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Where Do You Want to Work?

The Relationship between DPOAE and Behavioural Thresholds

Peer Reviewed

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"Smoking will stunt your growth"; "Smoking will cause hair loss"; "Smoking will make you go blind"… well, maybe this last one was about something else, but these and other common warnings of smoking were often heard when we were younger and were usually uttered by our parents. Now it seems that audiologists and others in the hearing health care professions have taken up the call warning against smoking.

Evidence is in that smoking can be a major factor in hearing loss and perhaps we should be warning the youth of today about smoking, in the same breath as when we warn them about the potential of hearing loss from recreational music. "Smoking and Hearing Loss" is a short summary article that can be freely copied from this issue of the *Canadian Hearing Report* and provided to your clients.

Summary reports such as this, and similar ones published by the American Medical Association give the impression that this is an open and closed case. It is true that the long-term effects of smoking can have dramatic implications for your health and even lifespan. It is, however, a more grey area regarding the short-term aspects of how smoking and hearing loss may be related. For example, Dengerik in the 1980s showed that a little bit of smoking was actually protective against hearing loss, as long as the worker had good cardiovascular function. And it's really all about good cardiovascular function, so keep doing those wind sprints, push-ups, and stair climbing exercises, … and don't smoke!

We continue to have input from students at the various Canadian universities. In this issue there are two article abstracts: The influence of early exposure to frequency-transposed speech on word recognition during infancy; and Systematic review of interventions for hearing loss in children. Both articles are clearly related and both offer good clinical information for the busy audiologist in practice. It's nice to have students do our work for us, on occasion!

Tiffany Johnson gives an interesting insight into the relationship between behavioural thresholds and otoacoustic emissions. One would suspect that the relationship have an inherent high degree of variability – after all, one is a measure of acuity, and the other of function. There should be a correlation, but can one be predictive of the other? And what about the time course? Does one measure degrade prior to the other and if so, is this always the case?

So, you are now ready for your first job as an audiologist. Or, you are considering a change to a different type of audiology facility. What are the strengths and weaknesses of each type of job environment? What are the benefits of working in a not-for-profit venue? How about having many colleagues around to bounce ideas off of? Or perhaps a solo private practice situation would fill the bill. In this issue we have an overview of all of these possibilities as discussed by some experienced audiologists who have been there, and now are sharing their perspectives with the rest of us.

Welcome to spring.

Marshall Chasin, AuD
Editor-in-Chief

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"Le tabagisme met en péril votre croissance"; "Fumer fait perdre les cheveux "; "Fumer vous rendra aveugle"… Peut-être cette dernière phrase a trait à quelque chose d'autre, mais ces avertissements et autres du genre contre le tabagisme sont souvent entendus dans notre jeunesse et souvent répétés pas nos parents. Maintenant, il semble que les audiologistes et autres professionnels des soins de santé auditive ont pris le relai de l'appel avertisseur contre le tabagisme.

Les preuves sont que le tabagisme peut être un facteur majeur dans la perte auditive et peut-être devrions nous avertir les jeunes d'aujourd'hui contre le tabagisme, dans le même élan quand on les avertit contre la perte potentielle de l'ouïe causée par la musique récréative. Vous pouvez librement copier l'article "Tabagisme et perte auditive" de ce numéro de la *Revue Canadienne d'audition* et le fournir à vos clients.

Les rapports sommaires comme celui-ci, et d'autres similaires publiés par the American Medical Association, donnent l'impression que c'est un dossier ouvert et clos. Il est vrai que les effets du tabagisme sur le long terme peuvent avoir des implications dramatiques sur votre santé et même pour la durée de votre vie. Cependant, la relation au court terme entre le tabagisme et la perte auditive est une zone plus grise. Par exemple, Dengerik dans les années 80 a montré qu'un peu de tabagisme protège contre la perte auditive, tant que le travailleur ait une bonne fonction cardiovasculaire. Tout est vraiment fonction d'une bonne fonction cardiovasculaire, alors continuez ces sprints courts, tractions, et exercices d'escaliers, ... et ne fumez pas!

La collaboration des étudiants des différentes universités canadiennes continue. Nous avons deux articles dans ce numéro: L' influence de l'exposition précoce au langage transposé par la fréquence sur la reconnaissance des mots durant l'enfance; et les révisions systématiques des interventions pour la perte auditive chez les enfants. Les deux articles sont clairement liés et les deux offrent une bonne information clinique pour l'audiologiste occupé dans son cabinet. C' est gentil d' avoir les étudiants qui font notre travail pour nous, occasionnellement!

Tiffany Johnson donne une perspective intéressante de la relation entre les seuils de comportement et les émissions oto-acoustiques. On penserait que la relation a un grand degré de variabilité inhérente – après tout, une est une mesure d'acuité, et l'autre de la fonction. Il devrait y avoir une corrélation, mais une peut-elle prédire l'autre? et la chronologie? Une mesure se dégrade-t-elle avant l'autre et si c'est le cas, est ce toujours le cas ? .

Donc, vous êtes prêt(e) maintenant pour votre premier emploi comme audiologiste. Ou, vous êtes en train de réfléchir à changer et aller dans une branche différente d'audiologie. Quels sont les points forts et faibles de chaque type d'environnement de travail? Quels sont les avantages à travailler dans un secteur à but non lucratif? Que diriez vous de tous ces collègues autour de vous avec toutes leurs idées? Ou peut-être une consultation en cabinet privé pour payer les charges. Un aperçu général de toutes ces possibilités racontées par des audiologistes expérimentés qui sont passés par la, et qui partagent maintenant leurs perspectives avec nous.

Bienvenu printemps.

Marshall Chasin, AuD
Éditeur en chef

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The Relationship between Distortion Product Otoacoustic Emissions and Behavioural Thresholds
BY TIFFANY A. JOHNSON, PHD, CCC-A

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Plea for Hearing Aids that Can Handle Music

My name is Tony Laviola and I'm a professional bass player. I have been playing all kinds of music for almost half a century. Over the past 20 years I have been aware of the slow and steady decline of my hearing, so about 10 years ago I was fitted with my first pair of in-the-canal hearing aids. I rejected them because of the poor sound quality, the occlusion effect and they made my ear canals sweat. About two years ago speech became harder to understand and I could tell people around me were getting tired of repeating themselves. Over this course of time I have been fitted with some "top of the line" hearing aid models with totally unacceptable results for music so I started looking around and found that they now had these open fit aids. I was intrigued but the last 14 months have proved to be a source of a kind of frustration I have never experienced before.

Having only received the hearing aids days before, I was excited to play my first gig until I got there. It turned out to be a small upscale restaurant where the din from the diners was often equal to the SPL of our three-piece jazz trio. As it turned out this was the worst possible environment for musicians with hearing aids. Not only did the sound level overwhelm the capacity of my hearing aids to sort out individual conversation so that I could only count on my ability to read lips to understand what tune the piano player 10 feet away from me was calling next but the sound processing made the pitches quiver with a quick Buffy St. Marie type vibrato. I had to look at my hand position on my acoustic bass to make sure I was close to the note! This is not easy when you're reading charts and I doubt I'll get a call back for that gig.

As a consumer, I started reading everything I could find on hearing aids and people's experiences and reviews of these devices. Being a musician I am familiar with what compression and anti feedback technology can do, but how they do it so poorly in the new digital hearing aids is a mystery. In the end I had to do and end run around the hearing aid industry in Canada and actually went to the USA to get them because they are not sold here in Ontario. When I finally got the Digi-K hearing aids, I couldn't believe I finally found something that worked so much better than anything else I'd tried and it was less than half the price of the other hearing aids available in Canada, even without the provincial support programs.

Finally I had hearing aids that I could wear at rehearsals and small gigs so I could understand what was going on. Next to natural hearing these are the best, most comfortable aids yet. I am still trying to get a pair with the original analogue K-AMP circuit from 1988 and with a sympathetic and helpful audiological ear, I now have a line on obtaining these hearing aids from just south of the Canadian border. As long as industry and governments regulate the industry for the good of the industry and not for the good of the hard of hearing consumer they will continue to provide a disservice to the people they say they want to help.

My heartfelt gratitude to Drs. Mead Killion and Marshall Chasin for the work they've done for all hearing impaired people and especially musicians.

Roll over Beethoven!

Tony Laviola,
Bass player and hard of hearing consumer

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The Canadian Hearing Society's Quest To Break Down Communication Barriers

SOLVE CLUES… LOCATE QUESTSTOPS… PERFORM CHALLENGES ... CROSS THE FINISH LINE… HAVE FUN … SUPPORT A GREAT CAUSE.

The Canadian Hearing Society is hosting its unique fundraising event, CHS Quest, on Sunday, May 29, 2011 in two cities: Toronto and Oshawa.

CHS Quest is a smartphone-based scavenger hunt, where teams of four people solve video clues delivered in spoken, written and sign language to find their way to a series of QuestStops scattered across the city. At each QuestStop, teams must perform a fun, challenging task. Think *Amazing Race* without the international travel!

CHS Quest is a pledge-based event, raising much-needed funds to support the 17 programs and services offered by CHS. Since 1940 CHS has been on a quest to break down barriers to communication faced by people with hearing loss. This fundraiser helps CHS to continue that all-important quest.

