2011 Conference on Implantable Auditory Prostheses

July 24-29, 2011

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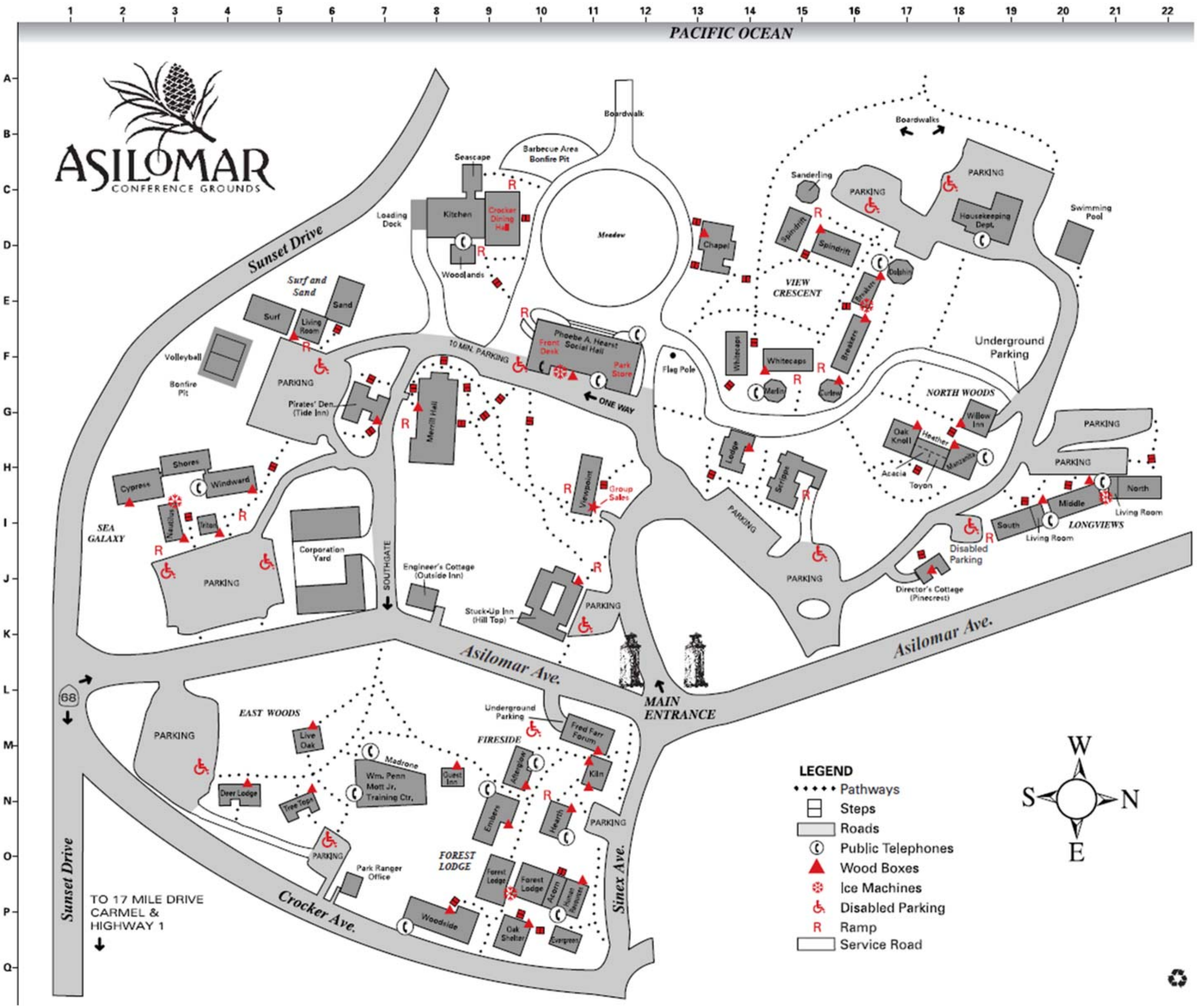

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FIRESIDE
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Embers
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Forest Lodge
Acorn
Hunter Rainbow
Oak Shelter
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<u>Monterey Peninsula</u>

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Christopher Brown

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Bob Carlyon

Andrew Oxenham

Monita Chatterjee

James Fallon

Andrej Kral

John Middlebrooks

Johan Frijns

PROGRAM OVERVIEW

Sunday July 24

3:00PM - 10:00PM	Registration
7:00PM – Midnight	Wine Tasting: Kiln Room, Reception: Fred Farr Forum

Monday July 25

7:30AM	Breakfast opens
8:30AM – 12:15PM	Session 1: Speech Perception, Language, Cognition
12:00 Noon	Lunch
1:00PM – 5:00PM	Poster Viewing
5:00PM – 7:00PM	Dinner
7:00PM – 9:35PM	Session 2: Plasticity
9:35PM – Midnight	Poster Viewing and Social

Tuesday July 26

7:30AM	Breakfast opens
8:30AM – 12:00PM	Session 3: Binaural Physiology
12:00 Noon	Lunch
1:00PM – 5:00PM	Poster Viewing
5:00PM – 7:00PM	Dinner
7:00PM – 9:50PM	Session 4: Hair Cell Development/Regeneration/Survival/Plasticity
9:50PM – Midnight	Poster Viewing and Social

Wednesday July 27

7:30AM	Breakfast opens
8:45AM – 12:05PM	Session 5: Implants Beyond the Cochlea & Other
12:05PM	Lunch
1:00PM – 1:45PM	Poster Viewing
1:45PM – 4:25PM	Session 6: Listening in Realistic Environments & Music
4:25PM – 5:00PM	Poster Viewing
5:00PM	Barbeque Dinner
7:00PM – Midnight	Dance Night

Thursday July 28

7:30AM	Breakfast opens
8:30AM – 12:00PM	Session 7: Signal Processing
12:00 Noon	Lunch
1:00PM – 5:00PM	Poster Viewing
1:30PM – 3:00PM	Young Investigator Mentoring Session
5:00PM	Dinner
7:00PM – 9:30PM	Session 8: Pitch
9:30PM – Midnight	Poster Viewing and Social

Friday July 29

7:30AM	Breakfast opens
8:30AM – 12:10PM	Session 9: Electroacoustic Stimulation
12:10PM	End of conference/Closing Remarks

Podium Sessions Schedule

Monday July 25, 8:30 am - 12:00 pm

Speech Perception, Language Development & Cognitive Issues
(Moderator: Andrew Oxenham)

8:30 Litovsky / Rosen **WELCOME TO CIAP 2011**
MonAM1: **8:45** Humes: Aging and Aided Speech Understanding: Contributions of "Higher-Level" Processing
MonAM2: **9:15** Lunner: On Cognitive Functioning and Effective Use of a Hearing Aid or Cochlear Implant
MonAM3: **9:45** Kishon-Rabin: Early Auditory Experience & Development of Speech & Language Development
10:15 BREAK (20 minutes)
MonAM5: **10:35** Gillis: Words and Linguistic Structures of 7-Year-Olds after Five Years of CI Experience
MonAM6: **11:05** Garadat: Selection of Sites of Stimulation Based on Temporal Modulation Sensitivity
MonAM7: **11:25** Donaldson: Static and Dynamic Cues; Vowel Identification by Cochlear Implant Users
12:00 LUNCH

Monday July 25, 7:00 pm – 9:35 pm

Plasticity (Moderator: Andrej Kral)

MonPM1: **7:00** Scott: The Cortical Processing of Speech: Intelligibility, Plasticity and Cognitive Factors
MonPM2: **7:30** Svirsky: Adaptation to Frequency Mismatch by Postlingually Deaf CI Users
MonPM3: **8:00** Galvin: Auditory Training in Cochlear Implant Patients: Go Easy or Go Hard?
8:30 BREAK (15 min)
MonPM4: **8:45** Reiss: Pitch Plasticity with Cochlear Implant Experience
MonPM5: **9:05** Fallon: Plasticity of the Primary Auditory Cortex

Tuesday July 26, 8:30 am – 12:00 pm

Binaural Physiology (Moderator: John Middlebrooks)

TueAM1: **8:30** McAlpine: Do Bilateral Implant Users Access the Same Binaural Brain Circuits as NH Listeners?
TueAM2: **9:00** Culling: The Overlooked Benefit of Bilateral Cochlear Implantation.
TueAM3: **9:30** Litovsky: Bilateral Cochlear Implantation in Children
10:00 BREAK (20 minutes)
TueAM4: **10:20** Goupell: Interaural Decorrelation for Modulated Stimuli in Bilateral CI Users
TueAM5: **10:40** Seeber: Binaural Hearing in Reverberant Space with Cochlear Implants
TueAM6: **11:00** Kral: Cortical sensitivity to binaural cues in bilateral and unilateral congenital deafness
TueAM7: **11:30** Hartley: Investigating Benefits Of Bilateral Cochlear Implants In An Animal Model
12:00 LUNCH

Tuesday July 26, 7:00 pm – 9:50 pm

Hair Cell development/regeneration/Survival & Plasticity (Moderator: James Fallon)

TuePM1: **7:00** Sanes: Loss and Rescue of Cortical Inhibition Following Early Hearing Loss
TuePM2: **7:30** Liberman: Permanent Cochlear Nerve Degeneration after Noise-Induced Hearing Loss
TuePM3: **8:00** Forge: Preventing Hair Cell Loss by Protection from Fatal Injury: A Brief Review of Strategies
TuePM4: **8:30** O'Leary: Steroids to Protect the Inner Ear During Cochlear Implant Surgery
TuePM5: **9:00** Jolly: Trends with CIs and Atraumaticity; Deep Electrode Insertion and Hearing Preservation
TuePM6: **9:30** Long: Neural Survival In Cochlear Implant Users (Inferences From Psychophysics, CT Scans, Speech Understanding, And Modeling)

Wednesday July 27, 8:45 am -12:00

Implants Beyond the Cochlea & Other (Moderator: Johan Frijns)

WedAM1: **8:45** Middlebrooks: Intraneural Stimulation for Auditory Prosthesis: Steps Toward Clinical Trials
WedAM2: **9:15** McDermott: Improved Sound Processing for Users of Auditory Implants
WedAM3: **9:45** McKay: Temporal Information Processing in The Central Auditory System
10:15 BREAK (20 minutes)
WedAM4: **10:35** Lim: Translating a New Double Shank Auditory Midbrain Implant (AMI) into Clinical Trials
WedAM5: **11:05** Richter: Infrared Neural Stimulation – A Vision for Cochlear Implants
WedAM6: **11:35** Shannon: New Developments in Auditory Brainstem Implants
12:05 LUNCH

Wednesday July 27, 1:45 pm – 4:25 pm

Listening in Realistic Environment & Music (Moderator: Chris Brown)

WedPM1: **1:45** Rosen: Envelope and TFS: What's all the fuss?
WedPM2: **2:15** Heinz: Perceptual Salience of Temporal Envelope and Fine Structure Cues
WedPM3: **2:45** Torppa: Effect of Musical Activities on Perception of Speech and Language Ability in Children
3:05 BREAK (20 minutes)
WedPM4: **3:25** Uchanski: Listening to Talkers and Musical Pitch
WedPM5: **3:55** Trehub: Speech and Music Perception by Child Implant Users

SPECIAL BBQ DINNER --- AND DANCE PARTY

Thursday July 28, 8:30 am - 12:00 pm

Signal processing (Moderator: Bob Carlyon)

ThuAM1: **8:30** Loizou: Channel Selection: A Panacea for the Interference Problem in Cochlear Implants
ThuAM2: **9:00** Wouters: Enhanced Temporal Coding Can Lead to Improved Sound Perception in CIs
ThuAM3: **9:30** Frijns: Neural Excitation Patterns of a Variety of Multipolar Electrode Configurations
ThuAM4: **10:00** Landsberger: Can Current Focusing Be Used to Improve Spectral Resolution?
10:20 BREAK (20 minutes)
ThuAM5: **10:40** Bierer: Characterizing the Status of the Electrode-Neuron Interface
ThuAM6: **11:00** Smith: Breaking Informational Bottlenecks in Auditory Prostheses
ThuAM7: **11:30** Litvak: Extending the Electrode Array Longitudinally Using Phantom Stimulation Protocols
12:00 LUNCH

Thursday July 28, 1:30 pm - 3 pm

Mentoring Session (Ruth Litovsky, Chair)

Thursday July 28, 7:00 pm - 9:30 pm

Pitch (Moderator: Gail Donaldson)

ThuPM1: **7:00** Chatterjee: Complex Pitch Patterns, Intonation & Lexical Tones: Results in Adults and Children with CI's
ThuPM2: **7:30** Oxenham: Pitch Perception: Basic Mechanisms and Implications for Cochlear Implants
ThuPM3: **8:00** Macherey: Place and temporal pitch perception with asymmetric pulses
ThuPM4: **8:30** Vandali: Optimization of Rate-Pitch in Cochlear Implant Hearing
ThuPM5: **9:00** Bruce: Physiological Insights Into The Problem Of Temporal Coding In Cochlear Implants

Friday July 29, 8:30 am – 12:10 pm

Electroacoustic Stimulation and Hearing Aids (Moderator: Monita Chatterjee)

FriAM1: **8:30** Launer: Hearing Instrument Technology – What Can We Learn For CI Development?
FriAM2: **9:90** Edwards: A Cognitive Approach to Hearing Aid Design and Assessment
FriAM3: **9:30** Francart: Signal Processing for Combined Hearing Aid and Cochlear Implant Stimulation
10:00 BREAK (15 minutes)
FriAM4: **10:20** Green: Contralateral Residual Acoustic Hearing; Speech Perception in Cochlear Implant Users
FriAM5: **10:50** Brown: Enhancing the Benefits to Speech Perception of Electro-Acoustic Stimulation
FriAM6: **11:20** Vollmer: Contralateral Masking In Binaural-Bimodal Stimulation In The Central Auditory System
FriAM7: **11:50** Kleine Punte: Spatial Speech reception in noise with electric stimulation in single-sided deafness

12:10 End of Conference, closing remarks, Lunch

Buses leave for SFO at 12, 1 and 2pm

MonAM1: Aging And Aided Speech Understanding: Contributions Of “Higher-Level” Processing

Larry E. Humes

Department of Speech and Hearing Sciences
Indiana University
Bloomington, IN 47405-7002 USA

Approximately 2/3 of the hearing aids sold in the U.S. are purchased by adults over 65 years of age. Cochlear implants have also seeing more widespread use in older adults recently. Whether a hearing aid or a cochlear implant, the ability of older adults to understand speech, both unaided and aided, may depend on age-related changes in “higherlevel” processing. These changes may be either modality-specific changes to the auditory portions of the central nervous system, often designated as “central auditory” processes, or changes to cortical areas mediating various amodal cognitive processes, such as various components of executive function.

This presentation will review available evidence on the contributions of higher-level processing to unaided and aided speech understanding in older adults. For aided listening, due primarily to the limitations of the data available, the focus will be placed on amplified speech, rather than speech delivered via cochlear implants.

In the first portion of this presentation, the results of a recent review by the American Academy of Audiology’s Task Force on Central Presbycusis, chaired by the presenter, will be summarized. Numerous smaller-scale laboratory studies of young and older adults have observed age-group differences on a variety of auditory temporal-processing tasks.

However, it is possible that such age-group differences do not represent modality-specific auditory deficits. Rather, they may represent more general cognitive or sensory-processing slowing, appearing to be “auditory processing” deficits only because sounds were used as stimuli. In the second portion of this presentation, the results of a large-scale (N=256) laboratory study of temporal processing in hearing, vision and touch for young, middle-aged, and older adults will be presented. The results suggest that auditory temporal processing, as measured in this laboratory study, is a modality-specific phenomenon and that many older adults do perform worse than younger adults on such measures. Finally, the implications of these findings, as well as those from experiments examining cognitive factors, to the aided speech-understanding performance of older adults will be discussed.

This work was supported, in part, by NIH-NIA R01 AG008293-18.

MonAM2: On Cognitive Functioning And Effective Use Of A Hearing Aid Or Cochlear Implant

Thomas Lunner[1,2,3], Mary Rudner[1,2], Jerker Rönnberg[1,2]

[1] Linnaeus Centre HEAD (HEaring And Deafness)
[2] Department of Behavioral Sciences, Linköping University, Sweden
[3] Eriksholm Research Centre, Oticon A/S, Denmark

The perceptual information transmitted from a damaged cochlea to the brain is more poorly specified than information from an intact cochlea and requires more processing in working memory before language content can be decoded. In addition to making sounds audible, current hearing aids include several technologies that are intended to facilitate language understanding for persons with hearing impairment in challenging listening situations. These include directional microphones, noise reduction, and fast-acting amplitude compression systems. However, the processed signal itself may challenge listening to the extent that with specific types of technology, and in certain listening situations, individual differences in cognitive processing resources, especially working memory, may determine listening success.

The Ease of Language Understanding (ELU) model is one example of a Cognitive Hearing Science model where the interplay between memory systems and signal processing is emphasized. When signals match, under optimal conditions, phonological processing is rapid, automatic and implicit, and lexical activation proceeds smoothly. Given a mismatch, lexical activation fails, and effortful working or short-term memory (WM/STM) processing is assumed to be invoked to engage in explicit repair strategies to disambiguate what was said in the conversation. Sub-optimal conditions may include environmental acoustic situations such as interfering speech and other sounds competing with the target speech signal. However, sub-optimal conditions can also include hearing loss, and/or sub-optimal hearing instrument/cochlear implant signal processing.

In a recent study, negative long-term consequences of mismatch were found by means of relating hearing loss to episodic LTM in a large sample of old hearing impaired listeners, while STM was intact.

Beneficial short-term consequences of a binary masking noise reduction scheme on STM was obtained in 4-talker babble for hearing-impaired individuals with high WM capacity, but not in stationary noise backgrounds. This suggests that individuals high on WM capacity inhibit semantic auditory distraction in 4-talker babble while exploiting the phonological benefits in terms of speech quality provided by binary masking.

Both long-term and short-term mismatch effects, apparent in data sets including behavioral as well subjective data need to be taken into account in the design of future hearing instruments and cochlear implants.

MonAM3: The Effect Of Early Auditory Experience On The Development Of Basic Skills Necessary For The Acquisition Of Speech & Language: Evidence From Infants With Cochlear Implants And Normal Hearing

Liat Kishon-Rabin

Communication Disorders Department, Sackler Faculty of Medicine,
Tel-Aviv University, Israel

The process by which infants acquire language continues to fascinate researchers and professionals world wide. For the infant, speech is a continuous stream of sounds with no reliable pauses between words or systematic acoustic markings of word boundaries. One of the basic tasks infants face in the process of language acquisition, therefore, is developing segmentation procedures that will allow them to determine where a word begins and ends. This is assumed to be accomplished by tracking distributional patterns of the language. To accomplish this, the infant is first required to tune in to his language and ignore other environmental sounds. Once "tuned-in", the infant calculates probabilities of occurrence of the linguistic units of the language. The latter is assumed to be facilitated by infants' sensitivity to predominant speech features of the ambient language. This sensitivity, meanwhile, is thought to depend on auditory acuity as well as on listening experience. While some of these early abilities have been demonstrated in infants with NH, very few studies have investigated their development in hearing-impaired infants with cochlear infants (CI).

The purpose of our series of experiments was to examine whether hearing-impaired infants who have their hearing restored via CI show the same perceptual biases in the process of language acquisition as infants with NH. If they do, we wanted to determine whether these biases depend on the auditory experience of these infants (with their CI). To date we have tested over 45 young infants with CI who had their implant before the age of 2 years and had listening experience with the CI between 2-6 months. For comparison purposes, we tested over 150 young infants with normal hearing. The Central Fixation Preference procedure was used to test infants' preference to speech compared to other sounds and languages, and the Visual Habituation procedure was used to test discrimination between different phonemes and stress patterns. Our data are the first to show that: (1) infants with CI prefer their language compared to other speech and non-speech sounds in a similar way as normal-hearing infants, even with minimal listening experience; (2) asymmetry in discrimination between linguistic units has been observed for NH and infants with CI. This supports a top-down influence of linguistic knowledge on auditory discrimination; (3) auditory experience influences perceptual bias of early linguistic skills similarly for NH and infants with CI; and (4) performance of infants with CI is strongly correlated with early auditory and preverbal skills. We conclude that despite impoverished input and impaired auditory system, infants with CI were able to develop early skills necessary for language acquisition and that these were dependent on auditory experience.

Work supported by the Binational Science Foundation and the Israeli Ministry of Health.

MonAM5: The Words And Linguistic Structures Of 7-Year-Olds After Five Years Of Cochlear Implant Experience

Steven Gillis

University of Antwerp, Belgium

Can listeners identify the speech of a 7-year-old child with a cochlear implant who received his/her device in the first two years of life? Does the speech of a 7-year-old congenitally deaf child with a cochlear implant sound like that of any other 7-year-old, or is there “something different”?

In a first, exploratory study the research question was very straightforward: can listeners identify the speech of a 7-year-old child with a cochlear implant? Short sentences produced by 7-year-old children with normal hearing (NH), congenitally deaf children with a cochlear implant (implanted in the first two years of life, CI) and hearing impaired children with a conventional hearing aid (HA) were recorded. These stimuli were judged in a forced choice task by three panels: a group of naïve judges who without any particular experience with children’s speech, a group of 1st and 2nd grade teachers with extensive experience with the speech of 7-year-olds, and a group of speech clinicians with extensive experience with children suffering from hearing problems and children with cochlear implants. The judges had to decide whether a stretch of speech was uttered by a normal hearing child, a hearing impaired child with a conventional hearing aid, or a congenitally deaf child with a cochlear implant.

The results clearly showed that the judges were able to identify the NH children, but had much more difficulties in distinguishing the speech of the CI and HA children. Hence, there must be “something different” in the speech of these three groups of children.

Analyses of segmental and suprasegmental characteristics of the speech of the three groups revealed significant differences. An acoustic analysis of the 12 steady-state vowels of Belgian Dutch produced by these 7-year-olds, showed that the vowel spaces of the HA and CI children were significantly smaller and centralized in comparison to the NH children. An acoustic analysis of the prosodic structure of words showed deviating pitch and durational characteristics in the production of disyllabic trochees.

Spontaneous speech samples of the same group of children with a CI were collected and compared with samples of NH age mates. An analysis of the morpho-syntactic structure of the language samples revealed that at the age of seven, after at least five years of device use, CI children’s utterances are significantly less complex and exhibit more errors in verb placement and verb morphology. Moreover, CI children have significantly smaller morphological verb paradigms.

The results of the present study show that – notwithstanding considerable individual differences – CI children’s language and speech still deviate from that of NH peers in particular areas after five years of device experience.

MonAM6: Speech Recognition In Cochlear Implant Users: Selection Of Sites Of Stimulation Based On Temporal Modulation Sensitivity

Soha N. Garadat, Teresa A. Zwolan, Bryan E. Pfingst

Kresge Hearing Research Institute, University of Michigan, Ann Arbor, MI USA

Factors related to variance in performance across cochlear implant (CI) recipients have been widely addressed but variation in performance within listeners has been given less attention. Differences across sites of stimulation are perhaps related to irregularities in neural survival in the vicinity of implanted electrodes as well as physiological and biophysical mechanisms that are likely to be patient specific. Although neural regeneration at those sites is theoretically feasible, it has not yet been effectively implemented at a clinical level. An alternative approach is to minimize stimulation at the suboptimal sites and to emphasize optimal sites. Although fewer electrodes will be stimulated, previous studies suggest the feasibility of this approach and the potential improvement in CI users' performance once the aberrant sites are removed (Zwolan et al., 1997). In general, this approach might hold a promising lead in the clinical domain with the hope that differences in performance across stimulation sites will provide a useful guide for CI fitting.

Previous work from our laboratory showed that differences across sites of stimulation can be identified using modulation detection thresholds (MDTs) measured in the presence of an interleaved masker. Results further showed that speech recognition was affected by improving or degrading mean temporal acuity. In this study, 12 CI recipients were tested on several measures of speech recognition. Their performance with their own clinical MAP on these measures was compared to that with an experimental MAP. The experimental MAP was similar to the subjects' clinical MAP with the exception that 5 stimulation sites were disabled. Subjects' electrode arrays were divided into 5 segments and the electrode with the worst masked MDT from each segment was disabled. Our aim was to maximize temporal acuity in each segment.

Consistent with previous studies, speech recognition was variable among CI users. Relative to their performance with the clinical MAP, subjects consistently performed better with the experimental MAP on sentence recognition in noise but showed less consistent results for the other speech measures. In addition, results showed that CI users with good sentence recognition had greater sensitivity for amplitude modulation, supporting the idea that temporal acuity is important for speech recognition. A follow-up study to examine whether real-world training would lead to further improvement is currently in progress.

This work is supported by NIH-NIDCD grants R01 DC010786 and F32 DC010318.

MonAM7: Contributions Of Static And Dynamic Cues To Vowel Identification By Cochlear Implant Users

Gail S. Donaldson[1], Catherine L. Rogers[1], Benjamin A. Russell[1] and Emily S. Cardenas[1]

[1]University of South Florida, Tampa, FL, USA

Much research in vowel perception has focused on the so-called "steady-state" segments of vowels that reflect the target positions of the speech articulators. Recently, however, there has been increasing focus on the dynamic aspects of speech, related to the movement of the articulators from one target position to another. As a result, there is now considerable evidence that normal-hearing (NH) listeners make use of *both* static and dynamic cues to identify vowels in syllable contexts. NH listeners' ability to use multiple acoustic cues likely contributes to their ability to maintain high levels of speech recognition in difficult listening situations, such as when speech is partially obscured by background noise.

Relatively little is known about cochlear implant (CI) users' comparative ability to make use of static vs. dynamic cues in vowel perception tasks. A study by Kirk et al. (1992; JASA 91,3487-98) tested vowel identification in users of early CI devices and speech processing strategies, using /wVb/ and /bVb/ stimuli that included different combinations of static, dynamic and duration cues. Their subjects had relatively poor vowel recognition, overall, and were able to derive limited benefit from the dynamic cues. Importantly, however, those subjects who demonstrated the best perception of dynamic vowel cues also exhibited the highest levels of word and sentence recognition.

In the present study, we completed a modified version of Kirk et al.'s experiment in CI users with contemporary devices and in a comparison group of young NH (YNH) listeners. Stimuli were seven /dVd/ syllables ("deed, did, Dade, dead, dad, dud, and Dodd") spoken by three female talkers. Vowel identification was tested for the unmodified stimuli, and for duration-neutralized stimuli that were modified to retain 60 or 80 ms of the vowel center ("center-only" conditions) or 30 or 40 ms of the initial and final vowel transitions ("edges-only" conditions).

YNH listeners achieved high levels of performance for the unmodified stimuli (avg. 99.8%) and for the center-only stimuli (90.8%); their performance dropped to more moderate levels (68.1%) for the edges-only stimuli. CI users demonstrated moderate performance for the unmodified stimuli (avg. 72.0%) but demonstrated substantial drops in performance for both the center-only (38.1%) and edges-only stimuli (25.1%).

These findings suggest that CI users 1) have difficulty identifying vowels in syllables when one or more cues are absent, and 2) rely more strongly on quasi-static cues from the vowel center as compared to dynamic cues at the syllable edges. The next phase of this research will investigate the extent to which CI users' poor perception of partial syllables stems from degraded spectral acuity versus other (e.g., cognitive) factors.

MonPM1: The Cortical Processing Of Speech: Intelligibility, Plasticity And Cognitive Factors

Sophie Scott

University College, London, UK

In the human brain, the processing of complex acoustic stimuli is associated with the dorsolateral temporal lobes. Within this system, we can identify distinct streams of processing associated with speech perception: for example, the linguistic information in speech is predominantly processed in the left temporal lobe, while other kinds of information (e.g. associated with speaker identity) are predominantly processed on the right. There is also an anterior-posterior dimension, with the greatest responses to intelligible speech in anterior temporal fields, and sensori-motor representations of speech in posterior fields. In this talk, I will set out this system, and demonstrate the ways that the speech perception and production systems interact to support verbal working memory phenomena. I will show how activity within the temporal lobes and beyond is associated with adaptation to realistic cochlear implant simulations, and how this interacts with performance and verbal working memory scores. I will finish by discussing the neural networks associated with the use of linguistic context to support the perception of noise vocoded speech.

MonPM2: Adaptation To Frequency Mismatch By Postlingually Deaf CI Users: Plasticity And Its Limitations

Mario A. Svirsky, Chin-Tuan Tan, Elad Sagi, Arlene Neuman, Matthew Fitzgerald, Ben Guo

Department of Otolaryngology, New York University School of Medicine

Cochlear implants (CIs) take advantage of the tonotopic structure of the cochlea, stimulating areas progressively closer to the base as the input sound frequency increases. One key fitting parameter in a CI is the frequency allocation table (FAT), which determines the input acoustic frequency range that is allocated to each electrode. Under current clinical practice, nearly all users of a given CI model are given a standard FAT set by the manufacturer. In postlingually hearing impaired CI users, this one-size-fits-all approach may introduce mismatches between input acoustic frequency and the characteristic frequency of the neurons that are stimulated. Previous research has shown that human listeners show a great degree of adaptation to these distortions. This is fortunate because it allows CI speech processors to use a fixed range of input frequencies that includes the most relevant information for speech perception, regardless of cochlear size, electrode location, and neural survival pattern.

However, there is growing evidence that this adaptation process may be incomplete, at least for some listeners. We will review several data sets from our laboratory and from other investigators, involving different experimental paradigms that shed light on the phenomenon of adaptation to different FATs. The data to be presented include pitch matching between acoustic and electrical stimulation; “vowel space” experiments; real time selection of frequency allocation tables; and mathematical modeling of vowel identification. Taken together, the data suggest that some CI users are not able to completely adapt to standard FATs. These data are consistent with the idea that the human brain is plastic, but not infinitely so. In consequence, it may be important to identify individuals who show incomplete adaptation to their FAT. In such individuals, customized fitting of FATs may improve speech perception.

Work supported by NIH-NIDCD; partial support provided by Cochlear Americas, Advanced Bionics Corporation, and Siemens.

MonPM3: Auditory Training in Cochlear Implant Patients: Go Easy or Go Hard?

John J. Galvin III, Sandy Oba, and Qian-Jie Fu

House Research Institute, Los Angeles, CA, USA

For cochlear implant (CI) patients, is it better to train with a relatively easy or difficult task? Training with an easier task may allow CI patients to “gain traction” on the trained percept, but may not generalize to more difficult listening conditions. Training with a more difficult task may better reflect challenging conditions, but may be too discouraging. Here, we report preliminary data for two training studies in which subjects trained with a relatively easy or difficult task.

In the first study, CI patients were trained to identify melodic contours. Before training was begun, baseline melodic contour identification (MCI) performance was extensively measured, with and without a competing masker. The masker pitch, timbre and timing were varied to see which cues (if any) subjects might use for segregation. After completing baseline measures, subjects were divided into two groups. One group trained with contours presented in isolation (relatively easy); the other group trained with contours presented with a competing masker (relatively hard). Both groups trained at home for ~half-hour per day, 5 days per week, for one month. Subjects were trained on pitch ranges not used for testing. While MCI performance with and without a masker improved for both training groups, preliminary results showed greater improvement with the more difficult training.

In the second study, normal-hearing (NH) subjects were trained to understand speech in noise while listening to an 8-channel acoustic simulation of bilateral CIs. In the simulation, the right ear was basally shifted by 3 mm, relative to the left ear. Before training was begun, baseline sentence recognition in noise (with and without spatial cues) was measured with the left ear, right ear and both ears together. Baseline performance with the right (shifted) ear was more than 20 points poorer than with the left ear. Subjects were divided into two groups. One group trained with both ears together (relatively easy); the other group trained with the right (shifted) ear alone (relatively hard). Both groups were trained to identify keywords in sentences presented in noise (without spatial cues); sentences were different than those used for testing. Subjects completed 10 hours of training. Preliminary results showed improved binaural performance for both training groups. However, performance with the right ear alone improved only for the unilateral training group, suggesting better overall outcomes with the more difficult training.

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MonPM4: Pitch Plasticity With Cochlear Implant Experience

Lina A.J. Reiss[1], Christopher Turner[2], Sue Karsten[2], Rindy Ito[1], Ann Perreau[2], Mary Lowder[2], and Bruce Gantz[2]

[1]-Oregon Health & Science University, Portland, OR, USA
[2] University of Iowa, Iowa City, IA, USA

The electric pitch percept perceived from stimulation of a cochlear implant (CI) electrode can be estimated by comparison with an acoustic reference, the residual hearing in the non-implanted ear. We recently demonstrated that pitch perceived through a Hybrid short-electrode cochlear implant (CI) can shift over several months of implant experience, by as much as 2 octaves (Reiss et al., JARO 2007). In addition, preliminary findings in a case study of a bilateral CI user with CIs at different insertion depths suggest that the pitch of a CI measured relative to a second CI may also shift with experience (Reiss et al., 2011).

We will review these recent findings of CI pitch plasticity, and describe new findings demonstrating similar pitch shifts in long-electrode CI users with residual hearing in the non-implanted ear. In addition, we will evaluate a hypothesized mechanism for these pitch changes: that the pitch changes are driven by spectral discrepancies introduced by the CI speech processor frequency-to-electrode allocations. The CI processors are typically programmed to provide important speech frequencies that are missing, independent of the actual cochlear place frequencies stimulated. As a result, large spectral discrepancies are often introduced between input sound frequency and cochlear place frequency stimulated via the implant. For bimodal or combined acoustic+electric stimulation, this also introduces a discrepancy between the acoustically and electrically stimulated cochlear place-frequencies. The patterns of pitch changes in Hybrid, bilateral, and long-electrode CI users suggest that pitch perception may adapt at least partially to reduce these spectral discrepancies.

This work has implications for the role of brain plasticity in auditory prosthesis perception, and suggests that experience-dependent changes also need to be factored into device evaluation and design.

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MonPM5: Plasticity Of The Primary Auditory Cortex: Effects Of Long-Term Deafness And Chronic Intracochlear Stimulation

James B Fallon[1, 2]

[1] The Bionic Institute, Melbourne, Victoria, Australia.
[2] Department of Otolaryngology, University of Melbourne, Victoria, Australia.

We have been using multi-channel recording techniques in the primary auditory cortex (AI) of the profoundly deafened cat to study plasticity in response to long-term deafness and chronic intracochlear stimulation (ES). The neonatal deafening technique (daily injections of an ototoxic agent from the day after birth) ensures minimal auditory experience and therefore models a pre-lingual hearing loss. We have established that without input from the periphery from an early age, there are significant changes to spectral (spatial) processing in AI. In particular, long-term deafness results in the loss of one of the key features of AI, its cochleotopic organization. In contrast, long-term deafness had no effect on temporal processing when assessed by measuring response latency, jitter (standard deviation of response latency), or the maximum rate at which units could be driven.

To assess the effects of chronic ES, we have used a modified clinical cochlear implant to deliver environmentally derived stimulation for periods of up to 6 months. Chronic ES from a young age (2 months of age) ameliorated the effects of long-term deafness on spectral processing (i.e. the cochleotopic organization of AI in these animals is near-normal). Interestingly, delaying the initiation of chronic ES until the animal is mature (8 months of age), did not reduce the effectiveness of the chronic ES. Although robust, this result was somewhat surprising given the initiation of the chronic ES was after the closure of the normal critical period. Chronic ES also resulted in a small, but significant increase in both latency and jitter but no change in maximum driven rate, whether it was initiated in the immature or adult animal.

Collectively, these results indicate that the development of temporal processing within the central auditory system is quite robust, while input from the periphery, whether via normal hearing or a cochlear implant, is vital for the development and / or maintenance of normal cochleotopy. What is less clear, is the time-course and behavioral consequences, if any, of these changes. Therefore, we have recently developed techniques to allow us to chronically record from multichannel arrays implanted in AI for periods of up to 8 months. We have also developed behavioral testing techniques to allow us to assess the performance of the cats on a range of tasks in 'real-world' listening environments. The combination of chronic cortical recordings and behavioral testing will provide essential insight into plastic changes that occur in AI during long-term deafness and chronic ES, and their critical role in clinical performance.

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TueAM1: Do Binaural Implant Users Access The Same Binaural Brain Circuits As Normal-Hearing Listeners?

David McAlpine
UCL Ear Institute, 332 Gray's Inn Road, London, WC1X 8EE, U.K

The extent to which bilateral cochlear implantation can provide for the restoration of binaural hearing remains a contentious issue. As well as underpinning the ability to locate the source of a sound, binaural hearing, particularly the ability to exploit differences in the temporal fine structure of sounds arriving at the two ears, also provides for improved detection in noise – a vital component of 'cocktail party listening'. A number of factors suggest that the exploitation of interaural time differences (ITDs) in particular might not be possible in bilateral implantation. The first relates to the complete absence of information concerning the temporal fine structure conveyed by current stimulation strategies. Although the ability to exploit ITD cues in the envelope of high-frequency sounds (cues most likely conveyed in electrical hearing) is well established for normal-hearing listeners, the extent to which they provide for any useful binaural abilities remains to be demonstrated. The second relates to the arbitrary nature of bilateral stimulation – the extent to which binaural temporal information can be accessed depends on the extent to which the signals at each ear are interaurally coherent – current fitting procedures. Although envelope modulations rates are relatively slow compared with fine-structure fluctuations, they provide for less potent binaural temporal cues, and are strongly affected by noise and reverberation. Here, I discuss the binaural brainstem pathways underpinning binaural hearing in normal and electrical hearing. I contend that the form of ITD processing evident in bilateral implant users may not be dependent on processing by 'traditional' binaural neurons in the brainstem but, rather, makes use of the auditory brain's ability to exploit rapid transients in the signals between the ears at multiple levels of brain processing. Such binaural listening can account for the relatively low ITD discrimination thresholds evident in some well-controlled psychophysical studies, as well as the absence of other, more pertinent, binaural abilities in bilateral implant users.

TueAM2: The overlooked benefit of bilateral cochlear implantation.

John F. Culling[1], Sam Jelfs[2], Alice Talbert[1], Steven S. Backhouse[3]

[1]School of Psychology, Cardiff University, Tower Building, Park Place, Cardiff, CF10 3AT, U.K.
[2]Philips Research Europe, High Tech Campus 36 (WO-p.076), 5656 AE Eindhoven, The Netherlands. (Current address)
[3]Princess of Wales Hospital, Coity Rd. Bridgend, CF31 1RQ, U.K.

Binaural hearing improves understanding of speech in background noise if the sources of the speech and noise are spatially separated. Bilateral cochlear implantees also experience this spatial release from masking (SRM), but all studies to date have shown only modest levels of SRM (4-5 dB), which do little to justify the expense of a second implant. However, these studies generally used the same sub-optimal spatial configurations; they contrasted a situation in which speech and noise were collocated in front of the listener with a situation in which the speech was in front and the noise at 90 degrees. The latter configuration underestimates potential SRM, because an approximately spherical obstacle, like the head, casts a relatively small acoustic shadow when a source is at 90 degrees. Moreover, SRM can be negative for a one-eared listener when this ear is towards the noise source. A computer model of SRM (Jelfs et al. Hear Res., in press) was used, to accurately predict SRM measurements from the literature in both normally hearing listeners and cochlear implantees. It was then used to predict the best and worst spatial configurations of speech and noise. New SRM measurements using these configurations in both normally hearing listeners and unilateral implantees again confirmed the model’s predictions. The reception thresholds for bilateral implantees were inferred using mirror-image spatial configurations to be 20 dB better than unilateral implantees in certain situations. Bilateral cochlear implantation is thus markedly more beneficial to speech understanding in noise than has previously been observed.

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TueAM3: Bilateral Cochlear Implantation in Children

Ruth Litovsky

University of Wisconsin-Madison, Waisman Center, 1500 Highland Ave, Madison WI 53705.

Bilateral cochlear implants (CIs), which were somewhat unusual in children a decade ago, have grown in vast numbers in recent years. Numerous studies have shown that children typically perform better on spatial hearing tasks with bilateral vs. unilateral CIs. However, it is unusual for bilaterally implanted children to perform at the same level as their normal-hearing (NH) peers. For example, in NH children, average errors on sound localization tasks range from 5-20 degrees; bilaterally implanted children rarely achieve such low error rates, even after several years of bilateral listening experience. Similarly, spatial release from masking (SRM), the improvement seen in speech intelligibility when the target speech and maskers are spatially separated, is small in CI users, in particular when the use of binaural cues is needed for source segregation.

This talk will present data from several studies on the emergence of spatial hearing skills in children who received their second CI between the ages of 1 and 4. The data are first considered for children with a chronological age of 6-7 years, with bilateral experience that varied from a few months to nearly 5 years. This broad range of bilateral experience enable us to examine the effects of bilateral experience on performance. Results from children who vary in age but have the same amount of bilateral experience provide insight into age-related factors.

The data will be considered within the context of evidence from studies in adult listeners, suggesting that bilateral CIs do not provide binaural cues with fidelity. The stimuli at the two ears are unlikely to be place-matched (frequency-matched) or loudness balanced; there are likely to be asymmetries in neural survival and dynamic range, as well as compression due to unmatched microphone settings. In addition, current spread, leading to electrode interaction effects may cause blurring of binaural signals. Our studies with adult listeners demonstrate that if binaural cues can be restored and introduced to listeners through research processors, there is a greater likelihood that the gap in performance can be minimized. The potential role of binaural cue restoration in the development of spatial hearing skills of children will be discussed.

Work supported by NIH-NIDCD

TueAM4: The Potential Problem Of Interaural Decorrelation For Modulated Stimuli In Bilateral Cochlear-Implant Users

Matthew J. Goupell, Alan Kan, and Ruth Y. Litovsky

University of Wisconsin, Madison, WI, USA

While there are a number of factors to consider when trying to present auditory stimuli to an individual using a cochlear implant (CI), the care needed in addressing these factors at least doubles with bilateral CI users. The purpose of this work is to understand how to maximize localization information in bilateral CI users for stimuli that change as a function of time (e.g., modulated sounds), which is a departure from a majority of bilateral CI psychophysics research that utilize constant-amplitude pulse trains. The future of bilateral CI research needs to incorporate stimuli with amplitude modulations because they are more similar to stimuli that people encounter in every day listening.

In these studies, bilateral CI users were tested with single pitch-matched pairs of electrodes under direct stimulation. In study 1, sensitivity to interaural decorrelation was evaluated as a function of stimulus bandwidth and pulse rate. Listeners could detect interaural decorrelation, although they were less sensitive to interaural decorrelation than normal-hearing (NH) listeners and NH listeners presented with a CI simulation. There was no effect of stimulus bandwidth, but lower thresholds were measured for higher pulse rates, contrary to binaural rate limitations for constant-amplitude pulse trains.

In study 2, we examined whether interaurally-correlated and modulated stimuli were likely to be perceived as interaurally decorrelated due to mapping of acoustic amplitude to current level. To achieve this, the perceived lateral position of constant-amplitude, 300-ms pulse trains with interaural level differences (ILD) added was measured as a function of overall level. It was found that the perceived intracranial location of the stimuli for a fixed ILD varied as a function of overall level. Therefore for modulated sounds like speech, interaural decorrelation is likely to be introduced in the mapping process, which may cause difficulties in sound localization and understanding speech in noise. Hence, it may be worthwhile to consider new mapping practices that attempt to minimize unwanted ILDs.

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TueAM5: Binaural hearing in reverberant space with cochlear implants

Bernhard U. Seeber[1,2], Stefan Kerber[1], Ervin R. Hafter[2]

[1] MRC Institute of Hearing Research, Nottingham, UK
[2] Department of Psychology, UC Berkeley, Berkeley, CA, USA

Benefits from bilateral cochlear implants (CIs) have been demonstrated for directional speech perception and sound localization. Most of these studies took place in laboratory settings which did not resemble real-world listening situations. There, patients frequently report localization problems caused by noise and reverberation. Normal-hearing listeners possess mechanisms to locate sources correctly despite the presence of sound reflections, but it is questionable if these precedence effect mechanisms are available to CI users. We have studied the impairment caused by reverberation which also sheds light on the involved binaural processes.

Horizontal sound localization was tested in the free-field of our “Simulated Open Field Environment”. Sound reflections of a small room were calculated and played from individual loudspeakers such that their spectral, temporal and spatial properties were reproduced. Results of the initial study by Seeber and Hafter with ten bilateral CI users showed that localization ability declined considerably in moderate reverberation. Whilst eight listeners were able to discriminate the side of sound incidence for a single word in anechoic space, only five preserved this ability in reverberation. Localization was better for repeated than single noise bursts, suggesting that binaural information needed integration over time.

In a subsequent study, localization ability was measured at varying direct-to-reverberant ratios (DRR). While normal hearing participants showed no localization impairment with spoken words down to about -8 dB DRR, localization of CI users was already affected at positive DRRs between 0 and +10 dB. In many natural listening situations, however, DRRs are negative. It is thus questionable if patients would receive the full (localization) benefit from their second implant when listening in rooms.

In order to better understand the underlying mechanisms, lateralization with interaural level (ILD) and time (ITD) differences was investigated in a direct stimulation paradigm. Whilst all participants were able to lateralize based on ILDs, only some showed adequate sensitivity to envelope ITDs. These also performed better in reverberant space, suggesting that envelope ITDs were used. Previous studies in anechoic space had instead indicated that sound localization with CIs is based mostly on ILDs.

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TueAM6: Cortical Sensitivity To Binaural Cues In Bilateral And Unilateral Congenital Deafness

P. Hubka, J. Tillein, R. Land, I. Teudt, A. Kral

Institute of Audioneurotechnology, Medical University Hannover, Germany

Previous studies from our lab have shown that sensitivity to interaural time differences (ITD) is rudimentary developed even in absence of auditory experience (Tillein et al., 2010, Cereb Cortex 20:492-506). However, the sensitivity to this cue is reduced and cortical aural representation severely affected by deafness (Kral et al., 2009, J Neurosci 29: 811-827). Sensitivity to interaural level differences (ILD) in congenitally deaf white cats and normal hearing cats are currently under investigation. Our preliminary data demonstrate a fundamental difference in cortical processing of ITD and ILD: e.g. sensitivity to ITD is significantly reduced in congenital deafness (reduced modulation depth), whereas it is less affected for ILD (same modulation depth as in hearing controls). Also, indirect measures indicate that ILD undergoes less cortical processing than ITD in hearing, acoustically stimulated animals.

Additionally, some cats in the white cat colony are born with normal unilateral hearing and complete deafness on the other ear. These cases are rare among white cats and provide an exceptional opportunity for investigation of effects of congenital unilateral (lifelong) experience on sensitivity to binaural cues with small influence of spiral ganglion cell degeneration on the findings (due to the slow degeneration of spiral ganglion cells). In these cats the binaural feature sensitivity was investigated in the auditory cortex using electrical pulse trains (same as in Tillein et el., 2010, Cereb Cortex 20:492-506). These results were compared to hearing and binaurally deaf cats. Due to the increasing number of implanted subjects suffering from single sided deafness this topic becomes clinically important.

Approximately 120 unit recordings per animal were obtained from the cortices ipsi- as well as contralateral to the deaf ear. In general, binaural feature sensitivity showed no significant difference between the ipsi- and contralateral side, demonstrating extensive reorganization of aural representation in unilateral deafness. Additionally, non-specific deprivation-induced functional deficits such as reduction in firing rate and increase in proportion of non-responsive units, normally observed in binaurally deaf animals, were absent in unilaterally deaf cases. In contrast to binaurally deaf animals, unilateral deafness leads to a significant increase in non-classified binaural responses, e.g. significantly flatter best-ITD and center-ITD function, and a further reduction in modulation depth of these functions when compared to binaurally-deaf animals.

In conclusion, in unilaterally-deaf animals, when compared to hearing cats, the same number of responsive units were found, whereas in binaurally-deaf animals these numbers were strongly reduced. There was, however, less sensitivity to binaural cues in unilaterally deaf animals than in binaurally deaf animals. Those units that were sensitive to binaural cues in unilaterally-deaf showed no physiological preference to certain binaural parameters, which was different from both binaurally deaf and hearing animals. In consequence, the binaural sensitivity disappeared nearly completely in monaurally deaf animals, despite the fact that non-specific deficits found in binaural deafness were compensated. This demonstrates the detrimental effects of unilateral deafness on binaural feature sensitivity.

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TueAM7: Investigating Benefits Of Bilateral Cochlear Implants In An Animal Model

Douglas Hartley[1], John Allen[1], Alex Wyatt[1], Tara Vongpaisal[1],
Peter Keating[1], Robert Shepherd[2], Andrew King[1], and Amal Isaiah[1]

[1]Dept. of Physiology, Anatomy & Genetics, Oxford University, UK
[2]Bionic Institute, Melbourne, Australia

Electrophysiological and behavioural measures of binaural processing were assessed in ferrets with normal hearing (NH), bilateral cochlear implants (BCI) and bilateral bimodal stimulation (BBS; combined electric and contralateral acoustic hearing). In implanted animals, hearing loss was induced with intra-scalar neomycin, prior to implanting

intra-cochlear multichannel electrode arrays in one or both ears. Initially, we characterized binaural responses in the auditory cortex of NH ferrets under ketamine anaesthesia. Onset and offset responses are seen in about 25% of neurons, and binaural sensitivity changes significantly between the onset and offset response in >95% of cases. Studies in NH individuals suggest that binaural sensitivity, specifically

to interaural time delays (ITDs), is enhanced using transposed stimuli. To further assess potential benefits of transposed stimuli to individuals with BCI, cortical sensitivity to ITDs was assessed using i) transposed and sinusoidally-amplitude modulated (SAM) acoustic carriers in NH animals, and ii) transposed and SAM biphasic pulse trains in deafened ferrets with BCI. Cortical onset and offset responses in NH animals

show greater ITD sensitivity with transposed, compared with the SAM stimuli. In animals with BCI, smaller spike rates are recorded in the offset response to transposed stimuli, whilst the number of binaurallysensitive units remains the same. Thus, transposed stimuli may prove beneficial to individuals with BCI.

We also investigated auditory brainstem responses (ABRs) in animals with BCI and BBS. Under both listening conditions, the binaural interaction component of the ABR is present, and strongly dependent on synchronization of stimulation between the ears. Free-field behavioural assessments of spatial release of masking(SRM) and sound localization were assessed in chronically-stimulated animals using positive conditioning paradigms. For chronic stimulation, intracochlear electrode arrays were connected via percutaneous lead wires to stimulator-receivers and ESPrit 3G processors (Cochlear Ltd.) worn in a jacket. NH animals have, on average, 6.4 dB SRM, whilst animals with BBS have, on average, 5.4 and 0 dB SRM with the cochlear implant switched on and off, respectively. SRM is highly variable amongst animals with BCI. BCI enhances greatly sound localization performance in most, but not all animals, compared with a single implant. The benefit of BCI on sound localization deteriorates at >77 dB SPL, potentially due to detrimental effects of automatic gain control activation.

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TuePM1: Loss And Rescue Of Cortical Inhibition Following Early Hearing Loss

Dan H. Sanes, Vibhakar C. Kotak, Anne E. Takesian, Brad N. Buran,
Emma C. Sarro, Francis A. M. Manno, Ramanjot Kang, Merri J. Rosen

New York University, New York, NY, USA

A general theory of sensory development holds that experience can influence central nervous system function during a finite period of maturation (i.e., a critical period), thereby shaping adult perceptual skills. If so, then one would expect developmental hearing loss to result in long-lasting deficits in perception and communication. However, most human research considers subjects with some degree of cochlear dysfunction and a history of remediation; this makes it difficult to evaluate the degree to which central nervous system dysfunction is involved. To begin addressing these unsettled questions, I will discuss observations at the level of behavior and synaptic physiology which suggest that central factors limit auditory perception, and that one of these - cortical inhibition - can be rescued in animals reared with persistent hearing loss.

To examine the potential impact of developmental hearing loss on perception, independent of cochlear damage, gerbils were reared to adulthood with a conductive hearing loss (CHL). Individuals were then trained and tested on a conditioned avoidance procedure to assess detection thresholds for amplitude or frequency modulation (AM, FM). Detection thresholds were significantly worse for animals reared with CHL even when adjusted for sensation level. Preliminary results suggest that the deficit was not as severe when CHL was induced in adulthood. These findings suggest that alterations to cochlear processing which attend hearing loss may not explain, entirely, diminished perceptual abilities.

The behavioral studies imply that developmental hearing loss must induce changes to CNS function that are substantial enough to impair perception. We have explored this prediction at many levels of the central auditory pathway, from brainstem to cortex, and have identified at least one general principle: the strength of synaptic inhibition plummets following developmental hearing loss. I will discuss evidence showing that developmental hearing loss leads to a dramatic reduction in inhibitory synaptic currents in auditory cortex, but this effect is not observed for an identical manipulation performed in adulthood; that is, there is a critical period for the emergence of inhibitory strength. Finally, I will present our recent findings that normal inhibitory synaptic strength can rescued permanently through pharmacological treatment during development, even in animals with cochlear ablations. This strategy should allow us to test whether restoration of a central nervous system property – inhibitory strength - is sufficient to improve behavioral performance.

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TuePM2: Permanent Cochlear Nerve Degeneration After "Temporary" Noise-Induced Hearing Loss: Evidence From Two Animal Models

M. Charles Liberman and Sharon J. Kujawa

Eaton-Peabody Laboratories, Massachusetts Eye and Ear Infirmary, Boston MA USA.

After acoustic injury, sensory cell loss can occur within hours, however loss of spiral ganglion neurons is not visible for weeks. This difference in degenerative time-course has suggested that hair cell loss is the “primary” event, and that neuronal loss occurs only “secondarily”. In mice and guinea pigs, we show that noise exposures adjusted to produce a large, but reversible, elevation of cochlear thresholds (as measured by ABRs and DPOAEs) lead to rapid synaptic degeneration, even with no hair cells loss and full DPOAE recovery. By immunostaining for pre-synaptic ribbons and post-synaptic terminals, we demonstrate a 50% loss of synapses within 24 hrs post-exposure. Spiral ganglion cell loss approaches 50% in noise-exposed animals, but only after months to years. Single-fiber recordings from the auditory nerve suggest the loss is selective for the fiber subgroup normally showing low spontaneous rates and high thresholds. This primary neural degeneration, which is reflected in ABR amplitude reduction but not in ABR threshold elevations, may contribute to hearing difficulties in noisy environments, though it does not affect thresholds in quiet.

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TuePM3: Preventing Hair Cell Loss By Protection From Fatal Injury: A Brief Review Of Strategies

Andrew Forge

Centre for Auditory Research, UCL Ear Institute,
332, Gray's Inn Road, London WC1X 8EE, UK

Loss of hair cells is the major cause of hearing impairment. In many forms both of acquired and congenital hearing loss the death particularly of outer hair cells (OHC) occurs commonly through apoptosis. Apoptosis is the end stage of a cascade of biochemical reactions triggered when a cell is under stress. It is a widespread phenomenon in which a cell dies without inducing an inflammatory response. A cell under stress activates stress response pathways, some of which enhance cell survival while others provoke apoptosis. Most commonly apoptosis is executed following activation of specific enzymes, known as caspases, though caspase independent apoptotic pathways are also recognised. One common trigger for cell stress is free radicals. Cells normally produce free radicals and express a variety of free-radical scavenging systems to remove them, but when free radical production exceeds the capacity of the scavengers, cell stress pathways are activated and programmed cell death may ensue. There is evidence for production of excess free radicals in the cochlea in response to noise, ototoxins and with ageing. Various stress response pathways have also been identified in traumatised cochleae. The identification of the triggers and biochemical pathways leading to hair cell death provides opportunities for interventions to rescue hair cells that would otherwise die and preserve auditory function. Thus the application of free radical scavengers or enhancement of natural scavenging systems might prevent triggering of cell stress pathways; stress-activated death pathways maybe inhibited or survival pathways enhanced by pharmaceutical targeting of specific components; or caspases themselves can be inhibited. There is some evidence from animal studies, which will be reviewed, for the success of each of these approaches in preventing hair cell loss and preserving hearing. Most of these approaches are aimed at the initial loss of OHC. Inner hair cell (IHC) loss is often delayed relative to that of OHC and to the initial traumatising event. It is possible that the cell death pathways in IHC and interventions likely to rescue them may not necessarily be the same as for OHC. Nevertheless, the use of hair cell protection strategies may have implications for cochlear implantation, for example for preservation of any residual hearing.

TuePM4: Steroids To Protect The Inner Ear During Cochlear Implant Surgery: Experiments And Clinical Translation

Stephen O'Leary, Joanne Enticott, Robert Briggs, Richard Dowell, Hayden Eastwood

Department of Otolaryngology, University of Melbourne
Royal Victorian Eye and Ear Hospital, 32 Gisborne St, Melbourne East 3002, Australia

Hearing preservation has emerged as an important method of improving both speech and music perception with a cochlear implant. Here a series of experiments are described which demonstrate that pharmacological treatment of the inner ear at the time of surgery can preserve residual inner ear function. The experimental work has been done in a guinea pig model of cochlear implantation, and where residual hearing is the primary outcome measure. These studies demonstrate that glucocorticosteroids can protect hearing during implant surgery when applied either locally to the inner ear, or systemically at high dose. The local delivery of steroids is only effective if the drug is applied at least an hour prior to cochleostomy, most likely because this is the time required for diffusion of the drug from the round window to the site of action within the cochlea. This suggests that systemic delivery may be the more practical method of drug delivery for hearing protection, when the time constraints within the operating theatre are considered.

Local delivery does however achieve good levels of drug delivery to the vestibule, as demonstrated by MRI imaging where Gadolinium is applied to the inner ear, suggesting that vestibular protection may be achieved with local delivery. In view of this, we have recently completed a randomised double blinded, placebo controlled trial (RCT) to assess the efficacy of this approach in reducing the incidence of dizziness after cochlear implantation.

