESS

- 81-year-old female (A.D.).
- Referred by the Cochlear Implant (CI) Team as part of the assessment for CI.
- History of vertigo in the past where episodes would last from minutes to hours.
- Two years prior to assessment the patient had sudden episode of vertigo and a force which was "trying to get her down" which lasted for about one minute.
- She also experienced fleeting episodes where she felt like she was "moving inside her head," even when stationary.
- Following this she had poor balance and would have to hold on to something when walking; was unable to walk in a straight line.
- This resolved after a few months and she was able to walk without holding on to things.
- Reports oscillopsia when trying to read a sign while walking or driving.
- Visual motion around her is bothersome and makes her feel off balance.
- She has difficulty walking in the dark in poor lighting.
- She was investigated for stroke which was negative.
- Severe flat sensorineural loss in the right ear and severe to profound loss in the left ear

CALORIC RESULTS

- No nystagmus response was noted for either cool or warm water irrigation.
- Results suggest bilateral peripheral disorder.

RECOMMENDATIONS

- Referral to falls prevention program.
- Vestibular rehabilitation therapy.

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Editor's note: For those who are interested in becoming involved in a new CAA interest group on vestibular issues, please contact either Maxine Armstrong (Maxime.Armstrong@uhn.ca) or Janine Verge (Janine.Verge@cdha.nshealth.ca).

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They are also the first custom product protected by our advanced moisture and wax protection system, HydraShield®[2], so they're our most reliable custom products, too.

From how they sound to how they fit to how long they last, no other custom products come close.

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