Here's what people had to say about last year's inaugural CHS Quest:

"Had a great day with family and friends"
"Excellent …it incorporated some sign language into the event which was fun to learn"
"Led me to parts of the city I didn't know were there"

There are lots of ways to get involved: (1) Form a team and come out and join the fun; (2) Sponsor someone; and (3) Volunteer.

The Honorary Chair is Andrew Younghusband, TV host of *Canada's Worst Driver* and *Canada's Worst Handyman*: "I am proud to be this year's honorary chair of **CHS Quest**, an event like no other. It's a chance to meet new people, to compete and win some fantastic prizes, and most important, it's a fun way to raise funds in support of The Canadian Hearing Society."

This year's Lead Sponsor of CHS Quest 2011 is Siemens. Partner sponsors include Wind Mobile and Compass Creative Media.

To find out more about CHS Quest 2011, check out chs.ca/quest.

Unitron Announces Appointment of New President and Chief Executive Officer

MICHAEL TEASE TO LEAD UNITRON'S GLOBAL OPERATIONS

Unitron, a global provider of world-class hearing innovations, announced today the appointment of Michael Tease to the position of president and CEO. Mr. Tease will lead Unitron's global operations from the company's headquarters location in Kitchener, Ontario, Canada.

"As a core brand of the Sonova Group, Unitron is an important growth driver in our global business strategy. Michael Tease brings to Unitron a significant track record for performance, a depth of leadership expertise, and a passion for the customer that will allow us to further build and extend Unitron's brand reputation around the globe," says Valentin Chapero, CEO, Sonova Group.

"I am incredibly excited about the opportunity to lead a world class organization such as Unitron. The hearing healthcare industry is poised for significant growth and expansion, and I believe Unitron has the right mix of people, products, and customer partnerships to achieve long-lasting brand leadership, and to make a true difference in people's lives," says Michael Tease.

David Kirkwood leaves The Hearing Journal

Wolters Kluwer Health recently announced that David Kirkwood is no long the editor of The Hearing Journal. They expressed their thanks to David for his years of work and dedication that contributed toward the success of *The Hearing Journal*.

Ontarian Honored at Oticon Focus on People Award

In December, Jennifer Gibson of Warkworth, Ontario was honored at as Oticon announced the recipients of its annual Focus on People Awards which recognize the accomplishments and contributions of individuals with hearing loss. Gibson, 40, is the author of the novel, *Sway*, which is based on her experiences as a hard-of-hearing teenager.

calendar of events

APRIL 6 - 9, 2011

AudiologyNOW!
Chicago, IL
http://www.audiologynow.org/

MAY 5 - 7, 2011

The New York State Speech Language Hearing Association
Annual meeting, Saratoga Springs, NY
www.nysslha.org

JUNE 18, 2011

HLAA 2nd International Hearing Loop Conference
Washington, DC
http://www.hlaa.org

JULY 13 - 15, 2011

Canadian Association of Educators of the Deaf and Hard of Hearing Conference 2011
Synergy:Working Hand in Hand for Deaf and Hard of Hearing Learners

JULY 14-16

13th Symposium on Cochlear Implants in Children
Chicago, IL
www.ci2011usa.com

AUGUST 19 - 21, 2011

Fifth International TRI Tinnitus Conference "The Neuroscience of Tinnitus"
Grand Island, NY

SEPTEMBER 8 - 10, 2011

19th Annual Conference on the Management of the Tinnitus Patient
The University of Iowa Registration Website: http://www.continuetolearn.uiowa.edu/conferences/conferences.htm

AUDIOLOGY TIME MACHINE

Photo of earwax scoops used by the ancient Romans that were excavated in Bath, England. Photo courtesy Meredith Chasin.

LETTERS TO THE EDITOR

Dear Editor,

In the article on the speed of sound and Jules Verne that appeared in the November 2010 issue of the *Canadian Hearing Report*, sound velocity was being related exclusively to density and not to elasticity. We recall from our hearing science classes, however, that density is related to mass, while elasticity (ability to resist being deformed) relates to stiffness. We usually associate these things with impedance – specifically that mass has it greatest effect on impedance in the lower frequencies while stiffness dominates the impedance in the higher frequency region.

Regarding the speed of sound, however, sound velocity is inversely related to density and directly related to elasticity. Greater density actually slows down sound, while greater elasticity speeds up sound. Steel is denser than air, and that alone would make sound go slower through steel. Sound in fact does go faster through steel however, because steel has way more elasticity than air. In other words, the greater elasticity of steel far outweighs its greater density.

The same reasoning can also be applied to inhaling helium balloons. Helium has similar elasticity to the air we breathe but less density. Sound therefore, goes faster through helium. Plug the speed of sound in helium into the formula for wavelength (the vocal tract is a 1/4 wave resonator), and it explains why we sound like Mickey Mouse when taking in a haul of helium.

Now I agree that Jules Verne probably didn't take Audiology 101 when he went to school in the nineteenth century but then again, he could have taken a short train trip to visit von Helmholtz; he'd have set him straight.

Ted Venema
Conestoga College

Smoking and Hearing Loss

By Marshall Chasin, AuD, MSc, Aud(C), Reg. CASLPO

THE RELATIONSHIP BETWEEN CIGARETTE SMOKING AND HEARING LOSS HAS ONLY REALLY BEEN STUDIED IN DETAIL FOR THE LAST DECADE.

The first well-controlled study was published in 1998 by the *Journal of the American Medical Association* and cited some compelling statistics. The study included 3,753 people aged 48–92 and there appeared to be a clear trend that increased hearing loss was proportional to the number of cigarettes smoked each day. Specifically, 25.9% of smokers in the 48 to 59 age group were suffering from hearing loss, but it was only 16.1% among non-smokers. Also, 22.7% of ex-smokers were suffering from hearing loss. This was also found in the older age groups.[1]

As can be imagined, research in this area can be quite difficult. Smokers may not provide exact information of the number of cigarettes smoked, and "ex-smokers" may not truly be "ex-smokers." One of the uncontrolled factors may be whether these smokers also had good cardiovascular function. It turns out that one major factor is how much oxygen reaches the inner ear. All cells require oxygen in order to function. Conceivably a heavy smoker that also has excellent cardiovascular function may have minimal hearing loss from smoking.

Another study performed in 2004 published in the *Archives of Otolaryngology, Head and Neck Surgery* at the University of Wisconsin at Madison found no relationship between smoking and hearing loss. In this study, cardiovascular function was controlled for.[2] Having said this however, most people that smoke also have poor cardiovascular function, so the 1998 study is probably correct in their conclusions. Alternatively, one may argue that if you smoke, you should also take steps to maintain your cardiovascular system. To further complicate matters, it turns out that factors of smoking, aging, and working in a noisy environment, together act "synergistically" to create a hearing loss that is greater than any one of these factors alone.

However, cardiovascular integrity and noise exposure history are not the only factors affecting whether smoking causes hearing loss. In 2008, an audiologist at the Western Michigan University, Dr. Bharti Katbamna published an overview of those factors that can interact with smoking to create hearing loss as well as some possible mechanisms of how that may happen.[3] There appear to be three different mechanisms of how smoking may affect the cochlea.

The first of these mechanisms has to do with how much oxygen is available in the cochlea. Nicotine and carbon monoxide from cigarette smoking may deplete the available oxygen levels thereby increasing the susceptibility of the various structures in the cochlea to damage (from noise and the aging process).

The second mechanism may be related to nicotine interfering with the neurotransmitter substances in the auditory nerve thereby altering the hearing transmission mechanism.

The third potential mechanism derives from studies on adolescent youths. The structures of the auditory nerve that takes neurological energy from the cochlea to the auditory centres of the brain are not well developed until late adolescence. It is possible that nicotine, along with other potentially toxic chemicals, may alter or prevent the various neurological pathways from developing properly.

Whatever the mechanisms, clients should be counselled against smoking for a myriad of reasons, but especially if they are young, and have poor cardiovascular function.

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Current Steering and Current Focusing in Cochlear Implants

By Lendra Friesen, PhD

Most cochlear implant (CI) users have excellent speech understanding in quiet; however, in noisy environments or, when listening to music, their perception rapidly deteriorates. Current CI devices provide up to 22 channels of information delivered directly to the auditory nerve. However, it has been demonstrated that most CI users are only obtaining information from 4–8 channels. Some of the reasons for this limitation are thought to include the broad current spreads from the stimulated electrodes and the resulting overlapping populations of activated neurons which might limit CI users' access to all of the frequency or spectral information transmitted by the device. These channel interactions ultimately limit CI performance in noise, particularly dynamic noise.[1,2] Recently, studies examining methods of reducing channel interaction and increasing the number of spectral channels have been conducted.[3,4] Results from these studies might help to design CI signal processing strategies that provide more information in complex listening environments.

The cochlea is arranged in a tonotopic manner with incoming high frequency sounds causing activity at the cochlear base and low frequency sounds at the apex. This pattern of activity is preserved up to the cortex. For someone having a CI, incoming sound is processed and converted to electrical signals. An external processor controls an internal receiver/stimulator that generates electrical signals and sends these to the electrode array implanted in the cochlea. Each electrode on the electrode array is assigned a frequency band of information, in a tonotopic manner, which it delivers to the nearby auditory nerve endings. This information is often termed a channel of information.