In the RCT, the aim was to preserve inner ear function with the local application of methyl-prednisolone (125 mg/ml) to the round window prior to cochlear implant surgery. Trial design: A double-blinded randomised placebo-controlled trial. Main outcome measures: The primary outcomes were dizziness for at least a week following implant surgery, and unilateral weakness scores from caloric testing. The trial was not powered to detect hearing preservation. Participants: Adult patients of the Cochlear Implant Clinic in Melbourne with residual caloric function in both ears prior to surgery. Methods: A soft surgery technique was used with Cochlear Advance electrodes using the advance-off-stylet technique. A 3 mm diameter pledget of the carboxymethylcellulose polymer, Seprapack (Genzyme) was adsorbed in the solution of methyl-prednisolone, and applied to the round window after the posterior tympanostomy had been performed. The application time was 30 minutes, prior to cochleostomy and implant insertion. Results: 47 patients were allocated. There were significantly fewer patients with dizziness in the steroid-treated group ($p<0.05$, conditional binomial exact test). Similarly scores of validated dizziness (DHI and ABC) indices were significantly improved, and electrode impedances reduced in the mid-electrode region.

We conclude that steroids reduced dizziness when applied to the round window prior to cochlear implantation in patients. With better targeted drug delivery it is hoped that hearing preservation may also be achieved.

TuePM5: New Trends With Cochlear Implants And Atraumaticity Demonstrated By Deep Electrode Insertion And Hearing Preservation

Claude Jolly[1]

[1]Med-EL, Innsbruck, Austria

Cochlear implantation with hearing preservation (HP) devices and surgery was initiated more than 10 years ago for combined electric and acoustic stimulation (EAS). EAS indications were limited to ski slope type audiograms showing a precipitous threshold drop at around 1 kHz and <50% speech understanding in quiet (monosyllables and sentence test). The prevailing view on EAS called for cochleostomy approach and electrode insertion of 20 mm or less along the lateral wall of scala tympani Deeper electrode insertion as well as perimodiolar placement were assumed detrimental for HP.

Within the CI candidate population today, a large percentage has some form of residual hearing. This is in contrast with the early candidate population whose duration of profound deafness extended several decades. No measurable hearing was present. With extended CI candidacy and early intervention the number of patients demonstrating some form of measurable hearing prior to surgery has increased many folds. The residual hearing in CI candidates is often too low or frequency limited to provide additional benefits in performance when a hearing aid is combined with the implant. However, the preservation of such residual hearing after surgery and electrode insertion has become a marker for high quality electrode design, placement, and excellence in surgical technique.

Remarkably, hearing preservation has been demonstrated in many cases with complete insertion of lateral wall electrodes up to the apex through a round window entrance. Any amount of hearing preservation post op or at the 1st fitting demonstrates that the electrode is in scala tympani and that the endocochlear potential is intact, even if residual hearing is subsequently completely lost, progressively or suddenly. Reaching the apex of the cochlea atraumatically may be beneficial in the context of coding strategies taking advantage of low frequencies, excitable, neural tissue. The high degree of performance in the EAS patients demonstrates the importance of reaching the apex acoustically. Implicitly, electrically excitable tissue is present.

Hearing preservation has been demonstrated not only in the low frequencies but in the mid to high frequencies in patients with flat measurable audiogram. A case of reimplantation and hearing preservation has been reported. Intriguingly, several patients have demonstrated a better audiometric threshold post op than pre op at certain frequencies, adding to the cochlear mechanics puzzle.

Cochlear implantation combined with residual hearing preservation is a fascinating concept which demonstrates the progresses made with surgical procedure and electrode design. These progresses benefit most the young and very young patients who will wear several CI throughout a life expectancy of more than 80 years. Maximum preservation of neural structure is required to allow future inner ear pharmaco therapies to be effective.

TuePM6: Neural Survival In Cochlear Implant Users (Inferences From Psychophysics, CT Scans, Speech Understanding, And Modeling)

Christopher J. Long[13], Tim A. Holden[2], Gary H. McClelland[3], Zachary M. Smith[1], Wendy S. Parkinson[1], Chris van den Honert[1]

[1]Research and Technology Labs, Cochlear Ltd, Centennial, CO, USA
[2]Washington University School of Medicine, St. Louis, MO, USA
[3]University of Colorado, Boulder, CO, USA

In this work, we examine the hypothesis that neural survival is a key factor effecting focused thresholds and speech understanding of cochlear implant (CI) users. For CIs, spatial focusing of the current with Phased-Array (PA), Bipolar, or Tripolar stimulation produces substantial variation of threshold across channels. Focused thresholds give a measure of the efficacy of stimulation for a given channel and may give insight into the local state of the neural tissue. For example, a high threshold could indicate (1) poor neural survival near a channel, (2) a greater electrode-to-modiolus distance, (3) that other factors are limiting current flow to the neural tissue, or (4) a combination of the above. One factor, the electrode-to-modiolus distance, can be directly measured from high-resolution CT scans and thereby controlled for in the statistical analysis, allowing inferences about the neural state near each electrode.

We analyzed high-resolution CT scans of six cochleae of CI users who had also undergone extensive psychophysical and speech testing. In particular, focused-stimulation thresholds were measured for all functioning electrodes. Subject-specific linear models of electrode-to-modiolus distance versus threshold were derived and used in subsequent analyses. Also, electro-anatomical modeling was used to examine the contributors to focused threshold.

For all subjects, the electrode-to-modiolus distance was a significant predictor of PA threshold ($p \leq 0.01$). CNC Word Scores were significantly, negatively correlated with mean PA thresholds when controlling for mean percent distance from the modiolus ($R^2 = 0.94$; $t(3) = 6.8$; $p = 0.006$; $n = 6$). That is, when factors increased a subject's focused threshold at a given distance, speech understanding was lower. The mechanism most consistent with our results is that threshold and speech understanding are negatively impacted by neural loss.

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WedAM1: Intraneural Stimulation For Auditory Prosthesis: Steps Toward Clinical Trials

John C. Middlebrooks[1] and Russell L. Snyder[2]

[1]University of California, Irvine, CA, USA
[2]University of California, San Francisco, CA; and University of Utah, Logan, UT, USA

We are testing the feasibility of penetrating auditory-nerve electrode arrays for use as an improved auditory prosthesis for humans. Our previous acute studies in anesthetized cats have demonstrated several benefits of an intraneural array compared to a conventional cochlear implant. Specifically, intraneural stimulation offers frequency-specific stimulation across the entire cochlear frequency range; excitation thresholds are lower; spread of excitation is more restricted; interference among simultaneously stimulated electrodes is markedly reduced; and transmission of temporal fine structure is enhanced. Our new and ongoing studies address two challenges that must be overcome prior to translation of intraneural stimulation to human trials.

First, our previous results were obtained in acutely deafened cats in which the auditory nerve was largely intact. In a clinical application, however, one might expect varying degrees of nerve fiber degeneration, which might result in less effective excitation by intraneural electrodes. We now have studied cats 6 months after chronic ototoxic deafening. Histologically, those animals showed around 30% loss of auditory nerve fibers. Physiologically, after acute nerve implantation, those animals exhibited thresholds for electrical stimulation, spread of excitation, and transmission of temporal fine structure that were within the range of our previous results obtained in acutely deafened animals. These results help allay our concern that the efficacy of intraneural stimulation might be particularly vulnerable to partial auditory-nerve degeneration.

Second, the silicon-substrate stimulating arrays used in our acute experiments are not suitable for chronic implantation because of the possibility of nerve damage produced by movement of the nerve relative to these stiff arrays and because of the lack of the flexible cable that would be necessary to connect a stimulator to the implanted electrode. We are evaluating two new arrays designed for chronic implantation. One, from Lawrence Livermore National Laboratories, consists of metal conductors deposited on a flexible polymer substrate. The second, from UC Irvine, consists of gold microwires embedded in an epoxy carrier. Our early tests have yielded results equivalent to those obtained with acute silicon-substrate electrode arrays. We have begun studies of chronic implantation and stimulation.

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WedAM2: Improved Sound Processing For Users Of Auditory Implants

Hugh J. McDermott

The Bionic Institute, Melbourne, Australia, and
The University of Melbourne, Victoria, Australia

All devices that create hearing percepts by means of electrical stimulation contain an explicit or implicit model of at least those parts of the auditory system that they are designed to replace or enhance. In cochlear implant (CI) systems, the functions of the outer ear, the middle ear, the mechanical components of the cochlea, and the hair-cells are replaced by a device comprising a microphone, a signal processor, and an array of electrodes that activate the spiral ganglion cells directly. In a CI sound processor, the acoustic characteristics of relevant parts of the ear are modeled to some extent by frequency-specific amplification and compression of sound signals. The tonotopic organization of the cochlea is modeled approximately by a method of spectral-shape estimation, and hair-cell function is replaced by the activation of neurons by current pulses. Although models such as those embedded in today's CIs are incomplete and inaccurate, they enable enough information to be presented to CI recipients about the varying intensity and overall spectral shape of sounds for satisfactory speech understanding, at least in favorable conditions.

When auditory information is provided by stimulation beyond the cochlea, however, the sound-processing models are required to be more sophisticated. Existing CI processors are unlikely to provide adequate perceptual performance to recipients of an auditory brainstem or midbrain implant (ABI or AMI). Improved performance may be achieved by incorporating into the sound processing models based on psychophysical observations obtained from implant users. For example, loudness for AMI recipients appears to depend strongly on the pulse rate at low rates, and may depend on the exact site and overall duration of the stimulation in ways different from the corresponding observations with CIs. If these findings were incorporated as models into the signal processing, then stimulus parameters (e.g., level and pulse rate) could be selected to ensure that the loudness experienced by AMI recipients approximates that of similar sounds when heard by CI users or (hypothetical) listeners with normal hearing.

Recently, psychophysical models of loudness have been added to conventional sound-processing schemes and evaluated with users of CIs, including recipients who also use residual acoustic hearing. The results of perceptual experiments show that such techniques can improve speech understanding. By incorporating models of loudness and other perceptual characteristics into sound-processing schemes designed specifically for AMIs and ABIs, improvements in speech understanding can be expected. In general, appropriate model-based processing may be beneficial for users of all types and combinations of hearing devices.

WedAM3: Temporal Information Processing In The Central Auditory System: Evidence From Auditory Brainstem And Midbrain Implant Psychophysics

Colette M McKay[1], Hubert Lim[2,3], Mahan Azadpour[1], Matthew P. Fraser[1], Minoo Lenarz[3], Thomas Lenarz[3]

[1] School of Psychological Sciences, University of Manchester, Manchester, UK
[2] University of Minnesota, USA
[3] Medizinische Hochschule Hannover, Germany

The perception of the temporal envelope in a speech signal is an important pre-requisite for speech understanding. It is, however, unclear how temporal information is encoded in the central neural pathways. Psychophysical and speech perception experiments were undertaken in which the perception of temporal information in speech, the detection of amplitude modulation, and the effects of temporal parameters (interpulse intervals and stimulus duration) on loudness were evaluated in users of auditory midbrain implants (AMIs) and auditory brainstem implants (ABIs). The ability of subjects to detect amplitude modulation of an electrical pulse train was generally poorer the more central the site of stimulation, with AMI users being unable to detect modulations at frequencies greater than 20-50 HZ. For stimulation at the level of the inferior colliculus (AMI subjects) the results of all the experiments, taken together, were consistent with a long absolute neural refractory time of 2 ms. Analysis of the data using a loudness model indicated that the short integration window of several ms, that, in normal hearing or CI hearing, models temporal resolution ability, is absent or non-functional in AMI subjects. The data are instead consistent with a dominance of the long integration window (> 100 ms) leading to a larger effect of duration on loudness than occurs in CI subjects. Some comparative data from ABI and CI subjects will also be presented, and the implications of these data for signal processing and electrode design for AMIs and ABIs will be discussed.

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WedAM4: Translating A New Double Shank Auditory Midbrain Implant (Ami) Into Clinical Trials

Hubert H. Lim[1], Thomas Lenarz[2]

[1] Biomedical Engineering Dept., University Of Minnesota, Usa
[2] Otorhinolaryngology Dept., Hannover Medical University, Germany

Over the past 10 years in researching and translating the current single shank AMI into patients, we have obtained a greater understanding of how electrical stimulation of the auditory midbrain, particularly the central nucleus of the inferior colliculus (ICC), activates the central auditory system and elicits varying percepts. AMI stimulation can achieve frequency-specific activation and coding of slower temporal modulations of a sound signal (usually <50 Hz) that have enabled some speech understanding and improvements in lip-reading capabilities. However, performance levels are still lower than what is achieved by cochlear implant patients. Our past animal and human studies suggest that current AMI stimulation strategies elicit strong refractory and suppressive effects and are not able to achieve sufficient temporal coding and resolution (i.e., for <5-10 ms features) that are typical of normal acoustic and cochlear implant stimulation. To minimize surgical risks, we initially designed the AMI with a single shank array (20 linear contacts) to stimulate different frequency regions of the ICC with time-varying pulse patterns and transmit both spectral and temporal information. However, we have discovered that the ICC is not well-suited for high rate activation of a single site within a given two-dimensional isofrequency lamina. These initial findings motivated us to return back to basic neurophysiology studies to understand how neurons along an ICC lamina code for the temporal pattern of relevant sounds (e.g., vocalizations). Furthermore, we investigated how these neurons within different subregions of the ICC laminae interact and activate higher auditory centers that could lead to various perceptual effects. We will present results from ongoing animal studies suggesting that the rapid temporal structure of a stimulus may be coded through a spike interval or synchrony code across neurons within an ICC lamina and that a double shank AMI array can access this coding mechanism to elicit enhanced cortical activity not possible through single shank stimulation. We will also present the safety considerations and required cadaver studies for translating this new device into clinical trials.

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WedAM5: Infrared Neural Stimulation – A Vision For Cochlear Implants

Claus-Peter Richter[1-3], Agnella Izzo Matic[1-2], Suhrud Rajguru[1]

[1]Dept. of Otolaryngology, Northwestern University, 303 E. Chicago Ave, Searle 12-561, Chicago, IL, USA
[2]Dept. of Biomedical Engineering, Northwestern University, 2145 Sheridan Road, Tech E310, Evanston, IL, USA
[3]The Hugh Knowles Center, Department of Communication Sciences and Disorders, Northwestern University, Evanston, IL, USA

Infrared neural stimulation (INS) uses a natural occurring chromophore in the body, water. The infrared radiation from lasers is absorbed by water in excitable cells, converted into heat, and an action potential is generated. The use of lasers has several appealing features when compared to electrical stimulation: no direct contact is necessary between the stimulating source and the tissue, a spatially selective stimulation can be achieved, no stimulation artifact is generated to deter simultaneous recordings of electrical responses from the neurons, and there is no electrochemical junction between the stimulation source and the tissue. At many of the radiation wavelengths used for INS, the radiation can be easily coupled to an optical fiber and delivered to the target tissue. Limitations of INS relate to the laser tissue interaction. Infrared irradiation of tissue will result in a transient temperature increase, which can result in thermal tissue damage. Thick absorbing or scattering layers above the target structure may prevent neural stimulation. It is also possible that the generation of a heat relaxation wave may generate mechanical events.

The safety and efficacy of neural stimulation has been tested in chronically implanted cats. Cats were implanted with a single channel device for about six weeks. The cochlea was stimulated for approximately 6 hours per day for five days a week. When the device was first activated, the animals displayed a behavioral response related to hearing sensation. The animals adapted within several hours to the continuous stimuli. Auditory brainstem responses indicated that the cochlear function did not deteriorate during the continuous stimulation. Histology following the four to six weeks implantation period suggested that the spiral ganglion neuron counts in the basal turn did not differ significantly between sham implanted and stimulated animals.

The next step in the realization of an INS based cochlear implant is the development and testing of a multi channel device.

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WedAM6: New Developments In Auditory Brainstem Implants (ABIs)

Robert V. Shannon

House Ear Institute, Los Angeles, CA, USA

Cochlear implants provide a surprising level of speech understanding in completely deaf patients. However, cochlear implants are not useful for patients with no remaining auditory nerve, so prosthetic devices have been designed to stimulate the cochlear nucleus in the brainstem and the inferior colliculus in the midbrain, using both surface and penetrating electrodes. I will present psychophysical results and speech recognition results from surface and penetrating electrodes at the level of the cochlear nucleus (ABI and PABI). Surprisingly, psychophysical measures of temporal, spectral and intensity resolution are mostly similar across stimulation sites and electrode types. Speech recognition is excellent in cochlear implants and in some patients with stimulation of the cochlear nucleus. Speech recognition in some NF2 ABI patients is as good as the best cochlear implant listeners, even though ABI stimulation is much more poorly connected to the tonotopic dimension of the auditory system. Recently, brainstem implants have produced high levels of auditory performance in a few young children born without a cochlea or auditory nerve. Quantitative comparison of results from electrical stimulation of the auditory system at different stages of neural processing, and across patients with different etiologies can provide insights into auditory processing mechanisms. An emerging hypothesis is that the normal auditory system contains a separate processing subsystem for speech patterns that is distinct as early in the system as the cochlear nucleus. I will suggest that there may be separate auditory processing streams for fine structure (both spectral and temporal) and global structure. Auditory prostheses provide sufficient information to allow the global system to extract speech from the highly impoverished prosthetic pattern of activation, but this assumed global system may be damaged during tumor removal.

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Wed PM1: Envelope And TFS: What's All The Fuss?

Stuart Rosen

UCL Speech, Hearing and Phonetic Sciences

Just as a spectral analysis can decompose a speech wave into constituent sinusoids, a temporal decomposition can allow speech to be expressed as the product of a slowly varying envelope (ENV) and a rapidly varying temporal fine structure (TFS). This approach not only has theoretical implications for the science of speech perception, but also practical ones arising from the claims that impaired TFS coding in hearing-impaired listeners and users of cochlear implants may contribute to problems in understanding speech, especially in noise.

While the typical method of TFS/ENV decomposition is mathematically unambiguous, it may not be ideally matched to the temporal structure of speech, making it difficult to relate some aspects of ENV and TFS to crucial auditory, phonetic and linguistic attributes. Another important factor to consider is the way in which a TFS/ENV decomposition of the whole signal differs from the decomposition of the outputs of a filter bank analysis, as in a cochlear implant and the auditory periphery in normal hearing.

In fact, it appears that ENV itself can be usefully decomposed into slower and faster components. Slow envelope modulations correlated across frequency channels tend to signal information about the manner of articulation of speech sounds; those that are uncorrelated convey spectral dynamics crucial for speech intelligibility. A third temporal feature, periodicity, can also be extremely useful in thinking about the temporal structure of speech (Rosen, 1992), and this feature (signaling voice pitch) is represented differently in ENV and TFS across frequency regions. Access to periodicity information may be crucial in allowing the ‘glimpsing’ of speech in fluctuating noise, an ability seriously compromised or absent in hearing-impaired listeners and users of cochlear implants.

References

Rosen, S. 1992. Temporal information in speech: acoustic, auditory and linguistic aspects. *Philosophical Transactions of the Royal Society London B*, 336, 367-373.

WedPM2: Psychophysiological Analyses Of The Perceptual Salience Of Temporal Envelope And Fine Structure Cues For Speech In Noise

Michael G. Heinz[1], Jayaganesh Swaminathan[1,2]

[1] Purdue University, West Lafayette, IN, USA
[2] Massachusetts Institute of Technology, Cambridge, MA, USA

Perceptual studies suggest that the slowly varying component of the acoustic waveform (envelope, ENV) is sufficient for understanding speech in quiet, but that the rapidly varying temporal fine structure (TFS) is most important in noise. These findings have potentially important implications for cochlear implants, which currently only provide ENV; however, neural correlates of these perceptual observations have been difficult to evaluate due to cochlear transformations between acoustic TFS and (recovered) neural ENV. In this study, the relative contributions of neural ENV and TFS were evaluated by quantitatively linking neural coding and perception of noise-degraded speech. The effects of signal-to-noise ratio (SNR) on vowel-consonant-vowel identification and phonetic feature reception were compared to neural coding predicted from a computational auditory-nerve model for intact and vocoded speech versions that differed in acoustic ENV and TFS composition. A regression model based on neural cross-correlation coefficients for ENV and TFS successfully predicted speech identification and phonetic feature reception at both positive and negative SNRs. We found that consideration of cochlear signal processing suggested that 1) neural coding of ENV (as both true and recovered ENV) was the primary contributor to perception at positive SNRs for all features (except nasality), 2) neural coding of TFS did contribute at negative SNRs, but always as the secondary cue to neural ENV (except for nasality), and 3) TFS coding was the primary cue for nasality. The present finding that the perceptual salience of neural TFS is less than neural ENV at negative SNRs contrasts with the commonly held belief that TFS is most important in noise, which has arisen primarily from psycho-acoustical studies. Differences in conclusions between psycho-acoustical and psycho-physiological analyses are likely due to cochlear signal processing that transforms TFS and ENV coding (e.g., recovered envelopes) in normal-hearing ears. Because these cochlear transformations do not exist in impaired ears, these findings have important implications for the development of stimulation strategies for cochlear implants, which will be discussed.

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WedPM3: Effect Of Musical Activities On Perception Of Speech And Language Ability In Early-Implanted Children

Ritva Torppa[1,2], Martti Vainio[2], Jari Lipsanen[2], Marja Laasonen[2], Minna Huotilainen[1,2,3], Andrew Faulkner[4]

[1]Cognitive Brain Research Unit, [2]University of Helsinki, Finland
[3]Finnish Institute of Occupational Health, Helsinki, Finland
[4]Speech, Hearing and Phonetic Sciences, University College London, UK

Aim: Voice F0 and detailed spectral cues can be fully exploited by the normally hearing (NH), but are much less accessible for individuals with a Cochlear Implant (CI). In NH individuals musical activities enhance auditory functioning, perception of prosody, auditory working memory and the ability to hear speech in background noise. Here we studied how musical activities at home and musical group activities are connected to speech perception, auditory memory and language ability in CI children.

Methods: 21 early-implanted children were compared to an age-matched NH group. The extent of musical activity was assessed by a questionnaire. Nine CI children participated in musical activities outside of the home between measurements. Prosodic perception, auditory digit span and identification of sentences in noise as well as discrimination of pitch, duration, and intensity were each measured twice (14 to 18 months apart), verbal and reading abilities once.

Results: For CI children, digit span and perception of prosody were better in children attending musical activities. Prosodic perception also correlated with discrimination of pitch and intensity differences. Musical activities, including exposure to parental singing, were associated with better word finding and verbal IQ. The CI group did not differ from the NH group in prosodic perception, but the two groups differed in speech in noise and auditory discrimination. The CI group had shorter auditory digit span, and lower scores on most language measures, but the groups were equivalent in reading age and some measures of phonological awareness.

Conclusions: In CI children musical activities and the ability to discriminate pitch and intensity changes are both associated with the perception of prosody. Musical activities are also associated with good verbal ability, especially word finding, and auditory memory. These findings suggest that music training may have an important role in the rehabilitation of implanted children.

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WedPM4: Listening To Talkers And Musical Pitch

Rosalie M. Uchanski

Washington University School of Medicine in St. Louis, St. Louis, MO, USA

Recently, many researchers have explored cochlear implant (CI) users' ability to perceive various properties of talkers, such as talker gender, identity and emotional affect. Though many acoustic characteristics are associated with these talker properties, fundamental frequency, or musical pitch, is often considered foremost.

Might the perception of musical pitch be different in very-early implanted pediatric CI users than in post-lingually deafened CI users? Because place- and temporal-pitch mechanisms may develop differently in these two populations, a difference in their musical pitch perception ability is plausible. This question is addressed by comparing the performance of adult post-lingually deafened CI users to that of pediatric, congenitally-deaf, early-implanted CI users on the perception of both musical pitch and of talker properties. Approximately 10-15 CI users of each population participated in experiments with both non-speech and speech stimuli. The CI users performed a pitch-direction discrimination task for tone complexes with five reference fundamental frequencies (76, 133, 180, 243, and 329 Hz), somewhat similar to the range of fundamental frequencies of the human voice (male, female, adult, child). Tone complexes, like those in other studies, varied in loudness and in the frequency of a single resonance (350, 475, 600, and 725 Hz) to limit the possibility of pitch cues being associated simply with a spectral energy center of mass. CI users also completed across-gender talker discrimination, within-female talker discrimination, within-male talker discrimination, emotion identification and emotion discrimination tasks. Comparative results will be presented.

Work supported by NIH-NIDCD.

WedPM5: Speech And Music Perception By Child Implant Users

Sandra E. Trehub

University of Toronto Mississauga, CANADA

Difficulties characteristic of adult and child cochlear implant (CI) users include talker identification, perception of affective prosody, and melody recognition. We are pursuing research in this domain with child CI users 4-7 years of age who have several advantages including (a) early implantation (bilateral CIs simultaneously or sequentially), (b) no known cognitive or learning difficulties, (c) regular habilitation (minimum of once weekly) by an auditory-verbal therapist, and (d) highly motivated parents who are native speakers of the language used in therapy and school, and (e) excellent speech decoding and speech production skills. Vongpaisal et al. (2010) found that child and teen CI users successfully differentiated their mother's sentence-length utterances from those of an unfamiliar man or girl although they performed less accurately than their hearing peers. They reasoned that the mother's voice and use of full sentences contributed to children's success. We found that younger

CI users (4-7 years) were highly accurate at identifying word-length and sentence-length utterances as produced by a man, woman, or child. Moreover, these children accurately identified the voices of familiar cartoon characters from TV programs watched regularly.

In the only published study of vocal emotion identification by child CI users, performance was at chance levels in a closed-set task when sentences with neutral content were spoken in a happy, sad, angry, or scary manner (Hopyan-Misakyan et al., 2009). With new materials and response choices reduced, we found highly successful identification of happy and sad utterances by our young CI users, who also correctly identified recorded music from the classical repertoire as happy or sad.

Adult and child CI users are typically unsuccessful at identifying familiar music from simple melodies, even with timing cues preserved. However, a number of children in our sample identified familiar music from melodies alone even though they usually heard the music with words and with different instrumentation. One child identified familiar music from pitch cues alone, that is, with timing cues removed. There is no evidence to date that postlingually deafened adults with CIs can do so. Finally, two children in our sample agreed to provide samples of singing. Research to date reveals that CI children sing with age-appropriate timing but pitch directional changes (up or down) unrelated to those of the target song. The child who recognized isochronous melodies (with equally timed notes) produced monotone singing, but a less perceptually capable child correctly produced all contours and many of the intervals when singing a familiar song from memory.

ThuAM1: Channel Selection: A Panacea For The Background Interference Problem In Cochlear Implants

Philipos C. Loizou, Oldooz Hazrati, Nima Yousefian, Kostas Kokkinakis and Fei Chen

Department of Electrical Engineering, University of Texas at Dallas, Richardson, TX, USA

Cochlear implant (CI) user's performance in noisy situations is highly dependent on the type of background interference present, i.e., whether it is steady noise (e.g., car noise, speech-weighted noise), competing talker(s) or reverberation. There is currently no effective coding strategy capable of tackling the various types of interference encountered by CI users in their daily listening environments. The present talk will present a family of coding strategies which are based on channel selection and are capable of addressing most, if not all, background interference challenges faced by CI users. These strategies are based on the idea that envelopes corresponding to channels satisfying an appropriate criterion should be retained and used for stimulation, while the remaining envelopes should be discarded in a manner similar to that in n-of-m type of strategies (e.g., ACE). A number of different channel selection criteria will be presented, some of which are appropriate for suppressing additive noise or competing talkers, and some that are appropriate for suppressing reverberation and/or the combined effects of reverberation and masking noise. Intelligibility data will be presented for both ideal and non-ideal scenarios. In the ideal scenarios, a priori knowledge of the target signal is assumed and the channel selection criterion is computed accurately and reliably. In the non-ideal (realistic) scenarios, the channel selection criterion is estimated directly from the mixture envelopes. The intelligibility data collected in the ideal scenarios are used to illustrate the full potential of the proposed channel selection criteria in as far as: (a) restoring the intelligibility of speech masked by noise and/or reverberation to the level attained in quiet, and (b) surpassing (in some conditions) the performance obtained by normal-hearing listeners.

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ThuAM2: Enhanced Temporal Coding Can Lead To Improved Sound Perception In Cochlear Implants

Jan Wouters, Tom Francart*, Michael Hofmann, Raphael Koning, Anneke Lenssen, Matthias Milczynski, Lieselot Van Deun, Astrid van Wieringen

ExpORL, Department of Neurosciences, K.U.Leuven, Leuven, Belgium
*also The Bionic Institute, Melbourne, Australia

The temporal structure of speech consists of three main levels based on dominant fluctuation rate: envelope related to (supra) segmental variation, periodicity related to fundamental frequency, and fine structure. In current signal processing of cochlear implants (CI) only the envelope cues are well encoded in the electrical stimulation waveform, and the periodicity in a very restricted way. Whereas speech perception in quiet is very good in many CI-patients, for many aspects of sound perception in more challenging listening situations CIs perform a lot worse than listeners with normal or moderately impaired hearing.

We hypothesize that some CI signal processing changes with emphasis on temporal coding, partly based on findings in auditory neurophysiology, may improve speech and sound perception.

In this contribution, examples of enhanced encoding of temporal aspects in the signal processing will be reported. An overview will be given of attempts to enhance onset and ongoing temporal cues across stimulation channels. The signal processing steps, with focus on onsets in the envelope and ongoing periodicity cues in multichannel stimulation, will be explained. Outcomes on speech understanding and interaural measures will be discussed with data obtained with vocoder simulations and cochlear implant users (also tonal language).

The different results support the hypothesis that an additional emphasis on temporal aspects in the signal processing in CI may improve speech and sound perception in certain listening conditions.

ThuAM3: Neural Excitation Patterns Of A Variety Of Multipolar Electrode Configurations

[1]Johan H.M. Frijns, [1]Randy K. Kalkman, [1]David M.T. Dekker, [1]Dirk Vellinga, [2]Filiep Vanpoucke, [1]Jeroen J. Briaire

[1]Leiden University Medical Center, Leiden, the Netherlands
[2]Advanced Bionics, Niel, Belgium

Both animal and clinical studies indicate that multipolar electrode configurations (bi-polar, (partial) tri-polar, and phased array) can reduce the spread of excitation and increase the dynamic range. Unfortunately, these benefits coincide with a higher sensitivity to deficiencies in the neutral structure, problems to attain sufficient loudness and increased power consumption.

This study uses computational modeling in conjunction with experiments in humans to compare the spread of excitation and loudness growth of various modes of multi-polar stimulation. A realistic 3D electrical volume conduction model of the implanted human cochlea is coupled with an active nerve fiber model. The model incorporates a histology-based neural compartment, including a realistic spiral ganglion (SG). The model is used to study of mono- and a number of multipolar electrode configurations and produces neural excitation profiles that can be used to estimate thresholds, loudness growth curves, dynamic range and spread of excitation. These are also the outcome parameters of an ongoing clinical trial (using psychophysics and eCAP recordings for multipoles) in a group of 12 postlingually deafened adult users of the HiRes90K implant.

In line with expectations the model predicted that multipolar stimuli result in a sharper focused excitation region and increased dynamic ranges. In these respects, multipoles are more effective for outer wall electrodes than for perimodiolar ones. The focused currents tend to penetrate deeply into the SG and recruit all nerve fibers in a region, while monopoles show less dense recruitment patterns in a broader region of the SG. Multipoles with less active contacts are more effective in reducing far-field ectopic excitation, but the presence of strongly active neighboring contacts makes the loudness growth curve non-monotonous. Phased array stimulation, involving all contacts, represents the other extreme, with gradual loudness growth, but considerable far-field effects.

It is concluded that multipolar stimulation is especially attractive with outer wall electrodes. Due to their confined region of stimulation they offer the opportunity for simultaneous, independent stimulation at multiple sites along the array. On the basis of our results a multipolar configuration with 5 active contacts is promising.

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ThuAM4: Can Current Focusing Be Used To Improve Spectral Resolution?

David M. Landsberger[1], Arthi G. Srinivasan[1,2], Monica Padilla[1]

[1]House Research Institute, Los Angeles, CA, USA
[2]University of Southern California, Los Angeles, CA, USA

While cochlear implants (CIs) typically provide 12 or more spectral channels, CI patients seem able to access only 6-8 channels, too few for difficult listening conditions (e.g., speech in noise, music, etc.). Most likely, current spread from each electrode induces channel interactions that limit CI users' functional spectral resolution. In our lab, we have been investigating whether current focusing via tripolar or quadrupolar stimulation can reduce channel interaction, and thereby improve spectral resolution. While current focusing may sharpen the stimulation pattern, the benefit of current focusing is ultimately subject to CI patients' patterns of nerve survival. With good survival, it may be possible to target specific regions; with poor survival, current shaping may offer little benefit. Thus, we hypothesize that current shaping can be used to improve spectral resolution for some, but not all patients.

For a fixed loudness, we found that current focusing reduced the spread of excitation (SOE) for half of the six CI subjects tested, as measured with a forward masking task. CI patients who exhibit reduced SOE might benefit from current focusing within a multi-channel signal processing strategy, while subjects who do not might perform as well with broad, monopolar stimulation. It would be clinically useful to quickly ascertain which CI patients might benefit from focusing. We found that subjective descriptors (e.g., clean, dirty, thin, full, etc.) of stimuli presented with and without focusing were strongly correlated with CI subjects' SOE functions. Correlations were also found between discrimination of varying levels of current focusing and subjects' SOE functions. Thus, clinicians might be able to quickly determine the appropriate stimulation mode using either simple subjective descriptors or a discrimination task. We have also found that current focusing improves electrode and virtual channel discrimination, measured in a single or mutli-channel context. Again, there was a benefit of focusing for some, but not all CI subjects. Nonetheless, these preliminary results are promising, and suggest that current focusing may be beneficial within a CI signal processing strategy for those patients with a reduced SOE.

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ThuAM5: A Multi-Faceted Approach To Characterizing The Status Of The Electrode-Neuron Interface

Julie Arenberg Bierer

University of Washington, Department of Speech and Hearing Sciences
Seattle, WA

Evidence suggests that the interface between cochlear implant channels and nearby spiral ganglion neurons varies from channel to channel and from patient to patient. Previous studies in my laboratory have attempted to assess the quality of the electrode-neuron interface with two perceptual measures: tripolar thresholds and psychophysical tuning curves. In this presentation I will describe how two additional measures, electrically-evoked potentials and loudness perception, provide further information about the nature of the electrode-neuron interface on a channel-by-channel basis. I will also discuss a preliminary analysis of how these distinct measures relate to errors in vowel discrimination.

Post-lingually deaf subjects implanted with the HiFocus I/HiRes 90K device were used in this study (Advanced Bionics Corp., Valencia, CA, USA). Initially, thresholds were measured on all available channels using the tripolar electrode configuration (one active intra-cochlear electrode and two adjacent electrodes sharing the return current). Channels with the lowest, median and highest threshold were identified for further analysis. Loudness growth functions and loudness balancing measures were then obtained for these test electrodes. In some subjects, response amplitude growth functions based on either the electrically-evoked auditory brainstem (EABR) or compound action potential (ECAP) were obtained for the same set of channels. The relationship between tripolar threshold and medial vowel identification using the Hillenbrand vowels was also explored.

Channels with high tripolar thresholds, previously shown to have broad tuning curves, generally had steeper loudness growth functions and steeper evoked potential growth functions. This finding was more pronounced when the growth functions were measured with a focused electrode configuration. It was also observed that pairs of phonemes having similar stimulation profiles and with significant current on one or more high-threshold channels, often had a higher chance of confusion.

Information obtained with the tripolar configuration regarding local interface irregularities could be used to improve the fitting of cochlear implants in the audiology clinic. It could also aid in the development of new sound processing strategies designed to maximize the delivery of spectral information for individual listeners.

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ThuAM6: Breaking Informational Bottlenecks In Auditory Prostheses

Zachary M. Smith

Research & Technology Labs, Cochlear Ltd., Centennial, CO, USA

One of the primary design goals of auditory prostheses is to restore hearing to the deaf through successful transmission of speech and other sound information from the device to the brain. While current systems are mostly successful in providing a large and significant benefit, there seems to be a limit to the amount of information that that these devices can convey to the recipient. How can we optimize cochlear implants and other auditory prostheses for maximal information transfer? In this talk, we discuss the historical evolution of sound coding for cochlear implants and identify methods for further increasing information transfer. Two example techniques are described that attempt to increase the number of informational channels and increase channel efficiency.

The first example is the use of current focusing (phased array stimulation) to improve the electrode-neural interface. By stimulating multiple electrodes in a coordinated fashion, current spread and channel interference can be reduced, thus increasing the number of effective channels. Results show increased spectral-temporal modulation sensitivity with focused channels and suggest that current focusing may increase information transfer.

The second example is an experimental sound coding strategy (FAST) that employs a sparse electrical representation of acoustic temporal modulations. By representing each cycle of amplitude modulation with a single current pulse, more precise timing information can be coded than conventional methods that sample the temporal envelope with fixed-rate pulses. Results in bilateral cochlear implant subjects show increased sensitivity to interaural time differences (ITD) and the ability to use ITD to better understand speech amongst competing sounds. This alternative coding method may increase channel efficiency and allow the introduction of additional timing information previously unavailable.

ThuAM7: Functionally Extending The Electrode Array Longitudinally Using Phantom Stimulation Protocols

Leonid M. Litvak[1], Aniket I. Saoji[1], Aparajita Bhattacharya[1], Smita Agrawal[1], Waldo Nogueira[2], Carolin Frohne-Büchner[2], Andreas Büchner[3], Charles Finley[1], and David M. Landsberger[4]

[1]Advanced Bionics Corporation, Valencia, CA, USA
[2]Advanced Bionics GmbH, Hannover, Germany
[3]Medical University of Hannover, Hannover, Germany
[4]House Ear Institute, Los Angeles, CA, USA

Phantom electrode stimulation refers to a simultaneous stimulation modality where multiple stimulation pulses are used to shift hypothetically the peak of the excitation in a direction that is away from the stimulation pair. This technique promises an ability to "extend" the electrode array apically and/or basally. To date, we have investigated several techniques that, when applied apically, generate lower pitch sensations as compared to that of the most apical electrode. However, the precise mechanisms by which this lowering occurs are unclear. In this presentation, we show that pulse shape, polarity, and electrode configuration have an effect of lowering the pitch percept generated by the excitation. We review several experiments which attempt to elucidate mechanisms of the lowering in the pitch sensation. Finally, we provide a report of the effect of apically extending the electrode array by adding a single apical phantom channel to a sound processing strategy on music perception.

ThuPM1: Complex Pitch Patterns, Intonation, And Lexical Tones: Results In Adults And Children With CIs

Monita Chatterjee[1], Shu-Chen Peng[2], Cherish Oberzut[1], Lauren Wawroski[3], Nelson Lu[2], Yung-Song Lin[4]

[1]University of Maryland, College Park, MD, USA
[2]United States Food and Drug Administration, Silver Spring, MD, USA
[3]Children's National Medical Center, Washington DC, USA
[4]Chi-Mei Medical Center, Tainan, Taiwan

The natural variations of voice pitch (F0) in everyday English speech convey critical information about the speaker's emotional and communicative intent, and are thought to be important for language acquisition by infants and young children. In tonal languages such as Mandarin Chinese, rapid F0 changes within words signal their lexical meanings. Given the constraints of present-day cochlear implants (CIs), patients must glean F0 information primarily from the periodicity of the temporal envelope of processed speech. Although these temporal patterns do not provide sufficiently salient pitch cues to support robust music perception, they appear to support moderate performance in tasks such as intonation recognition and lexical tone recognition. In addition, co-varying secondary cues such as intensity and duration changes may also play an important role when the primary cue (F0) is degraded.

In this presentation, we will report on studies examining these issues in adults and children with normal hearing and CIs. In the first half of the presentation, we will present results on temporal pattern processing by adult CI listeners in the context of both single and multi-channel stimulation, and discuss implications for pitch processing by CI listeners. Results suggest that concurrent stimulation on multiple channels can result in both interference and enhancement, depending on the nature of stimuli. This has important implications for temporal pitch coding in CIs.

In the second half, we will present results obtained in speech intonation and lexical tone identification experiments using controlled stimuli, both in adults and in children (native English speakers and native speakers of Mandarin Chinese) with CIs. Our recent studies have shown that adults place greater weight on co-varying secondary cues such as duration and intensity patterns when the pitch cue is degraded as with CIs. We have now begun to examine these issues in children with CIs. Results of ongoing experiments will be presented, with a particular focus on the age of implantation (neural plasticity) and linguistic (i.e., tone language) background.

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ThuPM2: Pitch Perception: Basic Mechanisms And Implications For Cochlear Implants

Andrew J. Oxenham

Department of Psychology, University of Minnesota, Minneapolis, MN, USA

The debate over whether pitch is represented by a place or time code (or both) in the cochlea has continued for well over a century, but the question has gained more urgency with the development of cochlear implants (CIs) and with the need to recreate usable pitch cues in the implanted ear. Technical innovations have been made to improve both the place and timing information provided by CIs, but it remains unclear to what extent these changes improve pitch perception for everyday sounds, such as voiced speech or music.

One way to distinguish between place and time coding in normal hearing has been to exploit the putative limits of spectral or temporal coding. For instance, cochlear filtering limits the degree to which individual tones within a complex sound produce distinct place cues, whereas phase-locking in the auditory nerve becomes less accurate at high frequencies, thereby limiting the potential use of a time code. Unfortunately, we do not have direct access to either the spectral or temporal codes in the human cochlea and auditory nerve, and so we are constrained to make inferences based on indirect behavioral (psychoacoustic) measures or comparisons with physiological data from animal models.

Another way to distinguish between different codes has been to process sounds using vocoder-based techniques to separate temporal fine structure (TFS) cues from temporal envelope cues. Unfortunately, even after processing, it remains unclear whether TFS is represented by a timing or place-based code in the auditory periphery.

This presentation will review recent psychoacoustic findings which suggest that place coding may be important for pitch and that, if phase-locking is used, then the upper limits of phase-locking in the human auditory nerve must extend much higher than is generally accepted at present. The findings also serve to highlight the potential pitfalls of using indirect measures to draw conclusions about how information is represented neurally in the human auditory system.

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ThuPM3: Place and temporal pitch perception with asymmetric pulses

Olivier Macherey[1,2], John M. Deeks[1], Robert P. Carlyon[1]

[1] MRC Cognition and Brain Sciences Unit, Cambridge, UK
[2] Lab. of integrative and adaptive neuroscience, Marseille, France

Pitch can be conveyed to cochlear implant (CI) listeners via both place of excitation and temporal cues. The transmission of these cues is however hampered by several factors. First, place cues may be limited by (1) the broad current spread produced by monopolar stimulation, (2) a shallow insertion of the electrode array, and (3) the limited number of implanted electrodes. Second, temporal cues are typically conveyed up to about 300 pps above which any increase in pulse rate does not produce a change in pitch. Most contemporary CIs stimulate the nerve with trains of symmetric biphasic pulses. In the following series of experiments, we exploited the polaritiy-sensitive properties of the auditory nerve and tested whether bipolar asymmetric pulses, consisting of a short, high-amplitude phase followed by a longer and lower amplitude phase could overcome these limitations and increase the range of pitch percepts perceived by CI users.

Place cues: Bipolar "BP+1" asymmetric pulses with the short, positive phase presented to the most apical electrode of the implant produced a lower place pitch than standard monopolar or bipolar symmetric pulses. Pitch matches performed by implant listeners with normal contralateral hearing showed that this pitch would be equivalent to that of a "virtual" electrode implanted 1 mm deeper than the physically most apical electrode. The pitch shift was in some cases even larger when a fraction of the current injected at the most apical site was returned to the external ground. Furthermore, changing the ratio of duration of the two phases of asymmetric pulses produced progressive pitch changes, intermediate to those produced by stimulation of physical electrodes.

Temporal cues: Bipolar "BP+1" asymmetric pulses with the short, positive phase presented to the most apical electrode of the implant also produced a higher upper limit of temporal pitch, compared to symmetric pulse shapes or to asymmetric pulses applied to electrodes in the middle of the array. Nevertheless, the pitch percept at high rates remained weak, as shown by the drop in performance on a melodic contour identification task for pulse rates higher than 250 pps.

ThuPM4: Optimization Of Rate-Pitch In Cochlear Implant Hearing

Andrew E. Vandali[1,2], Richard J. M. van Hoesel[1,2] , David Sly[1,2], Robert Cowan[1,2]

1. The Hearing CRC, Melbourne, Australia.
2. The University of Melbourne, Australia.

It has been well established that changes in pulse rate of an electrical pulse train can be used to elicit different percepts of pitch for rates up to approximately 300 Hz. Furthermore it has been shown that the relationship between pulse rate and pitch in cochlear implants (CIs) is consistent with that between fundamental frequency (F0) and musical pitch intervals for normal hearing. However, most current commercial CI sound coding strategies do not utilise pulse rate per se to encode information about F0. Instead they employ a higher stimulation rate to carry F0 information in the amplitude envelope of the stimulus signal. While earlier strategies did employ stimulation rates corresponding to F0, their lower overall pulse rate was shown to be partly responsible for reduced transmission of spectral and temporal envelope information in speech compared to more modern higher-rate strategies. Given that recognition of speech is most important to CI users, moderate-to-high stimulation rates are therefore preferable. Unfortunately F0 information is not very well represented in the envelope of current (vocoder-based) strategies and as a consequence pitch information is poorly perceived.

A number of experimental strategies have been proposed that enhance coding of temporal cues to F0 by effectively expanding the depth of F0 modulation within channels and minimising any differences in modulation phase across channels. These strategies have been shown to provide significantly better pitch discrimination as compared to clinical strategies, although performance is still below that of listeners with normal hearing. In addition, for some of these strategies the processing degraded aspects of speech perception compared to clinical strategies. To address this, a new strategy, referred to as eTone, has been developed, which modulates channel envelope signals at an estimated F0 rate, using a sharp-onset, rapid-decay, modulation function. That function was chosen to provide a salient and accurate representation of F0 in the auditory nerve because firing is expected to arise predominantly in response to the first pulse in each F0 interval. In addition, the modulation depth was chosen to promote a salient rate pitch percept without introducing an excessive reduction in channel loudness that can result when applying deep modulation.

To optimise performance with this strategy, the effects of modulation shape and depth on pitch salience, pitch height, and loudness are currently being investigated, and will be discussed. The results will lead to improved methods of enhancing rate-pitch salience and accuracy whilst maintaining satisfactory coding of loudness and speech information.

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ThuPM5: Physiological Insights Into The Problem Of Temporal Coding In Cochlear Implants

Ian C. Bruce[1,2], Andrew K. Wise[2], Mohamed H. Negm[1], James B. Fallon[2], Robert K. Shepherd[2]

[1]McMaster University, Hamilton, ON, Canada
[2]The Bionic Ear Institute, Melbourne, VIC, Australia

A long-standing view in cochlear implant (CI) research has been that auditory nerve (AN) fibers can encode the temporal properties of an electrical pulse train stimulus even better than they can those of an equivalent acoustic stimulus. However, attempts to exploit this in high-rate speech processing strategies or to provide rate pitch cues for higher frequencies have met with little success.

In this study we have analyzed cat AN fiber responses to CI stimulation and performed computational modeling to address this conundrum. The data come from one groups of cats (n=9) that were neonatally deafened and chronically stimulated with a clinical CI and processors for 6 month and a second group of cats (n=4) that were acutely deafened before the physiological experiments. The results of the data analysis show that many AN fibers do not entrain to pulse train rates above ~500pps in a sustained manner, and that there is heterogeneity in the temporal response characteristics preventing this entrainment—some AN fibers exhibit very long relative-refractory behavior, while others exhibit strong accommodation and/or adaptation to ongoing pulse trains. This latter class of fibers also appears to undergo slow fluctuations in excitability that leads to substantial variability in spike rates. Simulations performed with a model of AN fiber membrane dynamics, incorporating a number of different voltage-gated ion channels known to be expressed in the AN, provide insight into the mechanisms behind this diversity of AN fiber temporal coding characteristics.

The results of this study suggest that the AN fiber rate entrainment behavior may be more consistent with perception by CI users than previously thought.

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FriAM1: Hearing Instrument Technology – What Can We Learn For CI Development?

Stefan Launer

Phonak AG, 8712 Staefa, Switzerland

Digital technology offers many possibilities to optimally fit hearing instruments to the individual listening needs of hearing impaired persons. Today's hearing instruments contain many different adaptive control functions which automatically adapt the hearing instruments operational parameter settings according to the requirements of the respective acoustic environment.

Identifying the acoustic environment for selecting the optimal signal processing strategy requires an intelligent decision making process about the acoustic environment relying on different physical characteristics of the sound field. The automatic identification of the acoustic environment is a very important pre-requisite for the application of sound cleaning features, i.e. signal processing techniques improving the listener's communication abilities in adverse listening conditions. Such techniques include the adaptive multi-microphone technology which significantly improves the performance of noise reduction systems. Latest technologies also include means for reducing the very detrimental effect of reverberation on speech intelligibility especially for hearing impaired people. Recent studies clearly show an improvement in subjective and objective speech intelligibility in a variety of difficult listening situations. Furthermore wireless links between left/right hearing instruments and also to external devices have been introduced opening up a range of new applications. These technologies are being applied in today's hearing instruments and have been shown to be very helpful to the end user in a number of studies.

The design of the automatic control or program switching function bears several challenges and limitations which will be discussed. A major challenge is to design this feature to yield a robust and reliable identification of various environments a patient encounters in daily life and especially to avoid confusions and wrong "nervous" switching between various settings. Using more than 40 different acoustic features for analysing and identifying the characteristics of an acoustic environment, todays systems can rather reliably identify 4 broad classes of environments namely Speech in Quiet, Speech in Noise, Noise and Music. In order to achieve a reliable performance of the systems it is extremely important to have a large, properly recorded sound database covering a large variability of the various classes to be identified as well as many environmental sounds from daily life to avoid confusion and unintended switching behaviour of the system. A second challenge is the counselling of the patients about the potential limitations of this feature: the identification of an environment not necessarily is the same as the identification of the listening intent of a patient in a certain environment. Furthermore, individual patients might have different expectations to the switching behaviour of the system, some might prefer a more sensitive faster switching behaviour while other might prefer a smoother, slower switching behaviour.

One of the major functionality which is automatically controlled and switched by above automatic control function is the directional microphone system most of today's hearing instruments include. The large benefit of directional microphone systems for hearing impaired people has been in shown in various lab studies. However, in daily life this performance depends strongly on various factors. One major group of factors is the detailed electroacoustic design of the devices including aspects such as i) the detailed placement of the device on the head / behind the pinna / in the ear canal and the resulting directivity pattern of the directional microphone system; ii) the calibration; iii) the aging properties of the microphones used or in a binaural directional system the link jitter introduced. A second major group of factors is the acoustic environment in which a directional system is being used: i) number, acoustic characteristics and spatial distribution of interfering sources and ii) room acoustic aspects of the environment such as reverberation or source distance.

The goal of this talk is to discuss the state of the art signal processing focusing on user benefit of modern hearing instruments. Some of the algorithms already applied in hearing instruments are either already being used or being discussed for application in CI. Various hearing instrument signal processing algorithms underwent a significant learning curve in the transfer from laboratory devices to real world applications. A second objective of this presentation is to discuss the "lessons learnt" in this process.

FriAM2: A Cognitive Approach To Hearing Aid Design And Assessment

Brent W. Edwards

Starkey Laboratories, Berkeley, CA, USA

Hearing aid development has focused primarily on audibility and signal-to-noise ratio improvements for the vast history of its existence. The impact of hearing aid technology on higher-level processing has largely been ignored in the development, prescription, and assessment of hearing aids. While the impact of top-down processing on auditory function has been well documented, only recently has the impact of cognition on hearing aid benefit been demonstrated. Similarly, the impact of hearing loss and hearing aids has only recently been demonstrated to have an effect on cognitive function. Our laboratories, in collaboration with several partners, have investigated the impact that hearing aids have on higher level function. This research includes the development of new higher-level focused outcome measures, demonstrations of the impact of hearing aids on listening effort, measures of a hearing aid's effect on auditory scene analysis, and diagnostic correlates with cognitive benefit from hearing aids. This talk will review our laboratories' research projects in these areas, including the motivation for each, and will speculate on areas of applicability to cochlear implants.

FriAM3: Signal Processing For Combined Hearing Aid And Cochlear Implant Stimulation

Tom Francart[1,2], Anneke Lenssen[1], Hugh McDermott[2,3] and Jan Wouters[1]

[1] ExpORL, Dept. Neurosciences, K.U.Leuven, Belgium
[2] The Bionic Institute, Melbourne, Australia,
[3]The University of Melbourne, Australia

Due to the success of cochlear implantation there is an expanding population of implantees that use a hearing aid (HA) contralateral to their cochlear implant (CI). This is called bimodal stimulation. However, the signal processing techniques of the CI and HA were developed independently and preclude several important potential advantages of binaural stimulation.

For normal-hearing listeners, localization of sound sources and binaural unmasking of speech in noise depend on the perception of binaural cues: interaural level and time differences (ILD and ITD). In tests with bimodal listeners, we have found sensitivity to ILD with an average just noticeable difference (JND) of 1.7dB. Tests also indicated that subjects with sufficient residual hearing were sensitive to ITD, with JNDs in the order of 100-250us.

As JNDs in ILD approach those of NH listeners and JNDs in both ILD and ITD are smaller than the magnitude of these cues in many realistic signals, they should be usable in practice. However, neither cue is properly transmitted by current clinical devices. The main problems are temporal synchronization, loudness balance, and preservation of temporal envelope cues. We will present different algorithms that provide solutions to these problems.

If ITD cues are not available, either because of technical limitations or because the subject is insensitive to ITD, localization ability largely depends on ILD cues. Unfortunately, for most signals the ILD-versus-angle function is non-monotonic and flattens for angles of incidence from about 45 degrees (relative to sound arriving from directly in front of the listener). Moreover, most bimodal listeners can only perceive acoustic stimuli in the low frequency range, where ILD cues are very small. We developed an ILD enhancement algorithm addressing these issues. With this algorithm, horizontal-plane sound-source localization performance of 6 bimodal listeners improved by 4-10 degrees absolute error relative to baseline performance of 27 degrees.

While current clinical CI speech-processing systems can provide envelope ITD cues in some cases, the cues are not always consistent and depend on the spectral content and intensity of the input signal. We developed a new algorithm that introduces temporal modulations synchronously in all channels. We measured JNDs in ITD with five bimodal listeners for a vowel, processed with ACE, the standard strategy, and our new algorithm. With ACE, two listeners were not sensitive to ITD at all. With the new algorithm, all five listeners were sensitive to ITD and performed significantly better than with ACE, with JNDs in ITD in the order of 100-250us.

These findings suggest that with appropriate signal processing the sound source localization performance and potentially binaural unmasking of bimodal listeners could be significantly improved.

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FriAM4: Factors Affecting Benefits From Contralateral Residual Acoustic Hearing To Speech Perception In Cochlear Implant Users

Tim Green, Andrew Faulkner and Stuart Rosen

Speech, Hearing & Phonetic Sciences, UCL, London, UK

For some cochlear implant (CI) users a contralateral hearing aid provides significant benefits to speech perception. However, the sources of bimodal benefit are unclear. Possibilities include: spatial cues; additional spectral information to that provided by the CI; and additional temporal information. Temporally encoded cues to amplitude modulation, to periodicity, and to fundamental frequency (F0) might contribute directly to speech recognition, or may contribute indirectly through glimpsing in noisy conditions.

As a first step in identifying the role of additional temporal information the extent to which contralateral residual acoustic hearing provides enhanced perception of prosodic information relative to CI alone was assessed, both in CI users and in acoustic simulations. Tasks included identification of sentences read with different F0 contours as either question or statement and tests of the ability to perceive contrastive stress. Tests were carried out both with naturally spoken materials and with materials processed so as to ensure that only F0 cues were available.

With respect to additional spectral information an important question concerns the possible impact on bimodal transmission of speech spectral information of interaural conflicts due to mismatched frequency-to-place maps across ears. Sentence recognition in noise in 8 bimodal CI users was assessed in conditions in which there was an overlap in frequency coverage across ears, typical of clinical fittings, and where overlap was eliminated by disabling electrodes normally assigned to frequencies where there was residual hearing. To assess the possible influence of spatial cues Head-Related Transfer Functions simulated spatial separation of speech and multi-talker babble noise. While there was a bimodal advantage there was no evidence of a larger advantage for spatially separated speech and noise, either with or without frequency overlap, suggesting that, at least for these bimodal listeners, interaural difference cues are too degraded to allow benefit from binaural processing. Additionally, in bimodal conditions there was no difference in performance between no-overlap and standard configurations, although CI alone performance was poorer with low frequency electrodes disabled. This finding suggests that bimodal performance might be increased by remapping the CI to use the whole electrode array to cover only frequencies above the limit of useful acoustic hearing, thereby increasing the overall spectral resolution available.

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FriAM5: Enhancing The Benefits To Speech Perception Of Electro-Acoustic Stimulation

Christopher A. Brown

Arizona State University, Tempe Arizona, USA

The benefits to speech perception of electro-acoustic stimulation (EAS) over electric-only stimulation are often large. However, the speech reception of even the best EAS users is typically not as good as that of listeners with normal hearing. There is also considerable variability among EAS patients, such that the relative performance of some is rather poor, irrespective of audiometry.

One of the goals of some of the recent work being conduced in our lab has been to find ways of increasing the EAS benefit for both higher- and lower-performing users alike. One technique that holds promise in this regard is frequency compression. For lower-performing EAS users who possess an especially low audiometric 'corner frequency' frequency compression may provide a means of lowering target F0 (particularly for female and children target talkers) into a region of audibility for the listener. For higher performing EAS users, it may be possible to compress additional speech cues, such as F1, to be audible.

