Phonak Academy
13 - 14 giugno 2016
Milano

SORDITÀ E TECNOLOGIA AUDIOLOGICA TRA ATTUALITÀ E FUTURO

Chairmen
Sandro Burdo, Domenico Cuda

Abstracts
HEARING LOSS AND AUDIOLOGICAL TECHNOLOGY BETWEEN PRESENT AND FUTURE

Today, modern sciences have found a breeding ground in audio/otology to express the top of their practical applications. We are talking about molecular biology, genetics, neurology, psychology, physiology of sensorial apparatus, surgery, electronics, informatics, acoustics, bionics etc... We may say that today’s professionals involved in audio/otology are witnessing and enjoying different cultural revolutions. Modern biotechnology is changing every day clinical practice in a manner that could not be dreamt of in the past. This is luck.

The main topics discussed in this 2016 Phonak Academy meeting are related to these concepts. Genetics of deafness and molecular biology and histopathology of cochlear hair cells were pioneering fields of research. Concepts like cross-modal reorganization and auditory connectome have revolutionized the knowledge of neuropathology in general.

The applications of modern technology in diagnostic tools, hearing aids, cochlear implants and wireless sound transmitters have made it possible to face and solve problems that were without solution only a few years ago. Diagnosis in very young deaf children, elderly patients, unilateral deaf people are some examples of the new topics included in the 2016 Phonak Academy meeting with some of the best reputed experts in the field.

Sandro Burdo  
Audiovestibology Center  
Varese, Italy

Domenico Cuda  
ENT Dept. G. Saliceto Hospital  
Piacenza, Italy
Programma
# Day 1 – June 13, 2016

## Welcome and opening
Sandro Burdo (Varese, Italy) – Domenico Cuda (Piacenza, Italy)

## BASIC SCIENCE

### Genetica della sordità

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<th>Time</th>
<th>Topic</th>
<th>Speaker</th>
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<tbody>
<tr>
<td>10.00</td>
<td>Genetics of deafness</td>
<td>Alessandro Martini</td>
<td>Dept of Neurosciences, University of Padova, Italy</td>
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### Modelli murini della sordità ereditaria

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<th>Time</th>
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<tr>
<td>10.30</td>
<td>Mouse models of hereditary deafness</td>
<td>Fabio Mammano</td>
<td>CNR Institute of Cellular Biology and Neurobiology Roma, Italy</td>
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### Fattori neurocognitivi nel ripristino sensoriale della sordità precoce: un modello di Connettoma

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<tr>
<td>11.00</td>
<td>Neurocognitive Factors in Sensory Restoration of Early Deafness: a Connectome Model</td>
<td>Andrej Kral</td>
<td>Institute of Audio Neuro Technology Hannover Medical School, Germany</td>
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### Udito Bilaterale

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<th>Time</th>
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<tr>
<td>11.30</td>
<td>Bilateral hearing</td>
<td>Sandro Burdo</td>
<td>AudioVestibology Center, Varese – Children Hospital V. Buzzi, Milan, Italy</td>
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### Riorganizzazione cross modale nella sordità

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<tr>
<td>12.00</td>
<td>Crossmodal reorganisation in deafness</td>
<td>Pascal Barone</td>
<td>French National Centre for Scientific Research Paris, France</td>
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### Pathology

### Patologia cocleare nelle neuropatie uditive

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<tr>
<td>12.45</td>
<td>Pathology of the cochlea in clinical auditory neuropathy</td>
<td>Jean-Luc Puel</td>
<td>Institute for Neurosciences, Montpellier, France</td>
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### Disordini del processing uditivo

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<tr>
<td>13.15</td>
<td>Auditory processing disorders</td>
<td>Elisabetta Genovese</td>
<td>ENT Department, University Hospital Modena, Italy</td>
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### Buffet lunch

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<tr>
<td>13.45</td>
<td>Buffet lunch</td>
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14.45 Current perspectives on minimal and mild hearing loss in children
*Attualità in tema di lievi e medie ipoacusie nell’infanzia*
Anne Marie Tharpe
Department of Hearing and Speech Sciences
Vanderbilt Bill Wilkerson Center - Vanderbilt University, Nashville, TN - USA

15.15 Question time

**DIAGNOSIS**

15.30 Frequency-Specific Evoked Potential Audiometry: clicks, pips or chirps?
*Audiometria oggettiva specifica in frequenza: clicks, pips o chirps?*
Andy Beynon
Radboud University Medical Centre, Nijmegen, Netherlands

16.00 Aided corticals: bridging the gap between early fitting and behavioural assessment
*Potenziali corticali con protesi: strumento di unione tra l’adattamento protesico precoce e l’audiometria comportamentale*
Kevin J. Munro
School of Psychological Sciences, University of Manchester, UK

16.30 Behavioural testing of Infants and young children
*Audiometria comportamentale nei primo anno di vita e in età pediatrica*
Anne Marie Tharpe
Department of Hearing and Speech Sciences
Vanderbilt Bill Wilkerson Center - Vanderbilt University
Nashville, TN - USA

17.00 Adaptation of the STARR test (Adaptive Randomized Roving Levels) for adult Italian population: Normative data and results in adult cochlear implantees
*Adattamento dello STARR test (Adaptive Randomized Roving Levels) in lingua italiana: dati normativi nella popolazione adulta e risultati in pazienti con impianto cocleare*
Patrizia Mancini
Dipartimento Organi di Senso, Università degli Studi di Roma “La Sapienza”

17.30 Question time

17.45 Coffee break

**HEARING AIDS AND ASSISTIVE DEVICES – I**
**APPARECCHI ACUSTICI E DISPOSITIVI DI SUPPORTO – I**

18.15 Bimodal hearing
*Udito bimodale*
Domenico Cuda
ENT Department, “Guglielmo da Saliceto” Hospital, Piacenza, Italy

18.45 Single side deafness and cochlear implants
*Sordità monolaterale e impianti cocleari*
Alessandra Murri
ENT Department, “Guglielmo da Saliceto” Hospital, Piacenza, Italy

19.15 Happy Hour
Day 2 – June 14, 2016

HEARING AIDS AND ASSISTIVE DEVICES – II
APPARECCHI ACUSTICI E DISPOSITIVI DI SUPPORTO - II

09.00 Do older hearing aid users need particular gain compressions?
*I protesizzati anziani necessitano di compressioni di guadagno particolari?*
Nicola Quaranta
ENT Department, University Hospital Bari, Italy

09.30 New trends on frequency compression
*Novità in tema di compressioni in frequenza*
Michael Boretzki
Sonova Science and Technology
Stäfa, Switzerland

10.00 Clinical evidences about the use of new frequency compressions
*Evidenze cliniche sull’uso clinico delle compressioni in frequenza*
Michael Nilsson
Phonak AG, Switzerland

10.30 Coffee break

11.00 Remote Microphone Technology for Persons with Hearing Loss: Accessory or Necessity
*Microfoni a distanza per gli ipoacusici: accessori o necessità?*
Linda Thibodeau
University of Texas, Dallas, USA

11.30 Guidelines for assessing hearing aid output, features and fitting parameters in infants and young children.
*Linee guida per identificare le uscite protesiche, le caratteristiche ed i parametri di adattamento nel primo anno di vita e in età pediatrica*
Mariene Bagatto
National Centre for Audiology, University of Western Ontario
London, Ontario - Canada

12.30 Question time

12.45 Buffet lunch

COCHLEAR IMPLANTS
IMPIANTI COCLEARI

13.45 Hearing Preservation with the HiFocus™ Mid-Scala Cochlear Implant: a single United Kingdom centre experience
*La preservazione dell’udito con l’implan\-to Hi Focus Mid-Scala: l’esperienza di un centro inglese*
Dan Jiang
King’s College London, St. Thomas’ Hearing Implant Centre, London - UK

14.45 Hearing aid and CI in opposite ears: bimodal use, benefits and beamforming
*Associazione protesi acustica e impianto cocleare controlaterale: utilizzo bimodale, benefici e beam forming*
Robert Stokroos
Maastricht University Medical Center - Netherlands
15.15 Cochlear implants in elderly
   Impianti cocleari negli anziani
   Gaetano Paludetti
   ENT Department, University Hospital Gemelli, Roma, Italy

15.45 Acoustic Prescriptive Fitting for Bimodal CI Recipients
   Formula Prescrittiva per utilizzatori di soluzioni Bimodali
   Josef Chalupper
   Advanced Bionics GmbH – European Research Center
   Hannover – Germany

16.15 Question time

17.00 End of the conference
   CME test for the Italian participants
Abstracts
Negli ultimi 30 anni si è assistito ad un rapido sviluppo della genetica e delle tecniche di analisi del DNA che ha permesso di comprendere la struttura del genoma ed i meccanismi biologici alla base di moltissime malattie umane. I miglioramenti tecnologici e bioinformatici che si sono susseguiti nell’ultimo decennio hanno inoltre determinato una importante riduzione dei costi di analisi, offrendo, in ambito clinico, possibilità fino a qualche anno fa improponibili nella diagnosi genetica.

In generale, le forme genetiche di ipoacusia possono essere classificate in due principali categorie, ipoacusie sindromiche e non sindromiche, in base alla compresenza o meno di malformazioni dell’orecchio esterno o di anomalie in altri organi ed apparati. Più di 400 sindromi con ipoacusia sono state ad oggi descritte: esse possono essere causate da anomalie cromosomiche oppure da piccole mutazioni in singoli geni specifici (malattie monogeniche). Le ipoacusie genetiche non sindromiche sono invece generalmente malattie monogeniche causate da piccole mutazioni in specifici geni.