Current steering with virtual channels has been proposed to increase the number of frequency or spectral channels of information beyond the actual physical number of electrodes. Virtual channels are created by simultaneously stimulating two adjacent electrodes. The peak of excitation is "steered" or shifted between the component electrodes by varying the amount of current delivered to the apical and basal electrodes. This shifting can evoke an intermediate pitch percept.[5,6] For example, Donaldson et al. observed from two to nine place pitch steps in-between electrodes.[5]

Current steering is commercially implemented using monopolar stimulation where there is one active intra-cochlear electrode and one return electrode in the receiver/stimulator and current flows between the two electrodes. Because the active and return electrodes are widely spaced, current spreads over a wider area, stimulating a larger neuronal population and perhaps limiting sensitivity to spectral detail. Reducing current spread and neural interactions might allow CI users to

access more of the spectral cues provided by the device (whether via virtual or physical channels).

Current focusing or tripolar stimulation has been proposed to reduce current spread. Here, current is delivered to an active electrode, and an equal amount of current is simultaneously delivered to the two adjacent flanking electrodes. Because the current loop is entirely intracochlear with tripolar stimulation, current spread is reduced. However, it is sometimes difficult to achieve sufficient loudness.

To address the limitations of current steering and current focusing, Landsberger and Srinivasan proposed using quadrupolar virtual channels to combine current steering and current focusing.[3] Theoretically, quadrupolar virtual channels would use current steering to transmit more spectral channels beyond the number of implanted electrodes and use current focusing to reduce channel interactions, thereby providing better functional spectral resolution. Quadrupolar virtual channel stimulation consists of four simultaneously stimulated intra-cochlear electrodes: two center "steering" electrodes between which the current is divided and two outer "focusing" electrodes which act as a ground. In this study, they compared virtual channel discrimination between monopolar virtual channel and quadrupolar virtual channel stimulation modes in CI users. Results showed significantly better virtual channel discrimination with quadrupolar virtual channel stimulation than with monopolar virtual channel stimulation, suggesting less current spread with quadrupolar stimulation, although this was not directly measured.

In another study, Svrinivasan and colleagues measured current spread by comparing psychophysical forward-masked excitation patterns between monopolar virtual channel and quadrupolar virtual channel stimuli in CI users, at equally loud comfortable listening levels.[4] They found a sharper peak in the excitation pattern and a reduced spread of masking for quadrupolar virtual channel stimuli. Results from the forward masking study were compared with the 2009 study measuring virtual channel discrimination ability and showed a weak relationship between spread of excitation and virtual channel discriminability.

The results from these studies suggest that CI signal processing strategies that use both current steering and current focusing might improve CI users' functional spectral resolution by transmitting more channels and reducing channel interactions.

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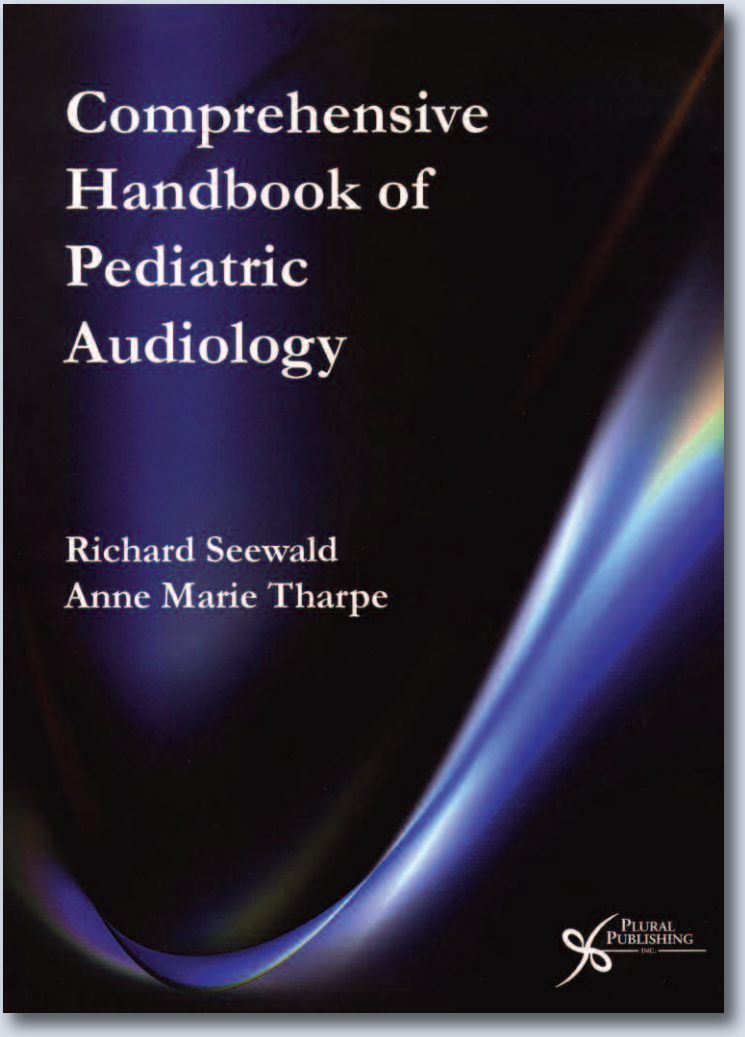

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Reviewed by Sheila T.F. Moodie, MClSc, Faculty of Health Sciences, The National Centre for Audiology, The University of Western Ontario, London, ON, Canada.

Comprehensive Handbook of Pediatric Audiology

THERAPEUTIC AREA

This book provides a comprehensive text for the specialty of pediatric audiology.

FORMAT

This handbook contains 41 chapters that are organized into eight sections: I. Typical Auditory Development, II. Etiology and Medical Considerations, III. Auditory Disorders, IV. Early Identification of Hearing Loss, V. Approaches to Assessment, VI. Hearing Technologies, VII. Management Considerations and VIII. Family and Educational Considerations. The 70 contributors to this book are considered leaders in the field of pediatric audiology.

AUDIENCE

The *Comprehensive Handbook of Pediatric Audiology* text is intended for use by students in graduate education programs in audiology. Because of the comprehensive nature of the text it will also be immensely useful to practicing audiologists and audiologist-researchers interested in pediatric audiology. Other health care providers (otolaryngologists, geneticists, speech-language pathologists, early interventionists, auditory-verbal therapists, etc.) who work with children with hearing loss and their families are also likely to find this book beneficial. Finally, the chapters focused on principles and methods of population hearing screening in early hearing detection and intervention (EHDI) programs (Chapter 16) and descriptive epidemiology of childhood hearing impairment (Chapter 5) will also prove useful to policy-makers and program evaluators.

CONTENT

Section I, Typical Auditory Development, offers four chapters on embryology of the ear, development of the

auditory system from periphery to cortex, infant speech perception and auditory development in children with normal hearing. Section II, Etiology and Medical Considerations, provides important epidemiological information relative to worldwide childhood hearing impairment, the genetics of childhood hearing loss, and offers the perspectives of both a pediatrician and otologist regarding medical considerations for infants and children with hearing loss. Section III, Auditory Disorders, is composed of seven chapters focusing on: conductive; unilateral; minimal/mild; and moderate to profound hearing loss. Section III also provides information on auditory neuropathy/dys-synchrony type hearing loss and (central) auditory processing disorders in children. The final chapter in this section focuses on false and exaggerated hearing loss in children. Section IV, Early Identification of Hearing Loss, offers two chapters. The first challenges the reader to critically examine principles and methods of population screening in EHDI programs and to consider areas for improvement. The second chapter provides an evidence-based review of factors that should be considered in the design, implementation and evaluation of screening programs for young children. Section V, Approaches to Assessment, provides chapters that cover relevant areas for best practice protocols for assessment of children with hearing loss. Chapters include middle ear measurement; otoacoustic emissions, frequency-specific ABR and ASSR threshold assessment, electrophysiologic assessment with auditory middle and late responses, and behavioural audiometry with infants and children. The final chapter in this section provides an overview of a systems approach to assessment and management of children with hearing loss that is culturally sensitive and family-centered. Section VI of the *Comprehensive Handbook of Pediatric Audiology* focuses on Hearing Technologies including: approaches to the fitting of amplification, FM systems, cochlear implants, bone-anchored hearing aids, and hearing instrument orientation for children and their families. Section VII, Management Considerations, has eight chapters which focus on audiological assessment, (re)habilitation, language learning and educational management to minimize barriers to communication for children with hearing loss and their families. The section begins with a history of management of hearing loss in children. The remaining chapters provide information about management of the listening environment and methods to facilitate early communication development, guidelines/protocols for delivering audiological services to families with toddlers and preschoolers, and managing the relationship of hearing loss to the listening and learning needs of school-aged children. Later chapters in this section focus on thorough management/monitoring plans for children with unilateral and minimal/mild bilateral hearing loss, children with cochlear implants and children with ANSD. Chapter 36 in Section VII provides modifications/adaptations that should be considered for assessment of hearing loss in children with multiple modality involvement. The final section of this comprehensive handbook, Section VIII, Family and Educational Considerations, provides the reader with the most recent information regarding family-centered practice, family support and informational counselling and provides information about the role of the pediatric audiologist as an advocate and professional collaborator in the educational setting. Chapter 40 in this section looks at how far we have come as pediatric audiologists in delivering quality services to young children with hearing loss and their families, and acknowledges where our EHDI programs still fall short. It concludes by providing information about ongoing initiatives aimed at closing gaps that still exist in delivering services to children with hearing loss and their families

USABILITY

This concise and comprehensive text book provides detailed information on the practice of pediatric audiology. The division of the book into eight sections results in easy navigation to particular topics of interest. The chapters are well-written and provide both basic science and research background, always linking the science to relevant clinical practice information. Each chapter has a significant number of pertinent and up-to-date references. Text, figures, tables, pictures, and appendices are of good size and impeccable print quality. Many chapters provide checklists, protocols, and/or handouts that will be useful for pediatric audiologists in clinical practice. Proceeds of the book are dedicated to a student scholarship fund at Vanderbilt University, TN, in memory of Dr. Judith Gravel who envisioned the need for such a book in pediatric audiology.