In all cases, frequency compression holds a distinct advantage over using a modulated tone, the other frequency-lowering technique we have developed. Specifically, it is immune to the presence of background noise. The modulated tone paradigm is reliant on the accuracy of the pitch algorithm used. Assuming an accurate pitch track, the modulated tone has been shown to work well in shifting mean F0 downward in frequency. However, any real-time implementation will have to deal with background noise, and pitch algorithms are well-known for relatively poor performance in noise. On the other hand, frequency compression is unaffected by the presence of background noise, which will be frequency compressed along with the target.

We have begun examining frequency compression as a means to shift target F0 lower in frequency, so that CI users with an especially low 'corner frequency' might perceive and use the cue. We have also begun testing the possibility that frequency compression can provide more benefit than typical EAS, even for higher-performing EAS users, because of the possibility that additional target speech cues, such as F1, might be made audible. Progress will be discussed.

Work supported by NIDCD.

FriAM6: Contralateral Masking In Binaural-Bimodal Stimulation In The Central Auditory System

Maike Vollmer, Tristan Bremer, Armin Wiegner

Comprehensive Hearing Center, University Hospital Würzburg, Germany

There is increasing evidence that the combination of electric and contralateral acoustic stimulation (binaural-bimodal stimulation, BBS) can result in significant benefits in speech perception. Little is known about the neuronal interactions to such signals. The present study investigates contralateral masking effects to BBS in the inferior colliculus (IC) and the dorsal nucleus of the lateral lemniscus (DNLL). Normal hearing, adult gerbils (Meriones unguiculatus) were unilaterally implanted with round window electrodes to maintain acoustic sensitivity. Earphones were sealed to the contralateral auditory meatus for acoustic stimulation.

Biphasic electric pulses (single pulses or low frequency pulse trains) and acoustic signals (single clicks or pure tones at the neuron's characteristic frequency) were presented using either a simultaneous- or a forward-masking paradigm. The temporal separation between the two modes of stimulation varied between 0-80 ms. Electric and acoustic stimuli served as both probes and maskers and were systematically changed in intensity. Extracellular single neuron responses were recorded ipsilateral to the acoustically stimulated cochlea. Contralateral bimodal (BBS) masking results were compared to contralateral acoustic masking results recorded in the same neurons.

In BBS, electric masking had a relatively weak influence on response strength and threshold of the acoustic probe. In contrast, acoustic masking strongly suppressed electric probe responses, resulting in increasing electric thresholds as the level of the acoustic masker increased. Moreover, acoustic masking on electric probe responses demonstrated longer time constants of suppression than electric masking on acoustic responses. The time constants of electric masking were similar to those of contralateral masking using binaural acoustic stimulation.

The results indicate a strong dominance of acoustic masking on electric responses in BBS, whereas electric masking is relatively ineffective. The magnitude of binaural masking between electric and acoustic responses in BBS appears opposite to that observed in ipsilateral combined electric-acoustic stimulation (EAS) [1]. Results will be discussed with respect to different mechanisms for contralateral and ipsilateral masking.

Support provided by MedEl.

[1]Vollmer, M., Hartmann, R., Tillein, J.: Neuronal responses in cat inferior colliculus to combined acoustic and electric stimulation. Adv Otorhino-laryngol. 67: 61–69, 2010

FriAM7: Spatial Speech Reception In Noise With Electric Stimulation In Single-Sided Deafness

Andrea Kleine Punte[1], Katrien Vermeire[1,2,3], Paul Van de Heyning[1]

[1]Antwerp University Hospital, Univ. Dept of Otorhinolaryngology and Head and Neck surgery, University of Antwerp, Antwerp, Belgium
[2] Christiaan Doppler Institute, Applied physics, Innsbruck Austria,
[3]Ghent University Hospital, Univ. Dept of Otorhinolaryngology and Head and Neck surgery, Ghent, Belgium

The combination of acoustic and electric stimulation for improvement in speech perception in noise has been investigated thoroughly the last decade. Bimodal stimulation in the same ear or contralateral ear can improve speech perception in noise compared to electric stimulation only. In this study the effect of bimodal stimulation with normal hearing in one ear and electric stimulation in the other ear is investigated. Cochlear implantation (CI) in single-sided deafness may have the potential of restoring spatial hearing in these patients by electrically stimulating the deaf cochlea in combination with acoustic hearing in the contralateral ear.

Cochlear implantation was performed at the Antwerp University Hospital in 30 patients. Ten patients were implanted with a MED-EL COMBI 40+ implant with a Medium electrode and eighteen patients received a MED-EL PULSAR CI100 or SONATA TI 100 implant with a FLEXsoft electrode, 1 patient received a MED-EL SONATA TI100 flexEAS electrode. Cochlear implantation was performed via cochleostomy in all cases. In all cases CIS based fittings were applied. Long-term follow-up data are available in 29 of these patients. 18 patients have normal hearing contralaterally and 12 patients use a hearing aid in the non-implanted ear. Speech reception in noise was assessed in three spatial configurations (S0N0, S0NCI, SCIN0) with the CI off and the CI on (bimodal). Tinnitus was measured by means of a Visual Analogue Scale (VAS) and the Tinnitus Questionnaire (TQ). Subjective improvement in daily situations was evaluated using the Speech Spatial and Qualities (SSQ) Hearing Scale.

Speech reception in noise improved significantly in both groups of patients after cochlear implantation. 36 months after first fitting a binaural summation effect of 1.6 dB in the NHgroup and 3.5 dB in the HAgroup was measured. Binaural Squelch was 2.1 dB and 4.0 dB in the NH- and HAgroup respectively. A combined Head Shadow effect and Squelch effect of 2.4 (NH group) and 6.7 dB (HA group) was found. Scores on the SSQ also showed significant improvement after cochlear implantation on the speech and spatial scale in the NH group and on the speech scale in the HA group. Tinnitus also decreased significantly after cochlear implantation from 8,5/10 to 2,7/10 on the VAS.

CI in single-sided deafness can improve spatial speech perception in noise. It seems as if several years of CI use is necessary to fully take advantage of binaural cues available from the CI in these patients. Although subjects with some hearing loss seem to benefit more from the CI, CI can significantly improve speech reception in noise in SSD subjects with single-sided deafness.

Poster Sessions

Poster Session A: Monday-Tuesday

A1-a The Relationship Between Place Mismatch and Detection in Noise Thresholds with Simulated Cochlear Implants
Justin M. Aronoff, Qian-Jie Fu

A1-b Binaural Processing is Abnormal in Children Receiving Bilateral Cochlear Implants Sequentially
Daniel D.E. Wong and Karen A. Gordon

A2 Effect of Mismatched Place-of-Stimulation on Binaural Sensitivity in Bilateral Cochlear-Implant Users
Alan Kan, Matthew J. Goupell, and Ruth Y. Litovsky

A3 An Android Auditory Training App For Sequential Bilateral Cochlear Implant Users
Erin Schafer, Behnam Azimi, and Yi Hu

A4 Binaural Time-Intensity Trading in Congenital Deafness
Jochen Tillein, Peter Hubka, Andrej Kral

A5-a Electrically Evoked Post-Auricular Muscle Response In A Cochlear Implant User
Stefan B. Strahl, Philipp Spitzer, Marek Polak, Martin Zimmerling

A5-b Bimodal Simulations of Speech Discrimination in Noise: Effects of Loudness Mismatch Between Devices
Daniel S. Brickman, Lina A. Reiss, Marjorie R. Leek

A6 The Contributions Of Harmonics To The Benefits Of Electroacoustic Stimulation
Qudsia Tahmina, Yi Hu, Christina Runge, and David R. Friedland

A7 Combined electric and binaural acoustic stimulation: improved speech recognition in complex listening environments
René H. Gifford and Michael F. Dorman

A8 The Effect of Hearing Aid Bandwidth on Bimodal Benefit for Cochlear Implant Users with Severe Hearing Loss in the Hearing Aid Ear
Arlene C. Neuman and Mario Svirsky

A9 Comparisons of Mandarin and English sentence perception in EAS simulations
Nathaniel A. Whitmal, III, Yinda Liu, and Richard Freyman

A10-a Identifying Coding Properties along Isofrequency Laminae of the ICC to improve Speech Perception in AMI Patients
Thilo Rode, Tanja Hartmann, Roger Calixto, Minoo Lenarz, Andrej Kral, Thomas Lenarz, Hubert H. Lim

A10-b Flexible Neural Electrode Arrays
Vanessa M. Tolosa, Kedar G. Shah, Angela C. Tooker, Heeral J. Sheth, Terri L. DeLima, Maxim Shusteff, and Satinderpall S. Pannu

A11-a Changes In Behavioral T- And C-Level Profiles As A Function Of Mean Stimulation Level
Bruna S. Mussoi, Carolyn J. Brown, Christine P. Etler, Paul J. Abbas

A11-b Improving Electrically Evoked Compound Action Potential Measures For Setting Current Levels In Cochlear Implantees
Kirpa N.K. Chandan, Catherine Siciliano, Karolina Kluk and Colette M. McKay

A12 Electrophysiological Recording During Cochlear Implantation: Results in Animals and Humans
Faisal I. Ahmad, Baishakhi Choudhury, Christine E. DeMason, Craig A. Buchman, Oliver F. Adunka, Douglas C. Fitzpatrick

A13 C-levels, ECAP Thresholds and Impedance Values for Infants who use the Nucleus Hybrid S12 CI
Christine Etler, Ben Kirby, Jennifer Fowler, Carolyn Brown, Tanya Van Voorst, Stephanie Gogel, Camille Dunn

A14 Evoked Compound Action Potentials Versus Implant Evoked Electrical Auditory Brainstem Resposnses In Cochlear Implant Recipients
Ralf Greisiger, Ole Tvete, Jon Shallop, Greg Eigner Jablonski

A15 Cortical Representations of Time-Varying Cochlear Implant Stimulation In Awake Primate
Luke A. Johnson, Charles C. Della Santina and Xiaoqin Wang

A16-a The Influence of Phonotactic Probability on Repetition Accuracy of Nonwords by Children with Cochlear Implants
Ann E. Todd, Jan R. Edwards, Ruth, Y. Litovsky

A16-b The Effect of Frequency Response on Music Perception by Cochlear Implant Users
Matthew P. Fraser, Emily R. Statham, Linor L. Williams, & Colette M. McKay

A17 Emergent Literacy Skills of Kindergarten Children with Cochlear Implants
Susan Nittrouer, Amanda Caldwell, Daniel Burry, Christopher Holloman, Joanna Lowenstein, Eric Tarr, and D. Bradley Welling

A18 The Mismatch Negativity Evoked by Pitch Contour Changes in Cochlear Implant Users
Fawen Zhang, Chelsea Benson, Lisa Houston, and Qian-Jie Fu

A19 Some Cochlear Implant Recipients Can Perceive Music Better Than Normal Hearing Listeners: A Case Study
Jeremy Marozeau, Mohammad Maarefvand and Peter Blamey

A20-a Place-Pitch Contour Discrimination Interference In Cochlear Implant Users
Ching-Chih Wu and Xin Luo

A20-b Attention/Memory Training Does Not Improve Auditory Performance for Cochlear Implant Users
Sandra I. Oba and Qian-Jie Fu

A21 Infrared Neural Stimulation of Cochlear Spiral Ganglion with Angle-polished Optical Fibers
Suhrud M. Rajguru, and Claus-Peter Richter

A22 Pulse Train Irregularity Detection in Normal-Hearing Listeners and Cochlear Implant Users
Etienne Gaudrain, John M. Deeks, Robert P. Carlyon

A23 Behavioral and physiological measure of frequency mismatch in cochlear implantees
Chin-Tuan Tan, Ben Guo, Brett Martin and Mario Svirsky

A24-a Observing The Enhancement Effect In Cochlear-Implant Listeners
Matthew J. Goupell and Mitch Mostardi

A24-b Temporal Modulation Transfer Functions For Child And Adult Cochlear Implant And Normal-Hearing Listeners
Min-Hyun Park, Jong Ho Won, Elyse M. Jameyson, Jay T. Rubinstein

A25 Relating Loudness Growth to Virtual Channel Discrimination
Arthi G. Srinivasan, David M. Landsberger, Robert V. Shannon

A26 Enhancement Effects In Cochlear-Implant Users
Ningyuan Wang, Heather Kreft, and Andrew J. Oxenham

A27 Changes In Ecap Amplitude-Growth Functions Over Time After Neurotrophin Treatment
Sara A. Bowling, Stefan B. Strahl, Deborah J. Colesa, Seiji Shibata, Gina L. Su, Yehoash Raphael and Bryan E. Pfingst

A28-a Optoacoustic stimulation of the Organ of Corti in situ and of isolated cells
Günter Reuter, Alexander Rettenmeier, Gentiana I. Wenzel, Michael Schultz, Alexander Heisterkamp, Thomas Lenarz

A28-b Channel Interaction During Infrared Neural Stimulation
Claus-Peter Richter, Suhrud Rajguru, Agnella Izzo Matic

A29-a Linked Bilateral Noise Reduction Processing for Cochlear Implants Users
Jorge P. Mejia, Harvey Dillon, John Heasman, Adam Hersbach and Richard van Hoesel

A29-b Benefit Of Directional Microphone Systems From Hearing Aids For Cochlear Implant Users
Carolin Frohne-Büchner, Waldo Nogueira, Lucas Hoeppner, Tobias Rottmann, Volkmar Hamacher, Thomas Lenarz, Andreas Büchner

A30 Silicon Cochlea Models for Enhancing Cochlear Implant Research
Tara Julia Hamilton, André van Schaik

A31 Speech Perception Improves With Randomization Of Starting Phases In Harmonic Complex Excited Vocoder
Tyler Churchill, Antje Ihlefeld, Alan Kan, Matt Goupell, Corey Stoelb, Ruth Litovsky

A32 Enhanced SPARSE Strategy for Cochlear Implants
Hongmei Hu, Guoping Li, Jinqiu Sang,Shouyan Wang, Mark E Lutman, Stefan Bleeck

A33-a A Patient-Specific Cochlear Implant Sound Coding Strategy Using a Model Of Electric Stimulation
Andrea Varsavsky, David B. Grayden, Hugh J. McDermott, Lawrence T. Cohen, John Heasman, Andreas Buechner, Thomas Lenarz and, Anthony N. Burkitt

A33-b Application of Real-Time Loudness Models Can Improve Speech Recognition For Cochlear Implant Users
Andrea Varsavsky and Hugh J. McDermott

A34 Evaluation of an algorithm for transient noise suppression in Cochlea-Implant systems
Lucas Hoepner, Waldo Nogueira, Tobias Rottmann, Volkmar Hamacher, Thomas Lenarz, Andreas Büchner

A35 Insights Into Multi-Channel Automatic Gain Control And Cochlear Implant Users
Patrick Boyle, Michael Stone, Leo Litvak, Brian Moore

A36-a Prediction of Success With Cochlear Implants Using Novel Measurement Procedures
Sabine Haumann, Nina Wardenga, Tobias Herzke, Volker Hohmann,
Thomas Lenarz, Anke Lesinski-Schiedat, Andreas Büchner

A36-b Evaluation Of Multiple Processing Options Available With The Nucleus System 5 Device Using The R-Space^{tm}
Lisa G. Potts and Kelly A. Kolb

A37-a Phonemic Restoration Of Speech In Users Of Cochlear Implants
Pranesh Bhargava, Deniz Başkent

A37-b Correlation Between Spread Of Excitation Measurements And Speech Perception In Adult Cochlear Implant Users
Birgit Philips, Ingeborg Dhooge

A38 Factors Affecting Cochlear Implant Outcomes
Laura K. Holden, Charles C. Finley, Timothy A. Holden, Christine A. Brenner, Gitry Heydebrand, and Jill B. Firszt

A39 Results Of A Multicentre Study On Cochlear Implantation In Patients With Long-Term Monaural Sound-Deprivation; Does The Choice Of Ear Matter?
Isabelle Boisvert, Catherine M. McMahon, Richard Dowell, Björn Lyxell

A40 Cerebral Reorganization and Cochlear Implantation Outcome in Post-Linguistically Deaf Adults
Diane S Lazard, Hyo-Jeong Lee, Anne-Lise Giraud

A41 Speech Recognition In Background Music With Cochlear Implants
Xin Luo, Megan E. Masterson, and Ching-Chih Wu

A42 Noise Suppression and Cochlear Implant Speech Understanding in Auralized Reverberant Sound Fields
Lucas H.M. Mens, Hannah Keppler, Weigang Wei, Ingeborg Dhooge, Ad Snik

A43 The Multimodal Lexical Sentence Test for Adults: Performance of Listeners with Hearing Loss
Karen I. Kirk, Lindsay M. Prusick, Amanda B. Silberer, Laurie S. Eisenberg, Nancy M. Young, Brian F. French, Nicholas P. Giuliani, Amy S. Martinez, Dianne H. Ganguly, Chad Gotch, Lisa Weber, Susan Stentz

A44 Growth of Tissue Around Cochlear Implant Electrodes – Indications From Impedance Measurements
Gerrit Paasche, Katharina Wuttke, Anke Lesinski-Schiedat, Thomas Lenarz

Poster Session B: Tuesday-Wednesday

B1-a Central Masking with bilateral cochlear implants
Payton Lin, Thomas Lu, Fan-Gang Zeng

B1b Effects of Auditory Experience On Spatial Release From Masking In Children
Sara M. Misurelli, Shelly P. Godar, and Ruth Y. Litovsky

B2 The Emergence Of Sound Localization Abilities In Toddlers Who Use Bilateral Cochlear Implants
Christi L. Hess, Samantha Harris, Erica A. Ehlers, Alyssa J. Lamers & Ruth Y. Litovsky

B3 Psychophysical Measures of Sensitivity to Interaural Time Difference Encoded in the Envelope and the Fine Structure with Bilateral Cochlear Implants
Victor A. Noel, Donald K. Eddington

B4 Neural ITD coding and phase locking to pulse trains with cochlear implants: Effects of interpulse jitter and anesthesia
Kenneth E. Hancock, Yoojin Chung, Sung-Il Nam, Bertrand Delgutte

B5-a Is Candidacy Responsible For The Improvements Seen In Cochlear Implant Outcomes?
Debi A. Vickers, Francesca Pinto, Jane Bradley, Sukhminder Johal and Vaitheke Selvanayagam

B5-b Spectral Ripple Density and Complex Speech Perception Performance In Normal Hearing and Cochlear Implant Listeners
Erin S. Maloff, Julie Arenberg Bierer

B6 Using Semi-Automated Software Tool For Programming Multiple Cochlear Implants In A Telemedicine Setting
Ishan Ann Tsay, Wendy Parkinson, Heather Haugen

B7 Cochlear Implantation in Single Sided Deafness: Spatial Release from Masking in Speech Perception and Localization of Sound Sources
Stefan M. Brill, Wilma Harnisch, Joachim Müller

B8 Cochlear Implantation In Adults With Asymmetric Hearing Loss
Jill B. Firszt, Laura K. Holden, Ruth M. Reeder, Lisa Cowdrey, Sarah King

B9 Simulation Data and a Model Approach for Speech Perception with Electric-Acoustic Stimulation (EAS)
Tobias Rader, Uwe Baumann and Hugo Fastl

B10 Auditory training in noise with patients with combined electric and acoustic stimulation
Ting Zhang, Michael F. Dorman, Qian-Jie Fu

B11-a Using Ecap Forward Masking Patterns To Predict Missing Information
Jill M. Desmond, Sara I. Duran, Leslie M. Collins, and Chandra S. Throckmorton

B11-b ECAP as a predictor of optimal stimulation rate in individuals?
Idrick Akhoun, Matthew P. Fraser, & Colette M. McKay

B12 ECAP artefact rejection with independent component analysis
Idrick Akhoun, Mahan Azadpour, Wael El-deredy and Colette McKay

B13 Auditory Nerve: Large Differences in Fiber Response
Leon F Heffer, Mark W White, James B Fallon, David J Sly, Rob Shepherd, Stephen J O'Leary

B14 Age-Related Changes and the Effect of Stimulation Pulse Rates on Cortical Processing and Speech Perception in Cochlear Implant Listeners
Lendra M. Friesen, Takako Fujioka, Vincent Lin

B15 Electrically Evoked Auditory Brainstem Responses to Different Pulse Shapes
Jaime A. Undurraga, Robert P. Carlyon, Jan Wouters, Astrid van Wieringen

B16-a Predictors of Language Outcomes In Children One To Three Years After Cochlear Implantation
Tinne Boons, Jan P.L. Brokx, Johan H.M. Frijns, Louis Peeraer, Birgit Philips, Anneke M. Vermeulen, Jan Wouters, Astrid van Wieringen

B16-b Polyphonic Contour Identification in Cochlear Implants
Meimei Zhu, John J. Galvin III, Bing Chen, Qian-Jie Fu

B17 The Development Of Speech Perception In Children With Cochlear Implants
Louise R. Yeager and Lynne A. Werner

B18 The Effect Of Perceptual Cues On Auditory Streaming In Cochlear Implant Listeners.
Jeremy Marozeau, Hamish Innes-Brown and Peter Blamey

B19 Music Preference Study With Cochlear Implant Recipients Using Multi-Track Recordings
Wim Buyens, Bas van Dijk, Marc Moonen, Jan Wouters

B20 On the Mechanism of Spectral-Ripple Discrimination by Cochlear Implant Users
Gary L. Jones, Ward R. Drennan, Jay T. Rubinstein

B21 Correspondence Between Behavioral And Objective Measures Of Temporal Rate Pitch In Cochlear Implant Listeners
John M. Deeks and Robert P. Carlyon

B22 Improvements In Rate Discrimination After Training In Adult Cochlear Implant Recipients
Raymond L. Goldsworthy, Robert V. Shannon

B23-a A Frequency-Place Map For Electrical Stimulation In Cochlear Implants: Change Over Time
Katrien Vermeire, Reinhold Schatzer, Andrea Kleine Punte, Paul Van de Heyning, Maurits Voormolen, Daniel Visser, Andreas Krenmayr, Mathias Kals, Clemens Zierhofer

B23-b The Effect of Stimulation Rate on Forward Masking Functions
Wai Kong Lai, Matthijs Killian, Norbert Dillier

B24 Categorical loudness growth measurements in CI users
Femke L. van den Hoek, Monique Boymans, Wouter A. Dreschler

B25-a Regional Protective Effects Of Chronic Intracochlear Stimulation Within The Cochlea In A Ferret Model Of Cochlear Implantation
Amal Isaiah, Tara Vongpaisal, Andrew King, and Douglas Hartley

B25-b Stimulating the Inferior Colliculus: The Effect Of Electrode Size
Roger Calixto, Thilo Rode, Behrouz Salamat, Minoo Lenarz, Thomas Lenarz, Hubert H. Lim

B26 Development Of An Improved Cochlear Electrode Array For Use In Experimental Studies
Andrew K. Wise, James B. Fallon, Kristien Verhoeven, Jin Xu, Frank Risi, Robert K. Shepherd

B27 *In Vitro* and *In Vivo* Effects of Rolipram on Spiral Ganglion Cells and Dendritic Cells via Nanoparticle Carriage
Hartwig Meyer, Timo Stöver, Florian Fouchet, Guillaume Bastiat, Patrick Saulnier, Wolfgang Bäumer, Thomas Lenarz, Verena Scheper

B28-a: Effects of Charge Distribution of Consecutive Stimulation Pulses in Cochlear Implant Patients
Sonja Karg, Werner Hemmert

B28-b: Effect Of Filterbank Parameters On Speech Perception Through Cochlear Implants: A Simulation Study
Shibasis Chowdhury, Carl Verschuur

B29: Effect of Fast AGC on Cochlear Implant Speech Intelligibility
Phyu P. Khing, Eliathamby Ambikairajah, Brett A. Swanson

B30: Noise Reduction Using Spatially Derived SNR for Cochlear Implant Sound Processing
Adam Hersbach, John Heasman and Pam Dawson

B31-a: Auditory Experience Enhances Temporal Processing In Both Deaf Juvenile And Long-Deaf Auditory Systems: Comparisons Between Auditory Midbrain And Cortex
Maike Vollmer and Ralph E. Beitel

B31-b: Supervised Sparse Coding in Cochlear Implants
Jinqiu Sang, Guoping Li, Hongmei Hu, Mark E Lutman, Stefan Bleeck

B32-a: Preliminary Results with a Harmonic Single Sideband Encoding Strategy for Improving Temporal Fine Structure Coding in Cochlear Implants
Kaibao Nie, Xing Li, Jong Ho Won, Nikita Imennov, Les Atlas, and Jay T. Rubinstein

B32-b: A Bio-Inspired Nonlinear Filter Bank for Cochlear Implant Speech Processors
Reinhold Schatzer, Blake S. Wilson, Enrique A. Lopez-Poveda, Mariangeli Zerbi, Robert D. Wolford, Jeannie H. Cox, Dewey T. Lawson, Clemens M. Zierhofer

B33: Constructing Patient-Specific Cochlear Implant Models From Monopolar And Tripolar Threshold Data
Joshua H. Goldwyn, Steven M. Bierer, Julie A. Bierer

B34: A F0 rate-pitch coding strategy for cochlear implants
Andrew E. Vandali, Richard J. M. van Hoesel

B35-a: Listening Effort With Cochlear Implants And Electric Accoustic Stimulation – A Simulation Study
Carina Pals, Anastasios Sarampalis, Deniz Başkent

B35-b: Effect Of Target And Masker Gender On The Perception Of Speech By Normal-Hearing (NH) Listeners Using Cochlear Implant (Ci) Simulations
Ramesh Kumar Muralimanohar, Christopher J. Long
Kathryn H Arehart

B36-a: Developing a Linguistic System through Cochlear Implants: A Multiple Case Study of Four- To Seven-Year Old Deaf Children Learning German
Katrin Skoruppa and Barbara Esser-Leyding

B36-b: Standardized Mandarin Sentence Perception in Babble Noise Test Materials for Children
Xin Xi, Aiting Chen, Jianan Li, Fei Ji, Mengdi Hong, Shiming Yang, Dongyi Han

B37: Modeling Speech Perception In Noise By Cochlear Implant Users
Elad Sagi and Mario A. Svirsky

B38: Cochlear implant model using Mel-Frequency Cepstral Coefficients
Preethi Mahadevan, Pavithra Balaji, Shri Ranjani Sukumar, Vijayalakshmi Parthasarathy, Nagarajan Thangavelu

B39: Transmission of Speech Temporal Information At Different Electrode Locations in CI And ABI Users
Mahan Azadpour and Colette M. McKay

B40: Using Sound Segregation Cues to Improve Cochlear Implant Vowel Recognition in Noise
Myles Mc Laughlin, Richard B. Reilly and Fan-Gang Zeng

B41: Normalization to Talker Gender And F0: Phonetic Category Adjustment By Cochlear Implant Users
Matthew B. Winn and Monita Chatterjee

B42: Continuous Impedance Measurement Tool During Electrode Insertion.
Chin-Tuan Tan, J. Thomas Roland, Shaun Kumar, Claudiu Treaba, Bernie Caessens, Mario Svirsky

B43: A Polymer Based Intracochlear Electrode for Low Cost, but Highly Effective Cochlear Implantation
Kyou Sik Min, Jin Ho Kim, Ho Sun Lee, Min Hyun Park, Seung Ha Oh, Sung June Kim

B44: Optogenetic Stimulation Of The Auditory Nerve: Toward An Optical Cochlear Prosthetic
Victor H. Hernandez, Gerhard Hoch, Matthias Bartles, Gerhard Vogt, Carolyn W. Garnham, Tim Salditt, George J. Augustine , Nicola Strenzke, Tobias Moser

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Poster Session C: Wednesday-Thursday

C1-a: Is Auditory Brainstem Implant Stimulus Rate Limiting Speech Perception Outcomes?
Stefan J. Mauger, Mohit N. Shivdasani, Graeme D. Rathbone & Antonio G. Paolini

C1-b: Development of sound localization strategies in children with bilateral cochlear implants and with normal hearing
Yi Zheng, Shelly P. Godar, Ruth Y. Litovsky

C2: Evidence For Benefit From Mismatched Binaural Speech Processors For Speech In Noise: Glimpsing or Combination Of Spectral Cues Across Ears?
Andrew Faulkner, Stuart Rosen, Catherine Siciliano

C3: Effects of Interaural Electrode Channel Offset on the Binaural Interaction Component of the Electrically Evoked Cortical Auditory Potential
Shuman He, John H. Grose, Craig A. Buchman

C4: Effect of Acute Between-Ear Frequency Mismatches on Speech Understanding in Users of Bilateral Cochlear Implants
Matthew B. Fitzgerald, Mario A. Svirsky

C5-a: Criteria of Candidacy for Bilateral Cochlear Implantation in Children
Rosemary E. S. Lovett, Deborah A. Vickers, A. Quentin Summerfield

C5-b: Perceptual Learning of Interrupted Speech With Cochlear-Implant Simulations
Michel R. Benard, Deniz Başkent

C6: Improved Language Outcomes For Children With Bilateral Cochlear Implants
Tinne Boons, Jan P.L. Brokx, Johan H.M. Frijns, Louis Peeraer, Birgit Philips, Anneke M. Vermeulen, Jan Wouters, Astrid van Wieringen

C7-a: Presenting Low-Frequency Cues Visually In Simulations Of Electric-Acoustic Stimulation
Marine Ardoint, Christopher A. Brown, Kate Helms Tillery, and Sid P. Bacon

C7-b: Consonant Recognition in Quiet and in Noise with Combined Electric and Acoustic Stimulation
Yang-soo Yoon, You-Ree Shin, and Qian-Jie Fu

C8: Frequency Contour Detection and Mandarin Monosyllable Perception in Native Mandarin Chinese Speakers With Electric-Acoustic Hearing
Hsin-I Yang and Fan Gang Zeng

C9: Effects of Electric Pitch Adaptation On Acoustic+Electric Speech Perception In Long-Electrode Cochlear Implant Users
Rindy A. Ito, David R. Wozny, and Lina A.J. Reiss

C10: Mechanisms of Bimodal Speech Benefit
Anisa S. Visram, Mahan Azadpour, Karolina Kluk, Colette M. McKay

C11: Emphasizing Modulations In Vowels Improves Perception Of Interaural Time Differences In Bimodal Stimulation
Anneke Lenssen, Tom Francart and Jan Wouters

C12: Cortical Evoked Potentials Recorded From Hybrid Ci Users: Effect Of Stimulation Mode And Programming Strategy
Carolyn J. Brown, Paul J. Abbas, Christopher Turner, Julie Jeon, Li X Chiou, Ben Kirby, Sue Karsten, Christine Etler

C13-a: The Usefulness and Limitations Of Spread Of Excitation Measurements For The Individual Fitting Of Virtual Channels
Dietmar Basta, Rolf-Dieter Battmer, Filiep Vanpouke, Patrick Boyle, Arne Ernst

C13-b: Variability In Intracochlear Electrical Spread Patterns
Eddy De Vel, Katrien Vermeire, Filiep Vanpoucke, Birgit Philips, Ingeborg Dhooge

C14: Auditory Stream Segregation In CI Simulations: Evidence From Event-Related Potentials
Yingjiu Nie, Yang Zhang, and Peggy B. Nelson

C15: Temporal Processing of Vocoded Speech in Human Auditory Cortex
Nai Ding, Monita Chatterjee, Jonathan Z. Simon

C16: EFI and In Vitro Field Measurements to Assess the Effect of Current Focusing and Current Steering Inside and Outside the Scala Tympani
Carlo K. Berenstein, Filiep J. Vanpoucke, Lucas H.M. Mens, Ad F.M Snik

C17: Ectopic Electrical Stimulation In Cochlear Implants
Charles C. Finley, Laura K. Holden, Timothy A. Holden and Jill B. Firszt

C18: Music Perception By Cochlear Implant Users
Joseph D. Crew, John J. Galvin III, Qian-Jie Fu

C19: Role of Brightness In Pitch Perception Tasks: Implications For Cochlear Implant Place Pitch
Vijay M. R. Marimuthu, Brett A. Swanson and Robert H. Mannell

C20-a: Infrared Neural Stimulation Of The Chronically Deafened Cochlea As Seen From The Inferior Colliculus
Agnella Izzo Matic, Suhrud M. Rajguru, Claus-Peter Richter

C20-b: Responses of the Cochlea to NIR LASER Stimulation in Thermal and Stress Confinement
Hannes Maier, Michael Schulz, Ingo Teudt, Peter Baumhoff, Andrej Kral

C21: Study on The Tonotopy Of Polymer Membranes Mimicking the Human Basilar Membrane
Won-Joon Song, Sung-Jae Bae, Junsik Park, Wan-Doo Kim

C22-a: Pitch of Dual-Electrode Stimuli As a Function of Rate And Electrode Separation
Paul A. Bader, Reinhold Schatzer, Katrien Vermeire, Paul Van de Heyning, Daniel Visser, Andreas Krenmayr, Mathias Kals, Clemens M. Zierhofer

C22-b: Simulation of Cochlear Implant Users' Speech Intelligibility Performance Using a Spiking Auditory Model
Stefan Fredelake, Birger Kollmeier, Volker Hohmann

C22-b: Simulation of Cochlear Implant Users' Speech Intelligibility Performance Using a Spiking Auditory Model
Stefan Fredelake, Birger Kollmeier, Volker Hohmann

C23: Preliminary Investigation of the Relationship Among Place Pitch, Musical Pitch and Speech Recognition of Cochlear Implant Users
Meng Yuan , Li-chuan Ping, Qing-lin Meng, Hai-hong Feng

C24-a: The Modulation of Auditory Feedback on Speech Production in Children with Cochlear Implant
Ningyuan Wang, Juan Huang

C24-b: Cognitive Effort and the Perception of Speech by Adult Cochlear Implant Users: A Survey
Rana A. Alkhamra, Brad Rakerd, Jerry Punch, Terry Zwolan,
and Jill Elfenbein

C25: The Importance of Segregation In Masking Release
Bomjun J. Kwon, Trevor T. Perry, Cassie L Wilhelm, Eric W. Healy

C26-a: Modelling Of Central Auditory Nervous System Processing In Cochlear Implant Mediated Hearing
Johan J. Hanekom, Stuart C.J. Smith, Pieter J. Venter

C26-b: Hemispheric Lateralization of Cortical Responses in Children Using Bilateral Cochlear Implants
Daniel D.E. Wong, Karen A. Gordon

C27: The Effects Of Multiple, Very Early Refelctions On Vocoded Speech Perception
Sarah F. Poissant & Nathaniel A. Whitmal, III

C28: Better Acoustic Simulation of Cochlear Implants
Diane S Lazard, Jeremy Marozeau and Hugh McDermott

C29: The Influence of Linguistic Skills on Speech Recognition in Noise in Cochlear Implant Users
Marre W. Kaandorp, Annette M. B. de Groot, Joost M. Festen, S. Theo Goverts

C30: Auditory Training in Adult Cochlear Implant Listeners using Spectrally-Rippled Noise Stimuli in an Adaptive, Single-Interval, Paradigm
Kathleen F. Faulkner, Kelly L. Tremblay, Jay T. Rubinstein, Lynne A. Werner, Kaibao Nie

C31-a: Forward Masking To Evaluate Place Specificity Using Monopolar and Tripolar Stimulation
Claire A Fielden, Karolina Kluk, Idrick Akhoun, Colette M McKay

C31-b: The Dynamic Range Involved In Accessing Temporal Fine Structure In The Presence Of A Modulated Masker
Michael A. Stone, Brian C.J. Moore, Christian Füllgrabe

C32: The Effects of Pulse Rate On Detection Thresholds And Maximum Comfortable Loudness Levels In Humans With Cochlear Implants
Ning Zhou, Li Xu, Bryan E. Pfingst

C33-a: Cochlear Implant Optimized Gain Function for SNR Based Noise Reduction
Stefan J. Mauger, Adam A. Hersbach & Pam W. Dawson

C33-b: Evaluation Of F0 Extraction Algorithms For Better F0 Coding In Future Cochlear Implant Processors
Matthias Milczynski, Jan Wouters, Astrid van Wieringen

C34: The Enhancement Of Onsets In The Speech Envelope Increases Speech Intelligibility In Noise Vocoder Cochlear Implant Simulations
Raphael Koning, Jan Wouters

C35: Model-based validation framework for coding strategies in cochlear implants
Michele Nicoletti, Werner Hemmert

C36-a: Speech Perception in a Competing-Talker Background with Temporal Fine Structure
Daniel Visser, Andreas Krenmayr, Reinhold Schatzer, Paul A. Bader, Andreas Griessner, Matthias Zangerl, Christian Neustetter, Clemens M. Zierhofer

C36-b: Performance of CI subjects using time-frequency masking based noise reduction.
Obaid ur Rehman Qazi, Bas Van Dijk, Marc Moonen, Jan Wouters

C37: How Does Phantom Electrode Stimulation Produce A Lower Pitch Sensation Than The Most Apical Electrode In Cochlear Implants?
Aniket A. Saoji, David Landsberger, Monica Padilla, Leonid M. Litvak

C38: Spread-Of-Excitation Measurements Using Masker And Probe Electrodes Which Are Both Current Steered
Lutz Gärtner, Andreas Büchner, Thomas Lenarz, Waldo Nogueira

C39: Investigating the Auditory Nerve Fiber Response through Numerical Modeling of the Cochlea to Compare Current Shaping Strategies
Nicolas Veau, Jessica Falcone

C40-a: The Use Of A Cochlear Implant And Cell-Based Therapies To Promote Nerve Survival.
Andrew K. Wise, James B. Fallon, Alison J. Neil, Lisa N. Pettingill, Marilyn C. Geaney, Robert K. Shepherd

C40-b: Long Term Hearing Protection In The Guinea Pig Model Of Cochlear Implantation With Locally Delivered Dexamethasone.
Hayden T Eastwood, Andrew Chang, Jason C Lee, Stephen J O'Leary

C41: High-Resolution Cone-Beam CT: A Potential Tool To Improve Atraumatic Electrode Design and Position
Sharon L. Cushing, Michael J. Daly, Claudiu G. Treaba, Harley Chan, Jonathan C. Irish, Blake C. Papsin, Karen A. Gordon

C42: Development of a Steerable Cochlear Implant Electrode and a Robotic Insertion System.
J. Thomas Roland Jr., Spiros Manolidis, Jian Zhang, Nabil Simaan.

C43: Pharmacological and electrical stimulus responses of spontaneously active spiral ganglion neurons on CNT electrode arrays
Kenneth H. Lee, Walter E. Voit, Taylor H. Ware, Edward W. Keefer

C44: Effects of Brain-Derived Neurotrophic Factor (Bdnf) On The Cochlear Nucleus In Cats Deafened As Neonates
Cherian Kandathil, Olga Stakhovskaya, Gary Hradek, Patricia Leake

Poster Session D: Thursday-Friday

D1-a: Exploring the Benefit From Enhancing Envelope ITD's For Listening In Reverberant Environments
Jessica J. M. Monaghan and Bernhard U. Seeber

D1-b: Restoration Of Binaural Hearing With A Cochlear Impla Nt In Single Sided Deaf Subjects
Rolf-Dieter Battmer, Dietmar Basta, Ingo Todt, Arne Ernst

D2-a: Binaural Benefits With and Without a Bilateral Mismatch in Acoustic Simulations of Cochlear Implant Processing
You-Ree Shin, Yang-soo Yoon, and Qian-Jie Fu

D2-b: The Benefits Of Acoustic Cues for Cochlear Implant Users In Reverberation
Kate Helms Tillery, Christopher A. Brown, William A. Yost and Sid P. Bacon

D3: Speech Intelligibility in Quiet And in Noise And Sound Localization Abilities For Digisonic® SP Binaural Cochlear Implant Users
Nicolas Verhaert, Diane Lazard, Dan Gnansia, Jean-Pierre Bébéar, Philippe Romanet, Eric Truy

D4: Effect of Head Movement On Sound Localization In Unilateral, Bimodal And Bilateral Cochlear Implantees
Kassandra-Anne H. Birtch, Ioan A. Curca, Ewan A. Macpherson

D5: Tonotopic Symmetry Of ITD-Based Lateralization And Channel Interference
Bernhard Laback, Virginia Best, and Piotr Majdak

D6: Investigation of the Electric-Acoustic Stimulation (EAS) Cochlear Implant Alone Listening Condition and Speech Perception In Noise
Margaret T Dillon, English R King, Marcia C Adunka, Emily Buss,Harold C Pillsbury, Oliver F Adunka, Craig A Buchman

D7: The Contributions Of Non-Integer Multiples Of F0 To The Benefits Of Electroacoustic Stimulation
Yi Hu, Christina Runge, David R. Friedland and Julie Liss

D9: Pitch Perception In Bimodal Listeners
Chasity S. Moore, Anthony J. Spahr, Michael F. Dorman

D10: Spectral Processing and Speech Recognition In Bimodal Implant Users
Ting Zhang, Anthony J. Spahr, Michael F. Dorman

D11-a: Estimating Behavioural Threshold from ECAP Variability: Comparison of Physiological Data With a Computational Model
Stephen D. Holmes David M. Landsberger, Arthi G. Srinivasan and Robert P. Morse

D11-b: A Microelectrode Array for Chronic Recording of Single-Unit Neuronal Activity In the Inferior Colliculus Of The Cat
Douglas B McCreery, Martin Han

D12-a: Effects of Amplitude Modulation of Pulse Trains and Pure Tones On Neuronal Activation Patterns Recorded In the Auditory Midbrain
Matthew C. Schoenecker, Ben H. Bonham, Olga A. Stakhovskaya, Russell L. Snyder, Stephen J. Rebscher, Alexander M. Hetherington, and Patricia A. Leake

D12-b: Electroporation of adherent cells with cochlear implant stimulation
Andrew Farrington, Carrie J Newbold

D13: ECAP Signals: Sigmoidal Fitting Functions for Amplitude Growth Sequences
Konrad E. Schwarz, Philipp Spitzer, Stefan B. Strahl

D14: Spread of Excitation in Bipolar Mode of Different Pulse Shapes.
Jaime A. Undurraga, Robert P. Carlyon, Olivier Macherey, Jan Wouters, Astrid van Wieringen

D15: Auditory Steady State Responses to High-Rate Stimuli In Cochlear-Implant Users
Michael Hofmann and Jan Wouters

D16: Language Production in Prelingual and Postlingual Hearing Impaired Adults: an fMRI Study.
Berit M Verbist, Ilya M Veer, Jeroen J Briaire, Johanneke HT Journee, Daan van de Velde, Mark A van Buchem, Niels O Schiller, Serge ARB Rombouts, Johan HM Frijns

D17: Lexical Organization In Children With Cochlear Implants
Deena Wechsler-Kashi, Yoed N. Kenett, Dror Y. Kenett, Eshel Ben-Jacob, Miriam Faust

D18-a: Musical Experience and Quality Of Life In Cochlear Implant Recipients
Christina D Fuller, Rolien H Free, Bert Maat, Deniz Başkent

D18-b: A Psychophysical Method For Measuring Spatial Resolution In Cochlear Implants
Mahan Azadpour and Colette M. McKay

D19: Cortical Processing Of Musical and Speech Sounds in Early-Implanted Children – Role Of Musical Activities
Ritva Torppa, Tommi Makkonen, Hannu Loimo, Jari Lipsanen, Andrew Faulkner, Minna Huotilainen

D20-a: Optical and Electrical Co-Stimulation In the Cochlea.
Michael J. Jung, Suhrud M. Rajguru, Ken Zhao, Claus-Peter Richter

D20-b: Enhanced Auditory Neuron Survival Following Cell-Based BDNF Treatment In The Deaf Guinea Pig
Lisa N. Pettingill, Andrew K. Wise, Marilyn S. Geaney and Robert K. Shepherd

D21: Infrared Neural Stimulation of the Cat Cochlea
Ken Zhao, Suhrud M. Rajguru and Claus-Peter Richter

D22: Modeling Of Peripheral Factors That Affect Neural Excitation In The Electrically Stimulated Cochlea
Tania Hanekom, Tiaan K Malherbe, Robert Jönsson, Johan J Hanekom

D23: The Effect Of Enhanced Temporal Pitch Cues On Perception Of Mandarin Chinese In Real And Simulated Electric Hearing
Matthias Milczynski, Jan Wouters, Astrid van Wieringen

D24-a: Hemispheric Lateralization of Cortical Responses in Children Using Bilateral Cochlear Implants
Daniel D.E. Wong, Karen A. Gordon

D24-b: Front-End Noise Suppression for Bilateral Cochlear Implants Using Estimated Binary Masks
Sara I. Duran, Leslie M. Collins and Chandra S. Throckmorton

D25: Audiovisual Crossmodal Plasticity in Adult Cochlear Implant Users
Yun Gong, Emily A. Tobey, Michael Devous, Sr., Thomas S. Harris, Peter S. Roland

D26: Pitch-related Perception by Bilateral and Bimodal Cochlear Implant Users
Tianhao Li, Qian-Jie Fu

D27-a: Stimulation Levels and Subjective Ratings
Anthony J. Spahr, Leonid M. Litvak, Sarah Cook, and Michael F Dorman

D27-b: Cochlear Implant Stimulating Strategy Incorporating Current Steering Scheme and Psychoacoustic Model
Charles T. M. Choi, Wen-Ya Tsai, Yi-Hsuan Lee

D28: Neurotrophin Induced Ectopic Growth Of Peripheral Processes Does Not Compromise The Cochleotopic Organization Of The Implanted Cochlea
T. G. Landry, A. K. Wise, J. B. Fallon & R. K. Shepherd

D29: Neurotrophic Effects Of BDNF and Electrical Stimulation In Cats Deafened At Birth
Patricia A. Leake, Gary T. Hradek, Alexander Hetherington,Olga Stakhovskaya and Ben H. Bonham

D30: The potential benefits of combining intracochlear current focusing techniques with dual electrode stimulation: a computational study
Randy K. Kalkman, David M.T. Dekker, Jeroen J. Briaire and Johan H.M. Frijns

D31: Sparse Stimuli Benefit Cochlear Implant Users In Noisy Environment
Guoping Li, Mark E Lutman

D32-a: Acoustic Landmark Detection: Realising A New N-Of-M Speech Processing Strategy For Cochlear Implants
Cherith M. Webb

D32-b: A Dual-Microphone Algorithm For Improving Speech Intelligibility In Competing-Talker Listening Situations
Nima Yousefian and Philipos C. Loizou

D33-a: Speech Perception Based On Acoustic Temporal Fine Structure In Cochlear Implant Listeners
Jong Ho Won, Kaibao Nie, Xing Li, Elyse M. Jameyson, Ward R. Drennan, and Jay T. Rubinstein

D33-b: Evaluation Of A New Signal Processing Strategy Including A Partial Bipolar Channel To Transmit Low Frequency Information
Waldo Nogueira, Alexander Foerstel, Aniket Saoji, Leonid Litvak, Volkmar Hamacher, Tobias Rottmann, Thomas Lenarz, Andreas Buechner

D34: Suppressing Reverberation in Cochlear Implants Using a Channel-Selection Based Strategy
Oldooz Hazrati, Kostas Kokkinakis and Philipos C. Loizou

D35: Clinical Fitting of Cochlear Implant Guided by Electrode Discrimination
Shaza Saleh, Debi Vickers, Leah Meerton and Shakeel Saeed

D36: A New Research Implementation Of Mp3000 To Improve Intermediate Pitch Percept Between Electrode Contacts
Andreas Büchner, Mark Schüssler, Thomas Lenarz

D37-a: The Benefit of Residual Acoustic Hearing to Auditory and Auditory-Visual Cochlear-Implant Consonant Perception
Benjamin M. Sheffield, Gerald Schuchman, Joshua G. Bernstein

D37-b: Modeling Speech Intelligibility by Cochlear Implant Users
Fei Chen and Philipos C. Loizou

D38-a: Effects of Environmental Sound Training On the Perception of Speech and Environmental Sounds in Cochlear Implant Listeners
Valeriy Shafiro, Stanley Sheft, Sejal Kuvadia, Kim Ho & Brian Gygi

D38-b: More Insights Into Cochlear Morphology And The Development Of An Insertion Model
Kim S. van der Marel, Jeroen J. Briaire, Ron Wolterbeek, Berit M. Verbist, Johan H.M. Frijns

D39: Recognition of Synthetic and Natural Speech by Normal-Hearing Listeners and Cochlear Implant Users
Caili Ji, Anting Xu, Qian-Jie Fu

D40: Free-Field Assessment of Temporal Auditory Processing and Speech Recognition in Cochlear Implant Users
Dan Gnansia, Diane Lazard, Claude Fugain, Denis Lancelin, Bernard Meyer, Christian Lorenzi

D41: Stability of Clinically Meaningful, Non-Linguistic Measures of Hearing Performance with a Cochlear Implant
Ward R. Drennan, Jong Ho Won, Elyse M. Jameyson, Jay T. Rubinstein

D42: Speech Perception in Music Backgrounds by Cochlear Implant Users and Normal Hearing Listeners
Elizabeth N. Eskridge, John Galvin III, Qian-Jie Fu, Justin M. Aronoff

D43: Effects of Speaking Styles on Speech Intelligibility by Mandarin-speaking and English-speaking Cochlear Implant Patients

Qian-Jie Fu, Xiaosong Wang, Yongxin Li, Hou-yong Kang, Guoping Zhang, Sha Liu, Deming Han

D44: Predicting the Insertion Depth of the Hi focus 1J Electrode Array Based on High Resolution CT Images

Olga A. Stakhovskaya, Lawrence R. Lustig, Patricia A. Leake

A1-a: The Relationship Between Place Mismatch and Detection in Noise Thresholds with Simulated Cochlear Implants

Justin M. Aronoff, Qian-Jie Fu

House Ear Institute, Los Angeles, CA, U.S.A.

In normal hearing (NH), there is a “binaural coherence” that binds the internal representations of sound from each ear. Interaural time differences (ITDs) are interpreted in relation to this binaural coherence. Cochlear implant (CI) processing may disrupt this coherence, greatly limiting CI users’ binaural perception. Depending on the electrode locations in each ear, an input acoustic frequency may stimulate different cochlear regions. This bilateral mismatch may disrupt the binaural coherence of the input, thereby limiting CI users’ perception of ITDs. To investigate the effects of bilateral mismatch, bilateral tone detection in noise was measured in normal-hearing (NH) participants listening to 8-channel CI simulations (sine wave carriers).

The goal of Experiment 1 was to determine whether a spectral mismatch (within or across ears) degrades sensitivity to timing cues. Ten NH listeners were asked to detect a tone in steady noise. The tone was always presented out of phase across ears. The noise presented to each ear was either 100% correlated or 100% uncorrelated. The carrier frequency was either matched to the analysis frequency, or shifted by 1 mm in one ear, or in both ears. Thresholds significantly worsened when the noise was uncorrelated. When the noise was correlated, thresholds worsened only when the carrier frequency shift was applied to one ear; when both ears were shifted, thresholds were largely unaffected.

The goal of Experiment 2 was to see the effects of a wider range of bilateral mismatches. The amount of carrier frequency shift applied to one ear or both ears ranged from 0.5 to 4 mm; the noise presented to each ear was 100% correlated. When both ears were shifted, tone detection thresholds were not significantly affected by the amount of shifting. When one ear was shifted, thresholds gradually worsened for bilateral mismatches up to 2 mm, beyond which thresholds were unchanged.

The sine-wave CI simulation data suggest that reducing bilateral mismatches will likely improve ITD perception. The data also suggests that a modest (e.g., 1 mm) reduction in the amount of mismatch may not improve ITD perception for large bilateral mismatches (> 2 mm). In the real CI case, bilateral mismatches may be somewhat mitigated by the broad current spread associated with monopolar stimulation. Still, the present results suggest that even small bilateral mismatches may greatly limit CI users’ binaural perception.

Work supported by NIH-NIDCD R01-DC004993; equipment provided by Cochlear Americas and Compreval, Inc.

A1-b: Binaural Processing is Abnormal in Children Receiving Bilateral Cochlear Implants Sequentially

Daniel D.E. Wong[1] and Karen A. Gordon[1]
[1]The Hospital for Sick Children, Toronto, ON, Canada

Introduction: Children receiving sequential bilateral cochlear implants (CIs) with > 2 years between the implantations are at risk of abnormal auditory system development due to the duration of monaural hearing they experience before the second CI is implanted and/or their age at the second implant. This study evaluates differences in cortical processing of binaural sounds between sequentially implanted CI patients (>2 year inter-implant delay, right ear implanted first), simultaneously implanted CI patients, and normal hearing controls.

In binaural hearing, interaction between the left and right auditory pathways as they cross at the level of the brainstem results in an inhibitory/facilitation effect. This effect can be measured from electroencephalography recordings as a binaural difference component. Our study examines the activity in both auditory cortices evoked by binaural auditory stimuli, relative to that evoked by left and right monaural stimuli.

Methods: 64-channel electroencephalography was recorded from 8 sequentially implanted patients, 8 simultaneously implanted patients, and 8 normal hearing controls. Cortical potentials were evoked using electrical stimuli in participants with CIs, and with acoustic tone stimuli in normal hearing participants. Cortical sources of evoked amplitude peaks were localized to the auditory cortex using a beamforming algorithm designed to suppress stimulus artifacts produced by the CI. For each hemisphere, we computed a binaural difference dipole moment (BDDM) as the difference between the sum of the dipole moments evoked separately by left and right ear stimuli minus that evoked binaurally.

Results: Preliminary analyses from normal hearing controls and three sequentially implanted CI patients show a reduction in the left hemispheric BDDM in sequentially implanted CI patients compared to normal hearing controls. BDDM measures in simultaneously implanted children were more similar to those in normal hearing children.

Conclusions: These findings indicate that there may be an advantage in simultaneously implantation for cortical binaural summation. Aberrant binaural summation may have implications for binaural sound processing.

A2: Effect of Mismatched Place-of-Stimulation on Binaural Sensitivity in Bilateral Cochlear-Implant Users

Alan Kan, Matthew J. Goupell, and Ruth Y. Litovsky
Binaural Hearing and Speech Laboratory, Waisman Center, University of Wisconsin

In bilateral cochlear-implant (CI) users, interaural mismatch in the place of stimulation is likely to occur due to differences in implantation depth. The implications of this mismatch on binaural listening are not well understood. A series of experiments were conducted in Nucleus CI users in order to systematically investigate the effect of mismatch on binaural sound image perception, lateralization and discrimination thresholds.

First, an experiment was conducted to find a pair of electrodes across the ears that are perceptually pitch-matched, and placed approximately in the middle of the electrode arrays. The pitch-matched pair was then level-balanced to provide a centered image for the subject at a comfortable listening level. Stimuli played on this electrode pair formed the reference or "matched" condition in the subsequent experiments. In the condition with mis-matched place of stimulation, the electrode used in one of the ears was the same as in the reference condition, but the electrode used in the opposite ear was 2, 4, or 8 electrodes away from the matched electrode in that ear. All stimuli had a 300-ms duration, 100-pulses-per-second stimulation rate, and were constant amplitude.

Subjects participated in three psychoacoustic tasks. In task one, subjects were presented with sounds from the matched and mismatched conditions and they provided a subjective description of the perceived sound image by choosing from a 10-category list that described various intracranial locations and degrees of fusion. In task two, subjects were asked to report on the perceived lateral position of the sound stimuli when interaural time differences (ITD) or interaural level differences (ILD) were applied to the sounds in the matched and mismatched conditions. In task three, a two-alternate forced choice task was conducted to investigate ITD and ILD sensitivity as a function of mismatch.

The results from the first task showed that subjects mostly reported a fused single image in all conditions, but the image was often reported as being lateralized to the side in the mismatched conditions. This lateralization of the sound image was also seen in the results of the second task, where with increasing distance from the pitch-matched electrode, the sound image perceived by the subject was often biased to one side, regardless of the ILD or ITD imposed on the stimuli. For the third task, subjects showed increased thresholds with increasing mismatch. The CI data from these three tasks were also compared to those taken in normal-hearing listeners with comparable pulsatile stimuli.

Work supported by NIH-NIDCD (R01 DC003083 to R. Litovsky; K99 DC010206 to M. Goupell)

A3: An Android Auditory Training App For Sequential Bilateral Cochlear Implant Users

Erin Schafer[1], Behnam Azimi[2], and Yi Hu[2]

[1]Department of Speech and Hearing Science, University of North Texas, Denton, TX, 76203, USA
[2]Department of Electrical Engineering & Computer Science, University of Wisconsin-Milwaukee, Milwaukee, WI, 53211, USA

Speech recognition performance of cochlear implant (CI) users is significantly degraded in noisy environments. One rehabilitative strategy for significantly improving performance in noise for people with CIs is the provision of binaural input with a second CI. For bilateral CI users, binaural benefit in background noise varies across individuals and binaural-listening effects. For instance, speech recognition studies reveal limited squelch effects (i.e., interaction) for bilateral CI users, but substantially larger head-shadow effects. These issues highlight the critical communication barriers of bilateral CI users in noise and support the need to remove these barriers through routine rehabilitation recommendations.

In the present study, we will provide evidence to support auditory training for individuals with sequential bilateral CIs; we propose to implement auditory training on Android phones. The rationale is threefold. First, adults using sequential bilateral CIs, approximately 76% of the bilateral CI population, are expected to show greater training benefits than simultaneous CI users because of the performance differences between ears. Second, existing programs were not designed to train on binaural-listening tasks and involved mostly unilateral CI users. Finally, most existing programs require home-based training, which limits the portability and accessibility of the auditory training program. Thus, the proposed Android auditory training App is expected to improve user convenience and compliance for completing auditory training.

A total of 20 subjects will participate in three testing sessions in the laboratory as well as four-week/20-session auditory training in the field on an Android smartphone. This experiment will train with suprathreshold dichotic speech and noise stimuli. Performance on the training tasks will be logged and uploaded to a secure web server to allow for monitoring by the investigative team. To examine generalization in the present study, speech perception in noise will be evaluated before and after training to assess the use of spatial cues in noise. Subjective reports of hearing disability in real-world listening situations and usefulness (i.e., convenience, accessibility) of the program will also be collected via questionnaires. Preliminary results with one sequential bilateral CI recipient showed significant gains in binaural benefit following auditory training exercises in noise, and she reported that the auditory-training exercises were very helpful.