In base al quadro clinico, è pertanto fondamentale scegliere caso per caso il test genetico adeguato cui sottoporre il paziente affetto da ipoacusia: una mutazione genetica che viene identificata mediante una determinata tecnica di analisi potrebbe non essere invece riconosciuta applicandone un’altra. Ciò sottolinea l’importanza di una collaborazione stretta tra lo specialista in ORL/audiologia e il genetista clinico nell’inquadramento diagnostico delle ipoacusie.

Le tecniche di analisi dei cromosomi includono l’esame cromosomico standard e ad alta risoluzione (tecniche di citogenetica classica), l’analisi FISH e l’analisi array-CGH (tecniche di citogenetica molecolare).

Lo sviluppo di tecnologie sempre più avanzate ha notevolmente ridotto i tempi ed i costi del sequenziamento del DNA, rivoluzionando l’analisi genomica. Tali metodiche, che si basano sul sequenziamento massivo parallelo di molecole di DNA e sono definite “next generation sequencing” (NGS), hanno permesso nel 2008 di sequenziare un genoma umano in un periodo di soli 5 mesi con un costo di circa 1.5 milioni di dollari. Il costo del sequenziamento si è poi ulteriormente ridotto in maniera consistente negli anni seguenti, tanto che oggi è possibile sequenziare tutta la regione codificante di un genoma (esoma) per meno di 1000 Euro.

Le applicazioni delle tecniche NGS permettono pertanto l’analisi di interi genomi ed esomi, ma anche lo studio di singoli geni di grandi dimensioni e pannelli di geni in breve tempo.

La grande sfida attuale per l’utilizzo delle tecnologie NGS in ambito diagnostico-clinico è rappresentata dallo sviluppo di software adatti all’analisi bioinformatica e soprattutto dalla corretta interpretazione dei dati ottenuti.

I vantaggi nella diagnosi sia delle ipoacusie sindromiche monogeniche (causate spesso da mutazioni in geni di grandi dimensioni) sia delle ipoacusie non sindromiche (caratterizzate da una estrema eterogeneità genetica) sono indubbiamente notevoli.

MOUSE MODELS OF HEREDITARY DEAFNESS
Fabio Mammano
Institute of Cell Biology and Neurobiology
Rome, Italy

KEY WORDS
Inner ear, utricle, hair cell stereocilia, PMCA2w/a , Connexin 26, Connexin 30, Ca²⁺ imaging, Ca²⁺ uncaging, patch-clamp, immunofluorescence, confocal microscopy, computational modeling, molecular dynamics.
Calcium ions (Ca^{2+}) regulate numerous and diverse aspects of cochlear and vestibular physiology. Using different mouse models of hereditary deafness, my laboratory has focused on the Ca^{2+} control of mechanotransduction (MET) in sensory hair cells, as well as on Ca^{2+} signalling in non–sensory cells of the developing cochlea.

Sensory hair cells of the inner ear detect sound stimuli, inertial or gravitational forces. These cause deflection of the cell stereociliary bundle and activate a small number of cation–selective MET channels that admit K^+ and Ca^{2+} ions into the cytoplasm. Stereociliary Ca^{2+} levels are homeostatically regulated by an unusual splicing isoform (w/a) of plasma–membrane calcium–pump isoform 2 (PMCA2w/a), ablation or missense mutations of which cause deafness and loss of balance in humans and mice. At variance with other PMCA2 isoforms, PMCA2w/a expressed in CHO transfectants increases only marginally its activity in response to a rapid increase of the cytoplasmic free Ca^{2+} concentration ([Ca^{2+}]_c). In this expression system, deafness–related mutations of PMCA2w/a decrease the pump ability to extrude Ca^{2+} both at steady–state and in response to a [Ca^{2+}]_c rise. Consistent with these findings, mouse strains in which the pump is genetically ablated or mutated show hearing impairment correlated with defects in homeostatic regulation of stereociliary Ca^{2+}, decreased sensitivity of the MET channels to hair bundle displacement and morphological abnormalities in the organ of Corti. These results highlight a critical role played by PMCA2w/a in the control of hair cell function and survival and provide mechanistic insight into the etiology of deafness and vestibular disorders.

Hearing relies not only on the functional maturation of hair cells, but also on differentiation and proper organization of non–sensory cell networks that transfer signaling, ion, and nutrient molecules through gap junction channels. In the mammalian cochlea, gap junction channels are formed primarily by connexin26 and connexin30 protein subunits, which are encoded by nonsyndromic hearing loss and deafness (DFNB1) genes GJB2 and GJB6, respectively. The fact that DFNB1 is the most common form of inherited deafness in Caucasian populations highlights the importance of connexins for hearing. Mouse models confirmed that connexin26 and connexin30 are essential for auditory function and for survival and development of the organ of Corti. These animal models also revealed critical gaps in our current understanding of the role played by connexins in the inner ear and the etiology of deafness due to absent or mutated connexins. Deafness and absence of an endocochlear potential in mice lacking connexin30 correlate with: (1) disruption of the endothelial barrier of the capillaries supplying the stria vasularis before endocochlear potential onset; (2) down–regulation of betaine–homocysteine S–methyltransferase; and (3) local increase in homocysteine, a known factor of endothelial dysfunction with no obvious link to gap junction channel function. Similarly, the hypothesis that connexin dysfunction impacts primarily on K^+ recycling is challenged by the identification of connexin26 human recessive deafness mutants, e.g. V84L, that are capable of forming functional channels. Studies performed in model cells indicate that connexin26 V84L mutant channels are as permeable to K^+ as wild type channels. However, the transfer of the Ca^{2+}–mobilizing second messenger IP_3 (and possibly of other key metabolites) through the mutant channels is impaired. Thus, the permeability of connexin gap junction channels to metabolites, and not simply to small inorganic ions, is likely to play an important role in development, physiology and etiology of connexin–related hearing impairment. Using a mouse model with defective expression of phosphatidylinositol phosphate kinase type 1 (PIPKI), we have demonstrated that: (a) PIPKI is primarily responsible for the synthesis of the PIP_2 pool in the cell syncytia that support auditory hair cells; (b) cochlear non–sensory cells of the lesser and the greater epithelial ridge share the same PLC– and IP_3R–dependent signal transduction cascade activated by ATP; (c) spatially graded impairment of this signaling pathway in cochlear non–sensory cells causes a selective alteration in the acquisition of hearing.

Altogether, these findings support the hypothesis that connexin dysfunction may ensue in a deafness phenotype due to impaired ATP– and IP_3–dependent Ca^{2+} signaling. This tenet is exemplified by a study of hearing loss based on the substitution of an evolutionarily conserved threonine by a methionine residue at position 5 near the N–terminus of connexin30 (connexin30 T5M). Connexin30(T5M/T5M) mice exhibit a mild, but significant increase of about 15 dB in their hearing thresholds at all frequencies. Western blot analysis of adult inner ear tissue shows significantly down–regulated expression levels of connexin26 and connexin30. In the developing cochlea, electrical coupling between cells, probed by
dual patch–clamp recordings, is normal. However, transfer of the fluorescent tracer calcein between cochlear non–sensory cells is reduced, as is intercellular Ca\textsuperscript{2+} signaling due to spontaneous ATP release from connexin hemichannels. Permeation of these two signaling molecules (ATP and IP\textsubscript{3}), which are both highly negatively charged and have similar size is most likely correlated. Therefore a point mutation that affects IP\textsubscript{3} passage through the channel pore may affect also the passage of ATP, and vice versa. Work is currently underway in our laboratory to confirm this hypothesis using molecular dynamics.

REFERENCES

8. Crispino G et al. (2011) PLOS ONE Volume: 6 Issue: 8 Article Number: e23279

NEUROCOGNITIVE FACTORS IN SENSORY RESTORATION OF EARLY DEAFNESS: A CONNECTOME MODEL

Andrej Kral (William G. Kronenberger, David B. Pisoni and Gerard M. O'Donoghue)
Institute of AudioNeuroTechnology (VIANNA) Hannover Medical School, Germany

Progress in biomedical technology (cochlear, vestibular and retinal implants) has led to remarkable success in neurosensory restoration, particularly in the auditory system. However, outcomes are characterized by considerable variation even if accounting for comorbidity: whereas some deaf children following cochlear implantation develop spoken language skills approaching those of their hearing peers, others fail to do so. Here we review evidence that auditory deprivation has widespread consequences on brain development, affecting its information processing capacity also beyond the auditory system. After sensory loss and deafness, the brain’s connectivity is altered within the auditory system, between the sensory systems, and between auditory system and centers serving higher-order neurocognitive functions. As a result, congenital sensory loss may be conceptualized as a “connectome disease”, with inter-individual variability in the brain’s adaptation to sensory loss underpinning much of the observed variation in outcome of cochlear implantation. Different executive functions, sequential processing, and concept formation are at particular risk in deaf children. A clinical test battery can allow early identification of neurocognitive risk factors. Intervention strategies that address these impairments in a personalized approach, taking interindividual variations into account, will further improve outcomes.
BILATERAL HEARING
Sandro Burdo M.D.
Audiovestiboloy Center, Varese, Italy

The act of listening is a binaural event, and it is not the effect of a mere sum of inputs from the two ears. This means the auditory apparatus fulfills its function when three organs are working together, i.e. the right ear, the left ear and the Binaural Processor (BP). The inputs from the two ears are not only merged but further processed.

The Binaural Processor is divided into two sites: Brainstem and Cortex. The Brainstem does the energetical optimization, while the Cortex does the informational one. Anatomically, the BP is located in the brainstem between the Cochlear Nuclei and the Inferior Colliculi, and the main relais is the Olivar Complex. Here the stimuli are analyzed and processed by dedicated neurons (Jeffres coincident neurons) in terms of interaural differences of time and loudness, which represent the so called Binaural Cues, and emphasized by the head-shadow effect and by the external ear. The cortical area involved with the BP is confined to a distinct subregion of the primary auditory cortex, located in both hemispheres at the lateral end of Heschl’s gyrus.