HIGHLIGHTS

The *Comprehensive Handbook of Pediatric Audiology* provides reading material for most courses focused on pediatric audiology offered in today's graduate audiology programs. It will save many students from having to buy multiple text books and save audiology faculty members from having to search for relevant, up-to-date, well-written readings and lecture materials in the

area of pediatric audiology. Audiologists in practice will find the text provides a wide range of clinically relevant information that will augment their knowledge and skills and improve the quality of services they are able to provide to children with hearing loss and their families. The chapters on epidemiology (Chapter 5), frequency-specific ABR and ASSR assessment (Chapter 20), cochlear implants for children (Chapters 27 and 35), bone-anchored hearing aids (Chapter 28), and auditory neuropathy spectrum disorder (Chapters 13 and 37) fill many gaps that exist in current pediatric audiology text books.

LIMITATIONS

There are minimal limitations to this text. Future editions of the text may benefit from inclusion of a chapter on vestibular evaluation of infants and children and on management of the child with progressive hearing loss. There is some redundancy in chapters, however, with 70 contributors and 41 chapters this is largely unavoidable, and the editors have managed to keep it at an acceptable level.

REVIEWER'S SUMMARY

The *Comprehensive Handbook of Pediatric Audiology* is a valuable and necessary reference for the library of pediatric audiologists, students, and other professionals interested in EHDI programs, hearing loss in children and the impact on families. The inclusion of a diverse range of information in a single text book makes it a "must-have" and sets the bar high for future text books in audiology. It will facilitate the training, and continued development of, highly qualified professionals in pediatric audiology. It is truly an exemplary reflection of what Dr. Gravel would want it to be: scholarly, scientific, clinically applicable and useful for teaching. Judy would be proud.

FINANCIAL DISCLOSURE

None reported.

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Systematic Review of Interventions for Hearing Loss In Children

Students:
Liz Johnston *(top)* and
Natalie Sanche

Supervisor:
Elizabeth Fitzpatrick, PhD

ABSTRACT

This research project was undertaken to provide an update of a systematic review of interventions for hearing loss in children, previously commissioned by Health Canada.[1] The review sought to evaluate the existing research pertaining to the effectiveness of interventions for children with permanent congenital hearing loss who received at least one of the following four interventions: oral communication, sign language, auditory-verbal therapy, or total communication. The updated study included articles from January 2001 through July 2008 inclusively. Consistent with predetermined eligibility criteria, all articles which reported communication outcomes on children with permanent hearing loss were included in this review. A total of 124 articles (and 23 dissertations) were retained. For this project, the 124 studies were analyzed and separated into direct and indirect evaluations of effectiveness of the four interventions. Data abstraction was conducted using synthesis tables to sort the studies according to (1) study population, (2) hearing loss, (3) intervention program, (4) co-interventions, and (5) family variables. A meta-analysis of the results was not possible due to the small number of studies which directly evaluated intervention effectiveness and the heterogeneity of the studies. Therefore a qualitative analysis was conducted. A variety of outcomes were documented, however, information pertaining to the subjects (e.g., age of intervention) and the intervention programs (length, intensity) was frequently not reported.

The overwhelming majority of studies focused on children with cochlear implants. However, in most cases, the goal of these studies was to evaluate the effectiveness of cochlear implantation rather than one of the four intervention programs. In general, these studies reported that participants using oral communication methods were more comparable to their hearing age-mates than participants using other communication methods. Objective comparisons of the effectiveness of each intervention program could not be made due to lack of information on the program and the participants.

REFERENCE

1. Schachter HM, Clifford TJ, Fitzpatrick E, et al. Systematic Review of Interventions for Hearing Loss in Children. Ottawa: Health Canada. Contract # 030SS.HT091-01001. November 2000.

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CHR would like to aplogize to Unitron for this page being inadvertently left out of the Janurary Product Review issue.

Where Do You Want to Work?

Now that you've graduated, you need to decide what kind of work setting will be best for you. There are many different options open to audiologists; in the articles below, we try to highlight the pros and cons of several settings.

By Rex Banks, MA, CCC-A, Reg. CASLPO
Director of Hearing Health Care
The Canadian Hearing Society

NON-PROFIT AUDIOLOGY PAYS HIGH DIVIDENDS IN JOB SATISFACTION

Week one on the job at my first audiology position right out of grad school, the office manager for the ENT physician that I worked for dropped a large bag of "slightly used" hearing aids (fresh from the local funeral parlor I might add) onto my desk. This ENT doctor served on the board of the local, non-profit Deaf Services Centre and for years had donated the services of his audiologists to what was called "The Hearing Aid Bank." My first act as a newbie audiologist towards serving the greater good was to determine which of these hearing aids were working and could be given to people in rural Kentucky who couldn't afford to buy a new hearing aid of their own. That was over 20 years ago and looking back, I realize that this altruistic ENT physician planted the first seeds of desire for non-profit work into my heart.

I embraced everything about The Hearing Aid Bank for the next couple of years before pulling up stakes and moving to South Florida. My next position was in a private practice setting that had a connection to Deaf Services and once again, I found myself sifting through donated hearing aids and finding new homes for them. I went on to work at a hospital and then finally, seven years into my career, I landed an audiology position at a charity called United Hearing and Deaf Services (now League for the Hard of Hearing Florida). I'll never forget the executive director telling me "Rex, you can be whatever kind of audiologist you want to be in non-profit, but it's really up to you to make it happen."

That was the day that I had an awakening, that as an audiologist, I could and should be doing much more than just pushing buttons and watching for hand signals for when people heard the beep – I could make a difference and non-profit was where I was going to do it. I spent the next six years of my life doing challenging, rich, and fulfilling projects that are nothing less than par for the course in non-profit work.

It was the mid 90s and the HIV/AIDS

epidemic was in full force in South Florida. I started noticing an increasing amount of people on my caseload who were HIV+ and exhibiting hearing loss. Although many of these individuals were working, they couldn't afford to buy hearing aids and weren't eligible for Medicaid. I developed a relationship with a local HIV/AIDS organization to bring awareness to the issue and through our partnership, we raised money to make sure those with HIV/AIDS had access to hearing aids and other devices at no charge. I also worked closely with The United Way and obtained grants for a whole range of important and diverse issues including providing free hearing aids, repairs, and ALDs to low socio-economic populations; ensuring that local hard-of-hearing support groups had access to real-time captioning; and providing speech language therapy for children with hearing loss long after their insurance companies stopped paying the bills. Running speech-reading groups, certifying people for hearing dogs, meeting with school social workers for deaf and hard-of-hearing kids – all in a day's work for the non-profit charity based audiologist.

Fate brought me to Canada in the summer of 2001. Upon my arrival to Toronto, I knew I wanted to continue my work in the non-profit sector and was hired as a staff audiologist at The Canadian Hearing Society (CHS) where my focus was on aural rehabilitation programs. My eyes were wide with excitement as I started to learn about all the wonderful things that were happening at CHS. The audiologists that had come before me had built a strong clinical environment based on compassionate values. Innovative ideas from running a week-long hearing awareness focused Elder Hostel to extensive development of materials around noise pollution to the most comprehensive aural rehab programming I had even seen, were all signs of committed, professionally like-minded audiologists who were clearly interested in making a difference on the hearing health care landscape. Rewarding opportunities like participating in health fairs, helping launch the Healthy Hearing component for The Special Olympics, providing school screenings to First Nations Cree children in Moosonee, and running a support group for people with acoustic neuromas are all things that were encouraged and supported for audiologists to pursue at The Canadian Hearing Society.