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A4: Binaural Time-Intensity Trading in Congenital Deafness.

Jochen Tillein[1,2,3], Peter Hubka[1], Andrej Kral[1]

[1]Experimental Otology, ENT Clinics, Medical University Hannover, Germany
[2]ENT Department, J.W.Goethe University Frankfurt, Germany
[3]MEDEL Innsbruck, Austria

The functional development of the auditory cortex is severely affected by total absence of auditory input. Nevertheless, basic functional units representing auditory spatial cues were sparsely found also in naive primary auditory cortex (Cereb Cortex 2010, 20:492). The present study is focused on the ability to integrate interaural time (ITD) and intensity (ILD) cues in the primary auditory cortex of congenitally deaf white cats (CDCs). Four CDCs and four hearing control cats (HCs) aged > 6 months were investigated. Acute deafening of control cats was achieved with intracochlear application of neomycin. Animals of both groups were electrically stimulated via binaural cochlear implants. Activity was recorded in the primary auditory field A1 by means of 16-channel microelectrode arrays. Unit responses were evoked by pulse trains (500Hz, 3 pulses) at intensities of 0-12 dB above brainstem response thresholds. In order to analyze influence of ITD on ILD functions, the ILD function (under same average binaural level) was measured at ITDs of ±400µs, ±200µs, ±100µs and 0µs, respectively.

Three categories of responses were found: 1. ILD responses that were insensitive to ITD changes (no time-intensity trading); 2. ILD responses showing a systematic contra- or ipsilateral shift, depending on ITD (systematic time-intensity trading); and 3. ILD responses that interacted with different ITDs in a nonsystematic manner (nonsystematic time-intensity trading). In hearing controls, the majority (~ 60%) of ILD responses were ITD insensitive, with a preference for contralateral ILDs. However, 30 % of ILD responses systematically shifted with ITDs. In contralateral ILD responses, ipsilateral ITDs (ipsilateral ear leading) led to a shift of ILD functions to the contralateral hemispace. In contrast, contralateral ITDs (contralateral ear leading) shifted the ILD function to the ipsilateral side. Only small number of responses (~ 10%) belonged to nonsystematic time-intensity group. In CDCs, 80% of ILD responses were "sensitive" to ITDs, however with the majority of responses belonging to the nonsystematic time-intensity trading group. Only a minor portion of ILD responses showed a systematic time-intensity trading. The remaining 20% of ILD responses did not trade binaural intensity and time differences.

These preliminary results demonstrate that despite of a rudimentary sensitivity to ILDs and ITDs in deaf cats, their in majority nonsystematic time-intensity trading responses reveal a deficit in integration of binaural cues. The high number of insensitive trading responses in controls indicates the preference of contralaterality which is reduced in CDCs.

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A5-a: Electrically Evoked Post-Auricular Muscle Response In A Cochlear Implant User

Stefan B. Strahl[1], Philipp Spitzer[1], Marek Polak[1], Martin Zimmerling[1]

[1]Research and Development, MED-EL GmbH, Innsbruck, Austria

A cochlear implant (CI) must be custom fit to optimize its operation with the specific patient user. For CI users with limited auditory experiences or insufficient communication abilities (e.g. small children), these fitting parameters are difficult to be determined behavioral and often objective measures are applied therefore. The commonly used objective measures show either weak correlations with the fitting parameters (eCAP, eABR, $r<0.6$) or are difficult to measure although showing high correlations (eSRT, $r=0.9$).

The post-auricular muscle reflex (PAMR) is a large myogenic response that occurs between about 10 and 25 ms after an acoustic stimulus. It has been reported that the PAMR threshold shows a high correlation ($r=0.8$) with pure-tone average thresholds in normal hearing subjects and in subjects with sensorineural hearing loss using an acoustic stimulation (Purdy 2005).

We successfully recorded an amplitude growth function of electrically evoked PAMR (ePAMR) responses in one MED-EL PULSARci100 cochlear implant user using single 30 µs biphasic pulses at a repetition rate of 19 Hz. The ePAMR occurred between about 5 and 20 ms after the electric stimulus and the negative ePAMR peak had a latency of 7.43 ± 0.09 ms post stimulus onset. We recorded a maximal ePAMR amplitude of 10.9 µV at 1000 current units stimulation level (cu; 1 cu ~= 1 µA). The ePAMR I/O function showed a threshold between 400 and 550 cu which was above the CI user's behavioral threshold of 365 cu for the applied recording stimulus. We further recorded an eCAP amplitude growth function with a maximal eCAP amplitude of 312 µV at 1000 cu and the eCAP I/O function showed a threshold between 444 and 556 cu. The eCAP response was verified by measuring an eCAP recovery function.

We could show that an ePAMR can be recorded within a CI user and that due to a low stimulation threshold an amplitude growth function over the full dynamic range of the CI user could be measured. Together with the knowledge that the PAMR shares parts of the neural pathway with the stapedius reflex, similar high correlations with the fitting parameters as with the stapedius reflex could be possible. This renders the ePAMR to a promising objective measure to improve the fitting of a CI user.

Purdy et al., *The Post-Auricular Muscle Response: An Objective Electrophysiological Method For Evaluating Hearing Sensitivity*, Int J Audiol, 2005, 44, 625-630.

A5-b: Bimodal Simulations of Speech Discrimination in Noise: Effects of Loudness Mismatch Between Devices

Daniel S. Brickman [1], Lina A. Reiss [1], Marjorie R. Leek [1,2]

[1] Oregon Health and Science University, Portland, OR. USA
[2] National Center for Rehabilitative Auditory Research, Portland VA Medical Center, Portland, OR, USA

Increasing numbers of CI recipients have residual hearing and can use a hearing aid (HA) in the non-implanted ear together with the implant (bimodal stimulation). Benefits of bimodal stimulation over a CI alone include improved speech recognition in background noise, music perception, and sound localization. Standard CI and HA fittings are currently performed independently and may result in substantial interaural loudness mismatches due to differences in intensity and frequency content. It is unknown how loudness mismatches affect bimodal benefits.

We explored this question using simulations of bimodal stimulation in 16 normal-hearing listeners. Stimuli of spondees in two-talker background noise were processed through a simulated HA created with a low pass filter at 500Hz and a simulated CI (8 and 22 channels) produced by a noise vocoder. The HA and CI simulations were presented simultaneously to opposite ears, and a loudness matching procedure was used to match the intensity of the HA simulation to a fixed CI simulation intensity. Word recognition thresholds (defined as the signal-to-noise ratio (SNR) required for 50% correct identification) were measured for 3 simulated loudness conditions between the CI and HA: -7 dB, 0 dB, and +7 dB relative to the loudness-matched HA simulation intensity.

On average, subjects loudness matched the HA simulation 7.46 dB (8 channel) and 8.94 dB (22 channel) higher in signal RMS intensity relative to the fixed intensity CI simulation. Threshold SNRs were not significantly different between the loudness matched and unmatched (+/- 7dB) conditions for the 8 or 22 channel simulation (p=0.78, 8 channel; p=0.98, 22 channel). Over this small dynamic range of acoustic intensities (14 dB), interaural loudness differences did not significantly alter subjects' ability to perceive the information relevant to speech understanding. This finding is consistent with humans' ability to fuse sounds between the two ears for a wide range of interaural intensity differences.

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A6: The Contributions Of Harmonics To The Benefits Of Electroacoustic Stimulation

Qudsia Tahmina[1], Yi Hu[1,2], Christina Runge[2], and David R. Friedland[2]

[1]Department of Electrical Engineering & Computer Science, University of Wisconsin-Milwaukee, Milwaukee, WI, 53211, USA
[2]Department of Otolaryngology and Communication Sciences, Medical College of Wisconsin, Milwaukee, WI, 53226, USA

Listening in challenging conditions, such as in background noise, still presents difficulties to cochlear implant (CI) users. A new listening modality, electroacoustic stimulation (EAS), is a recent innovation in CI technology and has shown great potential in improving speech recognition in noise for patients with residual acoustic hearing. To study the mechanisms underlying EAS benefits, experiments using acoustic simulation have been conducted on normal-hearing (NH) subjects with several studies showing that F0 cues are beneficial for improving EAS listeners' speech recognition in noise.

Most previous studies on the importance of F0 cues to EAS benefits used lowpass filtering techniques to isolate the F0 regions; however, the generated stimuli contained two or more harmonics in the voiced speech, and it is not precise enough to use these stimuli to study the importance of the first harmonic (F0) to EAS benefits. A different approach is investigated in this study focusing on a well-established acoustic model of voiced speech production. Our rationale is that since this model governs how acoustic cues (including F0) in the voiced speech are generated, it is more appropriate to use this model rather than lowpass filtering techniques to study the mechanisms underlying EAS benefits.

In the present study using EAS simulation, we propose a synthesis-driven approach based on harmonic modeling of voiced speech. More specifically, we synthesized the voiced speech segments using all harmonics above 600 Hz plus different number of harmonics below 600 Hz. This way we can precisely control the target cues included in the generated stimuli. Five conditions were examined: all harmonics (All), the first harmonic (F0), all harmonics except F0 (All-F0), the second harmonic (2xF0), and the third harmonic (3xF0). Synthesized clean IEEE sentences mixed with speech shaped noise at 4/7/10/13/infinite (clean) dB SNR were used as test materials. Results indicated that: 1) All and All-F0 are not significantly different at all SNRs, 2) All and All-F0 are significantly better than F0 at all SNRs; 3) for synthesized clean sentences, the average percent correct score for F0 condition is 80%, and the scores for other conditions are all above 90%; 4) 2xF0 and 3xF0 are significantly better than F0 at 4/7/10 SNRs. The present study demonstrated the contributions of different harmonics below 600 Hz to the benefits of EAS.

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A7: Combined electric and binaural acoustic stimulation: improved speech recognition in complex listening environments

René H. Gifford[1] and Michael F. Dorman[2]

[1] Vanderbilt University, Department of Hearing and Speech Sciences, Nashville, TN
[2] Arizona State University, Department of Speech and Hearing Science, Tempe, AZ

Cochlear implant recipients with hearing preservation in the implanted ear have binaural acoustic hearing which potentially allows for coding of interaural time and intensity differences as well as redundant acoustic information. The potential advantages of having binaural acoustic hearing will not be large when speech and noise are presented from a single loudspeaker—as is typically employed in most busy clinical settings. To assess the effectiveness of preserved hearing in the implanted ear, we have collected speech recognition data from 15 patients who were implanted with a Nucleus Hybrid S8, L24, conventional N24 series implant, or Med El Sonata implant. Speech recognition was assessed using the HINT and AzBio sentences in conditions including 1) a diffuse restaurant noise originating from eight loudspeakers placed circumferentially about the patient's head, 2) spatially separated speech and noise with speech originating at 0^{o} azimuth and noise originating from either 0^{o}, 90^{o} or 270^{o}, and 2) in reverberation with a reverberation time (RT) of 0.6 seconds. For all patients, speech recognition was assessed with the contralateral hearing aid alone, cochlear implant alone, cochlear implant plus ipsilateral hearing aid, cochlear implant plus contralateral hearing aid (bimodal) and the best aided EAS condition. Results showed a significant advantage for the EAS condition with the two acoustic hearing ears in noise ($p = 0.004$) and in reverberation ($p = 0.01$). Using spatially separated scores, robust head shadow was noted for both ears (though larger for the implanted ear), considerable spatial release from masking, modest binaural summation, and little to no evidence of binaural squelch. The current results are similar to trends observed with bilateral cochlear implant recipients as related to head shadow, summation, spatial release from masking and squelch. Further, these data demonstrate the efficacy of hearing preservation in the implanted ear with either a short or long electrode array for improving speech recognition in complex listening environments—and that using standard clinical measures of speech perception will not necessarily highlight this benefit.

A8: The Effect of Hearing Aid Bandwidth on Bimodal Benefit for Cochlear Implant Users with Severe Hearing Loss in the Hearing Aid Ear

Arlene C. Neuman and Mario Svirsky

New York University School of Medicine, New York, New York

Updated audiometric criteria have resulted in a quickly expanding group of cochlear implantees who have some usable residual hearing in the contralateral ear and are candidates for bimodal fittings; a cochlear implant in one ear (full-length electrode array) and a hearing aid in the contralateral ear. Research has shown that the addition of acoustic information to the electrical information provided by the cochlear implant (either ipsilaterally in the case of hybrid patients or contralaterally in the case of patients with a standard electrode array) can result in impressive improvements in speech recognition performance. Much of the basic research on the benefits of bimodal listening has been carried out on listeners with substantial low frequency hearing. It is unclear how much benefit is obtained from the acoustic signal by listeners with more hearing loss in the hearing aid ear.

In the clinical reports based primarily on retrospective review of clinical results, some listeners obtain bimodal benefit, others do not obtain benefit, and speech recognition performance may actually decrease in some bimodal patients when the hearing aid is used in conjunction with the cochlear implant. A limitation of the majority of clinical reports is the lack of information about the characteristics of the hearing aid used. A second limitation is that in most cases, both the implant and hearing aid have been fit using standard methodology, i.e., as if each was being fit alone. Currently, little information is available about whether the hearing aid used in conjunction with a cochlear implant should be fit using conventional prescriptive targets, or whether the prescriptive target needs to be modified so as to best complement the information provided by a CI.

In the current experiment, we investigate the effect of hearing aid bandwidth on bimodal speech perception of a group of patients with severe sensorineural hearing loss in the hearing aid ear and a standard-length electrode in the ear with the cochlear implant. Speech recognition performance is measured using the AZBio sentence materials with the implant alone, hearing aid alone (standard NAL-R fitting), and in four bimodal conditions (CI plus HA bandwidths of 125-500, 125-1000, 125-2000, and standard NAL-R “wideband” fitting).

Results to date indicate that on average there is significant bimodal benefit with hearing aid bandwidths extending to 2000 Hz or higher, but there are individual differences in the bandwidth yielding the highest speech recognition performance.

A9: Comparisons of Mandarin and English sentence perception in EAS simulations

Nathaniel A. Whitmal III, Yinda Liu, and Richard Freyman

University of Massachusetts, Amherst, MA, USA

Cochlear implants have improved the speech perception abilities of many patients with severe and/or profound hearing losses. Yet, even the highest performing cochlear implant patients still experience difficulties in the presence of background noise. These difficulties may be attributed in part to removal of low-frequency fine-structure (LFFS) cues, which can also affect music perception and tone recognition in tonal languages such as Mandarin Chinese. One promising solution to this problem for listeners with residual low-frequency hearing is electric-acoustic stimulation (EAS), in which low-frequency acoustic input from a hearing aid supplements the signal from the implant. Studies using both vocoder simulations and implant fittings show that EAS provides significant improvements in speech perception in noise relative to implant-only listening. These improvements might be expected to benefit Mandarin-speaking subjects even more than they benefit English-speaking subjects, since LFFS provides crucial lexical information in Mandarin. To date, this hypothesis has not been tested extensively through direct comparisons of subject performance.

The present study compared the speech reception thresholds of Mandarin-speaking and English-speaking subjects listening through EAS simulators. Subjects participated in adaptive trials of either the Mandarin or the English Hearing in Noise Tests (Wong *et al.* 2007; Nilsson *et al.*1994), using commercially-available sentences masked by speech spectrum noise (both steady-state and amplitude modulated) and female two-talker babble in either Mandarin or English. The sentences and noise were presented in five conditions: unprocessed, processed by a 16-channel tone vocoder, or processed by one of three 16-channel EAS vocoders in which a subset of low frequency channels (4, 8, or 12) remained unprocessed to provide LFFS to subjects. Results indicate that Mandarin-speaking subjects benefited significantly more from the added LFFS than English-speaking subjects, with the largest differences observed for masking by babble.

A10-a: Identifying Coding Properties along Isofrequency Laminae of the ICC to improve Speech Perception in AMI Patients

Thilo Rode[1], Tanja Hartmann[1], Roger Calixto[1], Minoo Lenarz[1], Andrej Kral[1], Thomas Lenarz[1], Hubert H. Lim[2]

[1]*Hannover Medical University, Hannover, Germany*
[2]*University of Minnesota, Minneapolis, Minnesota, USA*

The auditory midbrain implant (AMI) is currently in clinical trials. However, performance levels are significantly lower than what is achievable with cochlear implants.Previous animal and human studies suggest that the limited performance may be attributed to insufficient activation across an ICC isofrequency lamina for transmitting important temporal cues. Thus we investigated how temporal firing patterns of neurons simultaneously vary across the ICC isofrequency laminae in response to natural vocalizations in guinea pigs to identify potential stimulation strategies to more effectively transmit temporal information.

Data were obtained from 19 ketamine-anesthetized adult normal-hearing guinea pigs. Eight different vocalizations (30-70 dB SPL, 10 dB steps) were presented through calibrated loudspeakers and the corresponding multi-unit activity was recorded across the ICC. Multi-site electrode arrays (NeuroNexus Technologies) were placed into the ICC to record from 6-12 different locations across an isofrequency lamina in each animal. We confirmed the location of each site based on frequency response maps and histological reconstructions (arrays were stained with a red dye, Di-I). These reconstructions allow us to pool data across animals. Post-stimulus time histograms (PSTHs) and temporal patterns were compared to the envelope in the frequency band of the vocalization that corresponded to the frequency response area of the given multi-unit cluster.

We observed that firing patterns of neurons within a frequency specific lamina can be predicted based on the spectrotemporal structure of the bandpassed stimuli for some of the vocalizations (e.g. tooth chutter and squeal). However, for the less periodic and more complex vocalizations (with varying frequency modulations, such as the whistle), the temporal firings patterns were less predictable from the spectro-temporal pattern of the stimuli. Although neurons across a lamina generally synchronized to the slower temporal modulations of the stimuli, it remains to be shown how these ICC neurons interact and code for finer temporal features.By further analyzing the simultaneously recorded single-unit responses across an ICC lamina, we hope to identify improved stimulation patterns for transmitting temporal information with a new multi-shank AMI in future patients.

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A10-b: Flexible Neural Electrode Arrays

Vanessa M. Tolosa, Kedar G. Shah, Angela C. Tooker, Heeral J. Sheth, Terri L. DeLima, Maxim Shusteff, and Satinderpall S. Pannu

Lawrence Livermore National Laboratory, Livermore, CA, USA

Since FDA approval in 1984, cochlear implants have been implanted in over 100,000 patients. Despite their success, problems such as poor spatial hearing, poor pitch recognition, and poor performance in noisy environments have not been resolved. Significant advances in auditory prostheses are required to reach the goal of restoring normal hearing to the profoundly deaf or hard of hearing. Understanding the fundamental mechanisms and interactions of the auditory system and the effect of electrical stimuli on the surrounding environment and auditory nerve fiber will advance cochlear implant technology.

To address this technological need, we have developed flexible, penetrating multi-electrode arrays capable of intraneural stimulation and recording. We have utilized streamlined microfabrication processes to create biocompatible polymer electrodes with integrated cables. The electrode array design is fully customizable, including electrodes (material, size, spatial arrangement, electrochemical properties), percutaneous connectors (e.g., ZIF, Omnetics), and insertion tips (silicon, quartz, boro-silicate, titanium, tungsten). High-density two-dimensional arrays have been reproducibly fabricated and implanted chronically in humans as an epiretinal prosthesis. The one-dimensional arrays have been used for acute intraneural stimulation of the auditory nerve and acute recording in the inferior colliculus in animals. Individually addressable micron-sized electrodes allow for selective stimulation at varying pulse parameters. This ability, along with a laminar probe design composed of variable-sized electrodes were utilized to study the effects of frequency-specific stimulation of the auditory nerve, as well as to study optimal stimulating parameters for auditory prostheses. More recently, we have developed probes with electrode arrays on both surfaces. The electrodes on these dual-sided probes can be aligned, allowing for stimulation of and/or recording from neurons at the same depth but opposite sides of the shank, or they can be staggered, effectively reducing pitch without increasing the device size. Extensive testing and characterization have been performed on the electrode arrays including: electrochemical testing of electrode lifetime, lifetime accelerated soak testing, and stimulation and recording pulse testing under simulated *in vivo* conditions.

We have demonstrated a flexible, microelectrode array device capable of chronic animal implantation. This multi-functional neural device has been used as a research tool to study the auditory nerve in animals as well as a long-term implantable neural prosthesis in humans.

A11-a: Changes In Behavioral T- And C-Level Profiles As A Function Of Mean Stimulation Level

Bruna S. Mussoi[1], Carolyn J. Brown[1,2], Christine P. Etler[2], Paul J. *Abbas*[1,2]

[1] Department of Communication Sciences and Disorders, University of Iowa, Iowa City, IA, US
[2] Department of Otolaryngology – Head and Neck Surgery, University of Iowa, Iowa City, IA, US

Since the introduction of neural response telemetry, many studies have described the relationship between Electrically Evoked Compound Action Potential (ECAP) thresholds and the levels used to program the speech processor of cochlear implants. Unfortunately, the variance across subjects and electrodes is such that methods of predicting either T- or C-levels (behavioral thresholds and maximum acceptable levels, respectively) from the ECAP thresholds have proven to be only modestly successful. Recently it has been suggested that the variance in C-level profiles across electrodes (the C-level profile) is smaller than the variance in T-levels across the electrode array (the T-level profile). This observation led Botros and Psarros (2010) to propose a new method for predicting cochlear implant programming levels from ECAP thresholds. This method predicts flatter profiles as the mean ECAP threshold level is increased to predict C-levels. They derive their method on a relatively small group of 15 Nucleus Freedom recipients with either a Contour or Straight electrode array. While their finding seems plausible in terms of loudness summation and channel interaction, it is not known whether it can be replicated for a larger group of individuals with different devices.

The current study investigates how T- and C-level profiles are related to the ECAP threshold profile and how that relationship may vary as a function of stimulation level. Data from over 50 subjects with ECAP thresholds from 7 or more electrodes distributed across the electrode array, as well as programming levels at different rates were examined. Subjects were Nucleus 24M, 24R and 24RE adult cochlear implant users. Individual regression lines were computed in order to achieve the scale of best fit between the shifted and scaled ECAP threshold profile and T- or C-level profiles. The scales of best fit were pooled for all subjects and compared against their corresponding individual mean T- or C-level profile. Through linear regression, a single scaling factor to be applied to ECAP thresholds when predicting T-and C-levels was calculated (as in Botros & Psarros, 2010). Results from the regression analyses will reveal how T- and C-level profiles vary as a function of mean stimulation level. In addition, a scaling factor that is representative of a larger implanted population with diverse devices should be derived. The implications of these findings will be further discussed.

A11-b: Improving Electrically Evoked Compound Action Potential Measures For Setting Current Levels In Cochlear Implantees

Kirpa N.K. Chandan, Catherine Siciliano, Karolina Kluk and Colette M. McKay

School of Psychological Sciences, University of Manchester, UK.

The current procedure for fitting cochlear implants is time consuming and uses behavioural measurements that are sometimes difficult to obtain. Infants are currently fitted using some information obtained from the behavioural tests alongside ECAP thresholds. However, there are limitations to using ECAPs as the thresholds are not well correlated with behavioural thresholds at high rates of stimulation. Currently, ECAP measurements do not take into account the neural refractoriness that occurs in high-rate stimulation. Increasing the rate induces more refractoriness, but this effect may be patient-dependent. It is hypothesised that measuring refractoriness in ECAP measures that use pulse train maskers at different stimulation rates may lead to a measure that will improve correlation with behavioural data. This experiment investigated the relation between the effect of rate on loudness and the effect of rate on neural refractoriness.

Psychophysical thresholds and maximum comfortable levels at a mid-electrode position were determined for varying rates of stimulation (40 Hz, 250 Hz, 500 Hz, 900 Hz, 1200 Hz, 1800 Hz and 2400 Hz). Thresholds were measured using a 3-interval, 3-alternative forced choice task and a 2-down 1-up adaptive procedure. Loudness balancing across rates of stimulation was completed using a 2-interval forced choice task and a 1-up 1-down adaptive procedure at 90% and 60% of the dynamic range. ECAP measurements were made using pulse train maskers of the same rates. The degree of neural refractoriness at each rate was derived from the reduction in ECAP amplitude from the first to the subsequent pulses in the pulse train. This reduction in amplitude was correlated at each rate with the change in behavioural threshold between 40 Hz and the rate in question. Preliminary results will be reported.

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A12: Electrophysiological Recording During Cochlear Implantation: Results in Animals and Humans

Faisal I. Ahmad, Baishakhi Choudhury, Christine E. DeMason, Craig A. Buchman, Oliver F. Adunka, Douglas C. Fitzpatrick

Department of Otolaryngology, University of North Carolina at Chapel Hill, NC, USA

The combination of electric and acoustic hearing (EAS or hybrid stimulation) has been shown to improve speech discrimination scores, especially in background noise - a weakness of conventional cochlear implants. Development of an intraoperative recording algorithm during electrode insertion could optimize electrode placement and insertion depth and help to avoid intracochlear damage. We have established an animal model to identify physiological markers useful for this recording capability with the ultimate goal of translating these methods to humans.

The gerbil was used because it has good low frequency hearing and a readily accessible cochlea. The cochlear microphonic (CM) and compound action potential (CAP) were recorded in response to acoustic stimulation as the electrode was advanced through the round window (RW). Experiments used normal hearing animals to provide the most sensitive measure of the effects of electrode contact with cochlear structures, and noise-exposed animals to produce hair cell damage and hearing loss comparable to that of residual hearing candidates. The electrodes used were either a rigid wire or a flexible silastic electrode. Sites of cochlear damage (if any) were determined histologically.

In normal hearing animals, for both radial and longitudinal electrode insertions, contact with the basilar membrane caused a reduction in amplitude of the CM and/or the CAP across a range of frequencies and intensities. Since the changes were not restricted to near-threshold intensities or near the characteristic frequency of the recording site, a reduced stimulus set consisting of a single frequency and suprathreshold intensity was used to detect interactions across a wide region of the cochlea in real-time. The sensitivity was high enough that a small reduction could be detected that was reversible with electrode retraction. In noise-exposed animals, the potentials to preserved frequencies were large enough that the efficiencies of a small stimulus set were maintained; electrode-induced damage to preserved apical hair cells from basal trauma could also be detected. Preliminary results in human EAS candidates indicate that potentials for preserved frequencies are also large and detectible at the RW.

Reductions in intracochlear potentials provide a sensitive physiological marker of electrode contact with cochlear structures. Our results suggest that these markers can provide a sensitive and efficient means of determining cochlear health during an electrode insertion.

A13: C-levels, ECAP Thresholds and Impedance Values for Infants who use the Nucleus Hybrid S12 CI

Christine Etler[1], Ben Kirby[2], Jennifer Fowler[2], Carolyn Brown[1,2], Tanya Van Voorst[1], Stephanie Gogel[1], Camille Dunn[1]

[1]University of Iowa Hospitals and Clinics, Department of Otolaryngology, Iowa City, IA, USA
[2]University of Iowa, Department of Communication Sciences and Disorders, Iowa City, IA, USA

In this presentation, we compare C-levels, ECAP Thresholds and impedance values between ears in nine infants implanted with a short 10mm electrode array (Nucleus Hybrid S12) in one ear and a standard 24mm electrode array (Nucleus Freedom) in the other ear. These infants have profound bilateral sensorineural hearing loss and are participating in a feasibility trial aimed at validating a new approach to bilateral implantation for children. The use of a shorter electrode array may preserve the structures of the scala media and Organ of Corti without negatively impacting performance. Through comparisons between ears and comparisons with infants implanted with standard length arrays, the evaluation of this approach is continuing.

C-level, ECAP threshold and common ground impedance data are examined and differences between ears are described. Impedances between the shorter array and the longer array do not differ greatly after initial stimulation. Both C-levels and ECAP thresholds are higher on the short array ear than in the standard array ear.

Since this disparity is presumably not related to physiologic differences in the ears, we question whether it is due to the difference in the design of the electrode arrays and/or to dissimilarity in programming parameters between ears. Normative values for C-levels, ECAPs and impedances in a different group of infant users of the Nucleus Freedom with standard length arrays has been established and are used to make further comparisons.

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A14: Evoked Compound Action Potentials Versus Implant Evoked Electrical Auditory Brainstem Resposnses In Cochlear Implant Recipients

Ralf Greisiger[1,2], Ole Tvete[1], Jon Shallop[3], Greg Eigner Jablonski[1]
[1] Department of Otorhinolaryngology, Oslo University Hospital, Norway
[2] Department of Informatics, University of Oslo, Norway
[3] Mayo Clinic and Associate Faculty, University of Arizona, USA

Introduction / Study Objectives

During the last years Evoked Compound Action Potentials (ECAP) have been evaluated as a fitting help in Cochlear Implant (CI) patients. In this study we investigated the difference between ECAPs and implant Evoked Electrical Auditory Brainstem Responses (impEABR) at the same type of stimulation.

Method

30 patients have been examined by measuring the intra operative ECAP levels along the electrode array at stimulation levels of 220CL at 25us pulse width. Right afterwards the same stimuli was used for impEABR recordings.

Results

Preliminary results have shown very different amplitudes, for the different measurements, within patients. Patients with large ECAP responses did not have necessarily large impEABR responses. Other patients with very poor ECAP responses had good impEABR responses.

Discussion

ECAPs are very early responses from the auditory pathways compared with brainstem responses. Does impEABR give better feedback about the electro neural interface functions in CI patients?

Conclusion

ECAP and impEABR can give valuable information. ECAPs can indicate for example a tip fold over by using spread of excitation measurements. In case of cochlear nerve deficiency impEABR can show how much will be transferred.

A15: Cortical Representations Of Time-Varying Cochlear Implant Stimulation In Awake Primate

Luke A. Johnson, Charles C. Della Santina and Xiaoqin Wang

The Johns Hopkins School of Medicine, Baltimore MD, USA

The success and limitations of a cochlear implant (CI) depends on the central auditory system's ability to process and interpret intra-cochlear electric stimuli. We developed a new non-human primate model to study cortical processing of CI stimulation: the common marmoset. Marmosets have a rich vocal repertoire, are highly communicative, and have similar hearing range and brain structures as humans. These similarities make it a very valuable model to address important issues in CI research.

In our study, a multi-channel electrode was chronically implanted in one cochlea; the other cochlea remained acoustically intact. This enabled us to record and compare on a neuron-by-neuron basis responses to acoustic, electric or electric/acoustic combination stimuli. We found that CI stimulation elicits activity in primary auditory cortex (A1) spanning much of marmoset hearing range, including their vocalization range. In general fewer neurons are activated by CI stimulation compared to acoustic stimulation. This may be explained in part by broader cochlear excitation areas caused by electric stimulation compared to acoustic stimuli, and that many cortical neurons have narrow tuning and sideband inhibition.

A limitation of previous cortical neurophysiology studies of CI stimulation has been the use of anesthetized preparations, which have been shown to alter auditory cortex responses. We investigated single-unit responses to time-varying signals via CI stimulation in A1 of the awake marmoset. Electric current pulses were delivered at repetition rates of 2-256 Hz. Consistent with earlier CI studies, some A1 neurons showed stimulus-synchronized responses to slow pulse rates (<64 Hz), but poor or no synchronization at rapid pulse rates. Interestingly, we found another population of A1 neurons that had significant increases in firing rate to rapid electric pulse trains (>64 Hz) sustained throughout the stimulus duration. Often these neurons showed little synchronization in response to slow pulse trains. This population of A1 neurons was not observed in previous studies with anesthetized preparations. These results parallel findings from previous studies in normal hearing marmosets which show that A1 neurons utilize both temporal and firing rate-based representations to encode time-varying acoustic signals (Lu et al 2001), and suggest that A1 neurons utilize similar coding schemes to represent time-varying CI stimulation. This line of research improves our understanding how A1 processes time-varying CI stimulation, which is a fundamental issue in understanding how the brain processes natural sounds via a CI device.

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A16-a: The Influence of Phonotactic Probability on Repetition Accuracy of Nonwords by Children with Cochlear Implants

Ann E. Todd, Jan R. Edwards, Ruth, Y. Litovsky

University of Wisconsin, Madison, WI, USA

Phonotactic probability refers to the frequency with which sounds and sound sequences occur in words in a language. Children typically repeat high-probability sound sequences in “nonsense” words more accurately than low-probability sound sequences, presumably because children can map the high-probability sound sequences onto sound sequences that occur in the words that they know. It is unknown whether phonotactic probability affects the accuracy of nonsense word repetition by children with cochlear implants (CIs). Due to limitations in speech perception, children with CIs may have less robust phonological representations for the words that they know, and furthermore, may have smaller vocabulary sizes than normally hearing (NH) children. Therefore, we hypothesized that the effect of phonotactic probability on accuracy of nonsense word repetition would differ between children with CIs and NH children.

We presented nonsense words with initial syllables that varied in phonotactic probability in English, to 4- and 5-year-old children with CIs and to two comparison groups of NH children, chronological-age peers and receptive-vocabulary peers. All children were monolingual English speakers. The children’s repetitions of the nonsense words were recorded, and initial consonants were scored for accuracy. Results showed that for all groups, repetition accuracy was higher for high-probability sound sequences than for low-probability sound sequences. The effect of phonotactic probability on accuracy did not differ significantly between the children with CIs and either comparison group of NH children. However, the children with CIs showed greater variability in accuracy than the NH children when phonotactic probability was high. The results suggest that when encountering novel strings of sounds, children with CIs are influenced by the phonological structure of the words in their lexicons, but for some children with CIs, this influence is reduced compared to what is observed in NH children.

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A16-b: The Effect of Frequency Response on Music Perception by Cochlear Implant Users

Matthew P. Fraser, Emily R. Statham, Linor L. Williams, & Colette M. McKay

University of Manchester, Manchester, UK

Two studies investigated how the fitting parameters of a cochlear implant may be adjusted to improve satisfaction for music listening. The first study investigated the effect of increased input compression or flattened input frequency response on music perception. Ten Nucleus Freedom CI-users were tested using a forced-choice preference listening task involving pairs of music stimuli. Three different versions (original, compressed and flat frequency response) of each music extract were presented. Results revealed no significant difference in preference for original versus compressed versions, but a significant preference for the flat frequency response version over both original and compressed versions.

The second study investigated the effect of flattened frequency response in a take-home study. Two new programmes were created, one with a flattened frequency response and one with the standard rising frequency response. Real-life music-listening satisfaction was assessed in twelve CI-users, including two bimodal-listeners, in a take-home study using questionnaires to record preference between the rising and flattened frequency response for multiple music-listening experiences. Results showed no significant overall preference for either frequency response but individual preference varied and appeared dependent on experience, musical genre and environment. Anecdotal evidence in two listeners indicated that bimodal hearing may increase music satisfaction and increase preference for a flattened frequency response.

These studies suggest that an alternative frequency response may improve music enjoyment and should be considered when creating 'music-listening' programmes.

These experiments were financially supported by the UK Medical Research Council.

A17: EMERGENT LITERACY SKILLS OF KINDERGARTEN CHILDREN WITH COCHLEAR IMPLANTS

Susan Nittrouer[1], Amanda Caldwell[1], Daniel Burry[1], Christopher Holloman[2], Joanna Lowenstein[1], Eric Tarr[1], and D. Bradley Welling[1]

[1]Otolaryngology, The Ohio State University
[2]Statistical Services, The Ohio State University, Columbus, Ohio, USA

A key ingredient to academic success is being able to read. Deaf individuals have traditionally failed to develop literacy skills comparable to those of their normal-hearing peers, but early identification and implant technology have raised hopes that the situation will change. Here we present data on the emergent literacy skills of a group of children with cochlear implants (CIs) who were all identified early and received their first CIs early (typically before 2 ½ years). Children with two CIs generally had two or more years experience with bilateral stimulation. Roughly half the children had six months or more of electric-acoustic stimulation earlier in life. Some of those children got a second implant and some did not, but just one wore a contralateral HA at the time of testing.

Twenty-five children with one or two CIs from across the country traveled to The Ohio State University in the summer of 2010, after completing kindergarten, to be tested. Eight kindergartners with bilateral hearing aids (HAs) and 18 kindergartners with normal hearing (NH) were also tested. Other than hearing loss, all children were free from conditions that would be expected to affect language acquisition. All children with hearing loss had received early intervention designed to promote the development of spoken language, either on its own or with sign support. Time spent in intervention and credentials of providers were equivalent across programs attended by all children.

In 2008, the National Early Literacy Panel identified skills that contribute to early literacy, and those skills served as the focus of the emergent literacy assessments conducted. Testing included two tasks examining cognitive abilities that contribute to literacy: processing speed and working memory. Psycholinguistic skills that support literacy development were also examined, and results are reported for three of them: phonological awareness, auditory comprehension of language, and oral narrative skills. Reading skills examined were: word reading, reading comprehension, and fluency.

Results showed that children with CIs performed more similarly to children with NH or HAs on measures of cognitive functioning than on those of psycholinguistic skill. Children with two CIs did not consistently perform differently from children with one; when differences were observed, children with two CIs typically performed more poorly. Children with some electric-acoustic experience performed better on all tasks than those with no such experience. Interpretation was that children with CIs are at risk of encountering problems acquiring literacy. Among suggestions for ameliorating these problems is the idea of providing some period of electric-acoustic stimulation, when appropriate for a given child.

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A18: The Mismatch Negativity Evoked by Pitch Contour Changes in Cochlear Implant Users

Fawen Zhang[1], Chelsea Benson[1], Lisa Houston[1], and Qian-Jie Fu[2],

[1]University of Cincinnati, Cincinnati, Ohio, USA
[2]House Ear Institute, Los Angeles, California, USA

Melodic pitch perception is difficult for cochlear implant (CI) users, largely due to the relatively coarse spectral resolution afforded by the implant device (i.e., a peripheral limitation). Melodic pitch perception may also be limited by neural degeneration in the auditory system due to deafness (i.e., a central limitation). The mismatch negativity (MMN) for auditory evoked potentials (AEPs) occurs in a latency range of 150-250 ms, and is thought to reflect the automatic (pre-attentive) detection of sound changes in the auditory cortex. In this study, the MNN in response to five-note pitch contours was compared to melodic contour identification (MCI) performance using similar stimuli in normal-hearing (NH) and CI listeners.

To date, ten NH subjects were tested while listening to unprocessed stimuli and six CI subjects were tested while listening to their clinical processors and settings. In the MCI task, subjects were asked to identify five-note melodic contours (Rising, Falling, Flat, Rising-Falling, Falling-Rising, Flat-Falling, Flat-Rising, Falling-Flat, Rising-Flat); the spacing between notes in the contour was either one or five semitones. AEPs were recorded with a subset of stimuli used in the MCI test.

Preliminary results showed that the MMN could be identified from the best-performing (83% correct) CI subject in the MCI task. The obligatory event-related potentials (ERPs) and MMNs in this CI subject were comparable (in terms of amplitude and latency) to those in NH listeners with good performance in the MCI test (n = 6, >90% correct). MCI performance for the remaining CI subjects was <60% correct, with more errors for contours with 1-semitone spacing; AEPs for these subjects showed poor ERPs and/or missing MMN.

The results suggest that, for most CI subjects, cortical encoding of melodic patterns was degraded at the pre-attentive level, probably due to some combination of poor peripheral representation and (possibly) deafness-related compromise of pre-attentive brain substrates. It is unclear whether the good CI performer benefited from a better peripheral representation or better cortical processing. Indeed, better understanding of the neural mechanisms that underlie melodic pitch perception may benefit CI signal processing and/or reverse cognitive processing deficits via auditory training.

Work supported by NIH R15-DC011004.

A19: Some Cochlear Implant Recipients Can Perceive Music Better Than Normal Hearing Listeners: A Case Study.

Jeremy Marozeau, Mohammad Maarefvand and Peter Blamey

The Bionic Institute, East Melbourne, VIC, Australia
University of Melbourne

It is commonly that cochlear implant recipients (CI) have difficulty in perceiving music. They show poor performance in melody recognition, timbre identification and pitch direction identification. On the other hand, in studies on CI performance in music perception, it is not uncommon that one or two subjects outperformed the average result by more than 2 or 3 standard deviations. Such listeners are called “Star Performers”.

In a recent experiment that studied how well participants could segregate two interleaved melodies, one of our CI participants (“X”) outperformed normal hearing professional musicians. Therefore we decided to perform a comprehensive case study of her musical hearing ability.

X is a 30 year-old woman. She lost her hearing in both ears due to inner ear autoimmune disorder. She was implanted one year ago with bilateral Cochlear© Nucleus 5 using the ACE strategy. The implantation was highly successful and she reached 99% CUNY sentence recognition after 3 months of implantation. D. is a dedicated amateur musician and has been playing piano for 17 years. Before losing her hearing, she claimed to have perfect pitch.

Her audiogram reveals some residual hearing in her right ear (65 dB HL at 250 Hz) but no hearing sensation on the left. Therefore, she was tested in free field with stimuli presented at levels lower than 70 dB SPL with only her left processor and an ear plug on the right ear.

The following experiments were performed: 1] pitch direction identification (at base frequencies around 49, 196, 698 Hz), 2] melody recognition without rhythmic and lyrics cues, 3] absolute and relative pitch assessment, 4] dissonance rating and 5] timbre recognition.

The results indicated that she outperformed non-musically trained listeners in pitch direction identification (less than a semitone at every base frequency) and in melody recognition. She has lost her perfect pitch ability but still can show relative pitch identification within the range of non-musically trained listeners. Her dissonance ratings show similar patterns to musically trained listeners. Finally, her ability in timbre recognition was half-way between results from normal hearing listeners and CI users.

These results are proof that some CI recipients can achieve very good performance in many aspects of music perception with existing sound processors.

A20-a: Place-Pitch Contour Discrimination Interference in Cochlear Implant Users

Ching-Chih Wu[1] and Xin Luo[2]

[1]Dept. of Electrical & Computer Engineering, [2]Dept. of Speech, Language, and Hearing Sciences, Purdue University, West Lafayette, IN, USA

Dynamic changes in frequency components of speech and music convey important cues such as prosody and semantic meanings. In multi-channel cochlear implants (CIs), incoming sounds are filtered into different frequency bands and band-specific information is sent to corresponding electrodes based on the tonotopic ordering of the cochlea. For speech and music inputs, the place and/or temporal patterns on different CI channels are likely to have very different dynamic nature. Thus, understanding CI users' perception of dynamic pitch cues on multiple channels is important for enhancing CI stimulation strategies. Previous studies have shown that normal-hearing listeners' detection of a target frequency modulation (FM) is affected by the presence of a masker FM, depending on the frequency separation and modulation similarity between the target and masker. This study examined CI users' discrimination of a target pitch contour in the presence of a masker pitch contour on a different channel.

Adult users of the Advanced Bionics CI devices participated in the study. Rising or falling pitch contours were generated by steering current between two adjacent electrodes (referred to as one channel), while flat contours by stimulating halfway between the two electrodes. The target channel was fixed on electrodes (5, 6), while the masker channel was on electrodes (6, 7), (8, 9), or (10, 11). The procedure included the following steps: (1) balance the loudness of all single- and dual-channel stimuli with flat contours at the most comfortable level; (2) measure the discrimination thresholds for falling or rising pitch contours on each single channel using a 3-interval, 2-alternative, forced-choice task and a 2-down/1-up adaptive procedure; (3) measure the target pitch contour discrimination thresholds when a pitch contour (flat, falling or rising at the single-channel thresholds) was presented in an interleaved manner on the masker channel.

The results showed a large inter-subject variability and inconsistent effects of target-to-masker spatial distance and masker contour direction on target pitch contour discrimination. It is possible that masker contours at the single-channel thresholds were too small to interfere with target pitch contour discrimination in the dual-channel context. Besides, subjects had different patterns of single-channel pitch contour discrimination, thus subject-specific peripheral characteristics may have affected individual's outcome greatly in the dual-channel pitch contour discrimination task. The lack of effect of masker contour direction suggests that our CI subjects may not effectively integrate dynamic frequency information on different channels according to their pitch-change directions.

A20-b: Attention/Memory Training Does Not Improve Auditory Performance for Cochlear Implant Users

Sandra I. Oba [1] and Qian-Jie Fu [1,2]

[1]House Ear Institute, Los Angeles, CA, USA
[2] University of Southern California, Los Angeles, CA, USA

Our previous research has shown that auditory training can significantly improve cochlear implant (CI) users' speech recognition (in quiet or in noise) and music perception. However, it is unclear whether such training improves listeners' auditory perception skills or if the training merely improves attention to the task at hand. In this study, speech and music perception, as well as auditory and visual memory, were assessed in ten CI users before, during, and after training with a non-auditory, attention/memory task. A forward visual digit span (VDS) task was used for training in which the listeners were asked to immediately recall visually presented sequences of digits.

Prior to training, baseline performance was obtained for IEEE sentences in quiet, HINT sentences in noise, digits in noise, vowels, consonants, voice gender, vocal emotion, melodic contour identification, auditory digit span (similar to VDS, but auditory-only) and VDS (same as the trained task). Baseline performance on all test measures was repeatedly measured for a minimum of four sessions. For each test, the two best session scores were averaged for a measurement of pre-training baseline performance. After completing baseline measures, subjects trained with VDS at home on their personal computers using custom software (Sound Express) for ½ hour per day, five days a week, for approximately four weeks (10 hours of training in total). During the VDS training, a sequence of digits flashed on the computer screen; subjects were asked to type in the sequence. Visual feedback was provided and the level of difficulty was adjusted according to subject response. Performance on all tests was re-measured after completing 5 and 10 hours of training. After completing 10 hours of training, training was stopped. Participants returned to the lab one month later for follow-up measures.

Results showed that after training with VDS, mean VDS test scores significantly improved from 6.8 to 8.0 digits. However, there were no significant improvements observed for auditory digit span, melodic contour identification or any of the speech recognition tasks. These results suggest the post-training improvements observed in previous studies with CI users were not solely attributable to improvements in attention and/or memory. CI users may require specific, targeted auditory tasks for training to improve speech recognition and auditory perception.

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A21: Infrared Neural Stimulation of Cochlear Spiral Ganglion with Angle-polished Optical Fibers

Suhrud M. Rajguru[1], and Claus-Peter Richter[1, 2, 3]

[1]Department of Otolaryngology, Northwestern University Feinberg School of Medicine, Chicago IL, USA
[2] Department of Biomedical Engineering, Northwestern University, Evanston, IL, USA.
[3] Hugh Knowles Center, Department of Communication Sciences and Disorders, Northwestern University, Evanston, IL, USA

Recent work has illustrated the feasibility of cochlear implants based on optical stimulation of cochlear spiral ganglion with pulsed infrared radiation. We have shown the efficacy and safety of the radiation in several animal models. The next step in the designing of an optical implant is to test multi-channel light-delivery systems. Such systems will be based on individual optical fibers that are angle-polished to direct the radiation towards the local population of spiral ganglions. Here, we report results from stimulation of guinea pig cochleae with custom-designed 45º angle-polished fibers. We compared the optical energies required to evoke compound action potentials and responses in the central nucleus of inferior colliculus (ICC). We also studied the spread of activity in the ICC for different insertion depths of the angle-polished fibers. The normal hearing guinea pigs were deafened with intracochlear injection of neomycin. Angle-polished fibers (200 µm core diameter) were inserted into the basal turn of the cochlea and were advanced to stimulate different populations of the neurons. Input/output responses of ICC neurons were recorded by varying optical radiation energy delivered via the fibers. The ICC recordings were made with a multi-channel electrode array that was inserted perpendicular to ICC frequency plane. Spatial tuning curves were created from the ICC recordings using ROC analysis and evoked changes in neural firing rate. Preliminary results show that the activity of ICC was spatially restricted and that different populations of the spiral ganglion can be stimulated.

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A22: Pulse Train Irregularity Detection in Normal-Hearing Listeners and Cochlear Implant Users

Etienne Gaudrain, John M. Deeks, Robert P. Carlyon

MRC Cognition and Brain Sciences Unit, Cambridge, United-Kingdom

Temporal acuity can be measured using a discrimination task between regular and irregular click trains of the same average pulse rate. Dobie and Dillier [1985, *Hearing Research*, 18, 41-55] reported jitter detection thresholds of about 1% (standard deviation of the period) in normal-hearing (NH) listeners whereas detection thresholds were between 15% and 30% in two deaf patients who received a single-electrode extra-cochlear implant.

In the present study, jitter detection was investigated in NH listeners and in Cochlear CI24M recipients (CI). Crucially, the acoustic click trains were bandpass filtered so that the remaining frequency components were, in some conditions, unresolved by the peripheral auditory system so as to eliminate place-of-excitation cues. The electric pulse trains were delivered by direct stimulation either to a middle electrode or to a more apical electrode, and had a nominal pulse rate of either 100 or 300 Hz. Rate discrimination was also measured, so that we could determine whether performance in the two tasks varied in the same way across electrodes and baseline rate. Finally, we investigated whether listeners detected the temporal jitter by virtue of amplitude modulation in the neural response, caused by pulses occurring after long and short intervals being differently affected by neural refractoriness. This was done by including a condition in which the amplitude of each individual pulse was roved.

Overall, the obtained thresholds were similar in NH and CI participants, consistent with temporal resolution being similar in the two groups when place-of-excitation cues are eliminated. Refractoriness does not seem to play a role in the performance, neither in CI nor in NH.

A23: Behavioral and physiological measure of frequency mismatch in cochlear implantees.

Chin-Tuan Tan[1], Ben Guo[1], Brett Martin[2] and Mario Svirsky[1]

[1] Department of Otolaryngology, NYU
[2] Program in Speech-Language-Hearing Sciences, Graduate Center of CUNY

One challenge faced by postlingually-deafened adult cochlear implant (CI) patients is to adapt to a frequency mismatch between the incoming acoustic signal and the characteristic frequency of the neurons stimulated by the implant. To investigate this potential mismatch, we examined CI users who have residual hearing in the contralateral ear psychoacoustically and physiologically, by comparing the pitch percepts elicited by electrical stimulation with those elicited acoustically

We have developed a real-time pitch matching platform using the NIC V2 toolbox (Cochlear Americas) to present interleaving short intervals (500ms) of acoustic and electrical stimulation to CI patients. They are instructed to adjust the frequency of the acoustic tone to match the percept elicited by electrical stimulation. This procedure is repeated six times for several electrodes in the array. The first five CI patients tend to display progressively higher pitch percepts when more basal electrodes are stimulated. Many electrodes were pitch matched to frequencies that were quite different from the center frequency of the corresponding analysis band, suggesting that adaptation to the clinically used frequency tables was not always complete. We also used the same stimuli (but using 1000 ms rather than 500 ms intervals) while recording Auditory Evoked Potentials (AEP's) on 6 NH subjects and 2 CI patients using a Neuroscan system. Each pair of electric and acoustic stimuli was repeated 500 times and the recording trigger was inserted at the end of each electrical stimulus. For 4 NH subjects we presented a fixed tone of 500Hz to one ear. and tones of 250Hz, 375Hz, 500Hz, 625Hz and 1000Hz to the other ear. For the other 2 NH subjects, we presented a fixed tone of 1000Hz to one ear, and tones of 250Hz, 900Hz, 1000Hz, 1100Hz and 4000Hz to the contralateral ear. The CI patients received electrical stimulation in electrode 20 (which is associated with a frequency band centered at 500 Hz in the clinical map) and the other ear was stimulated with six different acoustic frequencies, ranging from 250 to 1000 Hz and including the frequency that was pitch matched to electrode 20 by each individual. In all cases, N1 latency for NH subjects was minimized when the same frequency was presented to both ears. In the case of CI patients, N1 latency was minimized when the acoustic stimulus was the same frequency that was pitch-matched to the stimulated electrode.

This result seems to suggest that the latency of N1 can be used as an objective measure of pitch matching across two ears for the CI patients. We will next attempt to verify the efficacy of using this measure to examine how CI patients adapt to the frequency mismatch over time.

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A24-a: Observing the Enhancement Effect in Cochlear-Implant Listeners

Matthew J. Goupell and Mitch Mostardi

University of Wisconsin, Madison, WI, USA

The auditory system has an amazing ability to detect novel changes in acoustic stimuli. One such detectable change occurs when eliminating and reintroducing a harmonic in a complex tone, which causes the harmonic to stand out separately from the rest of the harmonic complex. This effect has been called the enhancement effect in the psychoacoustical literature. Previous experiments in normal-hearing listeners demonstrated that listeners could very accurately match the pitch of enhanced harmonics up to at least the twentieth harmonic for a 200-Hz fundamental frequency [Hartmann and Goupell, 2006, J. Acoust. Soc. Am., 120, 2142-2157]. We wondered whether the enhancement effect was observable in unilateral cochlear-implant (CI) listeners using a similar task.

Seven CI users were tested in an enhancement experiment using direct stimulation. Stimuli contained 2, 4, 6, or 11 electrodes as a “background.” The stimulation rate was 1000 pulses per second, per electrode. A target electrode was alternated off and on over five 0.75-s intervals. The task of the listener was to match the place-pitch of a target electrode to the place-pitch of a single electrode played without a background. All listeners could detect an audible change in the when target electrode was alternated off and on. Most listeners could reasonably match the pitch of the target electrode within a few electrodes, although their electrode-matching ability was worse than their ability to discriminate single electrodes without a background. It appeared that places with better electrode discrimination (without a background) correlated with better electrode matching in the enhancement task. Listeners who could not perform the task seemed to match with electrodes near the center of the electrode array, which would be the spectral center of the background stimulus. For listeners who appeared to be able to perform the pitch-matching task, a regression effect towards the center of the electrode array was systematically observed. These data show that spectral notches in multi-electrode stimulation, while typically difficult to detect for CI users in static stimuli, play a role in stimuli that change over time.

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A24-b: Temporal Modulation Transfer Functions For Child And Adult Cochlear Implant And Normal-Hearing Listeners

Min-Hyun Park[1,2], Jong Ho Won[1], Elyse M. Jameyson[1], Jay T. Rubinstein[1]

[1]Virginia Merrill Bloedel Hearing Research Center, Department of Otolaryngology-Head and Neck Surgery, University of Washington, Seattle, WA, 98195, USA
[2]Department of Otolaryngology, Boramae Medical Center, Seoul Metropolitan Government-Seoul National University, Seoul, Korea

Our previous work showed that prelingually deafened children with CIs showed similar spectral sensitivity and speech perception to adult CI users, but worse Schroeder-phase discrimination and melody recognition. These latter two tasks may also require good temporal sensitivity. Previous studies in normal hearing listeners showed that a maturational effect exists in temporal sensitivity. The present study evaluated the temporal modulation transfer functions (TMTFs) in child and adult cochlear implant (CI) and normal-hearing (NH) listeners. Four different groups of subjects were tested to determine if the use of CIs allows prelingually deaf children to develop temporal sensitivity comparable to their NH age matched controls.

Ten implanted children, seven age-matched normal children, twenty four postlingually deafened implanted adults, and seven NH adults participated. Modulation detection thresholds (MDTs) were evaluated at six modulation frequencies including 10, 50, 100, 150, 200, and 300 Hz using a method adapted from Bacon and Viemeister (1985). The CI subjects were tested with their sound processors in the sound field to evaluate their clinically relevant performance. The subject groups were compared by two parameters: y-intercept representing sensitivity to modulation and the slope of the function representing the peripheral or device encoding of the modulation.

Results showed that modulation sensitivity decreased as a function of modulation frequency in all four groups. The y-intercept was similar for NH adults, NH children, and implanted adults, but implanted children showed a significantly lower y-intercept, suggesting that these children had generally worse modulation sensitivity compared to the other three groups. The slopes of the functions were shown to be the same for NH adults vs. NH children, and for implanted adults vs. implanted children, whereas the slopes for the implanted groups were steeper than the NH groups. This suggests that the peripheral encoding of the modulation was driven by the hearing mechanism (NH or CI), not by age. Taken together, although implanted children's performance on speech perception appears to be as good as CI adults, they showed worse temporal modulation sensitivity compared to NH children and implanted adults.

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A25: Relating Loudness Growth to Virtual Channel Discrimination

Arthi G. Srinivasan[1,2], David M. Landsberger[1], Robert V. Shannon[1,2]

[1]Auditory Implant Research, House Ear Institute, Los Angeles, CA
[2]Dept. of Biomedical Engineering, Univ. of Southern California, Los Angeles, CA

We collected virtual channel (VC) discrimination data as part of a previous experiment in our lab which showed a relationship between dynamic range (DR) in µA and VC discrimination ability. Subjects with very small and very large DRs tended to have worse performance than subjects with medium DRs; there seemed to be a “sweet spot” in DR with respect to VC discrimination ability.

We hypothesized that the size of the DR might indicate characteristics of the underlying physiology, in particular, the existence of surviving dendritic processes. We further hypothesized that the shape of the loudness growth curve might indicate whether surviving dendrites were stimulated. Subjects with small DRs might not have surviving dendrites, and their loudness growth functions might have only steep growth (from central axon stimulation). Subjects with medium DRs might have surviving dendrites stimulated at low amplitudes, and their loudness growth functions might have initially slow growth (from dendritic stimulation at low current levels), followed by steep growth (from central axon stimulation at higher levels). Subjects with large DRs might have a greater amount of surviving dendrites, and their loudness growth functions might have slower growth. However, with large DRs, the absolute amplitude used (for example, in the VC discrimination task) would be at a higher level than that used for the medium DR subjects. At a higher absolute amplitude, current spread increases, which might explain why larger DRs seem to have poorer VC discrimination compared to medium DRs.

Loudness growth functions were measured for 6 Advanced Bionics CII or HiRes90K users. Stimuli were single electrode biphasic pulse trains (226 µsec/phase) with 550 pulses per second at amplitudes between 5 and 100% DR, in 5% steps. Subjects were instructed to click on a line to indicate the loudness of the stimulus.