During normal listening, the stimulus is mainly processed through the crossed auditory pathways. In summary: the Cochlear Nuclei perform the spectral analysis, the Olivary Complex the spatial analysis and the Colliculus does the integration between the two. The Binaural Processor shows a critical feature, i.e. plasticity. It proves to follow a kind of scheduled “maturation calendar” and is also shaped during time by learning processes. This is only true during a well-defined Critical Period. That’s why we learn to listen binaurally and this ability may also be trained, as long as we do so within temporal limits. If we understand the concept of the BP as an individual organ, we can figure out situations and patients suffering from “a functionally sick” BP. This may depend on a primary condition, like in some Auditory Processing Disorders, or be secondary for example to unilateral hearing deprivation, as it is in unilateral implantation. In the past, the BP was widely studied but scientists tended to focus mainly on localization skills and listening in noise. Clinical observation has taught us a lot about other major advantages of binaural hearing, including listening to the TV and incidental listening skills.

We also evaluated the binaural benefits considering the individual performances (range between +50% and + 5%), because such data are more realistic than what commonly said about the mean improvement in speech recognition (20%) even if we can not inform the patients about the individual amount of the bilateral benefit before the surgery.

Another topic we have developed considering the physiology of the Binaural Processor is how to enhance the Binaural Cues by modifying the CI stimulation, i.e. by means of an asymmetric rate of stimulation. In terms of Bilateral Implantation, it is today well known that results are quite different between simultaneous versus long-time sequential implantation. Such differences in the outcome may be explained by comparing the Unilateral Sequential CI (explanted and reimplemented in the contralateral ear) versus the Bilateral Sequential CIs (with the first implant kept active).

This comparison demonstrates the important concept that the unsatisfying results in late sequentially implanted do depend on the hearing deprivation, but also on a process of Active Inhibition on the part of the first ear over the second. The discovery of such Active Inhibition leads us to more considerations.

The first is clinical, as the phenomenon is not limited to implantation but it is also true for any late therapy, including genetics. So the idea of preserving one ear for future therapies is totally inaccurate. The second consideration is practical, in terms of a correct programming of rehabilitation for Sequential Bilateral Implantation. Our efforts should not be limited to the deprived ear (the one implanted sequentially), but also to the inhibitor, that is to the first implanted one.

Experience teaches us that good results can be achieved also in late sequentially implanted patients, with dedicated rehabilitation strategies involving both the deprived and the inhibitor ear in simultaneous
trainings in order to use the natural crossed pathways.

Finally it is important to remember that technology today allows us to restore bilateral hearing in all cases of hearing loss: single side, asymmetrical or symmetric losses, by fitting and coupling, when necessary, hearing aids and Cochlear Implants. In other words we have today the chance to activate all the three organs (both ears and the Binaural Processor) in order to obtain the best listening quality.

On the other hand we must keep in mind the iatrogenic damage effects produced by unilateral fitting or surgery, because this means deprivation of two organs, not only one, that is one ear and the Binaural Processor.

REFERENCES

11) NICE Cochlear implants for children and adults with severe to profound deafness. Technology appraisal guidance [TA166] Published date: January 2009.
CROSSMODAL REORGANIZATION IN DEAFNESS
Pascal Barone
Cerveau & Cognition, CNRS, Toulouse, France

There is now a large body of psychophysical and neuroimaging studies in both animal and human subjects showing that auditory deprivation leads to functional compensations that favor the spared modalities. Perceptual crossmodal compensation in deafness is accompanied by functional reorganizations such as an invasion of the deprived auditory cortical areas by visual functions. The degrees of functional reorganization and cross-modal compensation are highly dependent on the age at which the sensory deprivation occurs, as a result of the decreasing capacities of adaptive plasticity of the brain from birth to adulthood. The objective of this presentation will be to elucidate the neuronal mechanisms of cortical plasticity in adult that support intra- and cross-modal reorganization after deafness. Further, since hearing can be restored through cochlear implant, the functional interactions between the visual and auditory modalities will be assess in light of the capacity of the auditory system to regain its original function. Altogether, this presentation will highlight on cortical plasticity as key factors for the functional recovery of the auditory cortex after cochlear implantation.

PATHOLOGY OF THE COCHLEA IN CLINICAL AUDITORY NEUROPATHY
Jean-Luc Puel,
Institut for Neuroscience of Montpellier – Inserm 1051

Auditory neuropathy is a variety of hearing loss in which the outer hair cells (OHCs) within the cochlea are present and functional, but sound information is not faithfully transmitted to the brain. Together with the otoacoustic emissions, the sound-evoked compound action potential (CAP) and its corresponding wave I of the auditory brainstem responses (ABRs), are commonly used to probe auditory neuropathy in experimental and clinical settings. Based on paired recordings of the single units and sound-evoked CAP, we previously report that the delay of the first-spike latency and its large jitter makes the low-SR/high threshold ANFs unlikely to contribute to triggered-CAP amplitudes and thresholds (Bourien et al., J Neurophysiol. 2014 Sep 1;112(5):1025–39.). This limitation led us to record the asynchronous activity of the ensemble of ANFs from an electrode placed on the auditory nerve. The electrical neural noise is classically described on the basis of its average spectral component (power spectrum density (PSD) response) which displays a predominant peak near 900 Hz. At low level, the PSD responses predominates in the 2,000 Hz area. Up to 30 dB SPL, a second component of responses centered on 16,000 Hz appeared. At 60 dB SPL, two patterns of responses was clearly identified, i.e. a bimodal distribution with a cut off frequency around 5.6 kHz. To probe that the bimodal shape reflects the distribution of the different pools of ANFs (i.e. high-, medium and low-SR fibers), we selectively destroyed the lowest-SR ANF by infusing 33µM ouabain onto the round window membrane. Together with a concomitant deletion of a small contingent of ANFs in the basal turn of gerbil cochlea (where the low-SR are located), we report a decreased of PSD responses in the 16,000 Hz frequency range, leaving the lower frequency region relatively unaffected. Thus, round window PSD responses may provide a useful tool to probe the distribution of ANF in humans or other species for which direct single unit recordings are not feasible.

AUDITORY PROCESSING DISORDERS
Elisabetta Genovese
Department of Head and Neck, Audiology and Phoniatic Service, University of Modena and Reggio Emilia, Italy

Auditory processing disorder (APD) is characterized by the presence of listening difficulties despite a
normal audiogram. APD is becoming ever more widely diagnosed in children, although the definition, diagnosis, and aetiology are controverted. This presentation deals with the current literature on definition and diagnosis of APD or central auditory processing disorder (CAPD). Because APD is one of the more difficult information-processing disorders to detect and diagnose, it may sometimes be misdiagnosed as ADD/ADHD, Asperger syndrome, and other forms of autism, but it may also be a comorbid aspect of those conditions (Moore, 2006). Interest in diagnosis and management of CAPD spans more than a half-century. Myklebust (1954) stressed the importance of clinically evaluating central auditory function, especially in children affected by communicative disorders. Tests used today to diagnose CAPD have roots in this early work, such as interaural intensity difference training and interhemispheric transfer training. CAPD is an auditory deficit; therefore, the audiologist is the professional who diagnoses CAPD (ASHA, 2005a; 2005b). Although efforts continue to develop more sensitive behavioural tests for the assessment of central auditory function, electrophysiologic, electroacoustic, and neuroimaging procedures may soon transform clinical auditory processing test batteries (see, e.g., the work of Estes et al., 2008). In our clinic, all participants with auditory difficulties are tested with a specific protocol, including audiologic evaluation with audiometry threshold, speech audiometry, and tympanometry. In a second step the patient is tested for his or her ability to understand speech with and without noise.

CURRENT PERSPECTIVES ON MINIMAL AND MILD HEARING LOSS IN CHILDREN

Anne Marie Tharpe
Dept. Hearing and Speech Sciences
Associate Director of the Vanderbilt Bill Wilkerson Center
Vanderbilt University, Nashville, TN - USA

Over the last several decades, professionals have learned a great deal about the impact of minimal and mild permanent hearing loss (MMHL) on children. Once considered a problem that could be easily managed by preferential positioning of the listener relative to the talker of interest or, in the case of school-age children, preferential classroom seating, research has accumulated over the last several decades concluding that children with MMHL are at risk of significant educational and psychosocial challenges. Therefore, despite the terms minimal and mild, no longer is a MMHL viewed as being inconsequential.

Minimal hearing loss is typically defined as:

- unilateral sensorineural hearing loss -- average air conduction thresholds (0.5, 1.0, 2.0 kHz) \(\geq\) 20 dB HL in the impaired ear and an average air-bone gap no greater than 10 dB at 1.0, 2.0, and 4.0 kHz, and average air-conduction thresholds in the normal hearing ear \(\leq\) 15 dB HL;
- bilateral sensorineural hearing loss — average pure tone thresholds between 20 and 40 dB HL bilaterally with average air-bone gaps no greater than 10 dB HL at frequencies 1.0, 2.0, and 4.0 kHz;
- high-frequency sensorineural hearing loss— air conduction thresholds > 25 dB HL at two or more frequencies above 2 kHz (i.e., 3.0, 4.0, 6.0, or 8.0 kHz) in one or both ears with air-bone gaps at 3.0 and 4.0 kHz no greater than 10 dB (Bess, Dodd-Murphy, & Parker, 1998).

It is clear that the term minimal hearing loss is as much about configuration of hearing loss as it is about degree of loss. That is, whether a unilateral hearing loss is mild or severe, based on the definition above, the loss is classified as minimal. And, mild hearing loss has traditionally been defined as hearing sensitivity between 26 and 40 dB HL.