Audiologists are usually familiar and comfortable with referring to and working with other medical professionals. In a non-profit environment, you also gain an understanding and appreciation for the importance and contribution of those with social service backgrounds. For instance, at CHS, audiologists may provide care in synchrony with employment counsellors, mental health clinicians, home-based social workers, and sign language interpreters with everyone working towards the same goal of improving the consumer's quality of life. Non-profit settings generally approach hearing loss from a holistic perspective, treating the entire person and exploring how far reaching hearing loss is and its impact on a person's life on multiple levels. Exposure to the unique sensitivities of various consumer groups including culturally Deaf, oral deaf, deafened, and hard-of-hearing people enhances the audiologists' overall perspective and scope of understanding of communication and the challenges that each group faces.

Yes, you do need to sell hearing aids in non-profit as well. It's a reality of being an audiologist for most of us. There is, however, a great sense of satisfaction in knowing that the proceeds are reinvested directly back into the charitable programs and activities offered by the organization.

It won't come as any surprise that in a non-profit environment we have to be good stewards of our financial resources and we take nothing for granted. Time and thought and resources have to be used as efficiently and effectively as possible. As challenging as that can sometimes be, there is nothing more rewarding in a non-profit environment than the stories of remarkable people who have overcome enormous challenges and barriers. It is from those consumers that we as audiologists can learn the most. By using these newfound insights and stories, we can help others achieve the same level of strength and success in their lives in coping and managing their hearing loss.

For audiology students who are about to transition from the classroom to the real world, I would definitely recommend taking a look at the non-profit sector as a potential career path. It's challenging, enlightening and rewarding – what more could you ask for?

PRIVATE OWNERSHIP PRACTICE

By Tani Nixon, MCl.Sc, Reg. CASLPO

In 1975 the number of private practice audiologists in Ontario could be counted on one hand. The number of audiologists dispensing hearing aids was also relatively small. Fifteen years later, audiologists realized that waiting for government-funded practices to open was not serving the public and that hearing aids were not always a priority. Slowly private practice has now grown to represent more than 50% of the various work settings for audiologists practicing in Ontario.

It's easy to identify the benefits of working for yourself. First of all, you make all your own decisions rather than comply with someone else's idea of how your practice should be run.

- You get to arrange your own schedule, determine how long appointments should be, set your hours to be convenient for your own life, and take vacations whenever it is convenient for you. (You can also decide to spend longer with some clients you KNOW require more time).
- You can choose to go to workshops you feel are appropriate for your practice.
- You can set up a location close to your home (or to your gym!)
- You can expand the practice as you see fit. (You can decide to work more when your practice is busy and less when it's not so busy)
- You can choose your own office management system and/or design your own setup for things like call backs, appointment length, non-standard hours etc.
- You can hire your own staff, pick people you get along with and approve their holidays etc., for the needs of the business. You can even hire your own kids to help with things such as university expenses, and ensure your kids will have a job even in difficult times.
- You can join a buying group if you choose, and after several years, you can anticipate higher income levels than a typical employee.

Perhaps the biggest advantage to private ownership is the freedom to organize your life and your work to suit your own personal needs and beliefs.

Sounds good? Okay, let's have a look at some of the potential problems with working in a private practice.

Having no other audiologist to talk to everyday can be lonely. It can be fun working in an audiology department with a group of audiologists. In private practice it's important to make time to talk to colleagues and to recognize that some will see you as the competition when previously they might have been your friends.

You are responsible for it all. You need to be a mature and responsible person who knows how to handle some tough situations with a calm and reasonable approach. Personally, I did not start private practice until I had worked as an employee for many years – including management. Experience and management training help enormously and make you aware of the obligations to and expectations of staff.

You need to have an understanding of staff supervision as you are bound to have at least a secretary who will have needs of his or her own. You need to understand labour laws and your responsibilities as an employer. If you have only one or two employees, their loss due to illness (or leaving) will have a much larger impact than in an organization with many staff. You will need to give some consideration to temporary help, if you can find it.

You are going to be fully responsible for managing all financial aspects of your business and so you need a reasonable understanding of business management and/or a great bookkeeper. Training in this aspect of your practice is very important and you can expect to spend a minimum of 10% of time on management functions. Some knowledge of business accounting will also help you to follow what your accountant is trying to tell you.

When starting a business you will need to develop a business plan for your bank. This plan will also help you to know if you are achieving your financial goals. A lawyer and an accountant can set up a corporation and do taxes annually. Look carefully at malpractice and liability insurance as these expenses will be much higher than for an employed individual. It is more difficult to organize a benefit package or a pension plan although an accountant may help with these problems.

There is often no one to help make the tough decisions. Do I need to spend $15,000 on new equipment? Am I doing too much? Can I afford to cut back? Can I stop doing ABR's and still get referrals

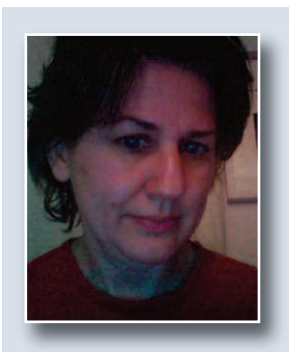
from local physicians for hearing aids? If I increase the cost of tests for seniors how will if affect my business? Do I need to move to a mall? These questions are ever present in the mind of a business person, as they should be. Independent audiologists need to constantly survey what is happening in our profession to be sure to remain current.

I have always found pricing to be tricky. Should you charge more or less than your competitors? And managing cash flow is a constant issue. It is important to understand billing procedures fully as you are the only one who will be looking to find problems. Collections are never fun. You will need to purchase equipment that you may not be familiar with, including phones, fax machines, photocopiers etc. Periodically you need to negotiate terms with manufacturers, and you will benefit from learning all about advertising, including what works in your community and for your patient profile.

Written policies and procedures are useful so that they are clear for new staff members and for students. It is important to stay abreast of your college's rules and regulations as well as laws that may affect your practice. And in a relatively small town you need to smile at everyone because that fellow coming along the street is bound to be the cousin of the sister of the uncle of the brother of the fellow that you just saw this morning.

Still thinking about private practice? Starting a business is a way of stimulating some brain cells that may not be used often. Certainly I can promise that you will never be bored in private practice. And if you're lucky, some day the practice can be sold and form part of your retirement funding.

MY LIFE AS A HOSPITAL AUDIOLOGIST



By Eloise Thurier, MCl.Sc, Reg. CASLPO

I have held two placements as a hospital-based audiologist. The first was at St. Joseph s Hospital in Thunder Bay, Ontario (two years) and since 1982 I ve been at Mount Sinai Hospital. These two work settings were like night and day. In the first I worked as a sole-charge and was "Director of Audiology" and in the second I have always been part of a team.

There are so many things to consider when you think about whether a hospital is the right choice for you. The field of audiology has evolved considerably since I graduated. I was, and still am attracted to working in a setting with plenty of variety, and Mount Sinai continues to provide challenging opportunities for professional growth. Not only do we have a busy diagnostic clinic and hearing aid dispensary, we also do teaching, and have a research division as well. I am not personally involved with it, but the department also provides services for the Infant Hearing Program.

We are also fortunate to have a number of "old-timers" providing a wealth of experience for the newer members of the team. On a "normal" day, I may be scheduled to work in the outpatient ENT clinic cranking out audiograms where patients are booked in 20 minute slots. This may be for an hour, or an all day job. Other slots are "Hearing Consultation," Hearing Aid Fitting, ABR, and ENG, all scheduled as one hour visits.

Some days I am assigned to staff a two hour hearing aid dispensary "Walk-in Clinic" where patients come to have urgent hearing aid problems diagnosed. Occasionally, I am scheduled to teach a "Hearing Information Class" to patients who are currently not hearing aid users but would like to understand more about their hearing loss and hearing aid options. Periodically I teach medical students or ENT residents from the University of Toronto Department of Otolaryngoloy and I also take a student from UWO for a two month externship every spring/summer.

We have weekly clinical meetings to review ENG cases, dispensary issues, or administrative updates. It is a constant whirlwind and can be stressful. For each patient encounter, there will be a certain amount of paperwork generated, and sometimes it is hard to keep up with all of it.

Mount Sinai has a busy ENT clinic and much of what our department does is driven by the demands of the ENT service. We strive to balance the ENT needs with other important activities. It can be an advantage to have the ENT staff nearby, for example when an unforeseen problem arises from taking an ear impression.

Working in a hospital means there are many protocols and procedures beyond what CASLPO guidelines stipulate governing how you work with patients. The hospital itself has a Policy and Procedure Manual and we also have a departmental manual which are fundamental for providing consistent quality of care/service to patients with safety and security in mind.

A hospital, like any corporation or business has a hierarchy and a budget, with admininstration and bureacracy, deadlines to meet, etc. We are continuously competing for space, resources, and money with other departments. Our level of funding depends on government, so we are tuned to the political and economic forecasts. For budget purposes, there are mandatory statistics that are gathered and reported to the Ministry of Health.

As the knowledge base for heath care is upgraded and as health challenges arise, the hospital is there to work with the challenges. In 2003, we had the SARS crisis, and before that, the spread of AIDS. We now face concerns dealing with resistance to antibiotics and an possible global flu epidemic. Our administration has a big job to fulfill being on the lookout for these events, which may not always be foreseeable, and then trying to disemminate the correct information to the staff and public.

I am not sure what the experience of other hospital based audiologists might be, but I feel privileged to work at Mount Sinai Hospital. We have a good administration and our group makes a good team.