Loudness growth functions were normalized for each electrode in terms of % DR. Power functions (of the form Loudness = a*xb*ampl.) were fit to the loudness growth estimates. Values of b close to 1 indicate linear growth, whereas values of b greater than 1 indicate non-linear growth (slow growth followed by steep growth). Results indicate a relationship between DR and the linearity of the loudness growth, with medium DRs having the most non-linear growth. Furthermore, there is a positive correlation between the linearity of the loudness growth and VC discrimination, where the most non-linear loudness growth (slow growth followed by steep growth) correlates with the best VC discrimination ability.

Additional studies (utilizing ECAPs) are in progress to further elucidate the relationships between DR, VC discrimination and spiral ganglion/dendritic survival.

A26: Enhancement Effects In Cochlear-Implant Users

Ningyuan Wang,[1] Heather Kreft,[2] and Andrew J. Oxenham[1,2]

[1]Dept. of Psychology, University of Minnesota, Minneapolis, MN 55455
[2]Dept. of Otolaryngology, University of Minnesota, Minneapolis, MN 55455

Auditory enhancement and context effects – similar to the negative afterimage and color constancy in vision – have been observed in auditory and speech perception in acoustic hearing. These effects may help "normalize" the incoming sound and produce perceptual constancy in the face of the variable acoustics produced by different rooms, talkers, and backgrounds. The neural mechanisms underlying auditory enhancement are not known, but one hypothesis is that the effects are due to changes in cochlear gain, produced by the medial olivocochlear complex (MOC) within the efferent system. It is not known whether cochlear-implant (CI) users experience similar context effects. If enhancement effects are found with CI users, then that would argue against the role of the MOC system, as the cochlea is bypassed in CI stimulation. On the other hand, if enhancement is not found in CI users, it may point to a potentially important aspect of hearing that is not currently captured by CI processors.

This study examined basic psychophysical auditory enhancement using simultaneous and forward masking, similar to the paradigm used by Viemeister and Bacon [J. Acoust. Soc. Am. 71, 1502-1507 (1982)]. In addition, the influence of enhancement on vowel perception was studied using a paradigm similar to that of Summerfield et al. [Percept. Psychophys. 35, 203-213 (1984)]. Performance was measured in CI users, normal-hearing listeners, and vocoder-based simulations of CI processing. For the masking experiments, thresholds were measured in CI users with both direct stimulation and via their daily speech processors. Initial results suggest some, but often reduced, enhancement in CI users for both simultaneous and forward masking. For vowel perception, some auditory enhancement, in the form of improved recognition for vowels preceded by an enhancer, was observed in all three subject groups. The results so far suggest that auditory enhancement effects may not be fully realized in CI perception, and that introducing enhancement-like effects through CI processing may help restore some important aspects of perceptual constancy.

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A27: Changes In ECAP Amplitude-Growth Functions Over Time After Neurotrophin Treatment

Sara A. Bowling[1], Stefan B. Strahl[1,2], Deborah J. Colesa[1], Seiji Shibata[1], Gina L. Su,[1] Yehoash Raphael[1] and Bryan E. Pfingst[1]

[1]Kresge Hearing Research Institute, Department of Otolaryngology, University of Michigan, Ann Arbor, Michigan, USA
[2]Research and Development, MED-EL GmbH, Innsbruck, Austria

Advances in preservation and regeneration of the peripheral fibers in the cochleae of animals promises future improvements in the nerve-electrode interface in cochlear implant patients. Electrically evoked compound action potentials (ECAPs) offer a non-invasive, objective measure of the condition of the auditory nerve. Prior studies have correlated EABR and ECAP amplitude-growth function thresholds and slopes with size of surviving nerve populations. We used neurotrophin treatment in deafened guinea pigs to regenerate peripheral fibers and measured ECAPs to assess the time course of changes in neural function.

We deafened SPF pigmented adult male guinea pigs by cochlear perfusion with 5% neomycin, inoculated the cochlea with either AAV.NT3 or AAV.empty and implanted with scala tympani implants with four intra-cochlear electrodes. ECAPs were recorded using four different stimulus paradigms. After inoculation and implantation, recordings for each animal were made every other day for the first two weeks, biweekly for the first month, and then monthly for 6 to 9 months.

Typically, neurotrophin expression peaks 10 days after inoculation and continues indefinitely. The changes over time in ECAP amplitude growth functions for the first ten days were erratic, probably due to variable effects of trauma, inflammation and recovery. During days 11-30, we found lower thresholds in the AAV.NT3 group compared to the AAV.empty group. We also found steeper slopes in the AAV.NT3 group, suggesting that a larger/healthier population of nerve fibers responded more robustly to each incremental change in the stimulus current. The implications of the ECAP measures will be assessed after histological analysis is performed on these animals. However, histological analysis from prior studies revealed that animals inoculated with AAV.NT3 had peripheral nerve fiber regrowth and greater spiral ganglion cell survival than those inoculated with AAV.empty. Given the ease of ECAP measurements, and the information obtained relating to the presumed cochlear health, ECAP measures in humans should be useful for estimating histopathological conditions while patients are still living, and may help determine parameters for improving cochlear implant function.

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A28-a: Optoacoustic stimulation of the Organ of Corti in situ and of isolated cells

Günter Reuter[1], Alexander Rettenmeier[1], Gentiana I. Wenzel[1], Michael Schultz[2], Alexander Heisterkamp[2], Thomas Lenarz[1]

[1]Department of Otolaryngology, ENT-Clinic MHH, Carl-Neuberg-Strasse 1, 30625 Hannover,
[2]Laser Zentrum Hannover, Hollerithallee 8, 30419 Hannover, Germany

Hearing impaired patients with residual hearing due to loss of the cochlear amplifier, the outer hair cells, might benefit of laser induced stimulation of the still functional inner hair cells. In contrast to the electrical current laser allow a more focussed stimulation in a fluid environment like the cochlea. We have previously demonstrated that green laser pulses applied at the cochlear level can activate the auditory pathway. The aim of this study was to assess if the physical process underlying this activation is the optoacoustic effect, the acoustic transient generated inside an absorbing tissue after pulsed laser irradiation.

Excised cochleae were dissected in artificial perilymph. The basilar membrane (BM; 1-3 turn) was exposed and stimulated with 10 ns laser pulses, 532nm and 355 nm wave length, at 10 Hz repetition rate, up to 30 µJ/pulse delivered by a Nd:YAG laser (Quantel Brilliant BW, France) via a 100 µm core diameter fiber. BM vibrations were measured with a Laser Doppler Vibrometer (Polytec, OFV 551, Germany).

The BM vibrations recorded consecutive to the laser irradiation showed a fast component (around 100 kHz) followed by a slower component (20 kHz) corresponding to the resonant frequency of the irradiated cochlear segment. These laser induced vibrations showed a direct correlation to the laser energy and an indirect correlation to the distance from the irradiation focus.

Whole-cell current recordings from HEK-293 directly stimulated via a glass fibre (532 nm, 250 µs, rep. Rate 100 Hz, 35 µJ, showed changes in dependence of repetition rate indicating opening of voltage depending channels at 90 mV potential.

We herein report a novel application of this physical process, the optoacoustic wave generation in the inner ear and subsequently the induction of basilar membrane vibrations. This novel stimulation strategy may be used in a new generation of cochlear implants to improve the frequency specificity during cochlear activation and thus enabling improved speech perception in hearing impaired patients with residual hearing.

A28-b: Channel Interaction During Infrared Neural Stimulation

Claus-Peter Richter[1-3], Suhrud Rajguru[1], Agnella Izzo Matic[1-2]

[1]Dept. of Otolaryngology, Northwestern University, 303 E. Chicago Ave, Searle 12-561, Chicago, IL, USA
[2]Dept. of Biomedical Engineering, Northwestern University, 2145 Sheridan Road, Tech E310, Evanston, IL, USA
[3]The Hugh Knowles Center, Department of Communication Sciences and Disorders, Northwestern University, Evanston, IL, USA

Spatial tuning curves were obtained from recordings of neural activity in the central nucleus of the inferior colliculus (ICC), while the cochlea was stimulated with infrared laser pulses. The results show that infrared neural stimulation (INS) in the cochlea evokes more selective responses compared to those evoked by electrical stimulation. However, it is not clear whether the increased selectivity can translate into a larger number of channels that can be identified independently by a user. With the present experiments, we examined channel interaction for INS during cochlear stimulation using a three channel light delivery system (LDS).

Channel interaction was examined during simultaneous or near simultaneous presentation of two optical stimuli. We measured the amplitude of compound action potentials evoked by the stimuli and compared the spatial tuning curves obtained from recordings of evoked activities in the ICC. The levels of the different stimuli were varied systematically. Two of the three stimulation sources on the LDS were used simultaneously and were separated by a distance of 1 mm and 2 mm. A Renoir and Capella Lockheed Martin Aculight laser, operating at radiation wavelength of 1860 nm, 100 μs pulse length, and pulse repetition rates of 10 Hz were used for the stimulation.

The results suggest that at 1 mm distance between the two sources, there was no interaction between the stimuli for low (~4 μJ/pulse) and medium stimulus levels (~20 μJ/pulse). Increasing the stimulus levels resulted in interactions between the electrodes.

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A29-a: Linked Bilateral Noise Reduction Processing for Cochlear Implants Users

Jorge P. Mejia[1,4], Harvey Dillon[1,4], John Heasman[2,3], Adam Hersbach[2,4] and Richard van Hoesel[3,4]

[1]National Acoustic Laboratories, Sydney, Australia
[2]Cochlear Limited, East Melbourne, Australia
[3]The HEARing Cooperative Research Centre (CRC)
[4]University of Melbourne, VIC, Australia

In recent years, noise reduction research has investigated processing that combines the outputs of microphones on both sides of the head. This bilaterally linked processing provides a greater output signal to noise ratio than is possible with conventional unilateral directional processing. Numerous algorithms have been proposed to achieve this, some of which rely on reference estimations of a known desired target signal while others are designed to produce super high spatial directivity (or super-directionality) and in so doing provide emphasis to a target sound emanating from a known spatial direction. The latter super-directional processing strategy presents an attractive prospect for a practical noise reduction application because in most listening situations listeners tend to naturally focus on frontal sound sources (frontal facing spatial direction). Here we examined the benefits of a super-directional linked bilateral noise reduction processing algorithm with unilateral implant users. Although our previous studies investigating super-directional processing with normal hearing participants have demonstrated 6 dB speech reception threshold improvements over unaided conditions, little is known about the potential speech intelligibility benefits with cochlear implant users under the same experimental conditions.

The super-directional linked bilateral beamformer was clinically validated in a number of unilateral Nucleus® cochlear implant recipients. For each subject, the performance of the algorithm was compared against the commercially available fixed directional microphone and the Focus® unilateral beamformer. Clinical performance for each test condition was determined by measuring adaptive speech reception thresholds (SRTs) targeting 50% sentence intelligibility for BKB-like sentences in competing noise (developed by the Hearing CRC). Two competing noise types were investigated, 4-talker babble and 20-talker babble. The individual talkers in the competing babble were spatially separated and roved from seven independent loudspeakers, equidistantly spaced around the subject. The audio test materials were recorded in a room with a reverberation time (T60) of 0.4 seconds representative of an average living room. Speech quality ratings of connected discourse in competing noise were obtained in each of the study sessions. A round robin tournament of paired comparisons was used to rank the programs with respect to sound quality. All clinical testing was conducted using the Cochlear ™ Nucleus ® real-time xPC system.

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A29-b: Benefit of Directional Microphone Systems From Hearing Aids for Cochlear Implant Users

Carolin Frohne-Büchner[2], Waldo Nogueira[2], Lucas Hoeppner[1], Tobias Rottmann[1], Volkmar Hamacher[2], Thomas Lenarz[1], Andreas Büchner[1]

[1]Medical University of Hannover, Department of Otolaryngology, Hannover, Germany
[2]Advanced Bionics European Research Center GmbH, Hannover
E-Mail: carolinf@abionics.fr

Even though directional microphones are state of the art for today's hearing systems, they are not consistently used in cochlear implant (CI) systems. This work evaluates the potential benefit of directional microphone systems from hearing aids for CI users.

A group of 14 adults with a HiRes90K system was enrolled in this study. The output of a high-end hearing aid from Phonak with an adaptive directional microphone system was coupled to the Harmony speech processor from Advanced Bionics. Speech perception with the directional microphone was compared to the speech perception with the omnidirectional setting. Speech reception thresholds were measured with the adaptive Oldenburger Sentence Test (OlSa). The signal was presented from the front speaker at variable levels, while uncorrelated noise was played at 60dB SPL(A) from three loudspeakers at 90, 180 and 270 degrees, aiming at a speech reception threshold of 50%. With the same setup, the benefit of a noise reduction algorithm was determined, without as well as in combination with the directional microphone.

The directional microphone led to a significant improvement of the speech reception threshold, from an average performance of +3.4dB SNR with the omnidirectional setting to -2.9dB with the directional microphone. By adding the noise reduction algorithm, the results could be further improved to a group performance of -4.5dB.

The data demonstrate the benefit of directional microphones for CI users. Especially when the directional microphone is used to shift the operating point of a concatenated noise reduction algorithm to a more favorable signal to noise ratio they yield significant improvements in noisy environments.

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A30: Silicon Cochlea Models for Enhancing Cochlear Implant Research

Tara Julia Hamilton[1], André van Schaik[2]

[1]University of New South Wales, Sydney, NSW, Australia
[2]University of Western Sydney, Penrith, NSW, Australia

A silicon cochlea is an integrated circuit (IC) that contains circuits that model the fluid dynamics as well as the mechanical and electrical behaviour of the biological cochlea. Researchers have been building, studying and improving silicon cochleae for over 20 years and before that discrete components were used to model the equations that underlie the behaviour of the cochlea. The biological cochlea is of great interest to engineers and mathematicians because of its large dynamic range, stability and noise immunity. Thus, the broad aim of silicon cochlea modelling has been to design a complex signal processing system that can be experimented with in real time.

We have developed a cochlea model that incorporates the nonlinear and active mechanisms of the biological cochlea. This model is 2-dimensional (2D) taking into account the longitudinal and vertical wave propagation within the cochlea. The basilar membrane (BM) is discretized into cochlear filter sections (specifically band-pass filters) that have exponentially decreasing characteristic frequencies. This models the systematic changes in the width and stiffness along the BM. The model has demonstrated a number of characteristics of the biological cochlea including nonlinear gain, two-tone suppression, odd-ordered distortion products, and so on. This cochlea model has been fabricated on an IC that contains fifty BM filter stages with individual digital control and programmability.

The link between silicon cochleae and cochlear implants (CIs) has been made by many researchers in the past; however, often the suggestion has been to replace the digital signal processor (DSP) in the CI with the silicon cochlea to improve power consumption and facilitate totally implantable CIs or CIs which have superior battery life. While this is a legitimate use for the silicon cochlea, the programming flexibility of the DSP cannot be denied. Thus, rather than propose the model as simply a replacement for the DSP, we show that the silicon cochlea can be a valuable tool in CI research. Specifically, the silicon cochlea can be used to assist understanding binaural signal processing and the cues necessary to enhance inter-aural level difference (ILD), noise reduction techniques, issues with automatic gain control (AGC) and speech intelligibility, and optimizing channel size; to name just a few.

While the silicon cochlea has been around for several decades, it is only recently, however, that it has the features necessary to assist in hearing, and particularly CI, research.

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A31: Speech Perception Improves With Randomization Of Starting Phases In Harmonic Complex Excited Vocoder

Tyler Churchill, Antje Ihlefeld, Alan Kan, Matt Goupell, Corey Stoelb, Ruth Litovsky

University of Wisconsin – Madison

Although cochlear implants (CIs) have been very successful at providing hearing to deaf individuals, abilities such as pitch perception, sound localization, and speech recognition in noise remain weak, and stimulation schemes seek to restore cues for these abilities. Temporal "jittering" of the electric pulses produced by CI electrodes has been shown to enhance interaural time difference (ITD) sensitivity, but the exact mechanism is unclear. Preliminary evidence suggests that temporal jittering can also improve the intelligibility of pulse train vocoded speech in normal-hearing listeners. To better understand the underlying mechanisms, we manipulated pulse train stimuli for acoustic hearing. This experiment examined the effects of randomizing the starting phases of individual frequency components of pulse train carriers for a channel vocoder on speech recognition.

A harmonic complex whose individual components' starting phases are zero is temporally and spectrally identical to a periodic pulse train. Whereas jittering the timing of pulses significantly changes the spectral structure, changing the phases of the harmonic complex partials leaves the spectral profile intact, allowing us to study effects of temporal changes. Single-syllable words were vocoded using harmonic complexes of varying amounts of randomization in their partials' starting phases as carriers. Vocoded words were presented diotically to normal-hearing listeners via headphones, who were asked to identify the word in a forced-choice task in quiet and with background noise. The percentage of words correctly identified was found to monotonically increase with increasing randomness in the starting phase distribution.

These results suggest that varying or spreading the temporal arrangement of information by shifting the component phases a random amount can lead to improved performance. Because phases of spectrally adjacent components of the complex are desynchronized, the theoretical excitation patterns in adjacent regions along the cochlea should also be desynchronized. If phase locking occurs, this may result in the temporal separation of neural responses in adjacent frequency-selective neuron populations and the overall temporal spread of neural response, supporting the proposed explanation of recovery from adaptation due to temporal spread in neural firing patterns. Temporal spread of excitation may also help overcome information transmission limitations due to refractory periods, and therefore in fact enhance synchrony in neural spike train patterns.

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A32: Enhanced SPARSE Strategy for Cochlear Implants

Hongmei Hu[1,2], Guoping Li[1], Jinqiu Sang[1],Shouyan Wang[1], Mark E Lutman[1], Stefan Bleeck[1]

[1]Institute of Sound and Vibration Research, Southampton University, UK
[2]Department of Testing and Control, Jiangsu University, Zhenjiang, China

Most cochlear implant (CI) users benefit from their devices, some of them can effortless communicate via telephone. However, speech quality and intelligibility generally deteriorate in the presence of background noise. To improve the performance of CIs in noisy environments, there are currently two main processing strategies: one focuses on noise reduction by trying to enhance the speech-to-noise ratio (SNR), such as spectral subtraction; the other focuses on enhancing information by redundancy reduction to make good use of the limited dynamic range of CIs and the impaired auditory system, such as MP3000 or SPARSE.

The SPARSE speech processing strategy, recently developed in our group, is based on sparse coding theory. It significantly improves speech intelligibility for CI users by reducing redundancy and increasing dynamic range simultaneously to overcome the bottleneck in information transmission. Here, we propose a novel strategy aimed to enhance the SPARSE strategy. The new strategy combines two established algorithms: noise reduction by Kalman Expectation-Maximize (KEM) and redundancy reduction by the SPARSE algorithm. By combining these two approaches, it is expected that the new “enhanced SPARSE” strategy will combine the benefits of both.

Most speech enhancement algorithms assume certain distributions for noise and speech signals. The original SPARSE algorithm assumes that the speech and noise have non-Gaussian distributions. In reality it is unlikely that the noise has either a purely Gaussian or completely non-Gaussian distribution, but is usually a mixture of the two. Such multiple types of noise distribution may reduce the performance and robustness of speech enhancement algorithms. In the presented enhanced SPARSE algorithm, Gaussian noise is reduced using the KEM method. A model-based KEM algorithm is derived in which the noisy speech is assumed to be a stochastic process with an autoregressive (AR) clean speech source contaminated with additive white Gaussian noise (AWGN). A distinct advantage of KEM algorithm, compared to alternative algorithms, is that it enhances SNR, while preserving its intelligibility and natural sound quality.

In the new composite algorithm, the noisy speech is first transferred to the time-frequency domain and the envelope in each frequency channel is extracted. Secondly, KEM filtering is applied to the envelope in each channel. Finally, the SPARSE strategy developed previously is used to generate more sparse stimulation. Objective and subjective experiments using normal hearing listeners and simulation of cochlear implant perception at three signal-to-noise ratios (SNR) were performed. Objective measurements confirmed that the kurtosis of enhanced SPARSE was higher than in SPARSE. In subjective experiments, the enhanced SPARSE yielded better speech perception in low SNR (0 dB) than SPARSE, but the advantage was not obvious for the higher SNRs (5, 10 dB). Although the results reflect the general trend that the recognition rate increases with increasing SNR, the differences were not statistically significant. We plan to perform higher powered experiments to confirm the trends.

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A33-a: A Patient-Specific Cochlear Implant Sound Coding Strategy Using a Model of Electric Stimulation

Andrea Varsavsky[1], David B. Grayden[1], Hugh J. McDermott[2], Lawrence T. Cohen[1], John Heasman[3], Andreas Büchner [4], Thomas Lenarz[4] and, Anthony N. Burkitt[1]

[1] The University of Melbourne, Melbourne, Australia,
[2] The Bionic Ear Institute, Melbourne, Australia,
[3] Cochlear Ltd, Melbourne, Australia,
[4] Medizinische Hochschule Hannover, Germany

The benefits of cochlear implants can vary significantly from individual to individual, and only approximately 50% of the variability in performance can be accounted for by known factors. All other factors are presumed to be user specific. A set of recent publications (see Cohen (2009a-e)) has outlined a detailed model of the person-specific parameters that could be responsible for explaining these differences. This model predicts the neural excitation pattern in the cochlea by considering the location of the electrode array, the spread of the electric current to nearby electrodes, as well as the neural survival and excitability specific to each recipient.

Using this model of neural activity, we have investigated the theoretical differences between the electrically evoked neural excitation pattern (using ACE, a standard speech processing strategy) and that generated by an acoustic stimulus in a normal listener. We have found that acoustic and electric neural activation differs significantly, in both timing as well as envelope, and that many features assumed to be presented by ACE are lost due to the interference between stimuli.

We propose a novel individualised electrical stimulation strategy that aims to replicate, as closely as possible, the neural activation patterns that acoustic stimulation generates in normal hearing. It is expected that such a strategy may improve speech intelligibility because patient-specific information can be exploited to better represent an acoustic stimulus. A pilot study of this strategy is currently underway, the results of which will be presented at this conference.

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Cohen LT (2009a-e) Hearing Research, Vol. 247, pp. 87-99, 100-111, 112-121;Vol 248, pp. 1-14, 15-30.

A33-b: Application of Real-Time Loudness Models Can Improve Speech Recognition For Cochlear Implant Users

Andrea Varsavsky[1] and Hugh J. McDermott[1,2]

[1] The University of Melbourne, Melbourne, Australia
[2] The Bionic Ear Institute, Melbourne, Australia

Loudness perception is an important aspect of hearing. In addition to other types of information, it provides cues that help listeners to localize the source of a sound, particularly by means of inter-aural level differences. However, in today's cochlear implants (CIs), loudness information is usually encoded only in a simple way: the electric stimulus level is determined by a monotonically increasing function of the input acoustic signal level. This acoustic to electric level conversion is applied independently to each frequency band (corresponding to each of the active electrodes). Commercial CIs incorporate no specific processing to ensure that the loudness perceived due to the electric stimulus is similar to that perceived by listeners with normal hearing. In a recent publication (McDermott and Varsavsky 2009), we used numerical models of loudness perception to confirm that there are large differences between how loudness is encoded in a CI sound-processing strategy and how loudness is experienced by normally hearing listeners in general.

We have recently developed a new CI sound-processing algorithm aimed at addressing this discrepancy. This strategy, named SCORE, modifies the output of an existing CI sound-processing scheme (e.g., ACE) so that the effects on loudness of changes in the characteristics of acoustic signals are specifically taken into account. Using mathematical models, the loudness of the input acoustic signal is estimated and compared to the loudness that would have resulted from the corresponding electric stimulus produced by the underlying sound-processing strategy. Before this stimulus is delivered to the electrodes, it is adjusted until its loudness is close to that of the acoustic signal. The adjustment is applied globally to the stimulus levels for all active electrodes so that their relative contributions are preserved. Thus the principal properties of the underlying stimulation strategies that have been proven effective for good speech perception are retained.

In practice, the differences between ACE and SCORE are subtle. SCORE affects the level of the stimulus on a relatively fine scale; for example, by reducing the level differences between consonants and vowels. The long-term average level of the electric stimulus is typically not affected. For speech intelligibility these differences would be expected to make the greatest difference at low input levels.

Five subjects (6 different ears) were tested for low-level speech understanding in quiet conditions. Using SCORE, subjects demonstrated an average 8.75% statistically significant improvement ($p < 0.02$) in the number of words correctly identified relative to ACE. These findings demonstrate that the encoding of loudness can affect speech intelligibility, particularly in non-ideal listening conditions.

McDermott H and Varsavsky A (2009), "Better fitting of cochlear implants: Modeling loudness for acoustic and electric stimuli", Journal of Neural Engineering, Vol 6(6)

A34: Evaluation of an algorithm for transient noise suppression in Cochlea-Implant systems

Lucas Hoepner[1], Waldo Nogueira[2], Tobias Rottmann[1], Volkmar Hamacher[2], Thomas Lenarz[1], Andreas Büchner[1]

[1]Medical University of Hannover, Department of Otolaryngology, Hannover, Germany
[2]Advanced Bionics European Research Center GmbH, Hannover, Germany

Hearing aids utilize a wide diversity of preprocessing algorithms to enhance the signal in various noise situations. Most of those algorithms is not or only in simplified implementations available to Cochlea-Implant (CI)-users. This study evaluates possible benefits of an algorithm for suppressing transient noise in CI users by an existing hearing aid pre-processing. The evaluation of this algorithm is made possible by coupling the output of a Phonak hearing aid into the input of an Advanced Bionic Harmony speech processor thus granting the CI user access to any hearing aid preprocessing.

13 experienced CI users were tested with the transient noise suppression algorithm called Impulsive Noise Canceller. Speech Reception Thresholds (SRT) were measured using the adaptive Oldenburger Sentence Test (OlSa). Speech and noise were presented from the front with speech level being adapted to achieve a SRT of 50% correct. Instead of the usual speech shaped noise signal from the OlSa a transient noise signal consisting of looped hammer strokes was presented at 80dB SPL. All signals were calibrated with dB SPL(A) slow settings.

The measurements show that CI users experience great difficulties in understanding speech in situations with present transient noise. For 11 CI users SRTs converged at 66.61dB SPL speech level without the algorithm. With the suppression algorithm activated, the overall mean improved to 63.89dB SPL speech level. This shows a highly significant improvement in SRT of 2.72dB. Two of the users had to be taken out of averaging due to limitations of the algorithm

Those findings show a huge potential of this transient noise suppression algorithm for CI users. Furthermore the algorithm is currently tuned for hearing aid users. This leaves room for further modifications in the future especially tailored to the needs of CI users, which again might yield even greater improvements in transient noise situations.

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A35: Insights Into Multi-Channel Automatic Gain Control And Cochlear Implant Users

Patrick Boyle[1, 2], Michael Stone[1], Leo Litvak[2], Brian Moore[1]

[1]University of Cambridge, UK
[2]Advanced Bionics LLC, California USA

Cochlear Implant (CI) users generally have small electrical dynamic ranges, typically about 10 to 15 dB. Such a small range means that Automatic Gain Control (AGC) is particularly important, in order to code the relatively large range of sound levels encountered in everyday life. CI systems incorporate single channel AGC (SCAGC), usually working on the broadband signal. This means that an intense narrowband sound can reduce the gain for the entire signal. Multi-Channel AGC (MCAGC) should overcome this effect and hence be beneficial for CI users.

Software realizations of one, two or four compression channels were assessed with 10 experienced adult Advanced Bionics CI users listening to speech in each of three maskers: speech-shaped noise, multi-talker babble and a more spectrally limited airplane noise. Each compression channel used a dual-time constant AGC previously found to be superior to a syllabic compressor for CI users. MCAGC benefited only five or six participants across the various processors and maskers. Some participants scored more poorly with MCAGC. Group mean results were not significantly better for any MCAGC processor for any masker.

Further measurements from a dummy implant were made in an attempt to explain these puzzling outcomes. MCAGC produced at least 10 dB of additional output compared to SCAGC when signals additional to a narrow-band signal were presented at a frequency remote from that of the narrowband signal. Free-field audiogram testing in the presence of band-limited noise maskers with bandwidths either from 4 to 7 kHz or from 0.8 to 1.3 kHz partially showed the expected outcome: in the presence of the high-frequency masker, audiometric thresholds at low frequencies were lower for MCAGC than for SCAGC. However, speech perception testing using IEEE sentences in the presence of broad or narrow-band maskers failed to show a clear advantage for MCAGC. The Speech Reception Threshold (SRT) for sentences was typically positive, in the range 0 - 10 dB. A spondee test was constructed which allowed signal-to-noise ratios (SNR) as low as –21 dB to be employed. Tests using this again showed no significant advantage for MCAGC.

The large variability in results suggest that there may be a trade-off between a benefit in release from masking and disruption of other critical cues on which some CI users may be more dependent, e.g. spectral tilt, particularly when listening in noise. However, a technical error in the MCAGC algorithm cannot be ruled out. Further experiments are being conducted using lower speech levels. More extensive bench measurements are also underway to better quantify the MCAGC performance, particularly for dynamic stimuli.

A36-a: Prediction of Success With Cochlear Implants Using Novel Measurement Procedures

Sabine Haumann[1], Nina Wardenga[1], Tobias Herzke[2], Volker Hohmann[2], Thomas Lenarz[1], Anke Lesinski-Schiedat[1], Andreas Büchner[1]

[1]Hearing Center of the ENT clinic of the Medical University of Hannover
[2]Center of Competence HörTech, Oldenburg, Germany

Background: With ongoing technological progress and increasing clinical experience the indication for cochlear implants (CI) was extended from complete deafness to severe hearing impairment. For defining the boundary between CI and hearing aids it is increasingly important to predict the success with CI before surgery. In this investigation, the performance of subjects implanted with a CI is compared to their performance prior to the implantation. Based on these data a statistical prediction model is being developed.

Methods: The investigation introduced into our clinical routine includes adults with profound hearing loss. Prior to surgery the subjects were tested with an optimally fitted hearing aid simulated with the Master Hearing Aid system [1]. Performed speech tests were Freiburg Monosyllables and Oldenburg Sentence Test (Olsa). To assess linguistic skills the visually presented Text Reception Threshold (TRT) Test was accomplished. General state of health, socio-economic status (SES) and subjective hearing were assessed with questionnaires. 6 month after surgery, the speech tests were repeated with the CI. Based on these data a statistical model for predicting CI success using weighted correlations was developed and is currently being enhanced.

Results: So far pre-surgically obtained data sets of 161 CI candidates are available with 111 of them having passed the six month appointment. Significant correlations between preoperative test results like TRT-Test ($r = -0.23$), Olsa with simulated hearing aid ($r = 0.46$) and SES ($r = -0.31$) and postoperative Olsa results with CI were found. With the statistical model the speech understanding with CI was predicted into a framing corridor of 25 % with an accuracy of 70 %.

Conclusion: The preliminary statistical model using the newly installed tests seems to allow more accurate predictions of CI performance. A more complex model is currently under development

[1] Grimm G., Herzke T., Berg D., Hohmann V. (2006): The Master Hearing Aid: A PC-based platform for algorithm development and evaluation. Acta Acustica united with Acustica 92(4), 618-628.

A36-b: Evaluation Of Multiple Processing Options Available With The Nucleus System 5 Device Using The R-Space^{tm}

Lisa G. Potts and Kelly A. Kolb

Washington University School of Medicine, St. Louis, Missouri, USA

Difficulty understanding in background noise is a primary report of cochlear implant recipients. To improve speech recognition in noise several processing options and combinations of options are available with the Nucleus System 5 device. These include Adaptive Dynamic Range Optimization (ADRO), Autosensitivity Control (ASC), Beam, and Zoom. ADRO reduces loudness individually in channels that represent high intensity sounds. ASC decreases the microphone sensitivity when the noise level is high. Beam and Zoom both preprocess the signal and noise, but utilize different directional filtering patterns. Beam adapts between cardioid, hypercardioid, and bidirectional patterns as the noise source moves, adjusting the null point from 90o to 270o. Zoom uses a fixed hypercardioid directional pattern with the null point at 180o.

The effectiveness of these processing options to improve speech recognition in noise has been shown in traditional laboratory simulations, but often individual reports of performance in everyday life are not as favorable. Compton-Conley and colleagues developed the R-SpaceTM to better represent a real-world environment. The R-SpaceTM consists of eight loudspeakers in a 360° array and uses restaurant noise.

The present study used the R-SpaceTM to measure speech recognition in noise with eight processing options: Beam, Beam+ADRO, Beam+ASC, and Beam+ADRO+ASC , Zoom, Zoom+ADRO, Zoom+ASC, and Zoom+ADRO+ASC. A CP810 speech processor, which has a dual omni-directional microphone, was programmed with each processing option, using the individual's preferred everyday program, with no additional processing, as the base MAP. Thirty-two Cochlear Freedom and System 5 recipients repeated HINT sentences presented at 0° azimuth with R-SpaceTM restaurant noise at 70 dB SPL. An adaptive reception threshold for sentences (RTS) was obtained for each condition.

Results showed significant differences between processing options. Of the eight processing options, Zoom+ASC resulted in the best mean RTS (5.7 dB), while Zoom resulted in the poorest (7.9 dB). Beam, Beam+ASC, and Beam+ADRO+ASC resulted in approximately equal RTS scores. The Beam+ADRO and Zoom+ADRO options performed notably poorer than the other processing options, with the exception of Zoom. The results suggest that in environments with loud diffuse noise, speech recognition can be improved through the use of processing options that incorporate directionality and noise reduction. However, the best processing option most likely varies between individuals and will be dependent on the configuration, level, and source of the competing noise.

A37-a: Phonemic Restoration Of Speech In Users Of Cochlear Implants

Pranesh Bhargava[1,2], Deniz Başkent[1,2]

[1]University Medical Center Groningen, Groningen, The Netherlands
[2]School of Behavioural and Cognitive Neuroscience, University of Groningen, Groningen, The Netherlands

As opposed to the Normal Hearing (NH) listeners, Cochlear Implant (CI) users find it difficult to understand speech in the noisy environments. We hypothesize that this may partially be because NH listeners are better at using the mechanism of Phonemic Restoration (PR) to their benefit than CI users. Phonemic Restoration is the phenomenon of perceptually restoring the speech sounds, made inaudible or masked due to noise in the environment, with the help of linguistic knowledge and contextual information. In the present study we explore the hypothesis that typical CI users may not benefit from PR as much as NH listeners, and the hindered PR may be one of the reasons for their poorer understanding of speech in noisy environment.

In the experiment, the subjects were native Dutch speaking CI users. The speech material was everyday Dutch sentences spoken in male voice, taken from the VU corpus made available by the University of Amsterdam. Sentences were either temporally interrupted (1.5 Hz and 10 Hz; at duty cycles of 50% and 75%) with silence or the temporal interruptions were filled with noise of different amplitudes (-10, -5, 0, 5 dB; as compared with the speech level). The subjects were asked to listen and repeat what they heard, and the percent correct of the correctly repeated words was measured as the intelligibility score. PR benefit was measured as the increase in intelligibility score with addition of noise in the silent gaps. Better intelligibility scores with noised filled gaps as compared with silent gaps would result in a positive PR effect and indicate PR benefit.

In preliminary results obtained with the CI users so far, we found that there appears to be a PR benefit at longer duty cycle on selective conditions. Different than previous findings with NH listeners, the CI listeners performed worse in identifying the sentences with gaps with noise than sentences with silent gaps.

CI subjects showed better intelligibility scores at the slower interruption rate of 1.5 Hz as opposed to 10 Hz. This result is in contrast with the previous findings with NH listeners who showed better intelligibility scores at 10 Hz than 1.5 Hz. This may be an indication of front-end processing of the speech affecting the intelligibility of speech at higher interruption rate, which takes away the advantage of more ‘glimpses per word’ at faster interruption rate. A negative correlation was found between the amplitude of the filler noise and intelligibility scores at 50% duty cycle.

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A37-b: Correlation Between Spread Of Excitation Measurements And Speech Perception In Adult Cochlear Implant Users

Birgit Philips, Ingeborg Dhooge

Ghent University, Faculty of Medicine and Health Sciences,
Ghent, Belgium

All multi-channel cochlear implants (CI) aim to take advantage of the tonotopic organization of the cochlea by selectively stimulating relatively independent neural populations. Hence, spectral representation of the incoming signal is mainly achieved through stimulation of various electrodes located along the longitudinal axis of the cochlea. Ideally, each electrode should selectively activate a distinct group of neurons in the cochlea, without activating adjacent neurons. It has been shown that the intra-cochlear electrical fields, generated by each electrode are not completely distinct from each other, but rather overlap to a large extent. This overlap causes interactions between the electrical fields themselves or between neural populations stimulated by different electrodes, which may ultimately affect perception with the CI. Therefore, it is important to gain insight in the spatial distribution of injected current.

In this study, spatial measurements were performed by means of RSPOM (research studies platform – objective measures) v.1.3.0 within 10 HiRes90k adult recipients and by means of Custom Sound EP v3.2 within 10 CI24RE(CA) or CI512 adult recipients. Three electrode stimulation locations were used: one apical, one mid and one basal. Width values were calculated at 80% of the peak of each spatial profile.

Furthermore, speech tests were performed in quiet (CVC-words (NVA) at 40, 55 and 70dBSPL and for sentences (LIST) the Speech Reception Threshold (SRT) was determined) and noise (SRT was determined for sentences (LIST) with variable speech and fixed speech-weighted noise). Also, the identification of consonants (C) in an intervocalic /a/ context (/aCa/ nonsense words) was performed in quiet. Twelve consonants were included: /m, n, p, b, d, k, s, z, f, v, t, g/.

The main objective was to gain insight in the possible correlation between spatial profiles and speech perception. The results of the tests and the correlation between spread of excitation measurements and the speech perception will be discussed.

A38: Factors Affecting Cochlear Implant Outcomes

Laura K. Holden[1], Charles C. Finley[2], Timothy A. Holden[1], Christine A. Brenner[1], Gitry Heydebrand[1], and Jill B. Firszt[1]

[1]Washington University School of Medicine, St. Louis, MO, USA; [2]Advanced Bionics, Valencia, CA, USA

Cochlear implantation improves the communication abilities of postlinguistically deafened adults; however, open-set speech recognition varies widely across individuals. There has not been consistent agreement between previous studies regarding the factors influencing cochlear implant (CI) outcomes. In 2003, Margo Skinner at Washington University began a prospective study of outcome variability to identify factors that affect word recognition in a large group of newly implanted CI users from a single center. Three main factors were examined: demographic and hearing history information, cognitive measures, and electrode position. We present the results of this research on behalf of the late Margo Skinner.

Subjects were 114 postlinguistically deafened adults. Sentence recognition testing, a baseline CT scan, and cognitive measures were obtained prior to implantation with either the Nucleus or Advanced Bionics CI systems. CNC monosyllabic word scores were obtained at 12 test intervals from two weeks to two years post initial activation. Post-operative electrode placement was determined by a final CT scan.

Subjects were divided into six linearly-spaced, performance groups based on the percentile ranking of their asymptotic CNC scores. Across all groups, significant positive relationships from low-to-high performance were identified (Jonckheere-Terpstra test) for tighter perimodiolar wrapping of the electrode array, greater number of electrodes in scala tympani as opposed to scala vestibuli, avoidance of overly deep insertions, and lower average sound-field threshold levels with the CI. Significant positive relationships were also observed for the subject factors of educational level, better verbal learning skills and better executive cognitive function, whereas age at implantation and duration of severe-to-profound hearing loss were negatively related. Controlling for age eliminates the educational level effects and suggests that reduced cognitive skills contribute to lower outcome in older CI users. No relationship was observed for pre-operative sentence recognition scores.

There are numerous factors which limit CI outcomes. They can act singularly or collectively to limit outcomes in individuals to varying degrees. The highest performing subjects are those with the least number of limiting factors. Knowledge of when and how these factors affect outcomes can favorably influence counseling, device fitting, and rehabilitation for individual patients and can contribute to improved device design and application.

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A39: Results Of A Multicentre Study On Cochlear Implantation In Patients With Long-Term Monaural Sound-Deprivation; Does The Choice Of Ear Matter?

Isabelle Boisvert[1], Catherine M. McMahon[1], Richard Dowell[2], Björn Lyxell[3]

[1]Macquarie University, Sydney, NSW, Australia
[2]Melbourne University, Melbourne, Vic, Australia
[3]Linköping University, Linköping, Sweden.

In the case of unilateral or sequential cochlear implantation, there is no clear consensus regarding which ear to implant in individuals with a long-term monaural sound-deprivation. This typically occurs in people with significant hearing loss in both ears, but who have been using only one hearing aid for many years.

Recommendations are either based on the preservation of the remaining hearing in the non-deprived ear (implant the sound-deprived ear), or on achieving the highest outcome with the implant (implant the non-deprived ear because it has received continuous auditory stimulation).

The current study draws its findings from retrospective data collected in five cochlear implant centres located in Australia, Sweden and Canada. Comparative analyses of speech recognition scores obtained in adults with monaural sound-deprivation of durations ranging from 15 to 65 years and implanted in the sound-deprived (n≈115) or in the non-deprived ear (n≈70) have been conducted.

Results show that similar functional outcomes can be achieved by the two groups when comparing the outcomes obtained in each subject's everyday listening condition (cochlear implant alone or bimodal hearing [i.e. cochlear implant in one ear and hearing aid in the other]). In addition, variable outcomes were observed in adults with a long-term monaural sound-deprivation who were implanted bilaterally.

The results of our studies provide insight into the importance of considering: A) the history of binaural hearing prior to implantation; and B) the impact of bimodal hearing on cochlear implantation outcomes and auditory training needs for people with a long-term monaural sound-deprivation.

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A40: Cerebral Reorganization and Cochlear Implantation Outcome in Post-Linguistically Deaf Adults

Diane S Lazard[1,2], Hyo-Jeong Lee[1,3], Anne-Lise Giraud[1]

1. Ecole Normale Supérieure, INSERM U960, Paris, France.
2. AP-HP, Hôpital Beaujon, Service d'ORL et Chirurgie Cervico-Faciale, Clichy, France.
3. Hallym University College of Medicine, Department of Otorhinolaryngology-Head and Neck Surgery, Pyeongchon-dong, Dongan-gu, Anyang-si, Gyeonggi-do, Republic of Korea.

By restoring oral communication to post-linguistically deaf adults, the cochlear implant (CI) is regarded as one of the major medical developments of the XXth century. However, outcomes for recipients vary, with at least 10% obtaining word recognition scores in quiet of less than 20% correct. Peripheral predictors (e.g., electrode-array design, insertion within the scala tympani or vestibuli, amount of residual neural population, and length of insertion) have been studied but do not fully explain this variability. Cerebral functional exploration has enlarged the potential for investigating the relationships between cognitive function and perceptual performance, and has led to the notion of the "auditory brain". The aim of the present work was to further explore such relationships.

Using a functional MRI paradigm, based on visual stimuli, with post-linguistically deaf adults who were candidates for a CI, we explored the cortical reorganization of auditory memory networks, which may occur during deafness. Tasks were rhyming phonological exercises, and auditory and color imagery tasks. Paired normal-hearing subjects were included as controls.

The fMRI data analyses, using SPM5 in a Matlab 7.1 environment, showed that left-hemisphere phonological processing progressively deteriorated in the course of profound deafness, yielding maladaptive right posterior temporal cortex recruitment. This process was driven by an early decline of right non-speech sound processing. The use of the dorsal network, based on visual, articulatory and motor associations, appeared a robust predictor for good CI performance. Conversely, the enhancement of ventral-network neural activity, using global identification and comparison with stored representations, was associated with poor CI speech recognition performance.

These findings suggest that specific cognitive rehabilitation that aims to preserve auditory memory in its various components (e.g., speech and non-speech, environmental sounds) should be offered to CI candidates.

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A41: Speech Recognition In Background Music With Cochlear Implants

Xin Luo[1], Megan E. Masterson[1], and Ching-Chih Wu[2]

[1]Dept. of Speech, Language, and Hearing Sciences,
[2]Dept. of Electrical and Computer Engineering, Purdue University, West Lafayette, IN, USA

Cochlear implant (CI) users' speech recognition in competing talker backgrounds has been studied extensively. Music is another common type of masker for speech communication in daily listening situations. However, speech recognition in background music hasn't been examined in CI users. A few studies with normal-hearing (NH) listeners showed that competing music generates less masking than competing speech, and the degree of familiarity and complexity of music may affect its masking effect.

This study measured speech recognition in background music by postlingually deafened CI users, NH listeners, and NH listeners listening to 8-channel CI simulation. All subject groups were age-matched older adults. Background music was randomly selected from 12 familiar melodies. Melodies with different pitch ranges (high, middle, low), instruments (organ, piano, violin, clarinet), with or without chords or rhythmic cues were tested to see if the spectral and temporal properties of music would affect its masking effect. A male and a female talker producing the IEEE sentences were also used separately as the masker in two other conditions. Target speech was the HINT sentences produced by a male talker (different from the male masker). An adaptive procedure tracked the target-to-masker ratio for 50% key-word recognition. Recognition of the 12 familiar melodies was also measured and correlated with speech recognition in music.

The results showed that CI users had significantly poorer speech recognition than simulation group, and in turn than NH subjects. For all subject groups, significantly less masking was found for background music than for competing talkers, possibly due to the acoustical and structural differences between music and speech. Only NH listeners made use of pitch differences between talkers and achieved significantly better speech recognition with the female than with the male masker. Speech recognition was similar across different music backgrounds for CI users, but was the best with the low-pitch organ melodies for NH and simulation groups.

CI users' melody recognition was similar to simulation results, and was significantly poorer than NH results. For both CI users and simulation group, melody recognition was better with piano than with clarinet, showing the effects of timbre on melody recognition. Their performance significantly worsened without rhythmic cues, but was not affected by pitch range or chord. In contrast, NH subjects performed more poorly with chord.

Finally, speech recognition in music was not correlated with melody recognition, suggesting that these two tasks are independent, and better recognized melodies do not necessarily lead to more or less masking.

A42: Noise Suppresion And Cochlear Implant Speech Understanding In Auralized Reverberant Sound Fields

Lucas H.M. Mens[1], Hannah Keppler[2], Weigang Wei[3], Ingeborg Dhooge[2], Ad Snik[1]

[1]Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands
[2]Ear, Nose, and Throat Department, Faculty of Medicine and Health Sciences, Ghent University, Genth, Belgium
[3]Department of Information Technology, Faculty of Engineering and Architecture, Ghent University, Ghent, Belgium

In positive signal-to-noise ratios and damped test rooms, the Advanced Bionics' ClearVoice (CV) noise suppression has been reported to result in significantly improved speech understanding (Büchner et al, Otol Neurotol 2010). This study aims to test CV in reverberant conditions, as found in a classroom, with stationary and multitalker noise. Furthermore, it is tested which setting of the Input Dynamic Range (IDR) is optimal when using CV. Users of strong compression (large IDR) possibly will benefit more from noise-reduction (assuming a positive signal-to-noise ratio), but may also suffer more from the elimination of parts of the signal.

All reverberant conditions were generated using the Odeon software (B&K, type 7837), simulating an actual classroom (T30: 0.7 s). In a control experiment in normal hearing subjects, recordings were made in this room, varying the direct-to-reverberant ratio by varying the distance from source to a head and torso simulator (B&K, type 4128-C). A similar increase of the SRT for sentences in quiet with increasing distance was found for the auralized and recordings in the actual classroom.

Experienced users of the Advanced Bionics CII and 90 K implant were provided with CV at the medium setting. All materials were fed to audio input of the Harmony processor. LIST sentences were presented in quiet and at a fixed signal-to-noise ratio. Two levels of reverberation were simulated (T30: 0.3 and 0.8s) at two distances (0.5 and 3.0m). Between conditions, levels were adjusted for constant audibility. Preliminary results for speech in quiet show a decrement with increasing reverberation with and without CV. However, CV reduced the effect of reverberation with added stationary noise in some subjects, which was not apparent in multitalker noise. Results for different settings of IDR will also be reported.

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A43: The Multimodal Lexical Sentence Test for Adults: Performance of Listeners with Hearing Loss

Karen I. Kirk[1], Lindsay M. Prusick[1], Amanda B. Silberer[1], Laurie S. Eisenberg[2], Nancy M. Young[3], Brian F. French[4], Nicholas P. Giuliani[1], Amy S. Martinez[2], Dianne H. Ganguly[2], Chad Gotch[4], Lisa Weber[3], Susan Stentz[3]

[1]University of Iowa, Iowa City, IA; [2]House Ear Institute, Los Angeles, CA; [3]Children's Memorial Hospital, Chicago, IL[3]; [4]Washington State University

Under natural conditions, listeners use both auditory and visual speech cues to extract meaning from speech signals containing acoustic variability introduced by different talkers, dialects, speaking rates, and background noise. However, clinical tests of spoken word recognition routinely use auditory-only presentation of words or sentences produced by a single talker using carefully articulated speech. Such constrained tests may not adequately characterize the performance of adults with hearing loss. The Multimodal Lexical Sentence Test for Adults (MLST-A), a theoretically motivated, audiovisual sentence recognition test was developed to more closely approximate real-world listening situations. Stimuli on the MLST-A were drawn from 320 semantically neutral sentences of 5-7 words in length created by Bell and Wilson (2001) and used with permission. Each sentence contains three key words that are controlled for the factors of lexical density (the number of similar sounding words, or lexical neighbors, to the target) and word frequency (how often the words occur in the language). Words with many lexical neighbors come from dense neighborhoods, and those with few lexical neighbors come from sparse neighborhoods. Key words are drawn from one of four lexical categories: 1) high frequency-sparse, 2) high frequency – dense; 3) low frequency-sparse, and 4) low frequency – dense. Five male and five female talkers were audiovisually recorded in high definition format while they produced the sentences. Talker intelligibility data, obtained from approximately 300 listeners with normal hearing, were analyzed in order to derive 30 multi-talker sentences lists that were equivalent when administered within a given presentation format (visual-only [V], auditory-only [A] or auditory-plus-visual [AV]).

A study currently is underway to examine the performance on the MLST-A of adults with hearing loss who use hearing aids and/or cochlear implants. To date 45 adults have been tested. Each participant is tested twice. In the first session, they are administered all 30 lists (10 lists per presentation format). In the second session, MLST-A testing is repeated and participants are given the HINT and NU-6 tests. The data will be analyzed as a function of presentation format and lexical category. In addition, reliability and validity of the new test will be reported.

Work supported by NIH-NIDCD.

A44: Growth of Tissue Around Cochlear Implant Electrodes – Indications From Impedance Measurements

Gerrit Paasche, Katharina Wuttke, Anke Lesinski-Schiedat, Thomas Lenarz

Hannover Medical School, Otolaryngology, Hannover, Germany

After cochlear implantation fibrous tissue is formed around the electrode carrier. This tissue formation is thought to be responsible for the increase in impedances during the first weeks after implantation. In patients impedances are typically monitored by impedance measurements with the fitting software. Measurements can be done in common ground (only electrodes inside the cochlear are used) or monopolar modes (measurement against an extracochlear reference electrode).

During the first three weeks after implantation of a cochlear implant electrode array, the electrical impedance at the electrode contacts increases before reaching a plateau. With the influence of electrical stimulation of the patients after first fitting, a temporary reduction of the impedance can be observed. This temporary reduction is only correlated with the impedance before starting electrical stimulation when patients received steroid treatment during implantation. Interestingly it also does not seem to be influenced by the measurement mode.

The initial increase in impedance can first be observed at basal contacts, later on also at apical contacts. This indicates a faster or stronger growth of tissue in the basal part of the cochlea. In additional animal experiments with micro-patterned electrode surfaces, impedances increased much faster with linear grooves parallel to the axis of the electrodes than with circular grooves around the electrode array. As it is known that edges can guide the growth of cells, this seems to support the hypothesis that the tissue growth around the electrode array starts at the entrance point of the electrode into the cochlea.

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B1-a: Central Masking With Bilateral Cochlear Implants

Payton Lin, Thomas Lu, Fan-Gang Zeng

University of California, Irvine, CA, USA

The population of cochlear implant (CI) recipients is growing with many CI users opting to receive a second cochlear implant. A clear binaural benefit is seen in normal hearing, and the goal of our research group is to learn how to maximize this benefit for bilateral CI recipients. Central masking experiments in normal hearing show that hearing thresholds are elevated when spectrally similar sounds are presented in the contralateral ear (Zwisklocki, 1972, 1978). An early central masking study with two bilateral CI users showed that thresholds were elevated by contralateral masking electrodes, but not in a place-dependent manner such as in normal hearing (Van Hoesel and Clark, 1997). The present study will continue in this line of research with a larger subject population using the latest cochlear implants (Nucleus 24, Freedom, and Nucleus 5). We will analyze bilateral masking patterns to investigate binaural interactions and their underlying psychophysical mechanisms.

Five electrodes spanning the length of the array were tested in both ears as the masker and the probe. The Spear3 research processor was used to stimulate electrodes at the same pulse rate and pulse duration. Using an adaptive 3IFC protocol, CI participants were required to select the interval that randomly contained a 200 ms probe in one ear, centered in the presence of a 500-ms masker stimulated at MCL in the contralateral ear.

Preliminary results on five bilateral cochlear implant users have shown place-dependent masking patterns. Preliminary trials also show that contralateral masking increases with masker intensity or if the masker onset coincides with the probe. Further analysis will be done to determine if the amount or pattern of masking is similar on each ear to determine if the interval between sequential implantation has effects on contralateral masking.

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B1-b: Effects of Auditory Experience On Spatial Release From Masking In Children

Sara M. Misurelli[12], Shelly P. Godar[12], and Ruth Y. Litovsky[1,2]

[1] University of Wisconsin, Madison, WI, USA
[2] Waisman Center, Madison, WI, USA

In complex auditory environments, it is often difficult to separate the target talker from interfering speech. Normal-hearing (NH) listeners benefit from spatial separation of target and competing sources, an effect known as spatial release from masking (SRM). SRM in NH adults is largest under binaural listening conditions with speech interferers. Speech reception thresholds improve by up to 10-15 dB when interferers are placed asymmetrically (+90°) relative to the head, while the target is in front (0°). SRM in children with NH is also largest under these conditions.

The current study investigated SRM in children with bilateral cochlear implants (BiCIs). It has been hypothesized that the provision of a second implant may facilitate spatial hearing abilities, including larger SRM due to the spatial cues that arise from bilateral hearing. Subjects included children who use BiCIs, and age-matched NH children, between the ages of 4-9 years. A 4-AFC speech intelligibility task was used, in which an auditory label was matched to a visual target. Two interfering speech stimuli were positioned in azimuth either symmetrically (+/-90°) or asymmetrically (+/+90°). NH children in two age groups (4.0-6.5 years and 6.6-9.0 years) showed significant SRM in both the symmetrical and asymmetrical conditions. SRM was larger for the older age group. The BiCI users, in contrast, showed very small amounts of SRM, with either symmetrically or asymmetrically placed interferers. These children, who were followed longitudinally, did not show increased SRM with additional use of bilateral hearing.

Small SRM in bilateral users may impede listening in noisy situations, and contribute to a gap in performance between NH and BiCI users. Insignificant SRM in BiCI users is likely due to a lack of coordination between the two CI processors, and absence of low-frequency fine structure cues. Implementation of these cues may be an important factor in future improvements in performance, in particular for tasks that are relevant for source segregation in complex listening situations.

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B2: The Emergence Of Sound Localization Abilities In Toddlers Who Use Bilateral Cochlear Implants

Christi L. Hess, Samantha Harris, Erica A. Ehlers, Alyssa J. Lamers & Ruth Y. Litovsky

The University of Wisconsin, Madison

Cochlear implants (CIs) successfully promote abilities such as speech perception and discrimination. However, spatial hearing abilities such as sound localization and listening in noise are challenging with one CI, and often improved with bilateral CIs (BiCI). In recent years, there has been a marked increase in the number of children receiving BiCIs. Bilateral implantation in young children provides a unique opportunity to study emergence of spatial hearing in individuals who experience a period of auditory deprivation prior to the onset of hearing. Previous findings from our lab suggest that sound localization abilities in children with BiCIs are better when in the bilateral listening mode compared with single-CI mode. However, children ages 5-14 perform significantly worse than their normal-hearing peers. In the present study, we investigated whether earlier bilateral activation might lead to the development of sound localization accuracy at a younger age, and at a level of performance that is more similar to what is seen in the normal-hearing population.

This study was conducted using a novel experimental paradigm, the “reaching for sound” approach, whereby children are trained to reach for sounding objects that are hidden behind a curtain. Ten toddlers, ages 27-42 months, were tested in both BiCI mode and unilateral mode. Their data were compared to those from a normally hearing (NH), chronologically age matched group of toddlers. Stimuli were white noise bursts presented at a level of 60 dB SPL, from one of 9 loudspeakers positioned in the horizontal plane at 15-degree increments. Preliminary results indicated that toddlers who use CIs can discriminate left vs. right, and do so significantly better when using two CIs compared with a single CI. When localizing from amongst 9 possible locations, RMS errors for the NH group ranged from 2.89 to 37.5 degrees and errors for the BiCI group ranged from 37.7 to 62.8 degrees. Overall, results show that localization abilities develop slowly following cochlear implantation.

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B3: Psychophysical Measures of Sensitivity to Interaural Time Difference Encoded in the Envelope and the Fine Structure with Bilateral Cochlear Implants

Victor A. Noel[1], Donald K. Eddington[1,2]

[1] Cochlear Implant Research Laboratory, Massachusetts Eye and Ear Infirmary, Boston, MA USA
[2] Department of Otology and Laryngology, Harvard Medical School, Boston, MA USA

Bilateral cochlear implant users have poor sensitivity to interaural time delays (ITDs) of high-rate pulses, which precludes their use to convey fine-structure interaural delay cues. Neuron recordings in the inferior colliculus of bilaterally implanted cats demonstrate good ITD sensitivity to a 1000 pulses-per-second train, but only if the pulses are sinusoidally amplitude modulated (SAM). We tested the hypothesis that modulation could restore ITD sensitivity to high-rate pulses in human bilateral cochlear implant users by measuring ITD thresholds for three conditions: ITD encoded in the modulated pulses alone, in the envelope alone, and in the whole waveform. Results showed no sensitivity to ITD in the 1000 pps carrier, even with modulation. These results therefore find no evidence for synchronizing of binaural processors to encode fine-structure ITD.