Auditory skills of individuals with MMHL have been thoroughly examined. For example, it is well known that children with unilateral hearing loss have more difficulty localizing sounds on the horizontal plane than children with normal hearing bilaterally. This has been demonstrated in infants as young
as six months and adults as old as 80 years of age with unilateral hearing loss (Morrongiello, 1988; Priwin, Jönsson, Hultcrantz, & Granström, 2007). Furthermore, children with unilateral hearing loss have difficulty understanding speech in the presence of background noise (Bess, Tharpe, & Gibler, 1986; Rothpletz, Wightman, & Kistler, 2012). Children with minimal bilateral hearing loss also exhibit problems with speech recognition ability, especially in noisy environments (Crandall, 1993). More recently, Lewis and colleagues revealed potential implications of minimal hearing loss on auditory performance in a simulated classroom environment for tasks with demanding cognitive loads (Lewis, Valente, & Spalding, 2014).

Compared to children with normal hearing, children with MMHL have been shown to experience considerable academic difficulties (e.g., Bess & Tharpe, 1984; Culbertson & Gilbert, 1986; Lieu, Tye-Murray, & Fu, 2012). Numerous studies have demonstrated that children with unilateral hearing loss and with minimal or mild bilateral hearing loss are more likely to have to repeat a grade in school or access resource assistance (e.g., Bess et al., 1998; Lieu et al., 2012). In fact, as many as 35-37% of children with unilateral or minimal/mild bilateral hearing loss have failed at least one grade in school. Numerous factors have been implicated as contributors to these academic difficulties in children with MMHL. Among those factors includes listening difficulties, behavioral problems, language deficits, listening effort, and fatigue. These factors, as well as management strategies for children with MMHL, will be addressed in the context of current research findings.

REFERENCES


FREQUENCY-SPECIFIC EVOKED POTENTIAL AUDIOMETRY: CLICKS, PIPS OR CHIRPS?

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To assess auditory thresholds objectively with electrophysiological tests, the most common clinical measurement is to elicit auditory potentials from the level of the brainstem. Depending on the goal, i.e.
oto-neurological or hearing acuity (determining thresholds), different stimuli are used. Traditionally, the most plausible stimulus for clinical use would certainly be the ‘click’ stimulus (Stapells & Oates, 1997). This stimulus evokes a clear neural typical response covering a relatively broad area of the cochlear basilar membrane. However, since its spectrum mainly contains higher frequencies (i.e. around 2-4 kHz), it is less sufficient for obtaining frequency-specific information of the auditory system. Therefore, the click stimulus is insensitive to discern between patients with flat versus pure high-frequency hearing losses.

However, the use of frequency-specific stimuli, like tone bursts or tone pips, seem to solve this problem (Stapells, 2005). The neural response morphology might be less prominent (lower signal-noise ratio) compared to the clearer click responses, and show different peak latencies in their responses, but is still used by experienced clinicians.

Another way to obtain frequency-specific information is to obtain auditory steady-state responses (ASSR), that – in contrast to conventional application ABR – does not analyze the responses in the temporal, but in the frequency domain. Unlike ABR, in these EEG responses FFT analysis and statistical variance testing (F-tests) lead to significant responses (or not). ASSR seem to have different advantages, such as stimulation at higher intensities, using multi-frequency stimulation, simultaneous stimulation and analysis for both ears, all in order to reduce test and recording times and last but not least, an objective way of data analysis based on statistics (Picton et al, 2003; Sturzebecher et al, 2001). Despite the fact that its basic principle is very plausible and elegant, there still is some policy of restraint, because of the ‘black box’ analysis that comes with most commercial systems. For this reason, alternative paradigm for stimulation and/or recording are still developed to improve neural synchrony that would result in better brainstem responses. Following the development of stacked-ABR (Don et al, 2009), the so-called ‘chirp’ stimuli have been introduced (Elberling & Don, 2010).

Besides the standard broad band (BB) chirp, also narrow band (NB), level-specific broadband (LS-BB), and level-specific narrow band (LS-NB) chirps are developed in the five years (Kristensen et al, 2012). In contrast to the stacked ABR that used a specific methodology to align and sum the auditory responses, chirp are designed in such a way that these stimuli a priori are compensated for the cochlear travelling wave delay by aligning the arrival time of each frequency component to evoke better synchrony of simultaneous neural firing. Clinical application still lags behind is probably due to a couple of reasons: 1) not every EP system is equipped with chirps 2) normative values are not available, thus restraining clinicians from applying these stimuli in their daily practice.

The possible surplus value of chirps above conventional stimuli (clicks, tone bursts/pips) in auditory evoked potentials are analyzed in the temporal domain. In the first experiment, electrophysiological responses are correlated with behavioural thresholds for different kinds of stimuli. Besides, the application of Level-Specific (LS) chirp responses are compared with standard chirp responses. ABRs obtained using click, BB-, LS-BB chirp, NB- and LS-NB- chirps (0.5, 1, 2 and 4kHz) were performed in normal-hearing adult subjects. In a second experiment, brainstem responses are obtained via bone conduction using the recently introduced B81 transducer, that should have less distortion compared to the conventional B71 transducer (Jansson et al, 2015).

Results show that chirp-evoked responses reveal higher EP amplitudes, compared to conventional click response ABR. This makes interpretation of auditory thresholds easier for the clinician. However, the chirp stimulus seems not suitable for otoneurological ABR diagnosis, since first peaks that are of main importance to diagnose the presence of an pathological interwave interval JI-III and JI-V, are lost due to the stimulus artifact that covers the first milliseconds of the response. However, responses to BB-chirps reveal the same or even higher JV ABR amplitudes compared to conventional clicks/tone bursts. First results in normal hearing subjects also reveal that low frequency NB chirps were more difficult to interpret than high frequency NB-chirps.

In contrast to 0.5 and 1kHz chirp stimuli, 2 and 4kHz chirps reveal significant correlations between subjective and objective thresholds. Preliminary data show no clear advantage of LS chirps compared to CE chirps were found at lower intensity levels, i.e. 25dB up to 60dB. Generally, chirp stimuli are a welcome addition in the range of auditory stimuli and should be exploited more for clinical applications. Preliminary data obtained using chirp stimuli via bone conduction
anyhow show reproducible responses and seem to be promising for future clinical application, since the response characteristic is less prone to distortion compared to conventional BC click stimuli.

REFERENCES


AIDED CORTICALS: BRIDGING THE GAP BETWEEN EARLY FITTING AND BEHAVIOURAL ASSESSMENT
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There is growing interest in using Cortical Auditory Evoked Potentials (CAEPs) to assess the presence of an aided response to conversational-level stimuli in hearing-impaired infants. This may be of particular relevance for those who are not developmentally able to provide reliable behavioural responses. CAEPs to conversational-level stimuli were recorded from 100 normally hearing infants (aged 4–40 weeks). Completion rates, test time, response detection, and parental acceptability all indicated that aided CAEPs may be a clinically feasible procedure for this population. In the next phase of the study, 200 hearing-impaired infants are being recruited from across England and Wales in order to determine whether the presence or absence of CAEPs provides clinically useful information when planning hearing aid management. Hearing-impaired infants initially undergo CAEP testing at 3–6 months of age. Testing takes place in the soundfield, with hearing aids fitted, using a range of frequency-specific stimuli presented at conversational level. The stimuli have been developed and tested to ensure they are processed by hearing aids in ways similar to natural speech. At age 7–9 months, behavioural testing is undertaken using the same test stimuli, so that audibility of the CAEP stimuli can be verified. The study will also investigate how the technique may be applied clinically, including test efficiency, optimum waveform detection methods, and a survey of parental acceptability of the test procedure. All testing takes place in our Mobile Hearing Unit (a sound-treated van designed for this study) that will visit families close to their homes, making participation simpler and less stressful for those involved.
BEHAVIORAL TESTING OF INFANTS AND YOUNG CHILDREN

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Some might argue that physiologic approaches to hearing assessment have supplanted the need for behavioral audiometry with infants and young children. However, some of these physiologic approaches might not be effective in assessing hearing under certain clinical conditions (e.g., neural asynchrony, otitis media with effusion), and might not be possible without sedation, which is not advisable in some cases (e.g., fragile medical conditions). Therefore, behavioral testing remains a crucial component of the audiologic test battery along with physiologic measures for thorough assessment of hearing in infants and children.

Operant conditioning principles are applied to the clinical hearing testing of infants and children. When a behavior generates a reinforcing consequence, there is an increased probability that similar behavior will reoccur. Operant behavior is increased or decreased in frequency by the changes it brings about in a child’s environment. The events in an environment can be classified as positive reinforcers, negative reinforcers, and neutral events. Neutral events have little or no specific effect on behavior. In behavioral audiometry with children, behavioral responses are strengthened by positive reinforcement. This approach recognizes a view of infants and young children as active receptors of auditory stimuli who, when given the opportunity, will interact with their auditory environment to increase subsequent positive consequences. For infants under about five months of age, visual reinforcement has little effect on responsivity. And, behavioral observation procedures without reinforcement are not considered appropriate for the estimation of hearing because of the high inter- and intra-subject variability in responses (Hicks, Tharpe, & Ashmead, 2000). For visual-reinforcement audiometry [VRA] with older infants, the behavioral response is a head turn. The traditional response in standard pure tone audiometry with children involves the raising of a finger or hand, or pressing a button. This is commonly referred to as conventional pure tone audiometry. A modification employs some form of “play” activity (pegs in a board, stacking blocks, placing blocks in a can) in establishing the conditioned response. This procedure is referred to as play audiometry.