MULTI-LOCATION PRIVATE PRACTICE SETTINGS

By Kate Dekok, MCI.Sc Aud(C), Reg. CASLPO
Chief Audiologist, ListenUP! Canada

It has been an exciting 13 years. Thirteen years into an audiology career that I could have never have imagined. Thirteen years of twists and turns that has brought me to work for the largest employer of audiologists in Ontario. Thirteen years of opportunities to develop my career; from working in a private practice, to an educational setting, to starting up my own audiology private practice, to partnering with ListenUP! Canada which was the most unexpected, and yet most rewarding change of all.

The transition from business owner to working in a multi-practice setting was a relatively easy one for me as I was already utilizing the expertise of other professionals such as bookkeeper, accountant and lawyer. Sure, there was stress that went along with handing over the reigns of my business to someone else. However it was relieved over time as I came to appreciate all the additional support that came along with this new partnership –from more professional and effective marketing to handing over the less attractive tasks of accounting, receivables and payables, payroll and professional support. My clients were pleased with the added value and perks that came along with the ListenUP! products and services, while still enjoying that personalized care that they had come to expect from me. So it was a win-win – my clients were happy and it was exactly what I needed at that stage in my career.

Partnering with ListenUP! Canada allowed me to maintain the professional autonomy I was used to in my clinical work and the sale of my business provided the financial freedom I craved. But most important, it provided an ideal solution that allowed me to achieve an incredible life/work balance that wasn't possible as a single owner/operator of a business. As well, with a larger and growing organization I have been able to extend the scope of my experience and career from clinician, to clinic manager, regional manager, and now to chief audiologist. Through these different roles, I have been presented with a multitude of opportunities that are unique to a multi-practice operation including mentoring other hearing health care professionals, participating in a variety of marketing initiatives, providing input on internal processes and management of both professional and support staff; and all under the umbrella of one company.

In addition to multiple career and learning opportunities, partnering with ListenUP! Canada was a wonderful opportunity to become part of a larger community of like minded hearing healthcare professionals who share common goals, problems and interests.

I now have an incredible network of over 100 peers and we enjoy sufficient scale to develop best practices from many inputs, have our own conferences, and throw a great annual conference and party with our own awards and prizes/trips – it is much less isolated than running my own business. It is also a privilege to be a part of something that has engaged the public so well, and is successful, growing and at the forefront of change in the industry.

When considering working within a large organization, I think there are three core questions you need to ask yourself. First: "Where or how will I fit in at a multi-practice organization?" One of the biggest advantages of a multi-location venue is the variety of opportunities, both geographically and professionally available. For example, at ListenUP! Canada, our focus is the provision of rehabilitative audiology services, primarily to adults. However, our size provides flexibility and multiple opportunities: we have locations that see a mix of children and adults, some clinicians do an extensive amount of testing for ENTs, some locations are rural and others urban, some locations are situated in medical centres while others are more retail or store front. All clinicians are not alike; they have different attributes, interests and preferences. In a multi-practice organization you are more likely to find a role that is just right for you – and one that has multiple career options in the future if that's what you want.

The second question is: "How can a large organization support me professionally?" The scale of a larger company provides the flexibility and structure to enhance and develop your skills and credentials. With designated professional development time, internal conferences and vendor training sessions customized to our needs, an internal certification program that in some cases goes beyond what you learned in school (i.e., mostly practical things that are essential for dispensing audiologists to know), the private sector, and ongoing training and development programs on core areas of competency to enhance your skills as a clinician, you will enjoy an enriched clinical environment. There are also extensive opportunities to share experiences and learn from a large variety of professionals, some with over 20 or 30 years of experience. Large organizations are simply better equipped to support their own staff through ongoing professional development investments and activities – and they are both willing and able to do so.

The third question you need to ask yourself is: "Is a multi-practice organization right for me?" I have already related many advantages available in a multi-practice organization; however, there is no question that large organizations, such as ListenUP! Canada may not be the right fit for all clinicians. For example, we are a quickly growing and evolving company which can bring with it ongoing challenges. One thing that does not change around here is that we are in a constant mode of change! We experiment, try new products and vendors, look for ways to constantly improve the value that our clients receive, and explore various clinical and development strategies. There is a constant focus on how or what can we do to be better. Change is not always a good thing but it is necessary for the growth that we have seen from two locations seven years ago to now over 80 locations. What worked for a company with two locations, will not work where we are at today. We strive to provide not only an exceptional hearing health care experience for our clients, but also to provide a rich and fulfilling work experience for our staff. To accomplish this, change is a key ingredient and it requires our staff to work in a very dynamic environment. While some clinicians excel in this environment, others may find it too challenging.

In addition to the changing environment, some people just fit better at ListenUP! For example:

- Many of our most successful clinicians have outstanding interpersonal and social skills such as a naturally outgoing personality, and poise and confidence in dealing with the public. These are often innate attributes that cannot be learned. How are your social skills?
- Some clinicians have a desire to progress into management roles and others do not – both fit well with us. What does your vision for a career look like?
- Some clinicians are comfortable with predetermined and set standards for protocols and practices which is important for success in a large organization. How do you feel about that?
- Being a team player is also critical for success here. The ability to work cooperatively in a collegial setting. Are you better off working on your own or with others?

The good news is that everyone fits well somewhere.

In summary, working in a multi-practice organization offers audiologists – both new grads and experienced clinicians – an incredible array of flexibility, growth opportunities and options. From clinical work and business development to mentoring and training, a multi-practice setting provides unparalleled career advancement opportunities or even

more importantly, a place to *practice* your profession without the headaches and significant risks of running your own business.

Which twists and turns will your career take? Perhaps the next turn of fate will bring you to a multi-practice organization where you too could grow in a variety of ways and utilize the broad ranging support available to practice audiology. Where will I be 13 years from now? That, I cannot answer. However, I do know for certain that right now, working at ListenUP! Canada, I am as challenged, happy and excited about my career as I was when I started 13 years ago.

Check out the job posting section of the CAA website www.canadianaudiology.ca/tools-and-resources/job-postings.html

FROM THE CLASSROOM: UNIVERSITY OF OTTAWA

The Influence of Early Exposure to Frequency-Transposed Speech on Word Recognition during Infancy

Student:
Jacynthe Bigras

Supervisor:
André Marcoux, PhD

ABSTRACT

During the last year, new hearing aids have been developed that incorporate a processing feature which may prove effective for cases of severe and profound loss that affect the structures related to the coding of high-frequency information. Frequency transposition holds the possibility of providing high-frequency speech cues to an auditory system with a deficient cochlear high-frequency partition. Frequency transposition is the extraction of information from frequency regions of the speech spectrum that corresponds to the dysfunctional high-frequency regions of the cochlea and the transposition of this information to a frequency region where function is more adequate. Frequency transposition studies with adult listeners have shown increased identification of high-frequency speech items, including syllables containing high frequency consonants. A few case studies have also shown a similar benefit with young children. Therefore, it can be hypothesized that transposed speech may also facilitate overall speech recognition in infants and children with severe levels of loss. However, it remains to be determined whether this will promote the language development. A child with high-frequency severe hearing loss may more easily develop language with transposed speech versus non-transposed speech simply because of the significant increase in available acoustic cues which become audible with frequency transposition. Although a logical argument exists for employing frequency transposition, it remains an empirical question whether the frequency transposition feature of hearing aids would enhance language development in infants and children with severe and profound high-frequency hearing loss.

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The Relationship between Distortion Product Otoacoustic Emissions and Behavioural Thresholds

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ABSTRACT

Otoacoustic emissions are used in a variety of research applications, but their clinical application primarily has been limited to the identification of the presence or absence of hearing loss. Here, we describe the relationship between distortion product otoacoustic emissions (DPOAE) responses and behavioural thresholds for a range of approaches to relating the two measures. The data reviewed here suggest that there is a relationship between DPOAE *levels* and behavioural thresholds. They also suggest that DPOAE *thresholds* show a moderately strong relationship with behavioural thresholds. Although these relationships are characterized by variability, DPOAEs can be used to provide some information regarding the degree of hearing loss, in addition to their more common application where they are used to screen for hearing loss.

OUTER HAIR CELLS, OTOACOUSTIC EMISSIONS, AND BEHAVIOURAL THRESHOLDS

In a normal, healthy cochlea sound is processed in a highly nonlinear manner such that the output of the cochlea may not be directly proportional to the input. The cochlear outer hair cells (OHC) are thought to be the source of this nonlinearity.[1] One important characteristic of OHCs is that they are motile and, therefore, move in response to sound stimulation.[2] The motile action of the OHCs serves to amplify the displacement of the basilar membrane for low sound levels and this action is responsible, in large part, for our ability to hear soft sounds. The motility and nonlinear behaviour of the OHCs also results in the production of otoacoustic emissions (OAEs). OAEs are soft sounds that are produced within the cochlea but can be recorded in the ear canal. OAEs are widely used in both clinical and research applications because they provide a noninvasive probe of cochlear function and can be used to predict the status of the cochlea.