Having only found sensitivity to ITD encoded in the envelope, we also measured envelope ITD sensitivity as a function of SAM modulation frequency. Sensitivity was best at a modulation frequency of 100 Hz and degraded rapidly outside of the narrow optimal range of 50 to 100 Hz. This was especially true at the lower modulation frequencies from 4 to 16 Hz, where much of the speech envelope's energy and information resides. ITD sensitivity was also measured using a manipulated version of the SAM signal to help determine which aspects of the low modulation frequency signals correlated with ITD sensitivity.

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B4: Neural ITD coding and phase locking to pulse trains with cochlear implants: Effects of interpulse jitter and anesthesia

Kenneth E. Hancock[1,2], Yoojin Chung[1,2], Sung-Il Nam[3], Bertrand Delgutte[1,2,4]

[1]Massachusetts Eye & Ear Infirmary, Boston, MA, USA
[2]Harvard Medical School, Boston, MA, USA
[3]Keimyung University, Daegu, South Korea
[4]Massachusetts Institute of Technology, Cambridge, MA, USA

Poor sensitivity to interaural time difference (ITD) constrains the ability of human bilateral cochlear implant (CI) users to listen in everyday noisy acoustic environments. ITD sensitivity to periodic pulse trains degrades sharply with increasing stimulus pulse rate, but can be restored at high pulse rates by jittering the interpulse intervals in a binaurally coherent manner (Laback et al., PNAS 105:814).

We investigated the neural basis of the jitter effect by measuring responses of single inferior colliculus (IC) neurons to trains of biphasic pulses in two animal models of CI. Cats were either congenitally deaf or deafened by ototoxic drugs, and were anesthetized during the neural recordings. To avoid the possible confound of anesthesia, a second group of animals consisted of awake rabbits.

High-rate periodic pulse trains evoked only an onset response in most IC neurons in anesthetized cats, but introducing jitter increased ongoing firing to pulse rates ≥300 pulses/s (pps) in about half of the neurons. An objective clustering analysis divided responses into two major classes based on sensitivity to pulse rate and effect of jitter. “Sluggish” neurons had very low cutoff pulse rates (≤20 pps) and minimal sensitivity to jitter, whereas “snappy” neurons had higher cutoff pulse rates (40-80 pps) and pronounced jitter effects. Sluggish neurons were more prevalent in congenitally deaf cats than in cats deafened by ototoxic drugs. Similar response patterns were observed in awake rabbits, but some neurons responded to periodic pulse trains over a much wider range of pulse rates than seen in anesthetized cats.

In bilaterally-implanted animals, neurons that had sustained responses to jittered high-rate pulse trains showed ITD tuning comparable to that produced by low-rate periodic pulse trains. Thus, jitter appears to reveal latent ITD sensitivity by restoring ongoing firing at high pulse rates. This is consistent with psychophysical results from human CI subjects.

Modeling analysis suggests that pulse-rate limitation in IC neurons may depend on at least two mechanisms, one of which is sensitive to jitter. The low pulse rate limit in sluggish neurons is consistent with a strong inhibitory circuit, whereas sensitivity to jitter in snappy neurons may result from dynamics of active membrane channels such as Klva.

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B5-a: Is Candidacy Responsible For The Improvements Seen In Cochlear Implant Outcomes?

Debi A. Vickers[1], Francesca Pinto[2], Jane Bradley[2], Sukhminder Johal[1] and Vaitheke Selvanayagam[1]

[1] UCL Ear Institute, London, UK.
[2] Royal National Throat Nose and Ear Hospital, London, UK.

There have been many technological advances in cochlear implant design both from the signal processing and from the hardware perspectives. There has also been an associated change in candidacy for implantation in adults over the same time period. All of these changes are intended to optimise outcomes and the success of cochlear implants.

Improvements have been reported in speech perceptual outcomes in recent years(Gifford and Levitt, 2010) but it is not clear whether these have predominantly arisen due to the changes in technology or candidcay.

This study compared the demographic distribution and the speech perceptual outcomes at 1 year post-implantation for adult cochlear implant users at the Royal National Throat Nose and Ear Hospital, from two, three-year time periods, 1996-1998 and 2006-2008.

Demographic data have been reviewed with respect to numbers who were implanted as adults with pre or peri-lingual deafness (upto 12 years old) and age distribution at implantation for the entire cohort. There were 43 and 101 patients in the 1996-1998 and 2006-2008 cohorts respectively.

There were 15 patients in each group with pre or peri-lingual deafness, suggesting a drop from 37% to 15% from 1996-1998 to 2006-2008. Regarding age distribution there was 1 (2%) patient in the 1996-1998 and 12 (12%) patients in the 2006-2008 cohorts over the age of 70 years.

For performance comparisons the pre and peri-lingual patients and those over 70 years were removed. Following this the distribution of age at implantation was no longer significantly different between the two groups (Mann-Whitney U=908.4,p=.90). Once candidacy had been controlled there were no significant differences seen on the Mann-Whitney test (p>.05) between the two year groups for BKB Sentences (in quiet and noise), CUNY Sentences (audio-visual) and AB word (both word and phoneme scores).

Preliminary analyses suggest that candidacy is the predominant factor influencing outcome. Multiple regression analyses will be conducted to confirm this finding.

Gifford, R. H.; Revit, L. J. (2010). Journal of the American Academy of Audiology, Volume 21, Number 7, July/August 2010 , pp. 441-451(11)

B5-b: Spectral Ripple Density and Complex Speech Perception Performance In Normal Hearing and Cochlear Implant Listeners

Erin S. Maloff, Julie Arenberg Bierer

University of Washington, Seattle, WA, USA

Previous research suggests that cochlear implant (CI) recipients with better spectral resolution will have high levels of speech understanding in quiet and in background noise. Recently, positive correlations have been demonstrated between non-linguistic measures of spectral peak resolution and single word or phoneme speech perception tests (Henry and Turner, 2003; Henry et al., 2005; Won et al., 2007; Drennan et al. 2008; Drennan et al., 2010). The present study seeks to replicate and extend those findings by examining the relationship between spectral ripple density thresholds and speech perception performance using single words and complex sentences in normal hearing (NH) and cochlear implanted (CI) adults. The Consonant-Nucleus-Consonant word identification test is used to replicate previous studies and the AZBio Sentences test presented both in quiet and in the presence of multi-talker babble noise is used as a more complex listening task.

Preliminary results in NH and CI listeners show a relationship between better spectral ripple density threshold and higher CNC words and phoneme scores, similar to previous reports. In CI and NH listeners, performance on complex speech tests is more variable and a clear relationship between this measure and spectral ripple threshold performance may require additional subjects. These preliminary findings suggest that spectral ripple density thresholds may be limited in their prediction of listener performance on complex listening tasks.

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B6: Using Semi-Automated Software Tool For Programming Multiple Cochlear Implants In A Telemedicine Setting

Ishan Ann Tsay[1,2], Wendy Parkinson[2], Heather Haugen[1]

[1]Clinical Sciences Program, University of Colorado, Denver, CO, USA
[2]Research and Technology Lab, Cochlear Ltd, Centennial, CO, USA

According to Hearing Loss Association of America, the demand for cochlear implants is increasing annually by 20 percent. Current resources to take care of these future patients in a sustainable way may be insufficient due to an uneven distribution of cochlear implant clinics across the nation and a high number of required face-to-face programming sessions with clinicians. The utilization of telemedicine is a solution that has been safely implemented by other medical devices such as pacemakers. Although a handful of previous studies have demonstrated the feasibility and equivalence of programming cochlear implants using commercially available programming software in a telemedicine setting, their methods are complicated. This research aims to create a novel method using a combination of custom-built semi-automated programming software and remote desktop technology to allow clinicians to simultaneously program multiple cochlear implant patients in a telemedicine setting. The custom-built software is intentionally not fully automated as the developers recognize the importance of the clinician's insight in obtaining a good device setting for the patients to hear well. Instead, the software promotes patient-directed programming and places clinicians in a supervisory mode.

This study was conducted using Nucleus® cochlear implant recipients over the age of 17. Two recipient programming sessions, staggered slightly in time and in separate locations, were supervised remotely by a clinician from a central location using a combination of remote desktop technology and custom-built semi-automated programming software. To simulate possible internet problems in a real-world setting, the recipients' computers were connected to the internet through 4G network cards. The maps made during the remote sessions were compared with the maps made using the traditional method, which was conducted with the clinician and recipient in the same room using Custom SoundTM programming software. As of March 30, 2011, 8 subjects showed equivalent Threshold and Comfort level measurements between the proposed novel method and the traditional method.

This study will revolutionize the way cochlear implants are programmed. It has the potential to provide a sustainable method for broadening patient access to quality hearing health care in a telemedicine setting.

Work supported by Cochlear Americas.

B7: Cochlear Implantation in Single Sided Deafness: Spatial Release from Masking in Speech Perception and Localization of Sound Sources

Stefan M. Brill[1], Wilma Harnisch[1], Joachim Müller[2]

[1]University of Würzburg, Würzburg, Germany
[2]University of Munich, Munich, Germany

In early cases the observed benefit of cochlear implantation with contralateral near-to-normal hearing was poor. However, more recent observations of non-tinnitus patients draw a different picture. In anectodal reports, patients report huge benefit and subjective "perfect" fusion of the CI and normal hearing. To assess benefit of CI in this patient group, we currently conduct both cross-sectional and longitudinal studies with users of the Med-El Pulsar and Sonata cochlear implants.

So far, eleven subjects participated in the cross-sectional study alone, all are experienced adult CI users. Speech perception thresholds were collected employing the OLSA sentence test with competing two talker babble noise, using an adaptive staircase procedure. The noise was presented in a free field setup from 0°, ±45° and ±90° incidence angles, while speech was presented from the front. All tests were conducted in NH (normal hearing ear alone) and CI+NH (CI + normal hearing ear) conditions. Additionally, HSM sentence and monosyllabic word tests were used in two levels of competing noise, where levels were defined by the preceding adaptive OLSA test. Sound localization abilities were assessed using a 1s CCITT noise stimulus in a setup with nine loudspeakers in the frontal horizontal plane.

Benefit of the CI+NH over the NH condition was greatest in the 45° and 90° (NH side) noise incidence angles. This benefit varied among subjects, but accounted to an average of a -5dB SRT shift, which is substantial. When presenting noise from the CI side angles, the benefit was smaller, however still demonstrable for some of the subjects. In the noise from front condition, we did not see a significant benefit. Localization with the NH ear alone was negligible to poor, while in the CI+NH condition we observed fair to good performance.

In contrast to a few early cases, patients with single sided deafness enjoy substantial benefit from modern cochlear implant systems. Most subjects report good fusion of the initially different perception from both sides and are everyday users of their CI. Similar results have recently also been reported from other centers, which may indicate that a CI can be an option for the large population with acquired single sided deafness.

B8: Cochlear Implantation In Adults With Asymmetric Hearing Loss

Jill B. Firszt[1], Laura K. Holden[1], Ruth M. Reeder[1], Lisa Cowdrey[2], Sarah King[2]

[1]Washington University School of Medicine, St. Louis, MO, USA
[2]Midwest Ear Institute, Kansas City, MO, USA

Patients with severe-to-profound hearing loss (SPHL) in one ear and a more moderate hearing loss in the other ear (asymmetric hearing) are not typically considered candidates for cochlear implantation. Amplification in the poorer ear may be unsuccessful due to reduced benefit, restricting the patient to unilateral listening from the better ear alone. The purpose of this study was to determine if patients with asymmetric hearing loss could benefit from a cochlear implant (CI) in the poorer ear with continued use of a hearing aid (HA) in the better ear.

Six adults with asymmetric hearing loss between ears participated. In the poorer ear, all participants met CI candidacy guidelines; in the better ear, all had open-set speech recognition. Assessment measures included word and sentence recognition in quiet, sentence recognition in four-talker babble and diffuse restaurant noise, localization and a hearing handicap scale. Participants were evaluated pre- and six-months post-implant. Three participants with postlingual onset of SPHL showed significant improvements in speech recognition after six months experience in the implanted ear. In addition, a bimodal advantage over the HA-alone condition was observed on at least one measure. Three participants had pre/perilingual onset of SPHL; only one had speech recognition with the CI after six-months. Two postlingual and one pre/perilingual participant had improved localization with bimodal input compared to either ear alone. Mean ratings of perceived hearing handicap were improved for all participants indicating the addition of the cochlear implant was beneficial in everyday life.

Patients with asymmetric hearing loss who are not typical CI candidates can benefit from using a CI in the poorer ear and a HA in the better ear. For this group, the three postlingually deafened participants showed greater benefits with a CI than the pre/perilingual participants; however, further study is needed beyond six months and with a larger sample to determine maximum benefit for those with early onset of hearing loss.

Supported by NIH/NIDCD.

B9: Simulation Data and a Model Approach for Speech Perception with Electric-Acoustic Stimulation (EAS)

Tobias Rader[1,2], Uwe Baumann[1] and Hugo Fastl[2]

[1] Audiologische Akustik, HNO-Klinik, Goethe-Universität Frankfurt, Germany
2 AG Technische Akustik, MMK, TU München, Germany

Electric acoustic stimulation (EAS) denotes simultaneous stimulation of high frequency hearing by means of a cochlear implant (CI) and of residual low frequency hearing up to 500 Hz by acoustic stimulation. Patients implanted and fitted according to the EAS concept show significantly higher speech intelligibility in complex noise environments compared to bilateral implanted CI patients. To investigate the effect of EAS on speech perception in noise we developed a simulation to mimic hybrid stimulation and obtained speech perception scores employing this simulation in a group of normal hearing subjects.

Speech recordings of a German sentence test (Oldenburg Sentence Test) and different types of competing noise (speech-like amplitude modulated noise (Fastl, 1997) and un-modulated noise) were used as stimulus and processed by the presented model to simulate hearing with EAS. The acoustic time signal was transformed by means of an ear related spectral transformation with subsequent peak picking into a stream called part tone time pattern (PTTP). Part tone frequency was reordered following the 12 center frequencies of a MED-EL DUET CI speech processor and resynthesized employing a 12 channel sinusoidal vocoder to simulate electrical stimulation. The acoustic part of the stimulus signal was generated in different patterns: 1) low pass filtering with corner frequencies set to 200 Hz or 500 Hz, 2) extracted fundamental frequency f0 with fixed level and 3) extracted fundamental frequency f0 with fixed frequency. The acoustic low frequency signal was then added to the 12-channel vocoder simulation to investigate the influence either of fundamental pitch (f0) or f0-level on speech perception in noise.

Speech reception threshold (SRT) was measured using an adaptive procedure. 12 normal hearing subjects participated in the experiment. Binaural presentation of test stimuli was accomplished via headphones. Results measured with modulated Fastl-noise were: 1) SRT=-0.4 dB SNR for 200 Hz and -10.1 dB SNR for 500 Hz corner frequency 2) SRT= 2.9 dB SNR for f0 with fixed level and 3) SRT=0.8 dB SNR for f0 with fixed frequency. Finally an optimized speech recognition system (HTK-Toolkit) was fed with the different stimuli to establish a model for speech perception with EAS or CI in quiet and in noise.

The present results demonstrate the benefit obtained with residual low frequency acoustic hearing in combined electric acoustic stimulation and thus underpin the importance of fundamental pitch fine structure information for speech perception in noise.

B10: Auditory training in noise with patients with combined electric and acoustic stimulation

Ting Zhang[1], Michael F. Dorman[1], Qian-Jie Fu[2]

1Arizona State University, Tempe, AZ
2 House Ear Institute, Los Angeles, CA

When cochlear implant (CI) patients have access to a low-frequency acoustic signal either in the same ear or in the opposite ear, their speech understanding in noise is best when electric (E) and acoustic (A) stimulation (S) are combined (EAS). However, there is considerable patient variability in EAS benefit. Recent studies have shown that the EAS benefit is primarily due to improved voice F0 information from acoustic hearing (Zhang, Dorman & Spahr, 2010). Therefore, the large variability in the EAS benefit may be due to the variability in patients' ability to make use of the additional acoustic information to achieve the synergistic effect of EAS. Recent studies have also shown that targeted auditory training can significantly improve both hearing aid (HA) and cochlear implant (CI) users' speech recognition performance both in quiet and in noise (Fu & Galvin, 2008).

The hypothesis of present study is that auditory training may help EAS patients better combine low-frequency acoustic information provided by hearing aids (HAs) with the electric stimulation patterns provided by CIs, thus maximizing the benefit of EAS. Speech and voice recognition in noise was assessed in bimodal patients before and after auditory training. Baseline performance in speech babble was obtained for identification of vowel, consonant, voice gender, and voice emotion; and recognition of CNC words and AzBio sentences. Baseline performance was measured in the A-alone, E-alone, and combined EAS conditions once per week for three weeks. Baseline performance was re-measured after 4th weeks of training and one month after training stopped. Subjective measurement was obtained using the Hearing Handicap Inventory for the Elderly (HHIE) before and after the training. Mean results showed significant improvement in speech recognition in noise in the E-alone and combined EAS condition after training. The performance of voice gender and voice emotion identification was not significantly improved after the training. The performance improvement in speech-in-noise recognition suggests that in addition to synergistic effect of combined EAS, closed-set training in noise may further improve EAS patients' speech understanding in noise.

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B11-a: Using Ecap Forward Masking Patterns To Predict Missing Information

Jill M. Desmond, Sara I. Duran, Leslie M. Collins, and Chandra S. Throckmorton

Department of Electrical and Computer Engineering, Duke University, Durham, NC, USA

Forward masking occurs when one stimulus (masker) elevates the threshold of a subsequent stimulus (probe). Forward masking is one measure of channel interactions, and it has been proposed as a mechanism that could be used to assess information that is being presented to but not being received by the user (Throckmorton and Collins, 1999). Determining the information that is not received by the user, or is masked, has the potential to provide guidance for the design of new speech processing algorithms that either work to reduce lost information or substitute unmasked information in its place.

Nogueira et al. (2005) investigated the potential for using forward masking to estimate masked information and found a limited benefit with information substitution; however, their findings were based on normal hearing psychoacoustic forward masking patterns. Given that forward masking patterns vary from subject to subject and electrode to electrode, measuring subject- and electrode-specific patterns has the potential to provide a more accurate assessment of masked information. Recently, it has been suggested that forward masking patterns can be measured physiologically via the electrically evoked compound action potential (ECAP) (e.g. Hughes and Stille, 2009) which may make it possible to measure the information necessary for a subject-specific assessment of masked information in a clinically relevant time frame.

This study utilizes ECAP measurements to estimate the forward masking patterns, and these masking patterns are used to estimate the masked stimuli. The estimates are validated using a speech reception threshold task to assess whether speech recognition is affected by removing “masked” pulses from a subject’s stimulation pattern. The masked stimuli are also used to statistically evaluate the segments of speech (vowel, consonant, or transition) that are most vulnerable to masking. These results provide insight into the impact forward masking may have on word and sentence intelligibility.

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B11-b: ECAP as a predictor of optimal stimulation rate in individuals?

Idrick Akhoun, Matthew P. Fraser, & Colette M. McKay

School of Psychological Sciences, The University of Manchester, UK

This study investigated whether the stimulation rate that optimises speech perception in individuals is correlated with measures of neural survival or function. Nucleus Freedom CI-users were assigned both a slower stimulation rate of 500 pps and a higher rate of 1800 pps compared to their clinically set rate (900 pps or 1200pps) in a longitudinal take-home study. Patients returned for fortnightly sessions at which their speech processors were programmed with an alternative rate. At each session speech tests were performed consisting of IEEE sentences in quiet and noise, and CNC lists in quiet. The clinical rate was tested at the start, mid-point and end of the study to control learning effects. ECAPs were recorded at different locations along the electrode array. For each rate, the mean ECAP attenuation in a pulse train was calculated as a measure of refractoriness. The effect of interphase-gap on ECAP amplitude-growth functions was a measure of auditory nerve survival status. Correlations between neural function and optimal rate will be presented.

Work supported by the UK Medical Research Council

B12: ECAP artifact rejection with independent component analysis

Idrick Akhoun, Mahan Azadpour, Wael El-deredy and Colette McKay

School of Psychology, Faculty of Medical and Human Sciences,
The University of Manchester, Manchester, UK

Electrically-evoked compound action potentials (ECAPs) reflect the synchronous whole auditory nerve activity, and can be recorded in situ on cochlear implant (CI) electrodes. A novel procedure (ECAP-ICA) is described here, based on independent component analysis (ICA), to isolate the ECAP from the interfering stimulation artefact. This was achieved by sequentially recording ECAPs with artefact (raw-ECAPs) for the same stimulation at the same current-level on 9 different intracochlear recording electrodes. The rationale was that the ECAP and the artefact could be separated by ICA as they should behave independently across these 9 recordings. In the absence of an accessible gold-standard, ECAPs obtained by ECAP-ICA and by forward-masking (ECAP-FM, Miller et al., 2000) were compared to in amplitude-growth functions and recovery functions. Correlated ECAP waveforms were obtained by the two methods, with an equal range of peak latencies, supporting the validity of the procedure. The main advantage of ECAP-ICA is that the use of maskers or alternating polarity stimulation is not needed. The technique could possibly be extended to peripheral neural response telemetry for other functional electrical stimulation devices.

Work supported by the UK Medical Research Council

B13: Auditory Nerve: Large Differences in Fiber Response

Leon F Heffer[1], Mark W White, James B Fallon[1,2], David J Sly[1], Rob Shepherd[2], Stephen J O'Leary[1,2]

[1] Dept. of Otolaryngology, The University of Melbourne, Australia
[2] The Bionic Ear Institute, Melbourne, Australia

Recent work1 indicates that careful selection of stimulated electrodes (and therefore, presumably, selection of ANF groups) can greatly improve CI patient performance, particularly for speech perception in noise. Here we focus on understanding those aspects of ANF responses that differ significantly from fiber to fiber.

Methods: ANF responses to electrical stimulation were recorded in acutely deafened guinea pigs. Electrical pulse trains of 100 ms duration were delivered via an acutely implanted scala tympani electrode using a monopolar electrode configuration. Stimuli were presented at rates of 200, 1000, 2000 and 5000 pulses/s. Stimulus current was varied to evoke a range of spike discharge rates between 0 and 250 spikes/s. We developed measures of each fiber's [1] accommodation (i.e., adaptation due to sub-threshold pulses), [2] refraction, and [3] facilitation (i.e., increased excitability due to prior sub-threshold pulses). For example, in one measure of accommodation, we determined the average time of the last spike during 100 ms bursts of 1000 pulses/s stimuli. Only responses to sets of bursts that exhibited first-pulse firing-efficiencies between 0.85 and 0.95 were utilized. If the last spike occurred within the first 10 ms, on average, this indicated the fiber had a high level of accommodation. For estimating refractory behavior, inter-spike intervals for 200 and 1000 pulse/s stimulation were examined to estimate the effect of a discharge on the probability of discharge to the immediately following stimulus pulse. In this manner, excitability was measured at 5 ms and 1 ms after each spike. Comparatively low discharge probabilities to the subsequent pulse indicated that the fiber had a relatively high-level of refraction. Because we analyzed data with spike rates below 150 spikes/sec, spike rate adaptation is unlikely to be present in this analysis.

Results and Conclusion: Measures from over 200 fibers indicate that refraction, accommodation, and facilitation vary broadly across fibers. Fibers with high levels of accommodation always exhibited quite long periods of refraction. However, the reverse was not true: Fibers exhibiting lower-levels of accommodation were not any more likely to exhibit short, intermediate, or long-durations of refraction. Facilitation measures were not correlated with measures of accommodation or refraction. Results from chronically deafened animals will also be presented. In conclusion, we believe that the large individual differences observed among AN fiber responses to 2nd and subsequent stimuli may be of primary importance in understanding and hopefully improving patient outcomes.

[1]Garadat, Zwolan, Pfingst, Across-Site Patterns of Modulation Detection: Relation to Speech Recognition. Presented at ARO 2011, Baltimore, MD, USA.

B14: Age-Related Changes and the Effect of Stimulation Pulse Rates on Cortical Processing and Speech Perception in Cochlear Implant Listeners

Lendra M. Friesen [1], Takako Fujioka [2], Vincent Lin [1]

[1] Sunnybrook Health Sciences Centre, Toronto, ON, Canada
[2] Rotman Research Institute, Toronto, ON, Canada

Because more individuals with hearing loss are being treated with a cochlear implant (CI), it is important to understand how aging affects physiological mechanisms underlying CI listening. It has been clinically observed that when older CI users' performance is poor, they tend to prefer listening with slower CI stimulation pulse rates. Also it has also been shown that with increasing stimulation pulse rate, perceptual most comfortable loudness levels (MCLs) decrease. We hypothesized that this perceptual sensitivity for the pulse rate difference may reflect aging-related changes in neural synchrony, which may in turn affect loudness perception and ultimately speech understanding.

Cortical auditory evoked potentials (CAEPs) reflect neural activity related to stimulus processing in the auditory cortex. In particular, the N1-P2 complex (responses at 50-200ms after stimulus onset) is known to be sensitive to age-related changes in acoustic feature processing such as the temporal properties of the stimulus. In CI users, with increasing loudness levels, there is an increase in evoked potential waveform amplitudes. However, how CAEP differs between older and younger adults regarding the interaction between perceived loudness level and stimulus rate has not been investigated. Also, the effect of stimulation pulse rates on speech understanding and the relationship to the N1-P2 response in elderly CI users has not been examined.

To date, over 7 subjects in a middle-aged group (40-55 years) and in an elderly group (65-80 years) have been tested. In the elderly group, decreased amplitudes and increased latencies were generally observed for higher pulse rates compared to lower stimulus pulse rates. Also, speech understanding improved for some of the lower rate conditions. Our results indicate that higher-order perceptual processing for speech sounds may be affected by neurophysiologic aging effects which also play an important role in processing with stimulation pulse rate in CI listening.

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B15: Electrically Evoked Auditory Brainstem Responses to Different Pulse Shapes

Jaime A. Undurraga[1], Robert P. Carlyon[2], Jan Wouters[1], Astrid van Wieringen[1]

[1] ExpORL, Department of Neurosciences, Katholieke Universiteit Leuven (KULeuven), Herestraat 49 bus 721, B-3000 Leuven, Belgium.
[2] MRC Cognition and Brain Sciences Unit, 15 Chaucer Road, Cambridge CB2 7EF, UK.

Recent studies have shown that electrically evoked compound action potentials (ECAPs) are mainly elicited by the positive (anodic) phase of the masker and the probe, in a forward-masking paradigm. An issue about the underlying mechanisms is that ECAP responses may not necessarily reflect the action potentials traveling to the central auditory system (orthodromic), but may reflect the action potential traveling to the periphery. Here we studied whether the anodic polarity causes compound action potentials traveling orthodromically, and whether polarity sensitivity changes at different intensities in human users of the CII or HiRes90K cochlear implant (Advanced Bionics). We recorded electrically evoked auditory brainstem responses (EABR) which represent brainstem auditory activity and should reflect action potentials traveling orthodromically. Responses were recorded for standard symmetric (SYM), pseudomonophasic (PS), reversed pseudomonophasic (RPS) and reversed pseudomonophasic with inter-phase gap (6 ms) (RPS-IPG) pulses presented for both polarities. Amplitude and latency analyses were obtained for peak V. Additionally, sensitivity to polarity at different intensities was studied by means of a loudness-balancing task between pseudomonophasic anodic (PSA) and cathodic (PSC) stimuli. Results show that EABR to SYM pulses have similar latencies and amplitudes for both polarities. Responses to PS and RPS show higher amplitudes and shorter latencies when the high-amplitude is anodic than cathodic. Latency differences between PS and RPS responses are in agreement with the timing of the high-amplitude phase. Responses to the second phase of RPS-IPG pulses are similar to the ones obtained with PS and RPS, i.e. higher amplitudes and shorter latencies for anodic than for cathodic polarity. The loudness balancing task shows that PSC stimuli require higher intensities than PSA stimuli to reach the same loudness, and that this holds for current levels ranging from 10 to 100 % of dynamic range. Results indicate that anodic stimulation is more effective than cathodic stimulation even at low levels, and that this difference can be observed in EABRs that must result from auditory-nerve action potentials that travel orthodromically.

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B16-a: Predictors of Language Outcomes In Children One To Three Years After Cochlear Implantation

Tinne Boons [1,2], Jan P.L. Brokx [3], Johan H.M. Frijns [4], Louis Peeraer [2], Birgit Philips [5], Anneke M. Vermeulen [6], Jan Wouters [1], Astrid van Wieringen [1]

[1] ExpORL, Department Neurosciences, K.U.Leuven, Leuven, Belgium
[2] Institute of Allied Health Sciences, Fontys University of Applied Sciences, Eindhoven, the Netherlands
[3] ENT Department, Maastricht University Medical Centre, Maastricht, the Netherlands
[4] ENT Department, Leiden University Medical Centre, Leiden, the Netherlands
[5] ENT Department, Ghent University, Ghent, Belgium
[6] ENT Department, Radboud University, Nijmegen, the Netherlands

Although children with a cochlear implant (CI) master linguistic skills relatively well, the large variability in performance remains a significant concern. Currently, the lack of insight in factors predicting language outcomes after pediatric cochlear implantation hinders an efficient follow-up and rehabilitation.

In this retrospective study the clinical follow-up results of standardized receptive and expressive language tests of 288 children with a CI up to 12 years of age were analyzed. Eleven possible predictive factors were incorporated in multiple linear regression models to examine independent factors related to language skills while adjusting for potential confounders.

Higher receptive and expressive language skills were associated with younger age at implantation. Linear regression analyses showed that in order to achieve good language skills, the first mapping of a cochlear implant should take place before the second birthday in congenitally deaf children. Additionally, contralateral auditory stimulation with a second cochlear implant or a hearing aid induced better language outcomes. Finally, the presence of an additional learning disability was a predictor for weaker language skills. These three factors appeared to be consistent one, two and three years after implantation. Furthermore, the effect of environmental factors increased over time. One year after implantation, multilingualism in the family was related to lower language scores. Two years after implantation, this factor was accompanied by low parental involvement in the rehabilitation process. Three years after implantation, a third environmental factor emerged. Children of parents using oral communication outperformed children of parents using total communication or sign language.

Understanding these causes of variation can allow clinicians to offer better prognoses to CI candidates preoperatively and can help parents and therapists creating the best possible circumstances for children with a CI to acquire language.

B16-b: Polyphonic Contour Identification in Cochlear Implants

Meimei Zhu[1,2], John J. Galvin III[1], Bing Chen[2], Qian-Jie Fu[1]

[1]House Ear Institute, Los Angeles, CA, USA
[2]Eye, Ear, Nose & Throat Hospital, Fudan University, Shanghai, China

While cochlear implants (CIs) have provided good speech understanding to many profoundly deaf individuals, music perception and appreciation remains difficult for CI users. CI users have even greater difficulty with polyphonic music, which need use pitch, timbre and/or timing cues to segregate the melodic and rhythmic components ("analytic listening") and to stream groups of instruments ("synthetic listening"). This study is to evaluate CI users' ability to use pitch, timbre and timing cues to segregate competing melodic contours in polyphonic music.

Melodic contour identification (MCI) was measured in 10 CI users and 8 normal hearing (NH) listeners, with and without a competing masker. The target contours consisted of nine five-note melodic patterns (Rising, Rising-flat, Rising-Falling, Flat-Rising, Flat, Flat-falling, Falling-Flat, Falling-Flat, and Falling), played by a piano sample. The root note (the lowest note) of the contour was A3 (220 Hz); the spacing between notes was varied between 1 and 3 semitones. The competing masker consisted of a single 5-note pattern; the same note was repeated 5 times (similar to the Flat target contour). The instrument timbre (piano or organ samples), instrument pitch (A3 or A5), and timing (simultaneous, successive and overlapping) were systematically varied. For both target and completing contours, the duration of each note and the interval between successive notes were fixed at 300 ms.

NH performance was largely unaffected by the competing masker. CI performance was highly variable without competing masker and significantly poorer in the presence of the competing masker. There was no significant effect of the masker pitch, timbre or timing, although there was a significant interaction between pitch and timbre. The simultaneous A3 piano masker produced the greatest interference and the successive A3 organ masker produced the least interference. CI users' difficulty in using pitch, timbre and timing cues to segregate the competing contours contributes their difficulty with polyphonic music perception. CI signal processing must provide better pitch and timbre representation to improve polyphonic music perception. The study can also give us a better view of the perceptual organization of CI users and provide important guidance for effective training methods to improve CI users' polyphonic sound perception and appreciation, which is crucial for real-world daily life.

Work supported by NIH grant.

B17: The Development Of Speech Perception In Children With Cochlear Implants

Louise R. Yeager and Lynne A. Werner

University of Washington, Seattle WA, USA

Cochlear implants (CI) facilitate the development of spoken language in children with severe to profound hearing loss. Difficulty acquiring spoken language in some children may stem from perceptual processes. One of these processes is the ability to recognize speech sounds with different physical properties, as the same speech sound.

This study followed children longitudinally after CI activation to determine when they could recognize the equivalence of a vowel spoken by different talkers. An observer-based method was used to assess children's discrimination of the vowels /a/ and /i/ in sound field. Children learned to respond when they heard the vowel identity change, but to ignore changes in talker alone. They completed tasks with 1, 2, or 6 talkers until they reached an 80% correct criterion. Children were tested at monthly intervals until they had reached criterion in all three tasks. Each child with a CI was matched to a child with the same "hearing age" and a child with the same chronological age. The children with CI ranged from 19 to 30 months in chronological age, and their hearing age ranged from 4 to 11 months. Larger groups of normal hearing children at the average hearing age of the children with CI, 6 months, and at the average chronological age of the children with CI, 20 months, were also tested to establish norms for each task.

Results suggest that normal hearing 6-month-olds take more trials to meet criterion than normal hearing 20-month-olds. The number of trials to reach criterion increased with an increase in the number of talkers. Some children with CI take a similar number of trials to reach criterion as the normal hearing children of the same chronological age. Other children with cochlear implants take a similar number of trials to reach criterion as children of the same hearing age. In this sample, children with bilateral implants, who were also implanted earlier, tended to be more similar to children of the same chronological age.

This work adds to our understanding of how children develop spoken language using the artificial input provided by an implant and how technological and/or habilitative strategies may improve spoken language outcomes for these children.

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B18: The Effect of Perceptual Cues On Auditory Streaming In Cochlear Implant Listeners.

Jeremy Marozeau, Hamish Innes-Brown and Peter Blamey

The Bionic Institute, East Melbourne, VIC, Australia

Enjoyment of music and the perception of speech in noisy environments both involve auditory streaming: the ability to segregate and combine auditory information according to its sources. This ability is based on differences in perceptual cues between sound sources. Similar sounds tend to be combined, and different sounds tend to be segregated into different streams. Hearing impairment reduces the perceptual differences between auditory sources, thereby reducing auditory stream segregation, and affecting the ability to enjoy music for both hearing aid and cochlear implant (CI) users.

Our main objective is to improve music appreciation in listeners with impaired hearing by automatically enhancing perceptual cues for auditory streaming. The aim of this study was to examine the effects of three perceptual parameters (the loudness, the brightness and the impulsiveness) on the difficulty of segregating a simple 4-note melody from a background of interleaved distracter notes.

In Experiment I, melody segregation difficulty ratings were recorded from CI users, and normally-hearing musicians and non-musicians while acoustic correlates of the three perceptual cues were varied for the distracter notes only. Intensity was varied for loudness, the spectral envelope for brightness and the temporal envelope for impulsiveness. Statistical analyses revealed no significant differences in difficulty ratings between groups in the temporal envelope condition, whereas CI users reported higher difficulty ratings in the spectral envelope and intensity conditions.

In Experiment II, listeners rated the similarity between pairs of 4-note melodies from “most similar” to “least similar”, while the pairs differed according to the same three parameters as in Exp I, followed by multidimensional scaling to identify perceptual dimensions. The perceptual and physical dimensions were significantly correlated for all groups and parameters except for the spectral envelope in the CI group.

Combining results from both experiments allowed us to derive the amount of perceptual change needed to induce melody segregation (streaming efficiency) for each cue. For musicians, loudness was the most efficient perceptual cue, with no difference between brightness and impulsiveness. For non-musicians, impulsiveness was the least efficient cue, with no difference between brightness and loudness. For CI users, preliminary results showed that there was no difference in streaming efficiency between any of the perceptual cues tested.

B19: Music Preference Study With Cochlear Implant Recipients Using Multi-Track Recordings

Wim Buyens[1 2 3], Bas van Dijk[1], Marc Moonen[2], Jan Wouters[3]

[1]Cochlear Technology Centre Belgium, Mechelen, Belgium
[2]Katholieke Universiteit Leuven - ESAT (SCD), Leuven, Belgium
[3]Katholieke Universiteit Leuven - ExpORL, Leuven, Belgium

Cochlear implant recipients nowadays often reach near normal speech understanding in quiet environments. However, speech understanding in noisy environments is still rather poor, resulting in an important focus of cochlear implant research on signal processing for improving speech understanding in noise. Also perception of complex pitch has received significant attention in recent years, for improving speaker identification, for tonal language speech perception as well as for music perception. Results on improving complex pitch perception have nevertheless been disappointing so far. Studies on subjective music perception with cochlear implant recipients suggest a preference for simple monophonic melodies and rhythmic sounds, whereas more complex, polyphonic music, such as pop, rock or classical orchestral music is often perceived as unpleasant and noisy. The assumption that cochlear implant recipients prefer a more simple or monophonic representation over a polyphonic representation is investigated in this study.

In general, pop and rock music consists of a band accompanying the vocalist singing the main melody. The band typically includes drums, electric guitar, bass guitar and keyboard. The test subjects were given a mixing console and separately recorded tracks with which they were asked to make an audio mix that sounded most enjoyable to them. Relative level settings of the different tracks will be shown and compared between cochlear implant and normal hearing subjects. In subsequent experiments, the relative level settings preference for the different instrument tracks from the pilot experiment has been investigated in more detail with more songs using a paired comparison analysis. Preference rating scores for different level settings will be shown and again compared between cochlear implant and normal hearing subjects.

The preliminary results show that for the pop songs provided, cochlear implant recipients prefer an audio mix with larger vocal-to-background music ratio compared to normal hearing subjects. Within the background music itself, cochlear implant recipients prefer an audio mix with prominent drums and attenuated piano and guitar.

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B20: On the Mechanism of Spectral-Ripple Discrimination by Cochlear Implant Users

Gary L. Jones, Ward R. Drennan, Jay T. Rubinstein

VM Bloedel Hearing Research Center, University of Washington, Seattle, WA, USA

Cochlear implant (CI) users can achieve remarkable speech understanding, but there is great variability in outcomes that is only partially accounted for by age, diagnosis and duration of deafness. Poor understanding of the factors that contribute to performance is a critical limitation affecting CI development. A promising path to improved results is the use of psychophysical tests to predict which sound processing strategies offer the best potential outcomes. In particular, the spectral-ripple discrimination test offers a time-efficient, nonlinguistic measure that is correlated with perception of speech and music by CI users. What makes this test time-efficient, and thus clinically relevant, is that it is a “one-point” measure: only the ripple density parameter is varied. However, there is controversy within the CI field about what this one-point test measures.

The current work examines the relationship between thresholds in the one-point spectral ripple test, in which stimuli are presented acoustically, and interaction indices measured under the controlled conditions afforded by a research processor. The resulting matrix of interaction indices, measured at all electrodes along the implant array and at multiple electrode separations, also forms a core component of a phenomenological model of spectral-ripple discrimination. Preliminary results are as follows: 1) in individual CI users, there can be large variation in the interaction index at each electrode separation, 2) interaction indices generally decrease with increasing electrode separation, 3) spectral-ripple discrimination thresholds increase with decreasing mean interaction index at electrode separations of 1 to 5 electrodes, 4) trends in thresholds predicted by the model are consistent with trends in the psychophysical data, and 5) the model can account for the spectral-ripple discrimination performance measured in individual CI users only when it is allowed to make within-interval (cross-channel) comparisons. These results are consistent with the view that the spectral-ripple discrimination test assesses the spectral resolution of CI users.

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B21: Correspondence Between Behavioral And Objective Measures Of Temporal Rate Pitch In Cochlear Implant Listeners

John M. Deeks and Robert P. Carlyon

MRC Cognition and Brain Sciences Unit, Cambridge, United Kingdom

When a pulse train is presented to one electrode of a cochlear implant, the listener typically hears a pitch that increases with pulse rate up to about 300 pulse per second (pps), beyond which increases in pulse rate are not detectable. However, individual listeners can depart remarkably from the trend, both in terms of the highest rate that they can discriminate, and in the baseline rate at which discrimination is best. Some subjects even show reversals whereby pitch drops with increasing pulse rate over a limited range (Kong et al. [2009, J. Acoust. Soc. Am., 125(3), 1649-57]). Wilson et al. [1997, Am. J. Otol. 18, s30-s34] measured ECAPs for individual pulses contained within pulse trains, and showed that for rates around 1000 pps ECAP amplitude alternated between relatively high values for odd-numbered pulses and low values for even-numbered pulses. At lower rates, this alternating pattern was replaced with more uniform amplitudes of ECAP to each pulse. It is thought that the alternating pattern reflects the refractory properties of the neurones. It could disrupt pitch perception by causing intervals equal to twice the true period being conveyed to the brain. Here we tested whether it correlates with rate discrimination scores.

We measured rate discrimination in nine users of the Freedom cochlear implant. A single mid electrode was used, and standard rates of 100 to 500 pps were compared to signal rates 30% higher than the standard rate using a 2I-2AFC task. We also measured ECAPs to every pulse in these pulse trains, using identical stimuli and the same subjects as in the behavioural experiment. The variation in rate discrimination performance with baseline rate differed considerably across listeners; most were best at low rates but there were also instances of performance that was best at intermediate rates, and where at some rates it was below chance, indicating a pitch reversal. For most subjects, ECAP measures showed no alternating pattern for 100 pps and a definite alternating pattern at rates of 300 pps and above. However, there was no correspondence between discrimination performance and ECAP measures. Hence the temporal pattern of auditory nerve (AN) activity, as measured by the ECAP, does not appear to be responsible for the variation in rate discrimination with baseline rate. We will also present additional information on the relationship between AN activity and pitch perception, obtained by comparing ECAPs and pitch judgements to alternating-interval and amplitude-modulated pulse trains.

B22: Improvements in Rate Discrimination After Training In Adult Cochlear Implant Recipients

Raymond L. Goldsworthy,[1,2,3] Robert V. Shannon[1]

[1]House Research Institute, Los Angeles, CA USA

[2]Massachusetts Institute of Technology, Cambridge, MA USA
[3]Sensimetrics Corporation, Malden, MA USA

We will report results from an ongoing study of stimulation rate discrimination in adult cochlear implant recipients. The focus of the study is to measure discrimination performance between 110 and 1760 Hz. The protocol requires subjects to take part in sixteen sessions with each session requiring approximately four hours of psychophysical training and assessment. The assessment measure used in this study is a two-interval, two-alternative, forced-choice method in which subjects are asked which of two intervals is lower in pitch. During the first eight sessions, stimuli are loudness-balanced, and an adaptive procedure is used to determine subjects' 70% difference limens for rate discrimination at standard rates of 110, 220, 440, 880, and 1760 Hz. During sessions nine to twelve, methods are repeated using level roving across intervals in order to quantify how robust rate discrimination is to level variations. In sessions thirteen to sixteen, methods are used to determine if rate discrimination performance at 1760 Hz is affected by a 100 Hz modulator. All measures are tested on four electrode positions along the implanted array.

Our preliminary results on two cochlear implant recipients indicate that rate discrimination improves significantly over the course of the study. On the first day of testing, subjects could not perform the task at 1760 Hz and performance at 440 and 880 Hz was worse than 30%. However, by the end of the protocol, both subjects obtained rate discrimination limens better than 10% for rates of 440 and 880 Hz. Both subjects could perform the task at 1760 Hz by the end of the study. Subject 1 obtained average limens better than 20%, and Subject 2 obtained average limens better than 40% at 1760Hz. Subject 1 did not exhibit any significant effect as to electrode position; subject 2, however, performed significantly better on more apically implanted electrodes.

We will discuss these findings with regards to the possibility that cochlear implant recipients require substantial psychophysical training to learn how to perceive subtle cues associated with stimulation rate.

B23-a: A Frequency-Place Map For Electrical Stimulation In Cochlear Implants: Change Over Time

Katrien Vermeire[1,2], Reinhold Schatzer[2], Andrea Kleine Punte[3], Paul Van de Heyning[3], Maurits Voormolen[4], Daniel Visser[2], Andreas Krenmayr[2], Mathias Kals[2,5], Clemens Zierhofer[2]

[1] Dept. of Otorhinolaryngology and Head and Neck Surgery, University Hospital Ghent, University of Ghent, Belgium
[2]C. Doppler Laboratory for Active Implantable Systems, Institute of Ion Physics and Applied Physics, University of Innsbruck, Austria
[3] Dept. of Otorhinolaryngology and Head and Neck Surgery, University Hospital Antwerp, University of Antwerp, Belgium
[4]Dept. of Radiology, University Hospital Antwerp, University of Antwerp, Belgium
[5] MED-EL GmbH, Innsbruck, Austria

Recent studies by Vermeire et al. (2008), Dorman et al. (2007) and Boëx et al. (2006) have determined frequency-place maps for the electrically stimulated cochlea from unilateral CI subjects with contralateral hearing. Reiss et al (2007) showed that in Hybrid patients electric pitch percepts shift in frequency, sometimes by two octaves downwards, during the first years of implant use.

The goal of this study was to look at the effect of experience on electric pitch sensations.

Five subjects with near-to-normal hearing in the contralateral ear have been provided with a MED-EL CI in the deaf ear in order to reduce intractable tinnitus. After loudness balancing, electric pitch percepts from unmodulated trains of biphasic pulses (1500 pulses per second, 50 µs/phase) were pitch-matched to contralateral acoustic pure tones. To look at the influence of experience, pitch-matching experiments were conducted before the first fitting, and after 1, 3, and 6 months of CI use. Matched acoustic frequencies were evaluated as a function of electrode insertion angles. Electrode placement and insertion angles were determined from high-resolution CT scans of the subjects' temporal bones (Xu et al., 2000).

The mean frequency-place function is about one octave below Greenwood's map in the basal turn, deviating by a lesser amount and coming close to Greenwood's function for more deeply inserted electrodes. No systematic changes can be found over time.

The results of this study do not show an influence of CI experience on electric pitch sensation. This is in contrast with the results found by Reiss et al (2007). A possible explanation might be the fact that patients included in this study were all implanted with a standard electrode, where the most apical electrode has a distance of 30.4 mm from the marker ring, compared to the 10.5 mm for the hybrid electrode used in the study by Reiss (2007). Because of this deeper insertion there is less mismatch between the predicted pitch sensation (based on Greenwood's map) and the center frequencies of the filter bands mapped to the individual electrodes.

B23-b: The Effect of Stimulation Rate on Forward Masking Functions

Wai Kong Lai[1], Matthijs Killian[2], Norbert Dillier[1]

[1] ENT Department, University Hospital, Zurich, Switzerland
[2] Cochlear Technology Centre Europe, Mechelen, Belgium

One of the main factors limiting the spatial resolution with electrical stimulation of the cochlea is the electric field spread which increases significantly with increasing stimulation levels.

Sound intensity is usually encoded by the stimulation level of the charge-balanced biphasic stimuli. The same loudness percept might also be generated by adjusting the stimulation rate, while keeping the stimulation level constant. Such a scheme would hypothetically keep channel interaction effects constant while still allowing changes in the sound intensity to be presented. This assumes that the electric field spread is primarily influenced by the stimulation level, and that keeping the stimulation level constant while increasing the stimulation rate will not result in significant increases or changes in the electric field spread.

The present study investigates the accompanying change in the electric field spread when using either the stimulation rate (at a constant stimulation level) or stimulation level (at a constant stimulation rate) to achieve the same change in loudness, with the hypothesis that the former results in less changes in the electric field spread compared to the latter.

Psychophysical forward masking functions were measured for three masker rate/level combinations as follows: first, the masker was set at a comfortable level for either 250Hz or 2000Hz. The respective stimulation levels L250 and L2000 for equal loudness percepts were determined using a loudness matching procedure. Typically, L250 was found to be larger than L2000. Additionally, the masker was set at 250Hz and L2000, corresponding to a lower loudness percept and assumingly a smaller electric field spread.

The 500ms masker stimulus was presented on electrode e11. The masked thresholds of a 100ms probe at 1000Hz, presented with a delay of 4ms after the end of the masker, and at locations on either side of e11, were then measured in an adaptive 2down-1up 3IFC task. The unmasked thresholds of the probe were also measured separately.

Initial results with 2 CI subjects, comparing the differences in the 50% widths of the corresponding forward masking functions, showed that changing the loudness using the stimulation rate (from 250Hz to 2000Hz at L2000) produced a smaller difference than when the same change in loudness was made using the stimulation level from L250 to L2000 at 250Hz.

The study is presently being completed with further measurements from additional CI subjects. The completed results will be presented and their implications discussed.

This work was supported by a research grant from Cochlear AG.

B24: Categorical loudness growth measurements in CI users

Femke L. van den Hoek, Monique Boymans, Wouter A. Dreschler

Academic Medical Hospital, Amsterdam, The Netherlands

There are numerous parameters for the fine-tuning of CI settings once a stable MAP has been found. This research focuses on the added value of matching the amplitude mapping to the loudness growth in the electrical domain with respect to speech intelligibility, sound quality as well as user preference. For this purpose a robust and reproducible loudness measurement tool is essential. For application with hearing aids in the acoustical domain the Adaptive Categorical Loudness Scaling (ACALOS) procedure has been designed. We extrapolated the ACALOS measurement procedure to the electrical domain and used it to determine the reproducibility of categorical loudness growth measurements in CI users.

We used the L34 research processor (CochlearTM) to present biphasic pulse train stimuli with 3 different stimulation rates (900-3600 pps) on 4 single electrodes across the array in post-lingually deafened adult CI users. The subjects were asked to judge the loudness of the stimuli by selecting one of the 11 ACALOS loudness scales on a touch screen. Each loudness growth measurement consisted of 4 measurement blocks which were not discernable to the subjects. During block 1 the dynamic range was estimated using two interleaved adaptive procedures. During the subsequent blocks, 4 or 5 loudness levels linearly spread across the dynamic range were estimated based on all previous trials of that measurement and presented in semi-random order.

Retest measurements were done during the same session and for a subset of the measurements during a second session. We compared the test and retest results to investigate the reproducibility of the measurements at different loudness levels, on different electrodes and for different stimulation rates.

Currently preliminary data is available for 8 subjects. For this dataset the mean squared error of the fitted loudness growth functions was significantly smaller than the resolution of the loudness scale. The intra-class correlation coefficients showed moderate agreement between the loudness growth functions for repeated measures, indicating that reproducible loudness growth measurements in the electrical domain using the ACALOS procedure are feasible.

For the preliminary data we analysed the variability in loudness growth functions between electrodes and subjects since this provides information about the relevance of electrode-specific and/or subject-specific amplitude mapping parameter optimization. Differences in loudness growth between implantees and electrodes have been suggested before in literature. Our results show some significant differences between loudness growth functions between subjects and electrodes. Future research should indicate if these differences are relevant for speech recognition and/or subject preference.

B25-a: Regional Protective Effects Of Chronic Intracochlear Stimulation Within The Cochlea In A Ferret Model Of Cochlear Implantation

Amal Isaiah, Tara Vongpaisal, Andrew King, and Douglas Hartley

Department of Physiology, Anatomy and Genetics, Oxford University, UK

We aimed to study potential beneficial effects of chronic intracochlear electrical stimulation (CIES) on spiral ganglion cell (SGC) survival within the cochlea, in a novel model of cochlear implantation, the ferret. Specifically, ferrets were deafened using aminoglycoside injections either as neonates (n=8) or adults (n=10) and, subsequently, either (i) implanted with multichannel electrode arrays in one or both ears, or (ii) remained unimplanted. Implanted animals received CIES within an acoustically enriched environment for 6 - 12 months, by connecting multichannel electrode arrays, via transcutaneous lead wires, to clinical ESPrit 3G processors (Cochlear Ltd.) programmed with a continuous interleaved sampling strategy. At the end of the experiment, temporal bones were harvested for morphometric analyses of spiral ganglion populations within the cochlea. Additionally, we investigated the relationship between serial recordings of evoked compound action potentials (ECAPs) and SGC survival. Neural survival was further analysed for potential effects of (i) age of deafening, and (ii) duration of CIES.

SGC density was markedly reduced in unstimulated cochleae (39 ± 6% of normal), compared with cochleae from normal hearing animals. CIES was associated with greater SGC survival in cochlear regions proximate to the array, and these effects were more pronounced in animals deafened as adults. Over the course of CIES, on average, a small increase in ECAP threshold was seen; however, there was no correlation between median ECAP threshold and SGC density.

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B25-b: Stimulating The Inferior Colliculus: The Effect Of Electrode Size

Roger Calixto[1], Thilo Rode[1], Behrouz Salamat[1], Minoo Lenarz[1], Thomas Lenarz[1], Hubert H. Lim[1,2]

[1]Hannover Medical University, Hannover, Germany
[2]University of Minnesota, Minneapolis, MN

Cochlear implants (CI) are the most successful neuroprosthetic to date with over 150,000 subjects implanted worldwide. However, in patients in which the cochlea or auditory nerve is congenitally malformed or damaged (e.g. trauma, tumor removal) a CI is not a viable option. As an alternative, our group has developed a new auditory midbrain implant (AMI) that targets the central nucleus of inferior colliculus (ICC). Currently, five patients have been safely implanted with the AMI and they all receive daily hearing benefits with the device. However, performance levels are still significantly lower than those achieved by CIs. Therefore we returned to the animal model to identify relevant modifications to the AMI design and stimulation strategies that could improve patient performance. One of the features of the implant design that we investigated was the effect of electrode size on neural activation and safety properties.

We performed experiments in ketamine-anesthetized guinea pigs in which either a two-shank AMI (11 sites per shank, 126,000µm2 site area; Cochlear Ltd.) or a Neuroprobe (NP) array (4 shanks, 8 sites/shank, silicon substrate array, 960µm2 site area; IMTEK) was inserted into and aligned along the tonotopic gradient of the ICC. Individual sites within similar frequency regions were stimulated with single biphasic pulses (200 µs/ph, cathodic leading). The responses were recorded from layer III/IV of the primary auditory cortex from a similar frequency region using multi-site silicon-substrate arrays (Neuronexus technologies). We analyzed the local field potentials and the multi-unit responses to compare thresholds, activation levels, and safety properties between AMI and NP stimulation.

Surprisingly, we did not observe significant differences in threshold levels as we initially expected. Local field thresholds were (in dB re. 1µA ±stdev) 29.6 ±4.08 for the AMI sites and 26.61 ±5.31 for the Neuroprobe sites, while spike thresholds were 34.2 ±3.19 and 32 ±5.59, respectively. However, there were significant differences in the supra-threshold spike responses. The AMI stimulation elicited a prolonged and increased spike rate compared to NP stimulation. Furthermore, due to the significantly higher charge density, the smaller NP sites could not usually achieve significant neural activation unless using current levels known to induce tissue damage (k>2.0). Therefore the use of NP sized sites does not appear to be a safe and practical alternative to the current electrode site.

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B26: Development Of An Improved Cochlear Electrode Array For Use In Experimental Studies

Andrew K. Wise[1,2], James B. Fallon[1,2], Kristien Verhoeven[3], Jin Xu[1], Frank Risi[4], Robert K. Shepherd[1,2]

[1]The Bionic Institute, Melbourne, Australia
[2]The Department of Otolaryngology, University of Melbourne, Australia
[3]Cochlear Technology Center Europe Belgium, Mechelen, Belgium
[4]Cochlear Ltd. Sydney, Australia.

Animal studies play an important role in establishing the safety and efficacy of cochlear implants and the development of new electrical stimulation strategies. In the present study we evaluate the safety and efficacy of a new electrode array designed to more accurately simulate the electrode insertion depths achieved clinically.

The insertion depth and trauma associated with the insertion of a new generation electrode array (Hybrid-L) was compared with a standard experimental electrode array. Each array was inserted into a cat cadaver cochlea (n=6) and a micro-focus X-ray imaged their anatomical location within the scala tympani. The implanted cochleae were then serially sectioned and at every 300µm they were photographed to determine the position of the array and to examine for insertion trauma.

Mean insertion depth for the Hybrid-L array was 334.8o (SD=21o; n=4) versus 175.5o (SD =6o; n=2) for the standard electrode array. This relates to an insertion depth of approximately 10.5 mm and 6 mm respectively. Each electrode array was located in the scala tympani and showed no evidence of electrode insertion trauma.

Two cats were chronically implanted with Hybrid-L arrays and electrically-evoked potentials recorded over a six month period. A similar insertion depth was measured in a chronically implanted animal with a Hybrid-L array. Evoked potential data from the chronically implanted animals exhibited significantly lower thresholds compared with animals implanted with a standard 8 ring array, with electrical thresholds remaining stable over the six month chronic stimulation period.

Cochlear's Hybrid-L electrode array can be safely inserted ~50% of the length of the cat scala tympani, placing the tip of the array at approximately the 4 kHz place. This insertion depth is considerably greater than is routinely achieved using a standard array (~12 kHz place). The Hybrid-L array has application in research associated with bilateral cochlear implantation, electric-acoustic stimulation and plasticity studies.

This work was supported by the NIDCD (HHS-N-263-2007-00053-C) and by Cochlear Ltd.