Unlike adult testing, the procedures for conducting behavioral testing with infants and young children have not been universally accepted and can vary widely from clinic to clinic. The three primary variants in VRA protocols across clinics and laboratories are (1) the use of conditioning or shaping the baby’s response, (2) the starting level (in dB), and (3) the step size (in dB) used in bracketing. Each of these factors can contribute to the overall efficiency of the behavioral test procedure. Given that behavioral test sessions are likely to last less than 30 minutes prior to a child’s habituation (Primus, 1991), it is important to focus on test efficiency. The results of computer simulations of VRA to examine these parameters point to the following recommended protocol (Tharpe & Ashmead, 1993):

• start level of 30 dB, increasing in 20 dB steps, if no response occurs;
• after initial level is determined and replicated, step size of 20 dB down, 10 dB up should be used on ascending and descending runs;
• training (i.e., pairing stimulus and reinforcer) should not be utilized as a matter of routine but, rather, the examiner should begin testing without training.

This presentation will review these principles and other techniques required for reliable and efficient behavioral testing of hearing in infants and young children.

REFERENCES


ADAPTATION OF THE STARR TEST FOR ADULT ITALIAN POPULATION: NORMATIVE DATA AND RESULTS IN COCHLEAR IMPLANT PATIENTS
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Objectives
Improvements in prostheses such as hearing aids and cochlear implants are very crucial to enabling the patient to reach her/his best potential. In parallel to such progress, there is an increasing need for new speech assessment tools that mimic challenging real life listening conditions where background noise is usually present and speech level varies according to vocal capacity and distance of the speaker. The present study aimed to introduce an Italian version of the Sentence Test with Adaptive Randomized Roving levels (STARR) test. This is a new test approach which uses a roving-level adaptive method, where the presentation level of both speech and noise signals varied across sentences. Adaptation of the STARR test to common Italian sentence lists was investigated using a within-subject design with repeated measures. The normative data for an adult population were collected and the interlist-variability as well as the learning effect was analyzed. Furthermore, the test was assessed in a group of subjects with profound/severe hearing loss who underwent to cochlear implantation (CI).

Design
Normal hearing subjects (NH), were represented by 32 adults, mean age 32 years, with no otologic history/hearing complaints. All had hearing thresholds ≤20 dB HL for frequencies between 250–8000 Hz on both ears. The CI group was represented by 31 subjects, mean age 55 years, median acoustic deprivation 12 months. The Italian STARR test made use of sentences from the standard Italian speech recognition test developed by Cutugno et al. Speech material was organized into 10 test lists, each of 20 sentences. The sentences were selected based on lexical and morpho-syntactic characteristics in order to make them more easily accessible to a heterogeneous group, of different age and coming from different regions of Italy. The STARR software was written in Visual Basic and provided the clinician with a graphical user interface to both deliver and score the test. Three presentation levels, typically explored in hearing instrument research, were used within each test list: 50, 65, and 80 dB SPL. A mean SRT was calculated averaging the SRTs for each participant across all test lists. The deviations for each test list were averaged across all participants in order to calculate correction factors. The SRT obtained using a given test list was corrected by subtracting the deviation for that list in order to compensate for differences in list difficulty. The reliability of SRT estimates was assessed by calculating the SD across all corrected SRTs (of all test lists) for each participant and this SD was averaged across all participants. To evaluate learning effects, the SRTs were averaged according to the order of testing without considering the list number. Furthermore, patients were tested with Cotugno et al standard test, in quiet and at a fixed SNR +10 and 5 dB with the primary signal at 65 dB. All subjects were tested in a sound proof rooms, with a loudspeaker positioned 1 mt from the subjects.

Results
The average speech reception threshold (SRT) for NH subjects was -8.4 dB SNR. The variability of mean SRTs across test lists was relatively small (≤1 dB for all test lists). The deviations for the majority of lists was <0.5 dB, exception for 2 of them where the largest deviations was 1 dB. The SD of the deviations was 0.7. The statistically significant differences between lists were eliminated after applying correction factors. On the basis of variability for the corrected SRTs, for normal-hearing subjects the effect of roving was minimal: a difference of 2.8 dB in SRT was meaningful for outcome comparisons using
one test list per condition while a difference of 2 dB was meaningful using two lists per condition. Statistical analysis did not show any significant learning effects. As far as CI recipients are concerned, the outcomes supported a noticeable difficulty under these challenging test conditions, showing a much greater difference with an average 12.5 (SD= 9.5) SRT value. Results were correlated with patient’s fixed SNR.

Conclusions
The STARR test was found particularly sensitive to lower level speech and is believed to provide a better estimate of improvements in technical settings of auditory prostheses. Findings in NH listeners suggested that the Italian STARR test could be a promising supplement to existing speech assessment tools. Outcomes were in line with previous research in NH population and the variability of mean SRTs across lists was relatively small (≤1 dB for all test lists). The correction factors were basic to improvement of reliability and the statistical analysis showed no significant learning effects. The significant correlation in the CI population of the STARR values with those obtained from fixed SNR reflects the reliability of the STARR test outcomes.

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BIMODAL HEARING
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An increasing number of patients with bilateral sensorineural hearing loss (SNHL) use now bimodal stimulation i.e. a cochlear implant (CI) in one ear and a hearing aid (HA) in the opposite side. This is the consequence of expanded CI indications that include patients with less severe bilateral or asymmetric SNHL. Some benefit in speech-in-noise perception and sound localization both in children and adults have been described although tests used and the magnitude of benefit differ greatly among them. A source of variability in bimodal outcomes is the HA fitting procedure; surprisingly enough it is not detailed in some studies although it seems to interfere greatly with results. For this reason there is now great interest in this topic by HA manufacturers and researchers. The residual hearing in the unimplanted ear represents another source of variability. Factors like low frequencies threshold, cochlear dead zones, aidable high frequencies and individual perception abilities can produce significant effects on the final results. Some studies included patients with severe-to-profound while others consider subjects with milder HL. The two situations differ greatly. In the first case, in fact, the target of HA fitting should be low frequencies audibility and interaural loudness balance optimization. In the second case a wider interaural frequencies overlap occurs; a more complex approach is required to optimize the balance across frequencies at different loudness levels. Finally, automatic gain control (AGC) differences and the lack of synchronization between HA and CI can degrade the potential benefit of bimodal stimulation. Data from three studies conducted at our institution will be presented to contribute at discussion on this special topic. The first is a survey on a consecutive sample of adult subjects with ‘classic’ indication to monolateral CI according to guidelines adopted in our country. These patients were counseled to continue using the HA on the contralateral side when they were implanted. A high percentage of them used bimodal
stimulation despite the HL severity. The bimodal perceived benefits and reasons that conducted non-bimodal patients to abandon their HA are discussed.

The second is a clinical trial conducted on patients with asymmetric SNHL. The HA bandwidth was switched from standard to a high-frequency (HF) extended configuration or vice-versa. Most of patients with aidable HL at high frequencies preferred the HF-extended bandwidth.

Finally some preliminary data of a prospective observational study on the new fitting formula developed for Naida® CI and HA platform will be presented.

In conclusion, bimodal is a proven useful hearing stimulation modality for selected patients. Flexible HA fitting strategies and a link between HA and CI are required to optimize outcomes.

SINGLE SIDE DEAFNESS AND COCHLEAR IMPLANTS
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Single-sided deafness (SSD) is often underestimated by clinicians although it’s not a rare condition. In the United Kingdom, + 7500 new cases a year occur (Baguley DM et al, 2006). The impairments due to unilateral hearing loss has been described since the mid-20th century (Fowler EP 1960; Giolas TG 1967).

Subjects who develop SSD become aware of the importance of binaural hearing in everyday listening conditions. In fact, they loss head shadow effect, binaural summation and squelch effect; consequently, both children and adults experience many disadvantages when placed in a challenging listening condition. They have difficulties in sound localization and speech recognition when the speaker is talking on the deaf side in the presence of background noise. As a consequence of unilateral deprivation children can develop delays in speech and language, cognitive and psychological domains. Adults can develop depression, disability at work and social misunderstanding. Finally, a significant number of patients may experience moderate to severe tinnitus.

“Wait and watch” has been for a longtime the standard approach for this condition. More recently contralateral routing of signal (CROS) with hearing aids, Bone-Anchored Hearing Aid (BAHA) and cochlear implants (CI) had introduced to treat SSD.

The CI has been used to treat the unilateral deafness as well as unilateral bothersome tinnitus in adults. Data from a prospective observational study conducted at our institution will be presented. We reported on 20 subjects with SSD and tinnitus treated with CI. The sample includes subjects who had short duration of single-side deafness (maximum 10 years), SSD and severe, intractable tinnitus, appropriate motivation, no depression and previous ineffective attempts made at remediation of tinnitus. The mean age at CI surgery was 50 years. Duration of single-side deafness was 48 months. The mean score at Tinnitus Handicap Inventory (THI) was > 60 (T3) pre-operatively. The mean follow-up was 27.4 months. There were not peri- and post-operative complications. All of them were full time CI users. A significant improvement in speech perception, when noise is presented in the normal hearing ear, was observed as well as an improvement in localization abilities with CI. The patients had also a significant reduction of tinnitus distress after CI surgery. Finally the Speech, Spatial and Qualities of Hearing scale revealed an overall benefit of CI use. In conclusion, accordingly to other papers, the CI is confirmed to be a safe and effective treatment for selected patients with tinnitus and SSD.

DO OLDER HEARING AID USERS NEED PARTICULAR GAIN COMPRESSIONS?
I PROTESIZZATI ANZIANI NECESSITANO DI COMPRESSIONI DI GUADAGNO PARTICOLARI?
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La presbiacusia o Age Related Hearing Loss (ARHL) è caratterizzata da una riduzione della sensibilità
uditiva che si associa all’alterazione della discriminazione vocale nel rumore maggiore di quanto ci si aspetti sulla base dell’audiometria tonale.