The most widespread use of OAEs is as a tool to screen for the presence or absence of hearing loss, typically in infants and young children. In this application, OAE level or signal-to-noise ratio (SNR) is used to make predictions regarding whether an ear is likely to have either normal or impaired hearing. In the event that a possible hearing loss is identified, no predictions are made regarding the

degree of hearing loss. However, the reason OAEs have been successful in screening applications is because there is a relationship between OHC function and both OAE level and behavioural-threshold level. If OHCs are damaged, OAE level is reduced and behavioural threshold increases. It is, therefore, reasonable to expect that there may be a relationship between OAE level and behavioural threshold that would allow behavioural threshold prediction from OAE responses. There have been reports of success in predicting behavioural threshold from transient-evoked OAE responses[3]; however, because the majority of the work in this area has been with distortion product OAEs (DPOAEs), we will focus on the results obtained with DPOAEs.

DPOAEs are produced in response to two pure-tones with slightly different frequencies (f_1, f_2; $f_2>f_1$). As a consequence of the nonlinear behaviour of the cochlea, stimulation with two tones results in the generation of distortion products at many different frequencies. In humans, the largest component occurs at $2f_1$-f_2 and, therefore, this is the component that is typically measured when recording DPOAEs. It should be noted, however, that the nonlinear process that produces the DPOAE arises primarily from locations near the f_2 characteristic place. Therefore, the DPOAE response (measured at the $2f_1$-f_2 frequency) is used to make predictions regarding the status of the cochlea near f_2.

DPOAE LEVELS AND BEHAVIOURAL THRESHOLDS

Several reports have been published suggesting there is a relationship between DPOAE level and behavioural threshold.[3–7] Dorn et al. described the relationship between DPOAE level and behavioural threshold for ears with thresholds falling in the normal-hearing range (i.e., thresholds between – 5 and 20 dB HL).[4] The level of f_1 (L_1) was fixed at 65 dB SPL and the level of f_2 (L_2) was fixed at 55 dB SPL. For these ears, there was a systematic decrease in DPOAE level as behavioural threshold increased from –5 to 20 dB HL. The mean DPOAE level for ears with behavioural thresholds of –5 dB HL was approximately 5 dB SPL while the mean DPOAE level for ears with behavioural thresholds of 20 dB HL was approximately –2.5 dB SPL, a decrease of 7.5 dB relative to ears with the best thresholds.

Gorga et al. report data that extend this relationship to behavioural thresholds between -5 and 55 dB HL.[6] These data are reproduced here in Figure 1. Here, audiometric (behavioural) threshold (dB HL) is plotted as a function of DPOAE level (dB SPL) for f_2 frequencies ranging from 750 to 8000 Hz (as indicated within each panel). For each f_2 frequency, L_1 and L_2 were set at 65 and 55 dB SPL, respectively. Within each panel, the dark, solid line represents the median DPOAE level and the shaded regions represent the interquartile range. These data suggest that there is a relationship between DPOAE level and

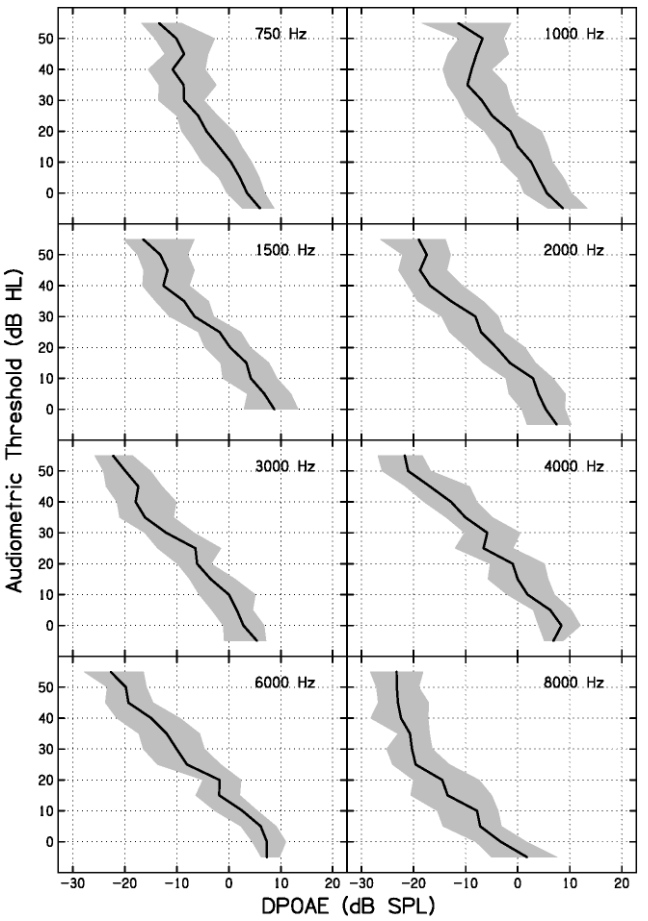

Figure 1. Behavioural (audiometric) threshold (dB HL) plotted as a function of DPOAE level (dB SPL) for eight frequencies (as indicated within each panel). Within each panel the solid line represents the median DPOAE level and the grey shaded region represents the interquartile range (Reprinted with permission from Gorga MP, Neely ST, Johnson TA, et al.[6])

behavioural thresholds ranging from –5 to 55 dB HL such that ears with poorer thresholds produce DPOAEs with lower levels than ears with better thresholds. The data in Figure 1 also illustrate that this relationship is characterized by variability as indicated by the width of the interquartile range. It should be noted that these data do not extend beyond behavioural thresholds of 55 dB HL. Complete loss of OHC function would not be expected to produce hearing losses exceeding 50 to 60 dB; therefore, it is unlikely that DPOAE level would relate to behavioural thresholds when the hearing loss exceeds 50 to 60 dB HL. Although the data in Figure 1 are variable, data such as these suggest that some information regarding behavioural threshold may be gained by examining DPOAE level.

DPOAE THRESHOLDS AND BEHAVIOURAL THRESHOLDS

Given the apparent relationship between DPOAE levels and behavioural threshold, it is reasonable to evaluate the relationship between thresholds predicted from DPOAE responses and behavioural thresholds. There have been two different approaches to predicting thresholds from DPOAE responses. The first approach involves recording DPOAE responses for decreasing L_2 levels until the response falls into the noise floor, i.e., until the SNR falls below some criterion level. We will refer to this approach as the SNR approach. The second approach involves recording DPOAE input-output (I/O) functions for a range of L_2 levels and then fitting the I/O function with a regression equation that is used to predict behavioural threshold. We will refer to this as the I/O approach. We will consider the results obtained with the SNR approach first.

Of the two approaches to determining DPOAE thresholds, the SNR approach is simpler to implement because the only requirement is to decrease L_2 until the DPOAE response is no longer distinguishable from the noise, which is often defined as the point at which the SNR falls below 3 dB. The L_2 at which this occurs becomes the DPOAE threshold. Several studies have explored the relationship between the SNR-based DPOAE thresholds and behavioural thresholds.[3,8–10] Across these studies, correlation coefficients ranged from 0.52 to 0.91. The strongest correlations are for f_2 's between 1.5 and 6 kHz, where correlations exceed 0.75 in most reports. These data suggest that there is a linear relationship between SNR-based DPOAE thresholds and behavioural thresholds, although there is variability in the relationship.

Boege and Janssen developed a technique for predicting behavioural threshold from the DPOAE I/O function.[11] In this approach, DPOAE levels were recorded for a range of L_2s, with L_2 not exceeding 65 dB SPL. If at least 3 L_2s produced DPOAEs with a 6-dB SNR or greater, the DPOAE levels (measured in dB SPL) were converted to pressure values (µPa). The resulting data were then fit with a linear-regression equation. For those I/O functions where the regression line was judged to be a good fit (based on evaluation of r^2, slope, and standard error values), the regression equation was solved for the L_2 where the DPOAE level equalled 0 µPa. This L_2 was defined as the DPOAE threshold, which was then correlated with behavioural threshold.