B27: *In Vitro* and *In Vivo* Effects of Rolipram on Spiral Ganglion Cells and Dendritic Cells via Nanoparticle Carriage

Hartwig Meyer[1], Timo Stöver[4], Florian Fouchet[2], Guillaume Bastiat[2], Patrick Saulnier[2], Wolfgang Bäumer[3], Thomas Lenarz[1], Verena Scheper[1]

[1] Department of Otolaryngology, Hannover Medical School, Hannover, Germany
[2] Laboratoire d'Ingénierie de la Vectorisation Particulaire, INSERM U646 University of Angers, Angers, France
[3] Institute for Pharmacology, Toxicology and Pharmacy, University of Veterinary Medicine Hannover, Hannover, Germany
[4] Department of Otolaryngology, Johann Wolfgang Goethe University Frankfurt, Frankfurt, Germany

To assure high efficiency of cochlear implants (CI) it is desirable to keep the density of spiral ganglion cells (SGC) on a high level and to reduce postoperative fibrous tissue growth.

Lipidic nanocapsules (LNC; with FITC for visualization) are used as drug carriers to increase the efficacy of conventional application methods. Rolipram, a phosphodiesterase inhibitor with proven neuroprotective effects, was chosen and encapsulated in LNC's core. We examined the biological effects of rolipram and encapsulated rolipram on SGC and dendritic cells (DC) in vitro and SGC in vivo.

In vitro SGC from neonatal rats were treated with LNC, rolipram-loaded LNC, rolipram or brain-derived neurotrophic factor (positive control). SGC survival and neurite lenghts (NL) were analyzed. Furthermore the effect of rolipram and rolipram-loaded LNC was examined on TNF-α release that plays a key role in pro-inflammatory processes. Therefore lipopolysaccharid stimulated murine DC were treated in four groups (rolipram, rolipram-loaded LNC, LNC and LNC without FITC).

For the in vivo study deafened guinea pigs were treated with 5 µl LNC, rolipram-loaded LNC, rolipram or PBS (control) via cochleostomy on day 7 of deafness. SGC density (SGCD) was measured on day 21.

Results indicate that LNC encapsulated rolipram increases the survival and NL of cultured SGC opposed to a slight effect of pure rolipram. In the DC study, rolipram and the rolipram-loaded LNC showed a potent TNF-α inhibition, though the effect of the pure rolipram was higher. In vivo data do not confirm the in vitro results. This might be due to a dilution of the test substances by the perilymph or an inadequate release of rolipram based on differing in vivo and in vitro conditions.

We conclude that rolipram is a very promising drug for inner ear treatment and that LNC have future potential as drug delivery system for inner ear treatment. LNC increased the biological effect of rolipram on SGC. Potentially rolipram loaded LNC can reduce SGC-degeneration and fibrosis after CI implantation. Further experiments with higher dosages might reveal biological effects in vivo.

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B28-a: Effects of Charge Distribution of Consecutive Stimulation Pulses in Cochlear Implant Patients

Sonja Karg, Werner Hemmert

Institute for Medical Engineering, Technische Universität München, Germany

Cochlear implants suffer from an information transmission bottleneck: the number of channels is limited by broad current spread of the electrodes and the dynamic range of the stimulated neurons is small. Therefore, coding strategies aim at increasing stimulation rates to encode as much information in the time-domain as possible. In this respect, we face one more limitation: activation of two electrodes at the same time causes instantaneous electrical field summation effects, usually interleaved sampling has to be applied. As a result, spiral ganglion neurons see very high rates of electrical pulses from neighboring electrodes. Due to the intrinsic neuronal dynamics, temporal interaction effects occur.

In human subjects we showed that temporal interaction due to sub-threshold stimulation lasts up to an inter-pulse interval (IPI) of 1ms. Here we studied the effect of charge distribution in two consecutive interacting pulses on perception threshold. The amplitude relation of the two pulses with reversed polarity (first cathodic, second anodic leading phase) was varied systematically between 0 and 5 (first pulse 0 or 5 times larger than second pulse). Threshold measurements were conducted at two IPI values (20 and 80µs) where interaction effects were large. We tested 5 subjects (7 ears) age 52 ± 21 (mean ± std) with MED-EL PulsarCI100 implants, who had at least 3 years CI experience. We controlled the implant directly via the research interface RIB II.

As expected, we found larger threshold reduction for larger pre-pulses. threshold reduction reached values of up to 44% ± 2% (20µs IPI) and 39% ± 2% (80µs IPI). If we consider the total charge of the double pulse, we found it was systematically less efficient compared with a single biphasic pulse. Efficiency reached a minimum when pre- and probe pulses had the same amplitude. In this condition, the total charge at threshold was 1.43 ± 0.06 (20µs IPI) and 1.62 ± 0.05 (80µs IPI) times higher compared with a single biphasic pulse.

Our results clearly show that temporal interaction affects neuronal excitation and provide first quantitative values to study this interaction. We conclude that coding strategies for cochlear implants must not only account for the effects of crosstalk due to current spread but also for temporal interaction effects.

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B28-b: Effect Of Filterbank Parameters On Speech Perception Through Cochlear Implants: A Simulation Study

Shibasis Chowdhury, Carl Verschuur

University of Southampton, Southampton, UK

Previous cochlear implant simulation studies used for evaluation of cochlear implant filterbank settings usually involved envelope extraction after band pass filtering the input signal into a number of spectral channels, and modulating those envelopes with either narrow band noise or with sinusoidal signals with centre frequencies corresponding to the centre frequency of each of the spectral channels. In a way these studies all simulated a fixed channel ‘m of m’ strategy. However, the study reported here used a simulation of ‘n of m’ peak picking strategy. FFT filterbank parameters were varied to systematically investigate the role of spectral and temporal cues for speech perception in quiet and in noise. FFT bin mapping was varied to study the effect of enhanced spectral resolution at low and mid frequencies, and also the importance of information above 5.5 kHz. Additionally, the effect of pitch shift was studied by varying the resynthesis filterbank during simulation.

Three different FFT filterbank conditions were constructed, named FFT 64, FFT 128 and FFT 256, with 4, 8 and 16 ms FFT analysis time window and best frequency and temporal resolution of 250, 125 and 62.5 Hz respectively. Additionally, 2 more filterbank conditions were constructed, named FFT 128 LR (low resolution) and FFT 256 LR to mimic the spectral characteristics of FFT 64 and FFT 128 respectively. The final filterbank condition named FFT 256 EFR (enhanced frequency resolution); involved 256 samples FFT filterbank analysis with enhanced low to mid frequency spectral resolution, with high frequency information restricted to 5.5 kHz, which contrasted with an upper cut off of 8 kHz for all other conditions. Performance evaluation was based on speech perception scores for BKB sentences and VCV syllables in quiet, and in noise at +10 dB SNR, and also by the ability to transmit the features of speech sounds. Results revealed no benefit with enhanced temporal resolution using shorter FFT analysis window. As the spectral resolution for the apical channels was improved by lengthening the FFT analysis window from 4 ms with FFT 64 condition to 8 ms with FFT 128 condition, a significant improvement in performance was observed only for noisy conditions, VCV syllables, and transmission place and manner of articulation features. No further improvement was observed with FFT 256 condition with a16ms FFT analysis window. Performance drop was observed with enhanced low to mid frequency spectral resolution with the FFT 256 EFR condition, possibly due to significant amount of pitch shifts or information loss above 5.5 kHz. Further results will be discussed based on the effect of pitch shift, importance of information above 5.5 kHz and importance of enhanced temporal information in perception of voiced onset time. Our findings suggest that spectral resolution in lower frequency channel is much more important determinant of speech perception in noise than temporal resolution.

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B29: Effect of Fast AGC On Cochlear Implant Speech Intelligibility

Phyu P. Khing[1], Eliathamby Ambikairajah[1], Brett A. Swanson[2]

[1] School of Electrical Engineering and Telecommunications
The University of New South Wales, Sydney, Australia
[2] Cochlear Ltd, Sydney, Australia

In this study we examined the effect of fast-acting Automatic Gain Control (AGC) on the speech intelligibility of cochlear implant (CI) users as a function of presentation level.

The Loudness Growth Function (LGF) is an instantaneous non-linear compression, mapping filter amplitudes to current levels. It prevents excessive loudness by limiting current to a maximum comfortable level (C-level).The role of the front-end AGC is to reduce the amount of clipping distortion in the LGF. Thus intelligibility at higher presentation levels was expected to be better with fast AGC than without.

Five post-lingually deafened adult cochlear implant recipients participated in this study. The amount of clipping was monitored using an in-house engineering tool. Slow-acting gain control (Automatic-Sensitivity Control (ASC), and Adaptive Dynamic Range Optimisation (ADRO)) was disabled. Both low and high signal-to-noise ratio (SNR) listening conditions were investigated.

Sentence-in-noise test results revealed that fast AGC did not give consistent improvements in intelligibility, although it substantially reduced the amount of clipping. In high SNR, fast AGC reduced the effective SNR by compressing the high level components of the speech more than the background noise components. Without fast AGC, speech scores were not significantly degraded until more than 25% of stimulation pulses were affected by clipping. In low SNR, fast AGC compressed both speech and noise components together, introducing partial correlation between them. Performance degradation started to become significant when the background noise level was relatively high (approximately 60 dB SPL) in both SNRs.

This implies that when slow-acting gain control is used to adjust the overall level, short intervals of clipping due to louder transients will not be very objectionable, and there is little need for fast AGC.

B30: Noise Reduction Using Spatially Derived SNR for Cochlear Implant Sound Processing

Adam Hersbach[1,2], John Heasman[1,3] and Pam Dawson[1,3]

[1]Cochlear Ltd, Melbourne, Australia,
[2]Department of Electrical and Electronic Engineering, University of Melbourne, Australia,
[3]The HEARing Cooperative Research Centre (CRC), University of Melbourne, Australia

Noise reduction based on binary masking has attracted attention in the application to cochlear implant speech processing. The objective is to remove components of the signal that have poor signal to noise ratio (SNR) whilst retaining those with good SNR. Typically, a binary mask is used to remove time-frequency points with a negative SNR, whilst those with positive SNR are passed on for further processing and ultimately stimulation in the cochlear implant. However, in a real-time device, the SNR is not known and must be estimated. Various techniques have been developed to do this, and are generally based on single channel or single microphone signal processing. The noise power distribution is estimated using a statistical approach by placing certain assumptions on the distribution of speech and noise and how quickly they change. From this noise estimate, the SNR can be estimated. An alternative approach to reducing noise in modern hearing devices is beamforming and directional processing which use more than one microphone input. Noise is removed based on the direction of arrival of sounds impinging on the microphone array, which, if different from the target direction, can be attenuated to some degree. In this study, we have combined a binary mask approach with directional microphones to create a composite, superior algorithm.

The new algorithm evaluated in this study (SpatialNR) uses fixed directional microphones to generate an SNR estimate. It is based on the presumption that the target direction is in front, but unlike an adaptive beamformer or adaptive noise canceller, the algorithm does not work on a null steering or beamforming basis. Instead, the SNR is estimated by analysing the ratio of front and rear facing directional microphones, and the SNR is used to apply a smooth attenuation function to remove the noise. The new algorithm has been evaluated clinically with CochlearTM Nucleus® cochlear implant users, and directly compared against commercially available fixed directional microphones (SmartSoundTM Standard and SmartSound Zoom) and adaptive beamformer (SmartSound BeamTM). Each subject performed adaptive SRT speech intelligibility tests in a variety of difficult noise conditions including reverberation and noise sources that changed location during the test.

In addition to the speech intelligibility results, an objective measure based on the binary mask concept has been developed to predict the benefit of the algorithms tested. Type I and Type II errors were assessed separately, and found to contribute in different ways to the prediction. Type I errors have a larger influence when Type II errors are relatively low. In spatially separated 4-talker babble noise at 0dB SNR for example, the algorithms (Standard, Zoom, Beam, and SpatialNR) had Type I error rates of 29%, 24%, 20% and 7%, and Type II error rates of 12%, 6%, 12%, and 15% respectively.

B31-a: Auditory Experience Enhances Temporal Processing In Both Deaf Juvenile And Long-Deaf Auditory Systems: Comparisons Between Auditory Midbrain And Cortex

Maike Vollmer[1, 2] and Ralph E. Beitel[2]

[1]Comprehensive Hearing Center, University Hospital Würzburg, Germany;
[2]Epstein Laboratory, University of California, San Francisco, CA, USA

In this study we compare temporal processing in the primary auditory cortex (AI) and the inferior colliculus (IC) in deaf juvenile and long-deaf adult cats with different histories of deafness and experience with intracochlear electric stimulation (ICES).

Methods: Neonatal kittens were deafened by injection of ototoxic drugs. In two juvenile groups (Jbeh, Jpass), in two long-deaf groups (LDbeh, LDpass) and in a prior normal-hearing adult control group (Apass), feline prostheses were implanted in the left scala tympani, and temporally modulated ICES was delivered passively for several months. One juvenile (Jbeh) and one long-deaf group (LDbeh) were also behaviorally trained to detect temporally modulated ICES. A third long-deaf group (LD) received ICES only during the acute physiological experiment at the end of study. In the physiology experiments, extracellular responses of neurons in the IC and AI to temporally modulated ICES were recorded with microelectrodes in anesthetized animals.

Temporal following: In AI, the stimulus repetition rates that produced the maximum number of phase-locked spikes (best repetition rate, BRR) and the 50% Cutoff Rate were equivalent in groups Jbeh and Apass and were significantly higher than in group Jpass. However, in the IC, BRR and Cutoff were equivalent in the three groups. In AI, BRR and Cutoff were significantly higher in group LDbeh than in group LDpass. However in IC, BRR and Cutoff were equivalent in the two groups. In AI and IC, BRR and Cutoff were lowest in unstimulated group LD.

Temporal precision: Mean minimum latency and latency variability in response to a single electric pulse were calculated for neurons recorded in each group. Comparisons among groups Apass, Jbeh and Jpass found no pattern of differences in AI, whereas precision in IC was significantly reduced in group JPass. In comparisons among groups Apass, LDbeh, LDpass and LD, the only consistent pattern in AI and IC was reduced precision in unstimulated group LD.

Conclusions: Behavioral training restored neuronal temporal following ability in AI, but not in IC, to levels comparable to those recorded in prior normal-hearing adult deafened animals. In long-deaf cats deprived of all auditory experience, temporal processing in AI and IC was severely impaired.

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B31-B: Supervised Sparse Coding in Cochlear Implants

Jinqiu Sang, Guoping Li, Hongmei Hu, Mark E Lutman, Stefan Bleeck

Institue of Sound and Vibration Research, University of Southampton, UK

The main issue for CI users to understand speech in noise is not that they don't get enough information, but not the right one. This is evident from the fact that most CI users can understand speech in quiet without problems. When, speech is masked by noise, too much noise related information is coded and uses up critical bandwidth. A possible solution is to select and transmit only the most essential speech related information while reducing the noise.

Sparse coding (SC) strategies offer a promising method to identify the most essential information. Recently, there has been significant development to explore sparse representations in the context of denoising and classification. SC strategies can be either 'supervised' or 'unsupervised'; a supervised strategy learns the dictionary from training data, an unsupervised strategy learns it in situ.

We have developed an improved SC strategy that is based on a coding strategy which was previously developed in our group [1] and that was successful in improving CI users' speech perception in noisy environment. On the basis of this existing unsupervised algorithm, we developed an enhanced supervised SC strategy, using the sparse coding shrinkage (SCS) principle. The new algorithm is implemented after the envelope extraction stage. SCS can help to extract and transmit the most important information from noisy speech. The supervised learning strategy is also motivated by experimental psychophysical research. For example, it has been shown that speech can be better understood if subjects were trained using data of a specific speaker [2].

In our paper, the two algorithms are compared for speech in babble and white noise (signal-to-noise ratios, SNR = 10dB, 5dB, 0dB) by objective measures via a cochlea implant simulation. Results show that the supervised SC strategy performs better in white noise, but unsupervised SC strategy performs competitively in babble noise. In future, we aim to further develop the algorithm and test the combination of a priori knowledge of training data and updating basis learning in situ.

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References

[1] G. Li and M. E. Lutman, "Sparse Stimuli For Cochlear Implants," in Proc. EUSIPCO, Lausanne, Switzerland, August 25-29, 2008.

[2] L. C. Nygaard and D. B. Pisoni, "Talker-specific perceptual learning in speech perception," Perception & Psychophysics, vol. 60, pp. 355-376, 1998

B32-a: Preliminary Results with a Harmonic Single Sideband Encoding Strategy for Improving Temporal Fine Structure Coding in Cochlear Implants

Kaibao Nie[12], Xing Li[2], Jong Ho Won[1], Nikita Imennov[1], Les Atlas[2], and Jay T. Rubinstein[1]

[1]VM Bloedel Hearing Research Center, Dept. of Otolaryngology-HNS
[2]Dept. of Electrical Engineering, University of Washington, Seattle, WA

Encoding temporal fine structure (TFS) in cochlear implants has been a challenge as temporal resolution in electrical hearing is mostly limited to the frequency range below 300-500 Hz. In our previous studies, a Harmonic Single Sideband Encoding (HSSE) strategy was proposed to enhance the delivery of TFS cues by cochlear implants. Psychoacoustic listening tests and biophysical modeling experiments have been conducted to evaluate the potential benefits of HSSE.

In order to evaluate the strategy, three preliminary studies were performed: 1) Acoustic simulations of HSSE. A sinusoidal vocoder was used to simulate sounds produced by the HSSE strategy. Ten normal hearing subjects performed listening tests of HSSE and the CIS strategy. The tasks included sentence recognition in noise or in a competing talker, melody recognition and musical instrument identification. Five native Mandarin speakers participated in another experiment to assess their ability to recognize Mandarin tones with HSSE; 2) Acute tests of HSSE in cochlear implant subjects. The HSSE strategy was programmed on a Nucleus research processor and 8 Nucleus implant recipients fitted with HSSE were acutely tested in melody recognition, musical instrument identification, and word recognition; 3) Analysis of biophysical model outputs to the HSSE stimuli. Neural spike patterns were simulated with a stochastic biophysical model of the auditory nerve fibers in response to the HSSE melody and tone stimuli.

Results: In comparison to CIS, the HSSE strategy significantly improved speech, music and Mandarin tone recognition in the acoustic simulation experiments. Nine implant subjects achieved significantly better ($p<0.05$) scores of musical timbre identification with HSSE, while maintaining comparable speech recognition performance to their clinical strategy. Two of the implant subjects were able to recognize more melodies with HSSE. Furthermore, neural firing patterns produced by the HSSE stimuli showed distinct pitch cues encoded in the interspike intervals. All three studies together suggest that the HSSE strategy could potentially better encode temporal fine structure cues in sound than envelope-based coding strategies.

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B32-b: A Bio-Inspired Nonlinear Filter Bank for Cochlear Implant Speech Processors

Reinhold Schatzer[1,2], Blake S. Wilson[2,3,4], Enrique A. Lopez-Poveda[5], Mariangeli Zerbi[2], Robert D. Wolford[2,6], Jeannie H. Cox[2,6], Dewey T. Lawson[2], Clemens M. Zierhofer[1]

[1] C. Doppler Laboratory for Active Implantable Systems, Institute of Ion Physics and Applied Physics, University of Innsbruck, Austria
[2] RTI International, Durham, NC, USA
[3] Duke Hearing Center, Duke Univ. Medical Center, Durham, NC, USA
[4] Department of Electrical and Computer Engineering, Duke University, Durham, NC, USA
[5] Neuroscience Institute of Castilla y León, Univ. of Salamanca, Spain
[6] MED-EL US Corp., Durham, NC, USA

Coding strategies for cochlear implants (CIs) provide only a crude approximation to the processing in the normal auditory periphery. While filtering at the basilar membrane and associated structures is highly nonlinear and compressed over multiple stages, CI processors utilize simple linear filter banks and an instantaneous end-stage compression.

A bio-inspired speech coding strategy for CIs is presented (Wilson et al., 2010). It replaces the conventional linear filter bank with a bank of dual-resonance nonlinear (DRNL) filters, a computationally efficient model for the highly nonlinear response properties of the human basilar membrane (Lopez-Poveda and Meddis, 2001).

The DRNL-filter-based coding strategy has been evaluated in acute experiments in two groups of six MED-EL or percutaneous implant users. In experiment 1, N DRNL filter channels were mapped to a smaller number M of electrodes by selecting the maximum of N/M adjacent channel envelopes for each electrode. In experiment 2, 21 filter channels were mapped to as many stimulation sites, using either single electrodes or simultaneous virtual channels. Speech perception for medial consonants and sentences in CCITT noise was acutely compared among DRNL and CIS strategies.

Results for experiment 1 showed equal consonant test performance for CIS and N-to-M DRNL in quiet (p=0.583), but inferior performance for N-to-M DRNL in noise (p=0.015). Results for experiment 2 showed significantly higher sentence test scores (p=0.004) and a statistical trend for better consonant performance (p=0.070) with the 21-channel DRNL strategy over CIS. These results suggest that noise suppression properties inherent to the DRNL filter are not preserved if outputs from DRNL filter channels are combined.

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B33: Constructing Patient-Specific Cochlear Implant Models From Monopolar And Tripolar Threshold Data

Joshua H. Goldwyn[1], Steven M. Bierer[2,4], Julie A. Bierer[3,4]

[1]Department of Applied Mathematics
[2]Department of Otolaryngology
[3]Department of Speech and Hearing Sciences
[4]Virginia Merrill Bloedel Hearing Research Center
University of Washington, Seattle, WA, USA

Improving listening outcomes for cochlear implant users will require a more complete understanding of interpatient variability in speech reception and intrapatient variability in perceptual measures. An ongoing focus of our laboratory is to combine psychophysical measurements and computational models in order to investigate potential sources of this variability. Our past modeling and psychophysical work supports the hypothesis that channels with elevated tripolar (TP) thresholds indicate regions of poor electrode-neuron interface. Here we extend those findings by fitting model parameters to threshold data obtained from individual subjects.

We present a computational modeling study in which two factors – electrode-to-neuron distance and neural survival – were varied in order to fit perceptual threshold current levels across all electrodes and multiple electrode configurations. For six subjects tested, this procedure provided excellent fits to TP and monopolar (MP) threshold data across the electrode array. To test the consistency of the model, we simulated threshold current levels for an intermediate configuration, partial TP, and found good agreement between the predicted and measured thresholds.

The modeling results support our hypothesis that elevated tripolar thresholds reveal regions of poor electrode-neuron interface. We observed positive correlations between TP thresholds and electrode-to-neuron distance for all subjects. In addition, several subjects showed negative correlations between TP thresholds and neural survival, suggesting an influence of neural dead regions. We also examined the simulated spread of neural activation along the cochlea and found that high TP thresholds correspond to broad patterns of activation when using the MP configuration. This supports our previous psychophysical finding that TP thresholds can be used to identify channels with poor spatial or spectral selectivity. The utility of the model in predicting forward-masked tuning curves and loudness growth in these listeners will be discussed.

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B34: A F0 rate-pitch coding strategy for cochlear implants

Andrew E. Vandali[1,2], Richard J. M. van Hoesel[1,2]

1. The Hearing CRC, Melbourne, Australia.
2. The University of Melbourne, Australia.

A sound coding strategy for users of cochlear implants, named Enhanced-Envelope-Encoded Tone (eTone), was developed to improve coding of fundamental frequency (F0) in the temporal envelopes of the electrical stimulus signals. It is based on the Advanced Combinational Encoder (ACE) strategy and includes additional processing that explicitly applies F0 modulation to channel envelope signals that contain harmonics of prominent complex tones. Channels that contain only inharmonic signals retain envelopes normally produced by ACE. The strategy incorporates an F0 estimator to determine the frequency of modulation and a harmonic probability estimator to control the amount of modulation enhancement applied to each channel. The applied modulation waveform has a sharp-onset and a rapid-decay so that so that most of the stimulation current in each F0 interval is imparted by a single electrical pulse so as to provide a good representation of F0 in neural response timing.

The abilities to hear changes in pitch and understand speech using the eTone strategy were tested in six cochlear implant users, and compared with performance using their clinical ACE strategy. Rate- and modulation rate-pitch difference limens (DLs) for fundamental frequencies (F0s) below 300 Hz were measured over five sessions. The rate-pitch DL tests provided us with information about each subject's ability to discriminate rate- and modulation rate-pitch, and also served to train subjects to attend to rate information when judging pitch. Subject-averaged DLs were consistent with previous results reported in the literature. Sung-vowel pitch ranking was measured for stimuli separated by three semitones, both before and after the training sequence involving DL measurements. Significant benefits in pitch ranking were observed for eTone compared to ACE, particularly after the training period, highlighting the importance of providing rate-pitch training to enable CI users to better attend to rate-pitch information. Equivocal scores for both strategies in the speech recognition tests showed that coding of segmental speech information by the eTone was not degraded.

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B35-a: Listening Effort With Cochlear Implants And Electric Accoustic Stimulation – A Simulation Study

Carina Pals[1,2], Anastasios Sarampalis[3], Deniz Başkent[1,2]

[1]University Medical Center Groningen, Groningen, The Netherlands
[2]School of Behavioural and Cognitive Neuroscience, University of Groningen, Groningen, The Netherlands
[3]Department of Experimental Psychology, University of Groningen, Groningen, The Netherlands

In clinical settings, the benefit of cochlear implants (CIs) is most commonly assessed by measures of speech perception performance. However, these measures cannot fully explain CI users' preference for certain processing strategies or additional devices. Recent studies suggest another important factor influencing perceived benefit: listening effort. This study evaluates the dual-task paradigm as a potential measure of listening effort, specifically for CIs. In dual-task studies, a primary and a secondary task are performed simultaneously. If the tasks are similar, they compete for cognitive resources; an increase in effort associated with the primary task will result in decreased performance on the secondary task.

The first experiment examines how well response times on two secondary tasks: a linguistic (rhyme-judgment) and a non-linguistic (mental-rotation) task, reflect changes in effort associated with the primary listening task. Participants are presented with sentences processed by 2- to 24-channel noise-band vocoders simulating CI signals. Preliminary results show that though speech perception performance plateaus at about 6 or 8 channels, response times on the rhyme-judgment task continue to decrease un to 12 channels. The mental-rotation task shows only a marginal decrease in response times between 6 and 12 channels. This confirms that a linguistic secondary task reflects changes in listening effort better than a non-linguistic task.

In the second experiment, participants are presented with combined electric-acoustic stimulation (EAS) simulations, using the rhyme-judgment task to assess listening effort. The EAS conditions consist of 5- and 6-channel vocoder signals to simulate electric stimulation of the ranges 600–6000Hz and 300–6000Hz respectively. Two different strategies for synthesizing the CI simulations are used: Either the analysis bands range from 80Hz to 6kHz (frequency compression condition), or they are the same as the synthesis bands (uncompressed condition). Combining these CI simulations with acoustic signals low-pass-filtered at 300Hz or 600Hz generates the EAS conditions. Preliminary results show longer response times for the frequency compression conditions compared to the uncompressed conditions.

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B35-b: Effect of Target and Masker Gender on the Perception of Speech by Normal-Hearing (NH) Listeners Using Cochlear Implant (CI) Simulations

Ramesh Kumar Muralimanohar[1], Christopher J. Long[1,2], Kathryn H Arehart[1]

[1]Department of Speech, Language, and Hearing Sciences, University of Colorado, Boulder, CO, USA
[2]Research and Technology Labs, Cochlear Ltd, Centennial, CO, USA

Differences in target-masker gender facilitate speech perception by NH listeners in multi-talker situations. The situation is much less clear for CI users with some studies showing no gains from pitch differences between the target and masker (Stickney et al. 2004; 2007) and others that show that pitch was useful, but to a smaller degree compared to NH (Cullington and Zeng, 2008; Qin and Oxenham, 2005).

The present study aims to understand how CI users segregate speech of two simultaneous talkers using talker gender cues. Specifically, this study uses simulations of bilateral and bimodal CI configurations to examine the ability of NH listeners to identify the content spoken by a target talker in the presence of a single competing masker. Sentences from the Coordinate Response Corpus (CRM) (Bolia et al., 2000) were presented in an adaptive speech recognition threshold (SRT) task. The gender of the target and masker were varied (i.e., male and female in all 4 possible sets) and the talker identity was always different between masker and target. In a pilot study with 4 listeners, a dramatic unmasking effect was found when using a female target and changing from a female masker to a male masker (12.4 dB, $t = 9.42$; $p < 0.0001$). A similar effect was not present when using a male target and changing from one masker gender to the other (0.7 dB, $t = .28$; $p = 0.79$). In addition, conditions with female targets resulted on average in a 6.65 dB poorer SRT compared to conditions in which a male target was used. Similarly, female masker conditions on average resulted in 5.86 dB poorer SRTs compared to male masker conditions.

The striking asymmetric effect of gender seen here may mean that CI users can use F0 cues in certain situations, but not in others. It is also possible that the particular voices (and their specific F0 and formant differences) used affected the results. Thus, a follow-up study with a larger number of subjects and a larger number of talkers is scheduled. If these results generalize across the larger corpus, this study may have implications for the mechanisms of masking in CI processing and the design of experiments looking at multi-talker speech in CIs, which now commonly only use a limited number of male target talkers with various maskers.

This research is supported by NIH NIDCD R03 DC008387

B36-a: Developing a Linguistic System Through Cochlear Implants: A Multiple Case Study of Four- To Seven-Year Old Deaf Children Learning German

Katrin Skoruppa[1] and Barbara Esser-Leyding[2]

[1] Speech, Hearing and Phonetic Sciences, UCL, UK
[2] Cochlear Implant Centrum Wilhelm Hirte, Hannover, Germany

Background: Many studies on language development in children with cochlear implants (CI) only include speech perception measures and/or standardized global language scores. The current study sets out to investigate the development of the language system after implantation in more detail, and to identify areas of strengths and weakness within the three major linguistic components of phonology, grammar and vocabulary/semantics.

Participants: A small number (n=6) of German-learning children with CI were assessed in detail. They were between four and seven years old. All children were severely to profoundly deaf from birth or prelingually deafened and had received one or two implants before their second birthday. They completed a normed test of preschool language development in German (Kauschke & Siegmüller 2003).

Results: Phonology: Most children's (n=4) auditory word identification was within normal limits for their hearing age. All children's speech production was well intelligible but affected by occasional substitutions, particularly for sibilants ([s], [ʃ], [ç]).

Vocabulary/semantics: Most children's receptive vocabulary skills were in the normal range for their hearing age (n=3) or chronological age (n=2). All children's productive vocabulary was age-appropriate. However, half of the children had some problems with semantic category organisation in an object sorting task.

Grammar: Most children's understanding of wh-questions was within the normal range for their hearing age (n=4). All of them had acquired the basic word order for German main clauses, but made occasional grammatical errors. Specifically, most children's (n=5) production of plural and case markings was at least one year delayed with respect to their hearing age.

Summary and discussion: The German children with CI studied here show a surprisingly good grasp of the sound structure of their native language, but they have persistent difficulties with the acquisition of morphology, especially with case markings and plural forms. Individual differences and the need for more research on morphology acquisition in children with CI will be discussed.

References: Kauschke & Siegmüller (2003). Patholinguistische Diagnostik bei Sprachentwicklungsstörungen. Urban & Fischer.

B36-b: Standardized Mandarin Sentence Perception in Babble Noise Test Materials for Children

Xin Xi, Aiting Chen, Jianan Li, Fei Ji, Mengdi Hong, Shiming Yang, Dongyi Han

Department of Otolaryngology, Chinese PLA General Hospital, Beijing, 100853

Tests of speech perception have been widely used in selection of cochlear implant candidates and rehabilitative outcome evaluation. To date, few standardized speech tests are available in China. We have established an assessment tool of BKB-like Mandarin sentences in babble noise, consisting of twenty-seven equivalent lists for adults.

In preschool children, we are concerned with the validity, reliability and norms of the new tool of Mandarin sentence perception in babble noise, as well as the effect of age on children's speech perception in noise. Fifty-four normal-hearing children aged 4 to 6 years were recruited from Beijing and were divided into three age groups (4.0-4.5, 4.5-5.0, and 5.0-6.0 years) containing 18 children each, half boys and half girls. According to randomized split-plot design, we examined their speech perception ability with 27 sentence-in-babble-noise lists in a sound-treated booth in a kindergarten (ambient noise <40dB A). The sentences paired with competing babble noise were presented at fixed intensity of 65 dB SPL with three different signal to noise ratios (SNR= +1, -2, -5 dB) by the same loudspeaker with 0º azimuth. Speech perception score were calculated based on the children's repetition of keywords in the sentence stimuli.

Results showed: ⑴Two-way (Lists & SNR) repeated measurement ANOVA and Post-Hoc Tukey HSD test revealed that no significant difference among the 27 lists. ⑵ Performance-SNR functions exhibited that the threshold was -1.96±0.19 dB SNR and the slope was 15.8±1.1%/dB for preschool children. ⑶Critical difference (CD) in 95% confidence was 24.6%. ⑷The repeated measurement ANOVA and Post-Hoc Scheffe test indicated that significant differences in performance were most pronounced between the 4.0-4.5 yr group and the other two groups (p<0.001), while there was no significant difference between 4.5-5.0 yr group and 5-6.0 yr group (p=0.90).

We can conclude that: The 27 lists of Mandarin speech perception in babble noise were equivalent among preschool children. The SNR50 corresponding to 50% perception score was close to -2dB SNR for preschool children, and the slope of Performance-SNR function was 15.8%/dB. Both of them were below the adult average. Total time taken to administer one list was on average 1.5 minutes. This material could be applied to city children aged 4.5-up years.

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B37: Modeling Speech Perception In Noise By Cochlear Implant Users

Elad Sagi and Mario A. Svirsky

New York University School of Medicine, New York, NY, USA

Most cochlear implant (CI) users complain about difficulty understanding speech in noisy environments. The aim of the present study is to develop models of speech perception by CI users in order to better understand the mechanisms they use to understand speech in noise. Twelve postlingually deafened adults implanted unilaterally with a CI were tested for vowel and consonant identification in quiet, and in the presence of steady-state speech-weighted noise. Resulting confusion matrices were modeled using a computational framework that produces confusion matrices based on a set of postulated speech cues coupled with estimates of a CI user's uncertainty for these cues. The speech cue measurements obtained for modeling were specific to the CI speech processor settings each subject used during testing. From the model's perspective, the presence of noise can cause speech cue values to shift and/or cluster together, making it more difficult to accurately identify one phoneme from another. Noise may also increase a listener's uncertainty for a given speech cue, or even mask it completely.

The better the model's fit to a subject's data, the better our description of the speech cues they employ. For example, a preliminary model that incorporates locations of mean formant energies along the implanted array as speech cues can account for the vowel data in quiet for 8 of the subjects tested, but for only 3 subjects' vowel data in noise. This suggests that other aspects of formant content, or other types of vowel speech cues are required to account for how the other CI subjects identify vowels in noise.

The latest modeling results for this data set will be presented. A future goal of this research is to use the best models that describe a CI user's data in order to predict and test speech processor settings that hold the greatest potential for improving that subject's speech perception in noise.

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B-38: Cochlear implant model using Mel-Frequency Cepstral Coefficients

Preethi Mahadevan, Pavithra Balaji, Shri Ranjani Sukumar, Vijayalakshmi Parthasarathy, Nagarajan Thangavelu

SSN College of Engineering, Kalavakkam, Tamil Nadu, India

The Mel-frequency cepstrum (MFC) is the linear cosine transform of the log power spectrum of the speech signal on a non linear Mel-scale of frequency. The Mel-frequency cepstral coefficients (MFCCs) are coefficients that collectively make up the Mel-frequency cepstrum. The Mel-scale approximates the human auditory system more closely than the normal frequency scale and hence the cepstral vocoder model can be used in the place of the conventional channel vocoder model for cochlear implants.

To extract the MFCCs, the speech signal is analyzed in frames of 25ms each and the power spectrum for each frame is obtained. The signal is then warped to the Mel-scale using triangular weighting functions. These spectral samples are then converted to cepstra by taking the log and then the discrete cosine transform (DCT) to obtain 13 cepstral coefficients for each frame of data. These coefficients have sufficient spectral information to get back the speech signal and can therefore be used in cochlear implants.

In the analysis section of the cepstral vocoder, the pitch and the voiced/unvoiced information are also determined. Features extracted from the speech, like short term energy, zero crossing rate and the autocorrelation main lobe width are used to determine whether each frame of speech is voiced/unvoiced. The pitch is extracted using the SIFT (Simplified inverse filter tracking) algorithm.

As cochlear implants are surgical procedures it is important to validate its functioning using simulation results before implantation. Thus the MFCCs are used to get back the spectral information by reversing the operations done in the analysis section. This is used along with the pitch and the voiced/unvoiced information in the synthesis section of the cepstral vocoder to reconstruct the speech signal.

This model was implemented for vowels, words from the LNT (Lexical neighbourhood test) database and sentences from the TIMIT (Texas instruments Massachusetts institute of technology) corpus. A performance analysis was also done with ten normal hearing subjects to grade the perceptual quality of the synthesized speech. The grading was done for a set of ten words from the LNT database, by each hearing subject. The quality of the synthesized speech was found to have an average grade of 3.1 on a scale of 5 and was intelligible with minimal strain.

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B39: Transmission of Speech Temporal Information At Different Electrode Locations in CI And ABI Users

Mahan Azadpour and Colette M. McKay

University of Manchester, Manchester, UK

The ability to detect temporal modulations of electrical stimulation is crucial for speech understanding with an auditory implant. Among the electrodes of an array, those that activate neural pathways that can better transmit temporal modulation information are expected to contribute most to speech understanding. The aim of this study was to evaluate the hypothesis that electrode locations in cochlear implant (CI) or auditory brainstem implant (ABI) users differ in their ability to transmit temporal information. Specifically, it was hypothesized that in CI users apical intracochlear electrode locations would allow better temporal information transfer than basal locations, and that in ABI users only a subset of ABI electrode locations would provide good temporal information transfer.

The bases for these hypotheses were that a) in normal hearing, the neurons in the apical cochlear region better encode temporal information than those in the basal region, through phase-locking mechanisms and b) the different neurons (and hence different electrode locations) in the Cochlear Nucleus have differing encoding functions in normal hearing and activate different efferent pathways, some of which are not useful for transmitting temporal information to the ABI user.

In this study transmission of speech temporal information was measured by performing closed set phoneme perception tests in CI and ABI users while a single electrode of the array was activated with the overall amplitude envelope of the signal. Separate confusion matrices were obtained for consonants and vowels and transmission of phonological features was measured for different locations of active electrodes in CI and ABI users.

In CI users, temporal speech information transmission for apical and basal electrode locations was compared. The results In ABI users were compared to those in CI users to assess how well temporal information can be conveyed by modulating the current amplitude on ABI electrodes. Also by identifying and choosing the ABI electrodes that better transmit speech temporal information it might be possible to improve performance of ABI users with the current processing strategies.

This study was supported by Deafness Research UK, the Royal National Institute for Deaf People, and the UK Medical Research Council.

B40: Using Sound Segregation Cues to Improve Cochlear Implant Vowel Recognition in Noise

Myles Mc Laughlin[1,2], Richard B. Reilly[2] and Fan-Gang Zeng[1]

[1] Dept. Otolaryngology-Head and Neck Surgery, UC Irvine, Irvine CA
[2] Trinity Center for Bioengineering, Trinity College Dublin, Ireland

Despite advances in cochlear implant (CI) technology, separating speech from background noise is difficult for CI users. Our research addresses this problem by studying psychophysical cues that allow CI users to separate speech from noise. Better knowledge of these cues will allow us to design speech processing strategies with improved performance in challenging listening environments. Here, we used a vowel-in-noise paradigm where we changed stimulation rate, amplitude modulation, rate modulation, and onset time, to study the cues underlying vowel recognition in noise for electric hearing.

Five vowels (/a/, /i/, /u/, /ɜ/ and /ɛ/) were represented by stimulating the two electrodes closest to their 1st and 2nd format frequencies at a constant rate of either 50, 145 or 795 Hz. Three different masker noises were represented by stimulating four electrodes, randomly chosen between trials, at a constant rate of either 50, 145 or 795 Hz. All nine rate combinations of vowel and masker were tested using a one interval, five alternative forced choice paradigm in 3 CI subjects with the Nucleus device. We found that a different stimulation rate for vowel and masker significantly improved vowel recognition but only if the masker was at a lower rate. Loudness balancing and amplitude roving procedures were used to ensure that this was not a loudness effect. These results were replicated in 3 normal hearing (NH) subjects using a noise vocoder CI simulation. The improved scores for conditions with lower rate maskers suggest that listeners may use longer temporal gaps in the masker to detect the vowel. This suggestion is supported by a model that uses the signal-to-noise ratio across electrodes or frequency bands, within a given temporal window (rounded exponential), to predict both CI and NH data.

In a 2nd experiment the vowel at 145 Hz was either rate modulated (8 Hz, 40% modulation depth), amplitude modulated (8 Hz, 5% modulation depth) or delayed (200 ms) and presented against the same noise masker conditions as in the first experiment. All three segregation cues improved vowel recognition for at least one listener, with the delay cue showing the largest and most reproducible improvements across subjects.

These results indicate that CI users can use temporal gaps in variable rate stimuli to improve vowel-in-noise detection. Speech processing strategies that enhance naturally occurring gaps and other segregation cues may improve CI performance in noisy environments.

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B41: Normalization to Talker Gender And F0: Phonetic Category Adjustment By Cochlear Implant Users

Matthew B. Winn and Monita Chatterjee

University of Maryland College Park, MD, USA

Phonetic perception involves not only sensitivity to acoustic dimensions such as frequency, duration and amplitude variation, but also to higher-level characteristics derived from spectral context, such as talker gender and vowel coarticulation. For example, a female /s/ sounds different than a male /s/, and an /s/ before /i/ is different than an /s/ before /u/. Some of the acoustic dimensions that distinguish gender and vowel context are exactly the type that are compromised in electric hearing – spectral cues such as F0, formant spacing and breathiness. Cochlear implant (CI) users can reliably perceive phonetic segments in quiet; can they also show sensitivity to spectral context when judging the acoustic boundaries between these segments?

This investigation focused on the ability of normal-hearing (NH) listeners and CI users to use spectral context to modulate the boundary between “s” and “sh” sounds in an identification task that featured multiple talkers (of both genders) and varying vowel contexts. Results showed that a significant phonetic boundary adjustment attributable to talker gender was eliminated in the spectrally-degraded conditions. In spite of this, gender identification was still excellent (virtually 100%), regardless of spectral degradation. Follow-up testing was done to explore the mechanism of this performance, using words whose F0 contours were raised, lowered, or gender-neutralized. For these words, there was a significant difference in performance in the normal (virtually 100%) versus degraded conditions (roughly 65%). It thus appears that gender identification under spectrally-degraded conditions is affected more heavily by F0, which is an insufficient cue for the talker-dependent spectral context effects observed in the phonetic identification task. Results with CI users reveal that performance is slightly better than that predicted by the simulations, but still significantly worse than that of NH listeners. These results highlight a potential explanation for why CI users may have more difficulty adjusting to multiple sequential talkers in conversation; they can identify some vocal characteristics, but not in a way that facilitates normalization of acoustic cues for phonetic segments.

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B42: Continuous Impedance Measurement Tool During Electrode Insertion.

Chin-Tuan Tan[1], J. Thomas Roland[1], Shaun Kumar[2], Claudiu Treaba[2], Bernie Caessens[2], Mario Svirsky[1].

[1]New York University School of Medicine
[2]Cochlear Ltd.

This study focuses on the development of a software tool that uses continuous impedance measurement during electrode insertion, as a way to assess and optimize electrode position and reduce insertional trauma.

Preserving and using residual hearing after cochlear implantation is of increasing interest and may lead to enhanced performance. Additionally, there is evidence that electrode position within the cochlea, including proximity to the stimulable neurons and electrode placement in the scala tympani may influence clinical outcomes. Thus, minimizing insertion trauma and obtaining precise electrode placement consistently is very important in current candidates for cochlear implantation, whose hearing loss may be in the moderate and severe ranges. Preserving residual hearing is particularly important to enhance outcomes in the case of "hybrid" cochlear implants.

Insertion trauma can be reduced through proper electrode design and surgical technique, and we have made many contributions along these lines over the last twenty years. However, other than fluoroscopy, real time feedback about the geometry and mechanics of electrode insertion to the surgeon is not available. However, all CIs incorporate electrode impedance measurements and therefore we propose a new approach that will provide surgeons information about electrode location with respect to the cochlear structures during insertion. The use of this information in the operating theatre may change the way CI surgeries are performed and enhance surgical capabilities.

These electrode impedance measures are primarily intended to verify electrode integrity when the patient's speech processor is programmed by audiologists. We propose to use the electrode impedance measurement functionality for a completely different purpose: to measure and display in real time how close the electrodes are to the cochlear walls during surgery, thereby allowing manipulations and steering in a real time fashion. A prototype program has been developed and we have successfully measured continuous impedance during two surgeries, proving the feasibility of the proposed idea. Data to be presented include our current results with the prototype software as well as new results obtained with a new version of the software that displays impedance measurements graphically in real time. New studies are performed with various electrodes in human cadaveric temporal bones.

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B43: A Polymer Based Intracochlear Electrode for Low Cost, but Highly Effective Cochlear Implantation

Kyou Sik Min[1, 3], Jin Ho Kim[1, 3], Ho Sun Lee[3], Min Hyun Park[2], Seung Ha Oh[2], Sung June Kim[1]

[1]School of Electrical Engineering and Inter-University Semiconductor Research Center, Seoul National University, Seoul, Korea
[2]Department of Otolaryngology-Head and Neck Surgery, College of Medicine, Seoul National University
[3] Nurobiosys Corporation, Suwon, Korea

Recently, there have been various efforts to facilitate residual hearings for making fine stimulation on cochlea. For this, the intracochlear electrode must allow deeper insertion without trauma (longer and finer electrode) while providing increased efficiency. It is difficult, however, to meet these requirements with conventional electrode makings. In this study, we report fabrication and performance of a polymer based microelectrode array-type cochlear electrode, which can meet these requirements at low cost.

A 25um-thick flexible liquid crystal polymer (LCP) film was used for electrode patterning. This method is extendable to monolithic integration with system package using the same substrate, further reducing the cost. We demonstrated previously feasibility of device encapsulation of the same material in vivo and in vitro accelerated soak tests. We also showed that the LCP electrode implanted in animal was sustained without degradation and caused no infection [1, 2].

For fine patterning on the flexible LCP substrate, we used photolithography and liftoff process, both commonly used semiconductor process. As a result, we realized reproducibly 4um-wide fine conducting lead wires and 10um-wide electrode patterns on LCP. Thus this technology can be used to print as many as hundred channels if desired.

As a prototype, we fabricated a 16-channel intracochlear electrode using LCP. Length of the final electrode was 31mm, and its width varied from 500um (apex) to 900um (base). Iridium oxide was sputter-deposited on Ti/Au layer for effective stimulation. Charge storage capacity and electrochemical impedance were 33.26 mC/cm2 and 1.02x103 kOhm (at 1 kHz) respectively in PBS solution. We are conducting human temporal bone study, and the result will be presented.

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[1] S. W. Lee, et al., "Monolithic Encapsulation of Implantable Neuroprosthetic Devices Using Liquid Crystal Polymers," IEEE Trans Biomed Eng, in press.
[2] S. W. Lee, et al., "Development of Microelectrode Arrays for Artificial Retinal Implants using Liquid Crystal Polymers," Invest. Ophthalmol. Vis. Sci., vol. 50, pp. 5859-66, June 24, 2009.

B44: Optogenetic Stimulation of The Auditory Nerve: Toward an Optical Cochlear Prosthetic

Victor H. Hernandez[1,2], Gerhard Hoch[1,2], Matthias Bartles[3], Gerhard Vogt[4], Carolyn W. Garnham[4], Tim Salditt[3], George J. Augustine[5,6] , Nicola Strenzke[2,7], Tobias Moser[1,2]

[1]InnerEarLab, Dept. of Otolaryngology, University of Göttingen Medical Center, 37099 Göttingen, Germany
[2]Bernstein Focus for Neurotechnology, University of Göttingen, Germany
[3]Department of Physics, University of Göttingen, Germany
[4]MED-EL Company, Innsbruck, Austria
[5]Program in Neuroscience and Behavioral Disorders, Duke-NUS Graduate Medical School, 8 College Road, Singapore 169857, Singapore
[6]Center for Functional Connectomics, Korea Institute of Science and Technology, 39-1 Hawolgokdong, Seongbukgu, Seoul, 136-791 Republic of Korea
[7]Auditory Systems Physiology Group, Dept. of Otolaryngology, University of Göttingen Medical Center, 37099 Göttingen, Germany

When hearing fails, direct electrical stimulation of spiral ganglion neurons (SGNs) by cochlear implants (CIs) enables open speech comprehension in a majority of deaf subjects. Still, while healthy listeners encode a wide range of sound pressures (106) and frequencies (103 in 2400 steps), CIs typically employ only a narrow range of electrical currents (up to 101) to encode sound intensity and no more than 22 channels for frequency coding. The latter limitation is caused by widespread current flow from each stimulating electrode, activating a large number of SGNs that represent many different sound frequencies. Optical stimulation enables more spatially precise activation of SGNs, in principle allowing for much better frequency coding. Here we demonstrate a proof-of-principle for optogenetic restoration of hearing. Optical stimulation of cochlear SGNs expressing the light-gated ion channel, channelrhodopsin-2, activated the auditory pathway in hearing mice and in mouse models of acute and chronic human deafness. Optogenetic auditory brainstem responses (oABR) had a minimum latency of approximately 4 ms and were present up to stimulus rates of 80 Hz. oABR amplitude encoded changes in irradiance over more than one order of magnitude. Telemetric activation of oABR was achieved using a micro-LED-based implanted optical stimulator. Optogenetic stimulation promises improved frequency and dynamic range coding in CIs.

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C1-a: Is Auditory Brainstem Implant Stimulus Rate Limiting Speech Perception Outcomes?

Stefan J. Mauger[1,2,3], Mohit N. Shivdasani[1,2,3], Graeme D. Rathbone[2,3] & Antonio G. Paolini[1,2]

[1] School of Psychological Science, La Trobe University, VIC 3086, Australia
[2] The Bionic Ear Institute, East Melbourne, VIC 3002, Australia
[3] Department of Electronic Engineering, La Trobe University, VIC 3086, Australia

The auditory brainstem implant (ABI) is clinically being used to restore hearing to patients unable to benefit from a cochlear implant (CI), but currently only provides limited speech perception. The ABI is implanted either adjacent to or on the surface of the cochlear nucleus (CN) in the auditory brainstem and utilizes stimulation parameters developed for auditory nerve stimulation with a CI. One of the most fundamental features of modern stimulation strategies since the general adoption of pulse train stimulation is the stimulus rate. Although a stimulus rate of 250 Hz is generally accepted for ABIs, only limited investigations have looked at the effects of pulse rate. Particularly, understanding of the effects of rate responses, temporal responses and the influence of inhibition from electrical stimulation would provide a strong basis for selecting a suitable stimulus rate for ABIs.

Experiments were performed on 15 anesthetized hooded Wistar rats. Ear bars were inserted into ears, and craniotomies were performed to expose the CN and inferior colliculus (IC). A 32-channel microelectrode was inserted into the CN and a single glass electrode was inserted into the IC. Acoustic broadband noise was presented through the ear-bars while the glass electrode was advanced through the IC until a neuron was found. Intracellular or extracellular traces were then recorded to acoustic tones at the neurons characteristic frequency (CF) and to electrical pulse trains of different rates from a CN electrode site closest to the neurons CF. Electrical stimulus rates of 100, 200, 400, 800 and 1600 pulses per second were used. After each experiment, animals were perfused and histology was performed to verify electrode placements. Artifact removal was performed for electrical pulse train traces to view intracellular recordings and to locate spikes in extracellular recordings.

Analysis of neural rate responses, neural temporal responses and neural inhibitory responses was performed. Response showed that rate-level functions not seen from cochlear stimulation were prevalent for some stimulation rates. Thresholds decreased, dynamic ranges increased, maximum firing rates increased and vector strength decreased with increased stimulation rate. Analysis of temporal similarity compared to the acoustic response was compared from each electrical stimulus rate. Low rates of 100 and 200 pps showed little similarity to acoustic stimulation, while high stimulus rates produced highly similar temporal responses. Analysis of both suppression and inhibition was also analyzed, showing that inhibition in the IC is common from electrical stimulation, and that it is dependant on stimulation strength.

Our results conclude that low stimulus rates currently used in ABIs do not produce the most suitable rate response or the most similar temporal response to acoustic stimulation. We also found that inhibition is activated through electrical stimulation, and is rate dependant. This study has demonstrated the complexity of response possible from electrical stimulation of the brainstem and analyses these responses to find an optimal stimulus rate for ABIs. We conclude that the common stimulus rate of 250 Hz is not most suitable for ABIs.

C1-b: Development Of Sound Localization Strategies In Children With Bilateral Cochlear Implants And With Normal Hearing

Yi Zheng[1], Shelly P. Godar[1], Ruth Y. Litovsky[1]
[1] Binaural Speech and Hearing Laboratory,
University of Wisconsin – Madison, Madison, WI, USA

The number of deaf children who receive bilateral cochlear implants (BiCIs) is increasing, in an attempt to provide them with improved spatial hearing skills, including improved sound localization abilities, compared with a single-CI listening mode. Children with BiCIs have relatively poorer localization performance than children with normal acoustic hearing. There is an open question regarding the development of localization strategies mediated by experience in children with BiCIs.

One experimental approach to investigate behavioral sound localization is the multi-sound source identification task, in which listeners are asked to locate a sound source from a multiple source locations. This approach was used to examine the emergence of sound localization ability in a group of 12 children with BiCIs (5 to 14-years-old). Testing was conducted longitudinally with ~12 months between tests. In addition, a group of 6 typically developing children with normal hearing (5-years-old) were tested.

A novel data analysis scheme was introduced, which is aimed at understanding how children map the acoustic space to a spatially-relevant perceptual representation. This information is not available from traditional root-mean-square (RMS) error calculation which provides a single metric over the entire loudspeaker array. Localization sensitivity was therefore evaluated using a non-parametric independent group comparison procedure, quantifying the independence of responses to difference sound source locations. The normal hearing group distributed their responses along a continuum, with high spatial sensitivity, indicated by numerous statistically-different response clusters. In contrast, BiCI users tended to classify sound source locations to a small number of clusters, typically left and right. With an increase in bilateral hearing experience, the BiCI group developed a perceptual map of space that was better aligned with the acoustic space. These findings suggest that children with early auditory deprivation and less experience make categorical judgments regarding sound source locations, and with time develop localization ability that improves first at midline and subsequently for lateral positions.

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C2: Evidence For Benefit From Mismatched Binaural Speech Processors For Speech In Noise: Glimpsing or Combination Of Spectral Cues Across Ears?

Andrew Faulkner, Stuart Rosen, Catherine Siciliano*

UCL, UK
*University of Manchester UK

The results of simulation studies of binaural listening with interaurally mismatched frequency-to-place maps have so far been consistent with a "better ear" account that predicts that the binaural combination is never better then the better of the two monaural constituents. However, these studies involved conditions in which one ear provided substantially better performance than the other. Here we investigated binaural conditions in which both ears alone lead to similar performance. This was achieved by the presentation of speech in quiet that was sine-vocoded with an upward frequency shift to one ear, while the other ear received speech in noise processed through an unshifted sine-vocoder. Vocoder processing used a total of 10 analysis bands split between the two ears as in a 'zipper' processor. Odd-order bands were presented to one ear with a frequency shift equivalent to 3.8mm on the basilar membrane, while the five even-order bands were presented unshifted to the other ear. The interleaving of bands ensured that the listener can, in principle, gain advantage from combining information across both ears. The SNR in the unshifted ear was 10 dB which resulted in a similar speech perception performance to that expected for the shifted ear in quiet. After several hours of training, the binaural combination of these inputs gave significantly better performance than either of the two ears alone. This binaural advantage may reflect the combination of spectral information over the two ears despite the frequency-to-place mismatch. Alternatively, it may reflect a glimpsing process by which the shifted but noise free input to one ear signals instants of relatively reliable input in the noisy signal that is presented to the unshifted ear. The possibility that a binaural advantage arose from glimpsing controlled by the amplitude envelope of the shifted input was tested in a follow-up experiment by eliminating all spectral envelope cues in the shifted input, such that each carrier was modulated by the wideband amplitude envelope of the speech input. While the binaural advantage found previously was replicated, there was no binaural advantage over the unshifted ear alone when spectral envelope cues were removed from the shifted input. In contrast to previous simulation studies, we conclude that listeners are able to combine speech spectral cues over two ears despite the presence of a mismatch of frequency to place map between the two ears, but that this may not be possible when one ear provides substantially more useful information than the other.

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C3: Effects of Interaural Electrode Channel Offset on the Binaural Interaction Component of the Electrically Evoked Cortical Auditory Potential

Shuman He, John H. Grose, Craig A. Buchman

Department of Otolaryngology—Head and Neck Surgery, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

Two important clinical trends in cochlear implantation are decreased age at cochlear implantation and bilateral implantation. These trends create tremendous challenges for clinicians who work with pediatric cochlear implant (CI) recipients. While behavioral measures have been used to maximize performance and demonstrate benefit in adults, undertaking these measures in children can be a challenge. There is an urgent need to develop objective tools that can be used to assess the impact of bilateral cochlear implantation, and to assist with the programming process of cochlear implantation in young children. The long-term goal of this program of research is to determine if the binaural interaction component (BIC) of the electrically evoked P1-N1-P2 complex is an effective measure for use in the programming of speech processors and/or in the assessment of benefit of bilateral stimulation in young patients with bilateral CIs. As an initial step, this project focuses on the effect of interaural spatial offset of electrode channels on the BIC of the P1-N1-P2 complex in adults and older children who use bilateral CIs.