Le alterazioni periferiche che si determinano la perdita uditiva sono state descritte da Schuknecht e Gacek, che hanno evidenziato 6 forme di presbiacusia: sensoriale, neurale, striale, conduttiva cocleare, mista ed indeterminata. Per spiegare sia le modifiche di soglia che si verificano con l’età, sia la compromissione della discriminazione vocale è stato proposto un modello fisiopatologico che prevede accanto ai fenomeni degenerativi periferici, l’invecchiamento delle vie uditive centrali a cui conseguono rallentamento del processing uditivo, deficit cognitivo e alterazione della discriminazione vocale.

E’ noto che il soggetto anziano ipoacusico, rispetto al giovane, non solo ha una discriminazione vocale peggiore, ma più frequentemente riporta difficoltà nell’utilizzo delle protesi acustiche con elevato tasso di non-user.

Il modello Ease of Language Understanding (ELU) descrive le correlazioni esistenti tra discriminazione vocale e memoria di lavoro (working memory-WM) e aiuta a capire i sintomi riportati dai soggetti presbiacusici. Secondo questo modello il linguaggio porta informazioni fonologiche, sintattiche, prosodiche e semantiche. Quando il messaggio udito trova un corrispettivo nella memoria a lungo termine, automaticamente il soggetto ne recupera il significato; quando invece il messaggio vocale non è chiaro o è distorto, interviene la WM che è in grado di processare ed immagazzinare informazioni e quindi permette l’interpretazione dell’input linguistico, mediante l’utilizzo di informazioni semantiche, di inferenze o l’inibizione di informazioni inutili.

Secondo questo modello la WM svolge un ruolo minimo in presenza di un segnale vocale chiaro e intenso, mentre svolge un ruolo fondamentale in condizioni di ascolto sfavorevoli. Diversi studi hanno dimostrato che la memoria di lavoro è sia correlata all’età che alla discriminazione vocale nel rumore sia senza sia con le protesi acustiche. In particolare le protesi acustiche digitali attivano la WM nel momento in cui vanno a modificare il segnale verbale modificandone l’intensità in maniera non lineare, riducendo digitalmente il rumore o comprimendolo in frequenza.


L’attivazione del WDRC può verificarsi con un tempo di attacco-stacco rapido (<200 ms) o lento (>200ms). In caso di tempo di attacco rapido il segnale è rapidamente amplificato con esaltazione della sua udibilità a fronte di una modifica dell’inviluppo dell’ampiezza; al contrario tempi di attacco lenti amplificano il segnale più lentamente, riducendone l’udibilità, ma mantengono un inviluppo più naturale.

Diversi studi eseguiti in soggetti affetti da presbiacusia portatori di protesi acustica digitale hanno dimostrato che la discriminazione vocale nel rumore è direttamente proporzionale alla WM quando si utilizza un protocollo di compressione rapida del WDRC, mentre è prevalentemente influenzata dalla perdita uditiva in caso di protocolli di compressione lenta.

I soggetti con maggiore WM sono infatti in grado di incamerare e processare un elevato numero d’informazioni simultaneamente e quindi di sfruttare al massimo il segnale inviato dalla protesi acustica, al contrario soggetti con WM limitata utilizzando protesi acustiche con protocolli di compressione rapida non riescono a gestire l’elevato numero di informazioni e quindi preferiscono protocolli di amplificazione ad attacco lento. Non vi è evidenza che algoritmi di soppressione digitale del rumore o di compressione frequenziale correlino con la capacità della WM dei soggetti.

In conclusione i soggetti anziani che oltre ad avere una riduzione della sensibilità uditiva presentano spesso un’alterazione della WM possono beneficiare maggiormente di protocolli di compressione del guadagno ad attacco-stacco lento, al contrario soggetti anziani presbiacusici con buone capacità cognitive e di memoria di lavoro possono sfruttare in maniera completa protesi acustiche che implementano protocolli di compressione ad attacco rapido.
Frequency lowering serves people with hearing impairment who do not get sufficient or appropriate audibility restoration from conventional amplification. This may be true because of the degree of hearing loss or because of the low level of the interesting signals. Frequency compression has been Phonak’s solution for frequency lowering (SoundRecover). The effect of amplification alone is limited with regard to the processing quality which the impaired human ear provides in the high frequency region (loudness recruitment, frequency resolution, dead regions) and with regard to technical limitations of hearing aids (feedback stability, saturation effects). With frequency compression the said restrictions can be mitigated considerably.

SoundRecover acts as a static instantaneous frequency compressor. Below the cutoff frequency linear frequency processing is applied, above it output frequencies are compressed with a particular compression ratio. This principle works nicely for a large range of hearing losses but has its limitation with profound hearing losses when cutoff frequencies below 1.5 kHz would be needed. A cut-off frequency below 1.5 kHz is not an option in SoundRecover. Cutoff frequencies below 1.5 kHz would – in case of harmonic sounds as to vowels or musical tones – distort the harmonic relation of overtones above the cutoff frequency too strongly and lead to a unnatural sound quality. SoundRecover2 has been developed to overcome this limitation. It replaces static frequency compression by an adaptive compression scheme. The input output function for frequencies has three segments. The first segment below the cutoff frequency 1 is linear. The lowest possible cutoff frequency 1 is 800 Hz. Between cutoff frequency 1 and cutoff frequency 2 the compression scheme is adaptive. This means the compressor behaves either linearly if the levels of the lower frequencies are dominant relative to the levels of the higher frequencies or compressively if the levels of the higher frequencies are dominant. This adaptive principle makes sure that the harmonic relations of the overtones of harmonic sounds like vowels or musical tones are maintained up to a higher frequency as being possible with the original SoundRecover, while fricative and other high frequency sounds are effectively compressed making them more audible. The third segment of the input output function is static compression as known from the original SoundRecover.

The adaptive compression principle offered to lower frequencies in SoundRecover2 – provides increased audibility for hearing impaired people, including profound hearing losses. The adaptive part of the compression scheme provides more natural sound quality and effective increase of high frequency sounds. In a sample of subjects with profound symmetrical sensorineural hearing losses SoundRecover 2 has been compared to the original SoundRecover (Internal study 2016). SoundRecover 2 was superior to the original SoundRecover with regard to detection and recognition thresholds of the Phoneme Perception Test (Schmitt et al. 2016). The stimuli have represented the phonemes /sh/ and /s/. In another study 14 children with severe-to-profound high frequency sensorineural hearing loss have been tested with the original SoundRecover and an advanced prototype of SoundRecover2 (Wolfe et al. 2016). SoundRecover2 led to superior word recognition in quiet and recognition of plural /s/.

The hearing care professional is provided with two parameters for adjusting SoundRecover 2 to the individual needs of the hearing impaired user. With fitting parameter “A”, he or she selects the balance between two factors related to auditory clarity: Audibility increase versus discrimination of audible sounds. With fitting parameter “B”, the hearing care professional can adjust the balance between increased clarity and naturalness of hearing. With the Phoneme Perception Test the hearing care professional can easily check if SoundRecover 2 is set appropriately for a hearing impaired individual.
CLINICAL EVIDENCE ABOUT THE USE OF NEW FREQUENCY COMPRESSION
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The implementation of mild frequency lowering to improve access to high frequency information has had a tremendous impact in hearing aid design, and has been added in many forms to all the major manufacturer's devices. The concept is to lower high frequencies that fall in areas of the cochlea that are not able to transduce the information, or where the amplified levels cause distortion or feedback that makes the information inaccessible. The lowered signal will now be audible and useable to the auditory system, increasing access to content. A revised version of Sound Recover, a frequency compression system implemented in Phonak devices, has recently been released, and a comparison of the original and revised versions was done to evaluate the changes. A group of 8 profound hearing impaired listeners were fit with both systems and thresholds for high frequency sounds were measured. The revised system generated lower thresholds, demonstrating the increased access to high frequencies in profound losses that was the goal of the new system.

The system includes an shifting compression with stronger compression to lower frequencies than previously allowed only when high frequencies are present and low to mid frequencies are not present and only in severe to profound hearing losses. This increased frequency compression could create some distortions in vowel sounds, and hence is set only to be triggered when high frequency information is available and not when mid and low frequency vowels are the information to be conveyed. This approach helps with sound detection and awareness, a high priority with these significant losses. Speech intelligibility scores are averaged across all materials, and the less frequent high frequency cues make improvements more difficult to quantify. Future work will extend the demonstration of the expected benefits.

REMOTE MICROPHONE TECHNOLOGY FOR PERSONS WITH HEARING LOSS: ACCESSORY OR NECESSITY?
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Wireless technology can be used across the lifespan for persons with hearing loss and with normal hearing. Benefits of wireless technology are evident in all levels of education, employment, social and leisure activities, and many aspects of daily function such as phone communication. Regardless of the age or hearing ability, there is a wireless configuration that can provide significant benefit. Because communication involves more than one individual, the ideal arrangement may include technology worn by the speaker as well as the listener. However, often the focus in hearing health is on personal ear-level instruments worn by the listener that may have only near-field wireless features. The use of an external microphone, direct-audio-input connection, or interface with telecommunication may be thought of as an accessory to the ear-level instruments. However, with the rapid increase in technology options for communication via wearable and stand-alone devices, it is imperative that a consumer’s lifestyle and frequent communication partners be considered in possible technology that can be integrated with ear-level instruments.

The TELEGRAM is a tool for assessing the lifestyle needs of an individual and can be used to determine the network of technology options that will provide the greatest benefit. The eight prompts guide the professional to evaluate a patient's interactions including telephone, education/employment, entertainment, group, recreation, alerting, and family activities as well as his/her knowledge of legislation that may lead to access to technology or funding sources. When these needs are determined, the network of devices to achieve optimal communication may be considered. Options may include use of a wearable wireless interface to receive audio signals from other devices such as a mobile phone or
Recently, the options for digital modulation (DM) wireless technology have expanded. Research has shown significant benefits of wireless DM arrangements over the traditional wireless FM devices. With DM technology use in high-noise levels, persons with hearing loss can hear significantly better than persons with normal hearing. Some technology networks may even include applications that can be downloaded on smartphones or tablets, where greater digital processing of a signal may be accomplished than is possible on an ear-level device with computation limitations. It is likely that with DM technology combined with speech-reading cues, listeners will be able to engage in communication in environments that would otherwise not have been possible.