Using this I/O approach, Boege and Janssen reported a correlation of 0.65

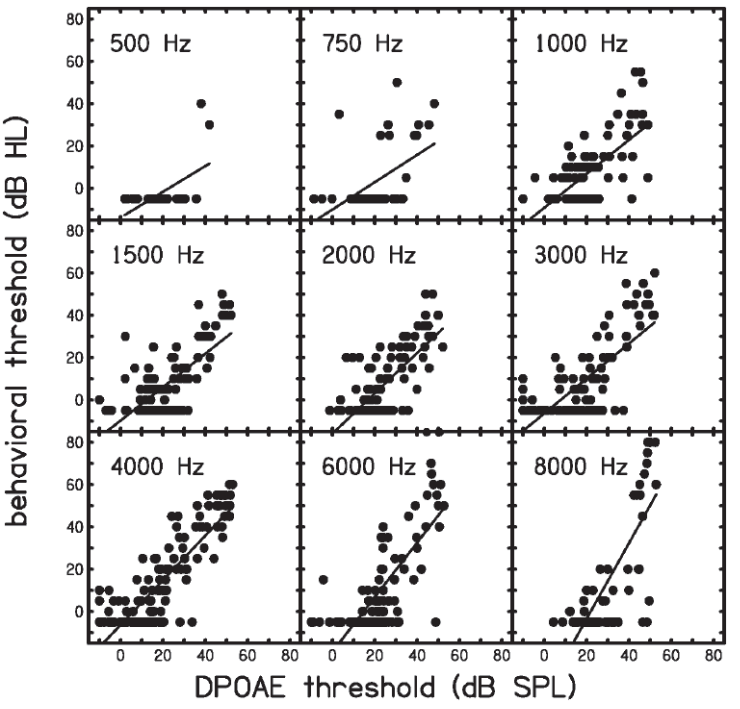

Figure 2. Behavioural threshold (dB HL) plotted as a function of DPOAE threshold (dB SPL) using the I/O approach to determining DPOAE threshold (see text for details). Each panel represents results for a different frequency and the solid line within the panels represents the linear regression line (Reprinted with permission from Gorga et al.[12])

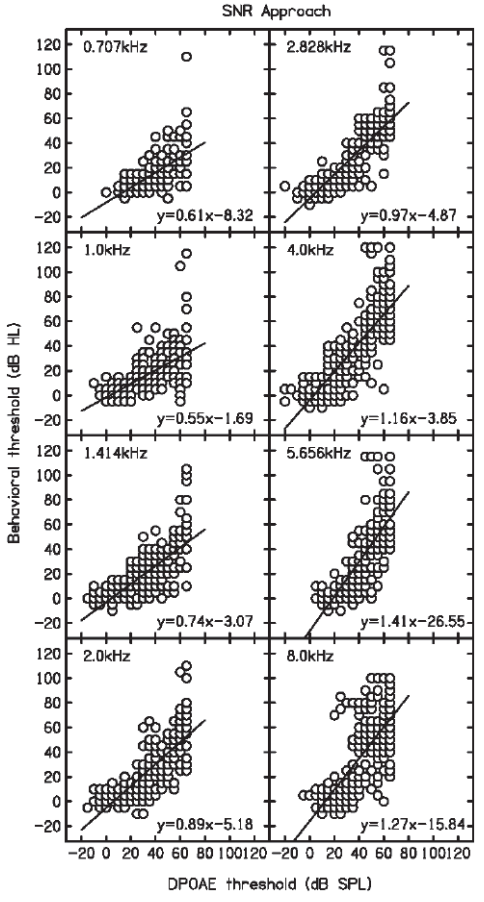

Figure 3. Behavioural threshold (dB HL) plotted as a function of DPOAE threshold (dB SPL) using the SNR approach to determining DPOAE threshold (see text for details). Each panel represents a different frequency. The solid line within each panel is the linear regression line whose equation is shown as an inset in each panel. Data plotted in Figures 3 and 4 were collected in the same group of subjects (Reprinted with permission from Johnson et al.[9])

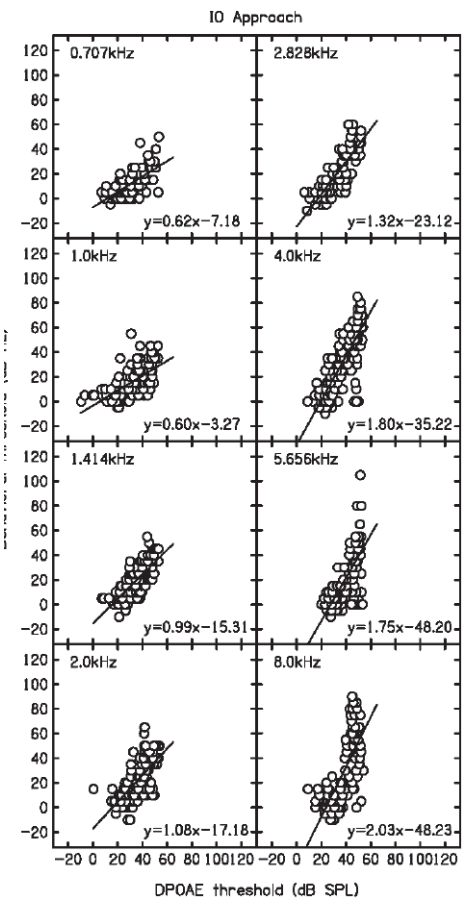

Figure 4. Behavioural threshold (dB HL) plotted as a function of DPOAE threshold (dB SPL) using the I/O approach to determining DPOAE threshold (see text for details). Each panel represents a different frequency and the solid line within each panel is the linear regression line whose equation is show as an inset. These data were collected in the same group of subjects as the data in Figure 3 (Reprinted with permission from Johnson et al.[9])

between behavioural thresholds and DPOAE thresholds, although they did not explore the extent to which this relationship varied across frequency.[11] Using a similar I/O approach to the one described by Boege and Janssen, Gorga et al. explored the relationship between DPOAE thresholds and behavioural thresholds as a function of frequency.[12] A summary of their data is reproduced in Figure 2. Here, behavioural threshold (dB HL) is plotted as a function of DPOAE threshold (dB SPL), with each panel representing a different frequency. The solid line within each panel is the best-fit line. Correlation coefficients ranged from 0.49 at 750 Hz to 0.85 at 4000 Hz. For low frequencies between 500 and 750 Hz, the correlations were ≤ 0.57, whereas the correlations were ≥ 0.66 for frequencies above 750 Hz and were ≥ 0.74 for frequencies above 1500 Hz. These data suggest that there is a relationship between DPOAE thresholds and behavioural thresholds for mid-to-high frequencies, although, as was the case for the SNR approach, the relationship is characterized by variability.

In addition to describing the relationship between DPOAE and behavioural thresholds, Gorga et al. also explored the characteristics of the ears not meeting the inclusion criteria for estimating DPOAE threshold from the I/O function.[12] Of those ears not producing three points on the I/O function with a 6 dB or higher SNR, the majority had hearing loss. For example, at 750 Hz 78% of ears not meeting the SNR criterion had thresholds ≥ 30 dB HL and at 4000 Hz 100% of the ears not meeting this criterion had thresholds ≥ 30 dB HL. In contrast, the majority of ears not meeting the criteria for goodness of regression fit (i.e., r^2, slope, and standard error values) had thresholds ≤ 30 dB HL These results suggest that some information regarding auditory status is available even for ears where a DPOAE threshold could not be estimated from the I/O function.

The data described above suggest that there is a relationship between DPOAE thresholds and behavioural thresholds using both the SNR approach and the I/O approach to estimating DPOAE threshold. Is there any advantage to using one approach as compared to the other? Johnson et al. explored the relationship between DPOAE thresholds and behavioural thresholds when both approaches were used to predict behavioural thresholds in the same group of subjects.[9] Figures 3 and 4 plot the results reported by Johnson et al. that describe the relationship between DPOAE thresholds and behavioural thresholds for the two approaches. Results for the SNR approach are plotted in Figure 3, with results for the I/O approach plotted in Figure 4. In both

figures, each panel represents data for a different frequency between 707 and 8000 Hz. The solid line in each panel is the best-fit line whose equation is shown as an inset in each panel. As can be seen in Figures 3 and 4, there is a relationship between DPOAE threshold and behavioural threshold for both approaches. Correlation coefficients were similar for the two approaches, ranging from 0.59 to 0.87 with correlations ≥ 0.67 for frequencies above 1000 Hz (with most cases exceeding 0.70). There was no consistent pattern of correlations favouring one approach as compared to the other. These data suggest that both approaches result in a similar linear relationship between DPOAE thresholds and behavioural thresholds.

Although the data plotted in Figures 3 and 4 suggest a similarity between the SNR and I/O approaches, Johnson et al. explored other aspects of the comparison that might be important in clinical implementations.[9] This included examining the number of ears for which a DPOAE threshold could be estimated. For the I/O approach, a DPOAE threshold could be estimated in 36 to 54% of ears, depending the frequency at which the prediction is made. In contrast, for the SNR approach, DPOAE thresholds could be predicted in 57 to 94% of ears for the same range of frequencies. The number of ears for which a DPOAE threshold could be estimated using the SNR approach exceeded the I/O approach by nearly 30 to 50% for most frequencies. However, it appears that the wider applicability of the SNR approach comes at the expense of the accuracy of the prediction. The standard errors for the I/O approach ranged from 7.29 to 19.61 dB and were less than approximately 12 dB for the frequencies 707 to 4000 Hz. In contrast, the standard errors for the SNR approach were between 11.64 and 21.59 dB, and exceeded 13 dB for all frequencies above 707 Hz. At every frequency, standard errors for the I/O approach were between 2 and 6 dB less than those observed for the SNR approach.

SUMMARY

The data reviewed here suggest that there is a relationship between DPOAE levels and behavioural thresholds, as might be expected based on the contribution of OHC function to both DPOAE responses and behavioural threshold levels. They also suggest that there is a moderately strong linear relationship between DPOAE thresholds (using either the SNR or the I/O approach) and behavioural thresholds. While the correlations between DPOAE thresholds and behavioural thresholds are similar for the SNR and I/O approaches, the I/O approach can be applied to fewer ears but yields a more accurate prediction than the SNR approach. Although there is variability in the relationship, the data reviewed here suggest that information regarding behavioural threshold can be obtained from recording DPOAE thresholds.

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