To determine if such technology is a necessity, speech recognition in noise may be assessed with use of just ear-level devices alone and then compared with the addition of the remote microphone system. The person with hearing loss will then realize the potential benefit as demonstrated in the clinical setting. However, another critical component is to use the wireless technology in everyday communication. Therefore, trials outside the clinic are a critical component of realizing the potential benefits not only for the person with hearing loss but also the communication partner. Ideally, these can be arranged through group outings such as dinners, tours, or theatre experiences where participants can learn from each other. Communication partners may be more committed to using a remote microphone when they also can experience the benefits that others in a group may receive. Given the solid research that supports the benefits of using remote microphone technology, audiologists may consider offering “network packages” as part of an initial fitting rather than offering just “ear-level instruments” which may perpetuate the “accessory” model rather than promoting a “necessity” model.

GUIDELINES FOR PROVIDING HEARING AIDS TO INFANTS AND YOUNG CHILDREN
Marlene Bagatto
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Background
For infants with permanent hearing loss, pediatric audiologists strive to initiate intervention by six months of age and many families choose hearing aid fitting as part of an overall intervention plan. Infants are not simply small adults who need hearing aids; they have different listening needs and present with unique physical and developmental challenges for fitting hearing aids compared to adults. For example, an infant’s ear canal is constantly growing and changing which impacts the sound pressure level (SPL) delivered to the ear. Additionally, an infant with hearing loss does not have experience with his/her native language like an adult with acquired hearing loss would. This means that the critical period for language learning must be accessed appropriately so that speech and language development are supported for the infant with hearing loss. Finally, infants are unable to provide verbal feedback about the hearing aid fitting therefore distinctive strategies are required when adjusting the hearing aid to meet the listening needs of the young pre-verbal patient.

Thus, the challenging and important work of infant hearing aid fitting requires systematic and pediatric-specific procedures. It is vital, then, to have a comprehensive protocol for fitting hearing aids in infancy to support consistent approaches among clinicians, as well as to effectively reinforce the infant’s development of speech and language. Evidence-based protocols and technology exist for the thorough assessment of hearing in infants as well as for accurate and suitable hearing aid fitting in this population.

The Pediatric Hearing Aid Fitting Process
Fitting hearing aids to infants and young children requires special consideration at each stage of the process. In the assessment stage, electrophysiological hearing threshold estimates must be adjusted appropriately so that an accurate hearing aid fitting can occur. Ear canal acoustics are also important to consider during the assessment stage of the hearing aid fitting process for infants. Strategies for
measuring the real-ear-to-coupler difference (RECD) in infants and young children are important for success. Clinicians must also take into account the electroacoustic and non-electroacoustic characteristics of the hearing aids that are chosen for the infant or young child with hearing loss. Following the selection stage, verification that the electroacoustic performance of the chosen hearing aid is meeting the auditory characteristics of the child is a vital part of the process. Considering the application and verification of additional technologies such as frequency lowering and noise reduction are also key to this practice. Finally, evaluation of the effectiveness of the device completes the hearing aid fitting process for infants with hearing loss. Each stage of the process is necessary so the fitting of hearing aids to infants and young children is optimal to support communication development.

Goal of the Presentation

The essential components of fitting hearing aids to babies are the focus of this presentation, which is presented in four sections. First, assessment considerations will be discussed in two sections: a) using electrophysiological threshold estimates for the initial hearing aid fitting and b) capturing the acoustic properties of infant ear canals. Next, a review of advanced hearing aid technologies and summaries of evidence about their potential use with infants will be provided. Third, a pediatric-friendly strategy for hearing aid verification will be discussed. Finally, an approach to the evaluation of device effectiveness (i.e., outcome measurement) will be presented. It is hoped that the clinical relevance of these topics will promote the use of effective evidence-based strategies for fitting hearing aids to infants.

HEARING PRESERVATION WITH THE HIFOCUS™ MID-SCALE COCHLEAR IMPLANT: A SINGLE UNITED KINGDOM CENTRE EXPERIENCE

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St Thomas’s Hearing Implant Centre, Guy’s and St. Thomas Hospital, London, UK

Objective

Evaluate the hearing preservation outcome of the new Advanced Bionics HiFocus™ Mid-Scala electrode in adult patients with residual low frequency hearing.

Study Design

A prospective case series.

Setting

A tertiary hearing implant centre in the United Kingdom.

Subjects and Methods

The study included all adult patients with residual low frequency hearing outside the current electroacoustic stimulation criteria, who underwent cochlear implantation with the Advanced Bionics HiFocus™ Mid-Scala at St Thomas’ Hearing Implant Centre between March 2013 and July 2014. The main outcome measure was the postoperative pure tone thresholds compared to preoperative levels. Complete hearing preservation was defined as postoperative hearing levels at 250, 500 and 1000 Hz within ≤ 10dB of preoperative thresholds. The presence of measurable hearing but >10dB deterioration was considered as partial hearing preservation.

Results

A total of 26 devices were implanted in 24 adults with residual low frequency hearing. Two patients (8%) had complete hearing preservation at all three frequencies. Complete loss of residual hearing occurred in six (23%) patients. Individual frequency analysis revealed hearing preservation rates of 27-43% complete hearing preservation, 22-32% partial hearing preservation and 35-41% total loss of residual hearing.

Conclusion

Our findings are consistent with a number of previous studies that have demonstrated the feasibility of hearing preservation with deep electrode insertion. The hearing preservation rate with the HiFocus™ Mid-Scala electrode appears to be in keeping with other studies.
HEARING AID AND CI IN OPPOSITE EARS: BIMODAL USE, BENEFITS AND BEAMFORMING.
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Background
With inclusion criteria broadening over the years, the number of cochlear implant (CI) candidates keeps increasing. Many still have useful residual hearing in the non-implanted ear and can therefore be fitted with a conventional hearing aid (HA). When electric hearing by means of a CI in one ear is supplemented with acoustic hearing by use of a conventional HA in the opposite ear, one speaks of bimodal hearing.

Many researchers have demonstrated the benefit from the HA in bimodal patients. Yet survey studies show that how patients perform in laboratory tests is not always related to how they rate their abilities in everyday situations. Moreover little research has been carried out to assess which unilateral CI recipients are most likely to become bimodal users in the first place. Addressing the occurrence of bimodal use and the experiences of bimodal users in daily life are however very relevant topics in counseling unilateral CI recipients and providing them with a tailored fitting.

Concerning outcomes it is known that speech perception in noise still remains one of the most challenging tasks for hearing impaired and cochlear implant recipients. This refers not only to the intelligibility of the speech but also to the effort it takes to trace speech amongst competing noise or talkers. Nowadays directional microphone systems are accessible for HA as well as CI. Both bimodal hearing and directional microphone systems are proven ways to improve performance in noise. They are considered to be complementary, but however have not yet been evaluated conjointly.

Objectives
- Investigate the occurrence of a unilateral CI recipients becoming a bimodal user
- Assess bimodal experiences in daily life listening situations
- Measure bimodal benefit on speech intelligibility and listening effort in noise
- Evaluate bimodal beamforming for speech perception in noise

Methods
A research project was carried out among the adult population of unilateral CI-recipients at Maastricht University Medical Center. A retrospective cohort chart review investigated the characteristics of those patients who continued or discontinued the use of their contralateral HA.

A set of bimodal self-assessment questionnaires was sent out to query the daily life hearing experiences within both groups. Furthermore, a bimodal test battery was validated and administered to a group of bimodal users measuring the degree of benefit from the HA aside the CI on speech intelligibility and listening effort in noise. Finally a subset of bimodal listeners were fitted with the same speech processor and state-of-the art hearing aid as to evaluate different directional microphone systems when activated in CI and/or HA.

Results
A bimodal HA retention rate of more than 60% was observed. Better pure-tone thresholds and unaided speech scores in the non-implanted ear, as well as a smaller difference in speech recognition scores between both ears were significantly associated with HA retention.

Comparisons between unilateral listeners and bimodal listeners show no difference in self-rated disability between the two groups. However, within the group of bimodal listeners, bimodal benefit is consistently observed across various daily life hearing situations.

Bilateral and binaural benefits of bimodal hearing for speech intelligibility in spatially separated noise were demonstrated. At high signal-to-noise ratios an additional reduction of self-rated listening effort could be demonstrated when listening with a HA aside the CI.

Monaural beamforming provided a substantial benefit for speech recognition in noise for bimodal
listeners. Most benefit was seen when beamforming was activated symmetrically in both CI and HA.

Conclusions
The majority of unilateral CI-recipients continued to use a conventional HA after implantation. Using a HA aside the CI provides substantial benefits in diverse daily life hearing situations. This bimodal benefit was objectively demonstrated for speech perception in noise. It was shown that performance in noise could further be improved by implementing directional microphone systems in both CI and HA. Results advocate for further bimodal co-operation.

COCHLEAR IMPLANTS IN ELDERLY PATIENTS
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The onset of hearing loss in elderly patients, regardless of etiology, results in a worsening of discrimination tasks in quiet and even more in noisy environments with a negative impact on communication skills and severe effects on quality of life. Scientific literature shows that hearing loss in the elderly leads to social isolation, physical decay and complete indifference to the outside world, which could also results in the development of a depressive mood disorder [Smeeth et al, 2002; Hogan et al, 2009]. Hearing impairment in subjects older than 60 years may also contribute to a depletion of cognitive reserves, resulting in a reallocation of neuronal resources into acoustic information processing with an early onset of dementia in clinical phase[ Lin et al, 2011].

The safety and effectiveness of rehabilitation with CI in patients aged over 60 years has been well documented in the literature, as suggested by the progressive expansion of surgical guidelines, which do not currently report an upper limit of age [Carlson et al, 2010;Hiel et al, 2015]. However, the variability of post-operative outcome may be linked to several factors, including age at implantation, pre-operative recognition performance, duration of auditory deprivation and related cortical plastic changes, rate of intra / post-operative complications and time of use of the device [Clark et al, 2012].

In the last two decades, literature has been enriched by several studies based on speech perception outcome, comparing pre and post-CI conditions as well as younger and older adult CI recipients. [Oyanguren et al, 2010; Budenz et al, 2011]. However, scientific research on cochlear implants have recently focused on the improvement of quality of life, especially regarding everyday experience, work activities and social relations [Vermeire et al., 2005; Knopke et al, 2016], which was often not related to audiological results [Ramos et al, 2013] and with a stable and lasting effect [Jolink et al, 2016].

A research work of Gemelli Hospital Cochlear Implants Center evaluated the impact of monolateral CI on speech performance and quality of life by an objective (state of physical and mental health, daily activities) and subjective (satisfaction level derived from CI) point of view in a group of 20 postlingually deaf elderly patients (Over60 years, mean age 72 years), comparing the results obtained with a population of younger adults (Under60 years)[Di nardo et al, 2013]. Speech recognition skills were evaluated through the administration of speech audiometry using Turrini et al. words and Burdo–Orsi sentences presented at 70 dB HL in quiet and noisy environment (SNR+10dB, SNR+0dB, SNR-10dB); QoL changes after CI were assessed by means of two different questionnaires : the Italian version of the validated Short Form-36 survey (SF-36) to quantify the changes in health status and the “Questionnaire for selfassessment of CI benefit” ( Acta Phoniatrica Latina vol.18, n.3,1996) to evaluate CI effects on daily conversation skills, use of multimedia devices and personal satisfaction.

As suggested by our data, in line with literature, performance measures of the geriatric population showed a significant benefit on speech recognition compared to pre- CI condition, though not identical to those of younger patients. No significant difference was found between the study and control group in physical and mental health status, conversation with an acquaintance and an outsider, use of TV and phone, while a significant difference (p<0.05) was reported about the overall satisfaction derived from CI, confirming the indisputable utility and the substantial benefit of this procedure. This results
could probably be explained by the skills lost due to deafness and those the patient hopes to earn back. So, with increasing age, the rehabilitation expectation and self-awareness of one’s own hearing loss decrease, but at the same time communication requests are progressively less pretentious and linked to family environment and simple communication.

On the other hand, despite the good recognition performance in advantageous conditions, some listening tasks are still tremendously challenging in elderly patients, with severe limitation in the global communicative field. In particular, poor results have been reported in telephone communication, (sometimes preferred for the speed of access to recipient) due to the reduced frequency range (300-3500Hz) of the telephone signal, the absence of visual reinforcement, the interference problems and the lack of specific maps. Our research group has therefore worked on the development of a specific Telephone Map (T-map), obtained by minimizing the current level in in the electrodes whose frequency fell outside of the phone signal range, without changing the allocation of frequency bands. The evaluation by speech audiometry with conventional and experimental map showed a significant difference (p <0.05) in the phone message recognition using T-map in both under60 and over60. This result was associated with a further improvement in the elderly population after three months of constant training [Di Nardo et al, 2014].

The encouraging results about speech perception, physical and social development and global quality of life obtained in CI elderly patients, lead future research to improve more and more, in particular to study the potential effects of cochlear implant on cognitive functions preservation in geriatric patients. The few experimental and clinical observations in this regard, have shown both that a long auditory deprivation can have a negative impact on cognitive performance, whether these cognitive abilities, if limited, reduce the resources responsible for auditory perception, thus amplifying the effects of deprivation [Fetoni et al, 2016].

Significant data about the benefit of cochlear implant on long-term assessed cognitive functions and therefore on the protective effect of rehabilitation with CI in the elderly have been not reported yet [Miller et al, 2015]. Some preliminary results in over65 patients evaluated with MMSE 6 and 12 months after CI show improvement both on quality of life than on cognitive abilities [Mosnier et al, 2015].

Therefore, our research group has recently set the purpose to perform through a prospective study (6-12-18 months) an accurate assessment of hearing and neuropsychological function (Mini Mental State Examination MMSE; Rey’s Auditory Verbal Learning test; Multiple Features targets cancellation, MFTC; Stroop Test) in over60 CI patients affected by post-lingual hearing loss and no other disabilities, in order to obtain scientific evidence about the long-term effect of cochlear implant on cognitive decline in the elderly.

REFERENCES


ACOUSTIC PRESCRIPTIVE FITTING FOR BIMODAL COCHLEAR IMPLANT RECIPIENTS

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The fitting process for hearing aids usually comprises two stages: first, a prescriptive fitting based on a fitting formula like NAL-NL2 or DSL v5 is performed, followed by individual fine-tuning. For different patient groups (patient type, hearing loss and hearing aid configuration, e.g. pediatric, open fitting, severe-to-profound) often different prescriptions are used by audiologists. Existing hearing aid fitting formulae, however, have been developed and verified for unilateral and bilateral hearing aid users and thus, may not be optimal for cochlear implant (CI) recipients using a contralateral hearing aid. Conventional hearing aid fitting does not account for certain specific characteristics of bimodal listening. Of particular importance are: low-frequency audibility, spectral overlap of electric and acoustic stimulation, loudness balance and (dynamic) synchronization of adaptive signal processing. In order to improve the efficiency of bimodal fitting, a prescriptive fitting formula has been developed that aims at accounting for the specific characteristics of bimodal listening by applying modifications on standard hearing aid prescriptions. As even within the group of bimodal users optimal modifications may vary considerably, a series of studies was conducted to determine which specific modifications should be applied depending on hearing loss and hearing aid configuration.

Method

The following modifications were implemented into hearing aid fitting software and evaluated for different hearing losses: (1) maximized effective audibility, (2) bandwidth limitation in case of dead regions, (3) temporal alignment of automatic gain control (AGC) and (4) aligned loudness growth. Experiments were conducted at seven research sites in Belgium, Germany, Netherlands and USA with more than ten subjects each. Outcome measures included speech understanding in noise, sound quality...
ratings and subjective preference. Audiograms ranged from profound with little aidable hearing at 125 and 250 Hz to flat and sloping moderate losses with aidable hearing up to 4 kHz. A randomized crossover design was applied whenever possible to evaluate the effect of bimodal fitting modifications both acutely and chronically.

**Results**

Because bimodal listeners are not homogeneous, a series of studies was conducted to determine which hearing aid program modifications should be applied depending upon hearing loss and hearing aid configuration. Experiments were conducted at seven research sites in Belgium, Germany, the Netherlands, and the United States. Participant audiograms ranged from profound hearing loss (little aidable hearing at 125 and 250 Hz) to flat and sloping moderate losses (aidable hearing up to 4 kHz). Outcome measures included speech understanding in noise, sound quality ratings, and subjective preference. A randomized crossover design was applied whenever possible to evaluate the effect of bimodal fitting modifications both acutely and chronically. Results from three of these studies are summarized here.

**Frequency Response Alignment: Study 1** (Advanced Bionics LLC, Valencia, USA, Chalupper et al. 2013)

Seven experienced bimodal subjects (aidable hearing < 750 Hz) were tested in noise (AzBio sentences at signal-to-noise ratios that resulted in scores 50% of their scores in quiet using the implant alone) using their own hearing aid program, and a hearing aid programmed with APD, NAL-RP, a bimodal formula with aligned frequency response, and a bimodal formula with aligned frequency response using the result of the TEN – Test to identify dead regions. Best sentence scores in noise were seen with the bimodal formula without the TEN-Test. The bimodal formula outperformed both APD and NAL-RP. Administering the TEN-Test to assess dead regions did not further improve bimodal benefit because the APDB correctly identified dead regions based on the audiogram.

**Frequency Response Alignment: Study 2** (EarGroup, Belgium, Govaerts et al. 2014)

Ten experienced bimodal subjects (aidable hearing < 1.5 kHz) were tested bimodally in noise (adaptive LIST test) using a hearing aid programmed with APD and with a bimodal formula with aligned frequency response. The ability to use temporal fine-structure (TFS) cues also was measured. Subjects with normal temporal fine-structure capability derived significant benefit from 329 additional low-frequency gain as prescribed by the Bimodal Formula. Subjects with degraded temporal fine-structure capability did not experience additional benefit.

**AGC Alignment** (Radboud University Nijmegen, the Netherlands, Veugen et al. 2015)

Fifteen experienced bimodal subjects were tested bimodally in noise (adaptive LIST test) using a hearing aid programmed with standard Phonak AGC (syllabic) and an AGC aligned with the Naída CI processor. The aligned AGC improved speech understanding over the standard Phonak AGC by 0.6–2 dB in competing talker situations. With speech from the front, when noise is presented on the hearing aid side (SONHA), a larger improvement was achieved compared to noise presented on the CI side (SONCI) or from both sides (SON+-90). The vast majority of subjects preferred the aligned AGC over the standard AGC (only one patient preferred standard AGC). Take-home questionnaires did not show any changes over time, suggesting no effect of acclimatization. Questionnaires also indicated that the AGC-matched hearing aid was ranked significantly better for understanding one person in quiet, understanding one person in noise, and hearing the timbre of sounds.

**Conclusion**

A new prescription for bimodal fitting which respects the special demands of bimodal hearing like low-frequency audibility, spectral overlap and dynamic synchronization was preferred by most bimodal subjects compared to a standard hearing aid fitting formula. Depending on hearing loss configuration, this bimodal fitting formula automatically applies different modifications on top of proven hearing aid prescriptions.