The P1-N1-P2 complex was recorded in child and adult bilateral CI recipients using a multi-channel Neuroscan system. To elicit the response, the speech processor was bypassed and the stimulation was delivered directly to individual electrodes. For each patient, the right ear electrode was fixed and it was systematically paired with one of 3-5 electrodes in the left ear. Stimulation level to the right ear electrode was set at 50% of dynamic range and stimulation level to the left ear electrode was adjusted to maintain equal loudness between electrodes in two ears. The P1-N1-P2 complex was recorded in response to left monaural, right monaural and bilateral stimulation for each interaural electrode pair tested. The BIC of the P1-N1-P2 complex was computed for each interaural electrode pair by subtracting the P1-N1-P2 complex recorded in response to binaural stimulation from the algebraic sum of the two monaural evoked potentials.

Data to date indicate that the BIC amplitude is affected by the amount of interaural spatial offset of the electrode pair. Specifically, the BIC is maximal for electrode pairs with small interaural spatial offsets and decreases in amplitude as spatial offset increases. Our preliminary results also suggested that 1) the BIC of the P1-N1-P2 complex can be recorded from bilateral CI recipients as young as 18 mos; and 2) there are maturational changes in the BIC of the P1-N1-P2 complex.

C4: Effect of Acute Between-Ear Frequency Mismatches on Speech Understanding in Users of Bilateral Cochlear Implants

Matthew B. Fitzgerald, Mario A. Svirsky,

New York University School of Medicine, New York, NY, USA

Bilateral cochlear implants (CI) provide many benefits, including improved speech understanding in noise and sound-localization abilities when compared to monaural CI use. These benefits are observed even though some patients may have a between-ear mismatch in insertion depth or neural survival. When sufficiently large, such mismatches can hinder sound-localization abilities. However, little is known whether between-ear mismatches can also affect speech understanding. As a first step toward addressing this issue, we measured CNC word and vowel recognition in quiet in a group of adult bilateral CI users after simulating a between-ear mismatch. All mismatches were imposed by deactivating either apical or basal electrodes in the more recently-implanted ear, and then reprogramming the frequency table. These simulated mismatches attempted to mimic a situation in which the electrode was inserted more deeply, or more shallowly, in one ear than the other. Four conditions of simulated mismatch were tested: Apical 2, Apical 4, Basal 2, and Basal 4. These four conditions simulated between-ear electrode mismatches of 2 or 4 electrodes in either the apical or basal direction, respectively. For each condition, CNC word-recognition and closed-set vowel identification scores were obtained bilaterally after allowing the participant a brief 5-10 minute period of acclimatization to the new mismatch condition. CNC and vowel-identification scores were also obtained in a baseline condition consisting of the standard frequency tables utilized in each patient's processor. Results of this investigation suggest that speech understanding scores deteriorate only slightly from the baseline in the Apical 2 and Basal 2 conditions. In contrast, scores in the Apical 4 and Basal 4 conditions were considerably worse than the baseline condition. While the acute nature of this experiment must be considered, on the whole these data suggest that small bilateral mismatches of 2 electrodes or less are unlikely to affect speech understanding in bilateral CI users, while large mismatches of 4 electrodes may hinder performance.

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C5-a: Criteria of Candidacy for Bilateral Cochlear Implantation in Children

Rosemary E. S. Lovett[1], Deborah A. Vickers[1], A. Quentin Summerfield[2]

1. UCL Ear Institute, University College London, London, UK.
2. Department of Psychology, University of York, York, UK.

Two trends have changed the provision of cochlear implantation for children in recent years. First, there has been a progressive relaxation of the criteria of candidacy. Second, it has become increasingly common to implant both ears. Consequently, children with residual hearing are now eligible to receive bilateral implants. In some cases, it can be challenging to predict whether a newly-diagnosed child would show better outcomes with implants or with acoustic hearing aids.

We are conducting a longitudinal comparison of outcomes for children with bilateral implants and children with bilateral acoustic hearing aids. The aim is to generate data that can be used to define criteria of candidacy for bilateral implantation in children. The study is novel in the combination of multiple outcome measures, a longitudinal design, and a focus on children who were provided with modern devices bilaterally at a young age.

We will recruit 80 children aged between 3.0 and 4.9 years. Two-thirds of the children will be users of bilateral acoustic hearing aids with hearing impairment ranging from moderate to profound; the remaining third will be users of bilateral implants. The primary outcome measure is a closed-set test of the ability to discriminate spoken words in noise. Secondary outcome measures include assessments of speech perception in quiet, sound-source localization, language skills, and quality of life. Children will complete the assessments twice: when they enter the study and a year later.

For each outcome measure, a regression function will be used to characterize the relationship between unaided hearing level and performance for children who use acoustic hearing aids. The distribution of scores for implanted children will be used to calculate, for a newly-diagnosed child with a known hearing level, the odds of better performance with implants than with hearing aids. A criterion of candidacy can be defined as the most advantageous hearing level for which the odds of better performance with implants exceed an acceptable ratio, such as 4 to 1 (Boothroyd, 1993). At the conference, we intend to present results from the first assessments of between 30 and 40 children.

The study is supported by RNID.

Boothroyd, A. (1993). Profound Deafness. In R. S. Tyler (Ed.), C*ochlear implants: audiological foundations* (pp. 1 - 33). San Diego: Singular Publishing Group.

C5-b: Perceptual Learning of Interrupted Speech With Cochlear-Implant Simulations

Michel R. Benard[1,2], Deniz Başkent[2,3]

[1]Audiologisch Centrum Zwolle, Zwolle, The Netherlands
[2]University Medical Center Groningen, Groningen, The Netherlands
[3]School of Behavioral and Cognitive Neuroscience, University of Groningen, The Netherlands

Hearing-impaired listeners and users of hearing aids or cochlear implants commonly complain about difficulties understanding speech in background noise. Normal-hearing listeners use several mechanisms that help in such difficult listening environments. One of these mechanisms is phonemic restoration in which the listener perceptually restores inaudible or masked portions of temporally interrupted speech, taking advantage of the context and redundancy in speech signals. Previous research has shown that this benefit is reduced or does not exist in cochlear-implant users. This research explores perceptual learning of speech interrupted with silence or noise intervals with and without simulations of cochlear implants.

The experiment is spread over three days with 3 sessions per day, each session comprising 26 Dutch sentences. The subjects were tested on the perception of speech interrupted by silence and by noise at the start and the end of the experiment. In-between, the subjects were trained on interrupted speech. Audiovisual feedback was provided during these training sessions.

Preliminary baseline results of 16 subjects with no implant simulations showed a clear increase in performance during the training sessions leading to a plateau after a few days. The phonemic restoration benefit was an increase of 10% in correctly repeated words, which was still present after intensive training. This means that phonemic restoration is not a side effect due to the unfamiliarity of the subjects with this kind of speech.

Furthermore, normal listeners were tested and trained with the same procedure using speech processed by an 8-channel noiseband vocoder, in order to create a simulation of Cochlear Implant (CI) speech. Preliminary results from 4 subjects showed that some subjects benefitted from interrupting by noise over silence after the training sessions. Hence, training produced a better phonemic restoration. None of the subjects showed this benefit before the training sessions.

The results of this study might influence rehabilitation of implant users since severely hearing-impaired listeners can benefit more from phonemic restoration by being trained on restoring missing fractions of speech.

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C6: Improved Language Outcomes for Children With Bilateral Cochlear Implants

Tinne Boons [1,2], Jan P.L. Brokx [3], Johan H.M. Frijns [4], Louis Peeraer [2], Birgit Philips [5], Anneke M. Vermeulen [6], Jan Wouters [1], Astrid van Wieringen [1]

[1)] ExpORL, Department Neurosciences, K.U.Leuven, Leuven, Belgium
[2)] Institute of Allied Health Sciences, Fontys University of Applied Sciences, Eindhoven, the Netherlands
[3)] ENT Department, Maastricht University Medical Centre, Maastricht, the Netherlands
[4)] ENT Department, Leiden University Medical Centre, Leiden, the Netherlands
[5)] ENT Department, Ghent University, Ghent, Belgium
[6)] ENT Department, Radboud University, Nijmegen, the Netherlands

Several studies have shown that a second cochlear implant in children has a positive effect on the auditory development. Improved localization and speech understanding skills enhance the ability to perceive speech in more challenging listening environments like noisy class rooms and family gatherings. This improved speech intelligibility could facilitate the ability to pick up language in everyday life. At this time, there is a lack of evidence on the long-term effect of bilateral cochlear implantation on language development. The goal of this study was to examine the benefit of paediatric bilateral cochlear implantation in comparison to unilateral cochlear implantation on language outcomes.

Since five CI centers, two in Belgium and three in the Netherlands, took part in this retrospective multicenter study it was possible to incorporate 288 Dutch speaking children with unilateral or bilateral cochlear implants. A group of bilaterally implanted children (n = 25) was carefully matched with a group of unilaterally implanted children (n = 25) on ten variables. Their chronological age varied between 3;08 and 5;06 years. Receptive and expressive language skills were evaluated three years after the first implantation.

On the receptive as well as on the expressive language test the bilaterally implanted children performed significantly better than the unilaterally implanted children. Since the two groups were matched on ten auditory, child and environmental factors, the difference in performance can be mainly attributed to the bilateral implantation. Shorter time between both implantations was related to higher language quotients. Children with two simultaneously implanted CI's performed better on expressive language tests than children with two sequentially implanted CI's. Although the positive effect of bilateral implantation in children on auditory development has been shown in several studies, this study is one of the first to demonstrate a positive effect on language outcomes.

C7-a: Presenting Low-Frequency Cues Visually In Simulations Of Electric-Acoustic Stimulation

Marine Ardoint, Christopher A. Brown, Kate Helms Tillery, and Sid P. Bacon
Arizona State University, Tempe, AZ, USA

Some cochlear implant listeners have residual low-frequency acoustic hearing in the ipsilateral or contralateral ear. Previous studies have shown large improvements in speech intelligibility in different kinds of background noise when low-frequency acoustic stimulation is combined with real or simulated electric stimulation, a configuration known as electric-acoustic stimulation, or EAS. Interestingly, presenting a low-frequency tone modulated in frequency to follow the target speaker's fundamental frequency (F0) and in amplitude to follow the slow amplitude variations of the target speech is sufficient to provide a large benefit to speech intelligibility. However, the mechanism underlying the EAS benefit is still unclear. According to one hypothesis, the pitch cue in the low-frequency region fuses with the relatively weak pitch cue delivered electrically into a single percept, which allows the user to better segregate target from masker. According to another hypothesis, the low-frequency cues indicate when to glimpse the cues already present in the high-frequency part of the speech signal. The present experiment has two main goals: 1) determine if the low-frequency cues important for EAS benefit could be transmitted visually instead of acoustically, and 2) investigate the mechanism underlying the EAS benefit. If fusion between the low-frequency part of the signal and the electric stimulation is required, then a visual cue is unlikely to provide any benefit, because the visual and auditory stimuli are very unlikely to fuse into a single percept. However, if a glimpsing mechanism underlies the EAS benefit, the visual cue could provide some help. This study has implications for cochlear implant users with no residual hearing, as it aims to determine whether those patients might benefit from the same low-frequency cues that underlie EAS benefit, but when those cues are presented visually.

In the present experiment, normal-hearing listeners were presented with vocoder simulations of electric hearing. In one condition, no low-frequency cues were combined with the vocoder. In the other conditions, the low-frequency cue added to the simulated electric signal was either i) the low-pass speech, or a tone carrying ii) the voicing cue, iii) the amplitude envelope cue, iv) the F0 cue, or v) all three cues from the low-pass speech. These cues were also presented visually with a dot on a computer screen that moved left to right with time, up and down with changes in frequency, and became larger and smaller with changes in amplitude. The results compare the benefit provided by each of the cues in each mode of delivery (visual or acoustic).

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C7-b: Consonant Recognition in Quiet and in Noise with Combined Electric and Acoustic Stimulation

Yang-soo Yoon, You-Ree Shin, and Qian-Jie Fu

House Ear Institute, 2100 W. 3rd St., Los Angeles, CA 90057

In bimodal hearing, listeners combine the acoustic information provided by hearing aids (HAs) with the electric information provided by cochlear implants (CIs). Depending on patient-related factors, processor-related factors, and the listening task, acoustic cues from HAs may enhance or interfere with electric cues from CIs.

In this study, thirteen post-lingually deafened subjects were grouped according to acoustic pure-tone average (PTA) thresholds between 0.25 and 1 kHz with the HA. In the Good group, PTA thresholds were < 50 dB; in the Poor group, PTA thresholds were ≥ 50 dB. For all subjects, closed-set consonant recognition was measured in quiet and in steady, speech-shaped noise. Consonant stimuli included (/b, d, g, p, t, k, m, n, f, s, ʃ, v, ð, z, ʤ, ʧ/) presented in a a/C/a context and produced by 5 male and 5 female talkers. The signal-to-noise ratio was 5 dB or 10 dB. For each subject, performance was measured with the CI alone, HA alone, and with the combined CI+HA; subjects were tested using their clinical HAs and CIs. Stimuli were presented at 65 dBA in soundfield from a single loudspeaker; subjects sat directly facing the loudspeaker. For the CI alone condition, the HA was removed and the ear was plugged. Results were analyzed in terms of overall percent correct for each listening mode, perception of consonant features (voicing, manner and place of articulation), and the amount of residual acoustic hearing.

Mean HA performance was significantly better for the Good group in quiet and in noise; there was no significant difference between groups for the CI and CI+HA listening conditions. For the Good group, CI+HA performance was significantly better than CI; for the Poor group, there was no significant difference between the CI and CI+HA conditions. Confusion matrices were analyzed in terms of speech information transmission. For the Good group, perception of voicing and place of articulation cues was significantly better with the CI+HA than with the CI alone. Further analysis showed that recognition of some consonants (/b, d, k, m, n/) was poorer with the CI+HA than with the CI alone, providing some evidence that the HA interfered with the CI. For the Poor group, there was no significant difference in consonant feature perception between the CI+HA and CI conditions. For the poor group, recognition of consonants /b/ and /f/ was poorer with the CI+HA than with the CI alone.

The patterns of results for the two subject groups suggest that the amount of residual acoustic hearing limits the benefit of bimodal hearing. The results also suggest that acoustic and electric signals should be optimized to reduce interference between modes.

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C8: Frequency Contour Detection and Mandarin Monosyllable Perception in Native Mandarin Chinese Speakers With Electric-Acoustic Hearing

Hsin-I Yang, Fan Gang Zeng

Department of Biomedical Engineering, University of California, Irvine, CA, USA

In Mandarin Chinese, four tones give distinctly lexical meanings of words and can be characterized by the duration and the variation of fundamental frequency. To correlate the abilities of detecting frequency contours and of recognizing lexical tones in real EAS listeners, four tones: flat (T1), raising (T2), raising-falling (T3), and falling (T4), with 300ms were synthesized. In an adaptive 3-alternative-3-forced-choice paradigm, two flat tones were served as references, and the target stimulus was one of the four contours to determine the frequency difference limens of four tone contours (T1:T1, T1:T2, T1:T3, and T1:T4) under three listening conditions (E-alone, A-alone, and EAS). The Mandarin monosyllable lexical neighborhood test was also performed in noise (SNR = 10 dB with speech-shaped noise) to evaluate the performances of perceiving words produced by a natural male sound under different listening conditions.

Seven EAS users and four normal hearing listeners are currently participating in the experiment. The preliminary data showed that no significant difference between E-alone and EAS in the task of frequency contour detection, and the performance of A-lone was usually the worst due to the severely-to-profoundly hearing loss. Moreover, T1 and T3 contours, compared with T2 and T4, could be detected with smaller difference limens in both EAS and normal hearing listeners. In lexical neighborhood test (LNT), EAS benefit was observed in consonant and tone recognition but not in vowel and word recognition, which suggested that the additional voicing information provided by acoustic stimulation did improve consonant recognition. Unlike tone contour detection, the T1 and T4 of the LNT words were much easier to be recognized, and lots of confusion between T2 and T3 existed. It implied that the ability to detect frequency contours was not the only factor to recognize tone correctly, and EAS listeners might distinguish T4 from others by means of tone duration. It was also found that the E-alone frequency difference limens in native Mandarin Chinese speakers were much smaller than those in the only one native English speaker in the current experiment, which suggested that continuous training on tonal language may enhance frequency discrimination of CI listeners.

C9: Effects Of Electric Pitch Adaptation On Acoustic+Electric Speech Perception In Long-Electrode Cochlear Implant Users

Rindy A. Ito, David R. Wozny, and Lina A.J. Reiss

Oregon Health and Science University, Portland, OR. USA

As cochlear implants (CIs) have improved, implantation criteria have expanded to include patients with more residual hearing. Many of these patients benefit from the combined use of a CI and hearing aid (HA), especially for music perception and speech perception in background noise. However, there is significant variability in the benefit. One area that has been relatively unexplored is the interaction between the electric and acoustic hearing. This interaction may also be influenced by mismatches in pitch perception between the two inputs introduced by the speech processor frequency allocations. We have found that some, but not all, CI users adapt their pitch perception so that the inputs are matched. This study aimed to measure electrode pitch perception in long-term CI users and compare whether pitch adaptation affects the way these inputs interact in speech perception.

Unilateral adult CI users with at least 1 year of CI experience and measurable hearing to at least 500 Hz in the contralateral ear were recruited for this study. All subjects wore a Cochlear N24 or newer internal device. Prior to pitch matching, all pitches in the acoustic ear and all electrodes in the implanted ear were loudness balanced. For pitch matching, 500 ms biphasic pulse trains were presented through direct stimulation to a Cochlear Freedom processor and a 500 ms acoustic tone was presented sequentially to the non-implanted ear with a Sennheiser HD 25-SP headphone. Subjects were asked to indicate which stimulus was higher in pitch in a method of constants procedure. Vowel perception was tested in a sound field using the subject's speech processor and with the following conditions: CI alone, CI + HA, and HA alone.

Preliminary findings show that 4 of 5 subjects had at least partial adaptation to the CI frequency allocation. The subjects that adapted all used a HA or had low-frequency residual hearing loss < 30 dB HL, while the subject that did not adapt did not wear a hearing aid and had thresholds >75 dB HL. Vowel perception results indicate that 3 of 4 subjects who had adapted pitch perception improved perception with the CI+HA over the CI alone, while 1 subject had worse perception or interference with the CI+HA compared to the CI alone. These findings will increase our understanding of how pitch adaptation between the CI and residual hearing relates to the integration of combined acoustic and electric inputs for speech perception.

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C10: Mechanisms of Bimodal Speech Benefit

Anisa S. Visram, Mahan Azadpour, Karolina Kluk, Colette M. McKay

University of Manchester, Manchester, UK

Although it is known that significant speech perception benefits arise from listening with a hearing aid in addition to a cochlear implant (CI), the mechanism of this benefit is poorly understood. This leads to difficulties in counselling patients as well as uncertainty of the best fitting methods to optimise benefit. A series of three studies investigated which acoustic cues provide bimodal speech perception benefit for cochlear implantees, how such cues are used, and how bimodal benefit may be optimised. Cochlear implantees with residual hearing in the non-implanted ear took part.

Study 1 investigated the speech perception benefit of different acoustically-presented speech cues including a fundamental frequency (F0) cue (amplitude and F0 modulated tone) or a spectral-shape cue (narrowband noise vocoded speech) in both quiet and noise. These conditions with isolated acoustic cues were compared to CI-alone and full-bimodal-speech conditions. A benefit of using the isolated F0 or spectral cues was not found: the only significant benefit of any of these cues over the CI-alone condition was provided by the full bimodal speech condition, in both quiet and noise.

Study 2 measured perception of a target sentence in a single talker background in both CI-alone and bimodal conditions. Various talker-masker conditions involving two male and two female talkers as both targets and maskers were used in a balanced design. It was hypothesised that more bimodal benefit would be obtained for target-masker combinations with more-different F0s (mixed male-female combinations compared to same-sex combinations) as acoustic perception of F0 may help in separating simultaneous voices. There was a significant overall bimodal benefit, and listeners performed better in the mixed target-masker combinations in both CI-alone and bimodal conditions. However, the degree of bimodal benefit was not related to degree of F0 separation, so the hypothesis was not supported.

Study 3 investigated the hypothesis that proportional frequency compression of the acoustic signal would increase bimodal speech perception benefit. Speech tests were performed in three conditions: CI-alone, uncompressed-bimodal, and bimodal with acoustic speech compressed at a ratio of 0.7. The subjective quality of speech in each condition was also measured. Preliminary results will be reported.

C11: Emphasizing Modulations In Vowels Improves Perception Of Interaural Time Differences In Bimodal Stimulation

Anneke Lenssen[1], Tom Francart[1,2] and Jan Wouters[1]

[1] ExpORL, Department of Neurosciences, K.U.Leuven, Leuven, Belgium
[2] The Bionic Ear Institute, Melbourne, Australia

Bimodal listeners, i.e. cochlear implant (CI) users using a hearing aid (HA) in the non-impanted ear, are sensitive to interaural time differences (ITDs) in modulated single and multiple channel stimuli. In contrast, they do not seem to be sensitive to ITDs in unmodulated low-frequency stimuli, which indicates the importance of envelope timing cues for ITD perception with bimodal stimulation.

The perception of envelope ITD is dependent on modulation depth, onset steepness and duty cycle. With current clinical devices, modulations are not always clearly transmitted in the electrical stimulus due to channel saturation and channel selection criteria.

In the current study we assessed ITD perception performance with synthetic vowel stimuli processed by either the standard clinical speech processing strategy (ACE) or by a newly developed strategy, a speech processing algorithm that introduces modulations in the electric signal, synchronized with modulations in the acoustic signal.

We compared ITD perception performance between ACE and the new strategy in five bimodal listeners.

All subjects showed significantly higher ITD perception performance with the new strategy than with ACE. With the new strategy four out of five subjects had JNDs in ITD in the order of 100-250us. The results encourage the further development of a speech processing strategy for bimodal stimulation that introduces amplitude modulations synchronized with modulations in the acoustic signal to improve the perception of ITD cues. Improved ITD perception can lead to better localization abilities and speech understanding in noise.

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C12: Cortical Evoked Potentials Recorded From Hybrid CI Users: Effect of Stimulation Mode and Programming Strategy

Carolyn J. Brown[1,2], Paul J. Abbas[1,2], Christopher Turner[1,2], Julie Jeon[1], Li Chiou[1], Ben Kirby[1], Sue Karsten[1], Christine Etler[2]

[1]Dept. Communication Sciences and Disorders
[2]Dept. Otolaryngology-Head and Neck Surgery
University of Iowa, Iowa City, Iowa, USA

Individuals with good low frequency hearing and steeply sloping audiometric configurations are difficult to fit with conventional amplification. The Iowa/Nucleus Hybrid cochlear implant (CI) was designed specifically for this population. It is a cochlear implant that has been designed to preserve low-frequency acoustic hearing. Successful Hybrid CI users are able to combine low frequency, acoustic signals routed through a hearing aid (HA) with high-frequency sounds that are coded electrically by the CI. Research has shown that Hybrid CI users outperform traditional long-electrode CI users on tasks such as music perception and perception of speech in background noise. This technology is still relatively new and to date little is known about how best to program the device to optimize performance.

The purpose of this study was to determine (a) if we could use cortical evoked potentials to assess how Hybrid CI users combine acoustic and electrical information provided to the same ear, (b) if cortical potentials evoked using spectrally complex stimuli can be used to predict overall performance with the device, and (c) if differences in performance that result from changes in the way the device is programmed are reflected in the cortical evoked potentials.

This research is ongoing, but we will report on the results from six participants who have completed the study to date. These subjects are postlingually deafened adults who have used the Nucleus Hybrid CI for at least a year prior to testing. We created a series of 3 experimental MAPs by varying the proportion of the acoustic signal routed to the CI and to the HA. Each subject was asked to use the experimental programs for two weeks before returning for testing. The effect of both programming and listening mode (Acoustic, Electric and Acoustic plus Electric) on amplitude of the cortical responses was then measured and compared with perceptual test results obtained using speech stimuli presented both in quiet and in noise. Preliminary results suggest that we can use cortical potentials to assess the benefit a Hybrid CI user obtains from each of the three listening modes. Comparisons between results of the speech perception testing and evoked potential studies will also be described.

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C13-a: The Usefulness and Limitations Of Spread Of Excitation Measurements For The Individual Fitting Of Virtual Channels

Dietmar Basta[1], Rolf-Dieter Battmer[1], Filiep Vanpouke[2], Patrick Boyle[2], Arne Ernst[1]

[1]Department of Otolaryngology at ukb, University of Berlin, Germany
[2]Advanced Bionics, European Research Centre, Hannover, Germany

The clinical application of virtual channel stimulation mode is typically undertaken without any further testing of electrode contacts beyond contact impedance checking. However, some patients benefit from current steering while others do not. Therefore, an individual test for the availability of additional pitch precepts between physical electrode contacts, as produced using current steering stimulation, should improve overall outcome. A psychophysical test, (e.g. frequency difference limens, FDL), is very time consuming and not appropriate in children, or non-compliant adults. A detailed characterization of the relationship between FDL values and the related spread of neuronal excitation (SOE) implies that the latter could be applied as a relatively fast and objective method of predicting individual benefit from a current steering strategy. We therefore, investigated the feasibility of predicting individual outcome from current steering strategies using SOE measurements. FDL and SOE measurements were performed at 3 electrode sites (basal, medial, and apical) in 24 adult patients with an Advanced Bionics 90k/Harmony system. CI usage was at least 12 months. FDL was determined by using a 3 alternative forced choice adaptive procedure with two similar and one different stimulation. Loudness was adjusted to the “loud but acceptable” level. Different pitches were created during FDL testing by current steering. A similar current level was applied for SOE and FDL measurements. The SOE was estimated by three different methods: width of the eCAP amplitude shape over the electrode array at 60 % after fitting a linear or exponential regression line, or without fitting a regression line. We did not find any significant differences between the results of the 3 analysis methods. There was a trend towards lower SOE without using a regression line. This method also produced the highest electrode correlation coefficients between FDL and SOE. The results enable a prediction between a good or poor outcome (classified by the FDL) of the individual patient when using a current steering strategy by a discrimination function with a likelihood of approximately 70 %. Although the bivariant correlation between FDL and SOE values was low, a classification prediction of individual benefit (good/poor) with a current steering strategy is possible by SOE values. This is of particular interest for non-compliant patients.

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C13-b: Variability In Intracochlear Electrical Spread Patterns

Eddy De Vel[1], Katrien Vermeire[1], Filiep Vanpoucke[2], Birgit Philips[1], Ingeborg Dhooge[1]

[1] Ghent University Hospital, ENT-department, Ghent, Belgium
[2] Advanced Bionics Research, Antwerp, Belgium

Modern multi-channel cochlear implants (CI) have the flexibility to electrically stimulate the auditory nerve and to capture various electrical signals inside the cochlear lumen. An example of such an objective measure is e.g. the family of eCAP (electrical compound action potential) measurements documenting the response of the peripheral auditory fibers to electrical stimulation. The auditory nerve response is driven by the intracochlear electrical field, These voltages can be captured through the electrode and the implant, a technique known as electrical field imaging (EFI) of intracochlear potentials. An EFI curve from a single contact demonstrates how the intracochlear potential is decaying as the recording contact is roved along the electrode array. Previous research has shown that the details of these electrical spread patterns depend on the local resistivity of the intracochlear tissues and on the position of the electrode. Therefore EFI has the potential to detect e.g. ossification or fibrosis of the cochlear lumen. Furthermore, it can be used for checking the electrode integrity (e.g. short circuits) or for detecting a fold over of the electrode tip. Although knowledge of the electrical field can also be useful towards choice of stimulation strategy and fitting, our primary interest in this study was to investigate the use of EFI as a quality tool for the surgery and to gain insight in the variability of this measure in our patient population.

We collected intra-operative EFI data sets in a group of 24 users of the Advanced Bionics HR90K implant with the Helix electrode. The EFI measurements were made with the EFIM research tool. EFIM implements time domain and frequency domain measurement paradigms in order to reach the accuracy needed to bring out differences in the cochlear tissues. The analysis of the measurements was performed by custom software in matlab. The resulting spread curves were analyzed for their decay constants towards apex and base. Local resistivity parameters in the longitudinal and transversal direction were derived and the amount of current flowing out of the cochlea along the array was determined. Finally the intracochlear position of the electrode was assessed.

Across the population significant differences are observed in the electrical spread parameters. On average we found a steeper decay towards the basal region than towards the apex. Therefore there is a tendency for the electrical current to leave the cochlea near the base. In a quarter of our subjects we found an increase in local impedances in the mid-cochlear region. In one of our subjects clear indication for ossification is found. No cases of tip fold-over were observed.

C14: Auditory Stream Segregation In CI Simulations: Evidence From Event-Related Potentials

Yingjiu Nie, Yang Zhang, and Peggy B. Nelson

Department of Speech-Language-Hearing Sciences
University of Minnesota, Minneapolis, MN, USA

Auditory stream segregation helps listeners segregate target speech from a background. Two mechanisms—primitive (pre-attentive) and schema-based (requiring attention)—have been reported as underlying factors (Bregman 1991). Spectral information available through a cochlear implant (CI) or simulation is substantially degraded, which results in weak primitive segregation abilities. As a result, complex listening may require more attention on segregation. The goal of this study was to explore the cues potentially available to CI users for stream segregation by measuring event-related brain potentials (ERPs) of normal-hearing participants listening to sequences of noise bursts.

Sequences of alternating A and B noise bursts were used to elicit stream segregation. The buildup of separate streams facilitated the detection of the final delayed B burst. The A and B bursts were either bandpass noises of separate frequencies (spectral cues) or they were broadband noise with the same frequency range (no spectral cues). ERP's were measured in both the ignore condition and the attentive condition. In the ignore condition, the listener's attention was directed away from the acoustic stimuli by watching a movie; in the attentive condition, listeners were directed to attend to the sequences with the last B burst delayed.

Preliminary data showed evidence for stream segregation based on spectral and temporal cues, and for the selective role of attention. P300 was found when the listener correctly identified the delayed B bursts in the attentive condition for both broadband (no spectral cue: P300 latency 345 ms) and bandpass (spectral cue: P300 latency 354 ms) conditions. In the ignore condition, a pre-attentive mismatch negativity (MMN) was found for the delayed B bursts for bandpass (spectral cue: MMN latency 319 ms) conditions but not for broadband conditions. No MMN or P300 was seen for the control condition of no-delay B bursts for either spectral condition.

The findings suggest that the large spectral difference between the two bandpass noises may elicit stream segregation preattentively, which may indicate the occurrence of primitive segregation. Temporal cues did not contribute to primitive segregation but may facilitate schema-based segregation. Results suggest that CI users may have cues for primitive segregation when their electrodes are stimulated far apart, and that when the same sets of electrodes are stimulated sequentially, the tempo cue in addition to focused attention may elicit stream segregation.

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C15: Temporal Processing of Vocoded Speech in Human Auditory Cortex

Nai Ding[1], Monita Chatterjee[1], Jonathan Z. Simon[1]

[1]University of Maryland, College Park, MD, USA

Given the relative lack of fine spectral cues, cochlear implant (CI) listeners must rely greatly on temporal cues for speech perception and therefore understanding speech in noise is particularly difficult for CI listeners. Here, we study how the temporal cues of simulated-cochlear-implant speech are encoded in human auditory cortex, and test the robustness of this neural code to degradation by background noise.

The cortical auditory neural activity was recorded from 4 normal hearing listeners, using Magnetoencephalography (MEG), while listening to either unprocessed speech or speech processed by a 12-band noise vocoder. The speech materials are 1-minute long excerpts from a narrated audio book. Both unprocessed speech and vocoded speech evoke a reliable auditory response that is phase locked to the slow temporal modulations (<10 Hz) of speech, i.e. the envelope. The neural representations of unprocessed speech and vocoded speech are found to be equally precise. Nevertheless, the neural response to vocoded speech is delayed, compared with the response to unprocessed speech, suggesting that the vocoded speech requires more processing before being encoded.

To investigate whether the noise susceptibility of this simulated-cochlear-implant speech is caused by degradation of temporal processing, we employed a vocoded noisy speech stimulus that contains speech-shaped noise 6 dB weaker than the speech, and also used unprocessed noisy speech at the same signal-to-noise level as a control stimulus. The −6 dB noise fills in the quiet periods of the speech stimulus and makes the temporal modulations in speech less salient. It has little impact on the intelligibility of unprocessed speech but reduces the intelligibility of the 12-band vocoded speech from ceiling to about 87 % (listeners' subjective estimates). Surprisingly, however, the cortical auditory response is still precisely phase locked to the temporal modulations of speech and even shows a higher gain, similarly for both unprocessed and vocoded speech. To summarize, we have demonstrated that the temporal cues of vocoded speech and unprocessed speech are encoded in roughly the same manner in human auditory cortex. This precise neural representation of temporal cues is not degraded by intermediate level (-6 dB) background noise. These results indicate that a coarse spectral resolution does not interfere with the neural processing of slow temporal cues (<10 Hz), leading to the hypothesis that any deficits in the understanding vocoded noisy speech do not stem from degradation of the neural processing of temporal cues.

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C16: EFI and In Vitro Field Measurements to Assess the Effect of Current Focusing and Current Steering Inside and Outside the Scala Tympani

Carlo K. Berenstein[1], Filiep J. Vanpoucke[2], Lucas H.M. Mens[1], Ad F.M Snik[1]

[1]Hearing and Implants, Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands
[2]Advanced Bionics European Research Center, Antwerp, Belgium

An accurate in vivo measurement of the intracochlear electrical field (Electrical field imaging, EFI) created by electrical stimulation of one or more electrode contacts is helpful to assess the effects of different electrode configurations, such as focused stimulation and current steering. Recording the intracochlear potential is possible on non-stimulating contacts. However, when recording on an active electrode, the electrical response is contaminated by the reactive impedance of the active electrode, rendering the near-field intracochlear potential driving the nerve at that site inaccessible. Earlier, we have introduced a method to estimate the potential peak from EFI (Hearing Research, 2010) by extrapolation of measurements from non-active electrodes.

The goal of this study is to validate this extrapolation method for mono- and tripolar configurations in a human temporal bone. We use a set-up similar to that of Ifukube et al. (IEEE Trans. Biomed. Eng. 1987). A specific question is how current level affects the field geometry in terms of magnitude, width and decay, inside and outside the implanted cochlea, and if these parameters can be related to the data from previous psychoacoustic studies where we documented the effect of current focusing on loudness.

In a pilot experiment, intrascalar potential measurements in our specimen and clinical EFIs showed similarities with respect to the importance of anatomical structures (e.g. a basal or mid-cochlear current pathway) and the use of an electrode positioner. Extra-scalar potentials are being collected.

EFI refined by knowledge from these experiments, in combination with radiological data holds promise for a better understanding of different electrode configurations in individual patients.

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C17: Ectopic Electrical Stimulation In Cochlear Implants

Charles C. Finley[1], Laura K. Holden[2], Timothy A. Holden[2] and Jill B. Firszt[2]

[1]Advanced Bionics, Valencia, CA, USA
[2]Washington University School of Medicine, St. Louis, MO, USA

We have noted physiological evidence of an ectopic (out of place) site of electrical stimulation that may produce competing neural activity and may be associated with diminished cochlear implant (CI) performance.

We have examined subjects implanted with the Advanced Bionics (n=16) and Cochlear (n=13) CI systems. All subjects were studied using high-resolution CT imaging, intracochlear evoked potential (IEP) recording, electrode pitch discrimination, and measures of speech recognition. IEP recordings included measures of the spatial spread of neural responses obtained by holding the site and level of monopolar-coupled stimulation constant and incrementally changing the recording electrode site longitudinally along the array. In this case, variability in the N1 latencies of IEP responses is frequently observed, whereas normally no latency shift would be expected. When the latency shifts are observed, the response latencies become progressively shorter as the recording site is moved basally away from the apical stimulation site. Conversely, stimulating basally will frequently produce similar shifts toward shorter latencies as the recording electrode is moved apically.

To explain these paradoxical latency shift results, we hypothesize that the recorded responses are the net sum of neural responses from two stimulation regions. One is the ganglion cell body region in the vicinity of the stimulating electrode which responds with a long latency response traveling anterogradely out of the cochlea. The other is a site at the base of the cochlea where the VIII nerve exits through the cochlear canal (CC) into the internal auditory meatus (IAM). This secondary ectopic site is stimulated as monopolar-coupled current injected into the bone-enshrouded cochlea exits through the CC region into the IAM, thus producing a local, short-latency neural response that travels both anterogradely toward the brain and retrogradely back into the cochlea. At the recording electrode within the cochlea, the recorded response is the net summation of responses from these two regions. By changing the position of the recording electrode, the relative contribution of the long- and short-latency sources is altered resulting in an apparent latency shift in the net response. Stimulation at the ganglion cell site is thought to be tonotopically-specific, whereas stimulation at the CC is thought to be tonotopically-nonspecific, giving rise to conflicting acoustic percepts. Some subjects with this phenomenon report competing noise and grunt/echo-like sounds which occur only when someone is speaking.

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C18: Music Perception By Cochlear Implant Users

Joseph D. Crew[1], John J. Galvin III[2], Qian-Jie Fu[1,2]

[1]University of Southern California, Los Angeles, CA, USA
[2]House Ear Institute, Los Angeles, CA, USA

Cochlear implants (CIs) have given profoundly deaf people the ability to understand speech in quiet environments. However, the perception and appreciation of music remains challenging. This study aims to identify music perception tasks that are especially difficult for CI users.

In this study, CI subject performance was measured using several music perception tasks and one speech-in-noise task. Subjects were recruited without regard to musical training or experience, device type, or device configuration. All subjects had more than 2 years of implant experience. Music perception tasks included: musical note discrimination, music chord (major/minor) identification, melodic contour identification (MCI), MCI with an overlapping or non-overlapping masker (in terms of pitch range), musical instrument identification, and familiar melody identification (FMI) with or without rhythm cues. Speech reception thresholds (SRTs) were adaptively measured using HINT sentences presented in speech babble. CI subjects were tested using their clinically assigned speech processors and settings. All stimuli were presented in a sound treated booth at 65dBA via a single loudspeaker.

In terms of mean performance, the most difficult task was major/minor chord identification, followed by MCI with an overlapping masker, FMI without rhythm cues, MCI with a non-overlapping masker, musical instrument identification, MCI with no masker, FMI with rhythm cues, and finally, musical note discrimination. As with previous studies, the results showed a wide range in CI subject performance. The FMI and MCI tasks exhibited very high across-subject variability, while the major/minor chord identification task exhibited relatively low variability (because all subjects performed at chance-level). MCI performance was poorer with a competing masker, and FMI performance was worse, for some subjects much worse, when the rhythm cues were removed.

In general, CI performance was much poorer when multiple notes were presented in unison (i.e., MCI with or without a masker, note discrimination vs. chord identification). For the MCI tasks, the pitch of the masker did not have a consistent effect on performance; some listeners seemed to attend to the highest frequency components and others to the lowest. Some listeners may have been able to discriminate between major and minor chords but could not identify them. As such, training may help to improve CI performance for more difficult music perception tasks.

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C19: Role of Brightness In Pitch Perception Tasks: Implications For Cochlear Implant Place Pitch

Vijay M. R. Marimuthu[1], Brett A. Swanson[2] and Robert H. Mannell[1]

[1]Macquarie University, Sydney, Australia
[2]Cochlear Ltd, Sydney, Australia

Researchers have speculated that cochlear implant (CI) place-pitch is more akin to the brightness attribute of timbre than pitch. As brightness can be ordered on a low-to-high scale, it could allow high scores on ranking and discrimination tests. An operational definition of pitch is that variation in pitch can convey melody, thus a test involving melody perception is preferred. A recent study (Swanson et al., 2009) using the Modified Melodies test supported the hypothesis that CI place cues are sufficient to convey a melody. Although anecdotal reports from subjects suggested that they were indeed hearing a melody based on pitch changes, the possibility that subjects were recognising patterns of brightness changes could not be completely ruled out.

The aim of the present study was to investigate the role of brightness in pitch perception tests in normal hearing individuals. 18 normal hearing adults participated in four experimental procedures: 4AFC discrimination, ranking, and Modified Melodies test (Backwards and Warp modifications), using three stimulus conditions: (i) Pitch sequences: harmonic tones varying in pitch, with constant brightness; (ii) Brightness sequences: harmonic tones varying in brightness, with constant pitch; (iii) Noise sequences: Low-pass noise bands, varying in cut-off frequency.

The scores for discrimination and ranking were high for all three stimulus conditions, and d-prime analysis revealed that the subjects' performance was better in discrimination than ranking.

In the Modified Melodies test, when subjects were required to detect a melody contour change, scores were high for all three stimulus conditions. Conversely, when the melody contour was preserved but the musical intervals were changed, scores using pitch sequences were high, while scores using brightness or noise sequences were at chance-level.

Thus subjects were able to discriminate and rank brightness, and were able to detect brightness contour changes, but were unable to make judgements of musical intervals for brightness. These results suggest that the cochlear implant recipients in the previous study (Swanson et al., 2009) perceived place cues as pitch rather than brightness.

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C20-a: Infrared Neural Stimulation Of The Chronically Deafened Cochlea As Seen From The Inferior Colliculus

Agnella Izzo Matic[1-2], Suhrud M. Rajguru[1], Claus-Peter Richter[1-3]

[1]Dept. of Otolaryngology, Northwestern University, 303 E. Chicago Ave, Searle 12-561, Chicago, IL 60611
[2]Dept. of Biomedical Engineering, Northwestern University, 2145 Sheridan Road, Tech E310, Evanston, IL 60208
[3]The Hugh Knowles Center, Department of Communication Sciences and Disorders, Northwestern University, Evanston, IL

Over the last several years, infrared neural stimulation (INS) has been investigated as a means of stimulating spiral ganglion cells in the cochlea. In contrast to previous studies in which most of the data were acquired from animals that were acutely deafened, here we present data in which the cochlea was chronically deaf. A chronically deaf preparation will better mimic the physiological state of an individual with a cochlear implant, which is one possible implementation of INS technology. In the present study, we characterize the spatial and temporal patterns of neuronal activity to irradiation of the cochlea with infrared pulses.

To chronically deafen the guinea pig, one transtympanic dose of neomycin (~200μl, 20mM) was administered in the left cochlea under sedation. The guinea pigs were allowed to wake up and survive for ~4 weeks to allow for complete deafening and neural degeneration. For the recordings, a multichannel electrode was placed in the central nucleus of the right inferior colliculus (ICC) using ipsilateral acoustic stimulation. ICC neural activity was recorded in response to INS of spiral ganglion neurons. Data analysis included spatial tuning curves (STCs), peri-stimulus histograms (PSTHs), and entrainment. To measure the entrainment of the ICC neurons, the pulse repetition rate was varied from 10 to 300 pps.

No CAP could be evoked with acoustic stimuli, even at the highest sound levels of the speaker. However, cochlear laser stimulation was still possible in all animals. Data show similar results and patterns to previously collected data in acutely deafened guinea pigs. Spatial tuning curves were narrow. PSTHs show latencies of the neural response to be ~4.9 – 5.4 ms. Neurons were entrained to the stimulus up to ~200Hz stimulation rate.

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C20-b: Responses of the Cochlea to NIR LASER Stimulation in Thermal and Stress Confinement

Hannes Maier[1], Michael Schulz[1, 2], Ingo Teudt[1], Peter Baumhoff[1], Andrej Kral[1]

[1]Institute of Audioneurotechnology & Dept. of Experimental Otology, ENT Clinics, Medical University Hannover, Germany,
[2]Laser Zentrum Hannover, Germany

Optical stimulation of neural tissue within the cochlea is described as a possible alternative to electrical stimulation. Most optical stimulation was performed with pulsed lasers operating in near infrared (NIR) light in thermal confinement.

Here we demonstrate that near-infrared laser radiation at a typical wavelength for neural stimulation (λ = 1850 nm) can result in stress relaxation waves with considerable pressure levels. Sound pressure levels up to 62 dB peak - to - peak equivalent SPL (dB ppe SPL) at 0.17 J/cm2 were recorded. In ambient air the sound field in front of the optical fiber was created in a longitudinal volume along the optical pathway. The acoustic events depended on absorption in water. Hydrophone measurements demonstrated the presence of audible pressure waves in a swimming pool under similar conditions as used for cochlear stimulation.

Cochlear responses to laser pulses in µs and ns range were further investigated in rodents. In animals with normal cochlear function laser evoked compound action potentials (LCAPs) were recorded while irradiating the round window (RW) or a location next to the middle turn. Similar responses were recorded when the fiber was inserted into the scala tympani. The LCAPs showed a two domain response, consisting of a component with short latency ranging from 0.27 to 0.29 ms, and a component with a longer latency ranging from 1.12 to 2.11 ms.

Amplitude-radiant exposure and latency-radiant exposure functions demonstrated different behavior for the two components. Amplitudes of the second component saturated on average for radiant exposures above 0.12 J/cm2. More importantly this component could be masked by acoustic white noise in contrast to the first component that was insensitive to masking. The characteristics of the components indicate that the first one is an acoustic cochlear microphonic potential and the second one the compound action potential induced by the laser beam.

Our results demonstrate that with NIR lasers, pressure waves are generated, resulting in acoustic cochlear microphonics and compound action potentials in hearing rodents. When NIR optical stimulation is used to evoke responses from the hearing or partially functional cochlea, care must be taken to distinguish between responses to sounds generated by the laser beam from direct neural excitation by laser pulses.

This work is supported by the German research council SFB TR 37.

C21: Study on the Tonotopy Of Polymer Membranes Mimicking the Human Basilar Membrane

Won-Joon Song, Sung-Jae Bae, Junsik Park, Wan-Doo Kim

Korea Institute of Machinery & Material, Daejeon, South Korea

As an important functional part of the cochlea, the basilar membrane is responsible for frequency separation of the stapedial vibration. In current study, scaled-up polymer membranes configured by mimicking the human basilar membrane were used for investigation of the tonotopic characteristic. Spatial distribution of velocity on each polymer membrane was acquired by Laser Doppler scanning vibrometer and post-processed in frequency-by-frequency manner. The locations of the maximum displacement were collected for specific frequency range to produce the space-frequency map of individual polymer membrane. The influences of the membrane thickness and material properties on the variation of the membranal tonotopy were discussed.

C22-a: Pitch of Dual-Electrode Stimuli As a Function of Rate And Electrode Separation

Paul A. Bader[1], Reinhold Schatzer[1], Katrien Vermeire[1], Paul Van de Heyning[2], Daniel Visser[1], Andreas Krenmayr[1], Mathias Kals[1], Clemens M. Zierhofer[1]

[1]C. Doppler Laboratory for Active Implantable Systems, Institute of Ion Physics and Applied Physics, University of Innsbruck, Austria
[2]Dept. of Otorhinolaryngology and Head and Neck Surgery, University Hospital Antwerp, University of Antwerp, Belgium

Previous studies have investigated the effects of electrode separation and pulse rates on pitch perception for dual-electrode stimuli in cochlear implant users. Results were mixed in that some studies suggested that subjects hear an aggregate temporal pitch for smaller electrode separations, while other studies did not.

Pitch perception for dual-electrode stimuli in monopolar configuration was investigated in five MED-EL subjects. The participants had near-to-normal hearing in the contralateral ear and received an implant in the deaf ear as an effective remedy against otherwise intractable tinnitus. Loudness-balanced dual-electrode stimuli consisting of unmodulated trains of biphasic pulses at different rate configurations were pitch-matched to contralateral acoustic pure tones. Apical electrode pairs E1/E2, E1/E3, and E1/E4 were stimulated at rates of 100 pps/200 pps and 100 pps/100 pps, respectively, with zero phase delay.

Across rate conditions, results show no differences in perceived pitch for different electrode pair separations from 2.4 mm to 7.2 mm. Both rate conditions were matched slightly above 100 Hz, with the 100/200 pps rate pairs being matched consistently higher than the 100/100 pps pulse pairs. However, pitch differences among rate conditions are not statistically significant.

Results do not show a significantly different interaction across channels as a function of electrode separation, as pitch percepts do not differ among smallest and largest separations. However, as the 100/200 pps pulse pairs were consistently matched to slightly higher pure tone frequencies than the 100/100 pps pulse pairs, channels are not completely perceptually independent.

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C22-b: Simulation of Cochlear Implant Users' Speech Intelligibility Performance Using a Spiking Auditory Model

Stefan Fredelake, Birger Kollmeier, Volker Hohmann

Medizinische Physik, Universität Oldenburg, Oldenburg, Germany

The speech recognition performance for, e.g., speech in noise, exhibits a high variability in a cochlear implant (CI) user population. Some CI users show speech reception thresholds (SRT), which are comparable to the SRT of normal hearing listeners. Other CI users need slightly or considerably increased signal-to-noise ratios to achieve the same speech intelligibility score.

These large performance differences of individual CI users can be attributed to different individual preoperative duration of deafness, residual hearing before surgery and preoperative speech intelligibility. The main physiological origins of these performance differences are assumed to be degenerative functional changes of the auditory nerve. However, no quantitative models exist, which account for the relation between parameters of the auditory processing and the speech perception with CIs. This contribution presents a functional spiking model of the electrically stimulated auditory system applied to the speech recognition simulation in CI users.

The model consists of an auditory nerve cell population, which generates delta pulses as action potentials in dependence on the temporal and spatial distribution of the electric field with a simulated CI signal processing strategy. Afterwards, the delta pulses are spatially and temporally integrated resulting in an internal representation, i.e., a time-varying activity pattern. Finally, internal representations, derived with speech items from a German sentence test in noise, were classified using a Dynamic-Time-Warping speech recognizer, and therefrom the SRT was predicted for several model parameter sets.

Several model parameter sets, each related to different degenerative functional changes in the auditory nerve, were evaluated. For example, the number of auditory nerve cells was systematically decreased, while the width of the spatial spread function of the electric field within the cochlea was increased. Furthermore, cognitive processes during the speech recognition were modeled using multiplicative internal noise with different standard deviations to account for different cognitive performance.

Reducing the number of auditory nerve cells while increasing the spatial spread function resulted in poorer speech recognition. Furthermore, a reduced cognitive performance with increased internal noise showed an additional negative impact on the speech recognition, especially if only a few auditory nerve cells were available. A physiologically plausible variation of model parameters resulted in a SRT range that was also quantitatively observed in clinical studies with a large CI user population.

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C23: Preliminary Investigation of the Relationship Among Place Pitch, Musical Pitch and Speech Recognition of Cochlear Implant Users

Meng Yuan [1], Li-chuan Ping[1, 2], Qing-lin Meng[1, 2], Hai-hong Feng[1]

[1] Shanghai Acoustics Laboratory, Chinese Academy of Sciences, Shanghai, China
[2] Graduate University of Chinese Academy of Sciences, Beijing, China

The main goal of this study is to investigate the relationship among place pitch perception, musical pitch discrimination and Chinese speech recognition of cochlear implant (CI) users.

Pitch ranking test was carried out to evaluate the place pitch perception of CI users. Musical pitch discrimination and Chinese speech recognition experiments were also conducted. Four post-lingually deafened CI users were recruited. The d prime of pitch pitch perception was evaluated. The preliminary test results showed that the place pitch was increased generally along with the electrodes from apex to base. However, large individual difference among the subjects was observed. It was shown that musical pitch discrimination and Chinese speech recognition of CI users were related to their place pitch perception ability. Speech recognition performance was good (94.8% - 100% correct for closed-set and open-set evaluation of 3 subjects and 75.7% and 71.7% correct for another subject). The musical pitch discrimination for all the four subjects were not as good as their speech recognition performance (3-15 semitones). It indicated that the current signal processing of CI system cannot provide sufficient information for music perception of CI users. To a certain extent, music perception was determined by their place-pitch abilities.

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C24-a: The Modulation of Auditory Feedback on Speech Production in Children with Cochlear Implant

Ningyuan Wang[1], Juan Huang[1,2]

[1] Key Laboratory of Machine Perception (Ministry of Education), Department of Intelligence Science, Peking University, Beijing, 100871, People's Republic of China
[2] Mind and Brain Institute, Johns Hopkins University, Baltimore, MD 21218, USA

Cochlear implant (CI) provides impoverished auditory stimulation to users who often display impaired auditory perception and production. Speech perception in CI users has been extensively studied and well documented. In contrast, much less has been studied for speech production by CI users. Auditory feedback, especially when listening to one's own voice, has been shown to play a critical role in speech production and learning. In the present study, we aimed to investigate that to what extent auditory feedback could modulate speech production in CI users. Twelve Mandarin-Chinese speaking children with unilateral cochlear implant were tested under three conditions: (1) Vocalizing Mandarin syllables based on visual reminder, (2) Vocalizing Mandarin syllables based on visual reminder with CI turned off, (3) Vocalizing Mandarin syllables after listening to playback of the same syllables. Objective and subjective evaluations were carried out on the recorded Mandarin syllables produced by the subjects. Fundamental frequency, consonants, vowels, and Mandarin tones information were analyzed. The results showed that auditory feedback influenced vowel and tone production. Tuning CI off significantly decreased the intelligibility of vowels and recognition of tones but not consonants. In addition, there was a strong correlation between the accuracy of subjects' vowel production and the standard deviation of F2/F1 from their production. Our results provide important clues for designing efficient speech rehabilitation training program for CI users.

C24-b: Cognitive Effort and the Perception of Speech by Adult Cochlear Implant Users: A Survey

Rana A. Alkhamra[1, 3], Brad Rakerd[1], Jerry Punch[1], Terry Zwolan[2], and Jill Elfenbein[1]

[1]Michigan State University, East Lansing, MI, USA
[2]University of Michigan, Ann Arbor, MI, USA
[3]University of Jordan, Amman, Jordan

Postlingually deafened adults who receive a cochlear implant (CI) often recover the ability to perceive speech. At the same time, the CI-processed speech signal that they receive lacks a number of acoustical features that are available to listeners with normal hearing. The present survey study tested the hypothesis that adult CI users must therefore make a substantial commitment of cognitive effort in order to achieve perceptual success when listening to speech.

Survey respondents (n=127) rated the cognitive effort that they expend when listening to speech in a wide variety of everyday circumstances. They also rated the effort needed at various points in time, both pre- and post-implant. Finally, they provided demographic and hearing history information, which was examined in relation to the cognitive effort ratings.

The respondents reported experiencing a sharp reduction in speech listening effort during their first days and weeks post-implant and continuing but lesser reductions in effort for several months thereafter. Listening effort was reported to increase significantly whenever background noise is present and to be sharply dependent upon the noise level. Effort was also reported to increase significantly when there are multiple speakers in a conversation, when the topic of the conversation is unfamiliar, when one or more of the speakers is unfamiliar, and when a speaker is either non-native or speaks rapidly. Finally, CI users who regularly wear a hearing aid in the opposite ear reported less effortful listening under challenging conditions than did users who do not wear a hearing aid.

A potential clinical benefit of this survey study is that the results point out the potential importance of using a hearing aid in the opposite ear. Respondents who use a hearing aid often reported exerting less cognitive effort than those who do not use one, especially when listening in situations that pose special challenges. In addition, clinicians need to be aware of the importance of top-down processing skills for speech perception by all CI users. An individual's ability to use top-down processing may affect both the period of acclimation to a new CI and also the long-term benefit that may be derived from sustained CI use.

C25: The Importance of Segregation In Masking Release

Bomjun J. Kwon, Trevor T. Perry, Cassie L Wilhelm, Eric W. Healy

The Ohio State University, Columbus, OH, USA

Normal hearing (NH) listeners maintain robust speech understanding in fluctuating noise through masking release (MR), in which listeners extract information when the instantaneous amplitude of the background is low, then combine this information to restore the content of speech. Literature indicates that cochlear implant (CI) listeners, on the other hand, generally do not show such resiliency -- given an impoverished input, the task of "glimpsing" or "connecting-the-dots" using fragments of speech may be more challenging. In most previous studies, temporal masking of speech segments occurs at random, making it difficult to address to what degree MR is attributed to the temporal arrangement of speech and masker making speech understanding more or less favorable, and/or to what degree MR is accounted for by top-down processes in the listener, occurring despite speech information compromised by the masker. We directly examined this issue by testing 9 NH and 9 post-lingually deafened CI subjects' speech understanding in noise in a condition where MR was artificially promoted. That is, the short-term energy of the masker was adjusted in inverse proportion to the speech envelope (the masker became more intense when the speech was less intense, and vice versa), thereby making the temporal overlap between speech and masker minimal. Speech understanding was also measured in steady noise as a reference condition. The Speech Reception Threshold (SRT) measured with IEEE sentences indicated that NH subjects showed, not surprisingly, a substantial amount of MR, as much as 16 dB. Interestingly, three CI subjects, who had been considered "excellent" users, demonstrated a significant amount of MR, as much as 6-10 dB. However, the amount of MR in the remaining subjects was not significant (i.e., no significant difference in SRT between the steady and fluctuating masker conditions).

A tentative conclusion can be made that MR can occur in CI subjects who demonstrate excellent speech understanding. Yet it is puzzling that the "average" CI users are unable to utilize intact speech information interspersed with the fluctuating noise. This suggests that the ability to segregate the target speech from the background is essential for MR, and lacking in these CI users. Supplementary experiments are currently underway to confirm this account, where (i) the fluctuating masker consists of competing speech from the same speaker, to make segregation more difficult, and (ii) the masker is restricted to only a small number of fixed electrodes, to make segregation easier. Preliminary findings to date are in line with the expectation that MR appears to be critically affected by these cues for segregation.

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C26-a: Modelling Of Central Auditory Nervous System Processing In Cochlear Implant Mediated Hearing

Johan J. Hanekom, Stuart C.J. Smith, Pieter J. Venter

University of Pretoria, Pretoria, South Africa

Ideally, models of cochlear implants should be able to predict diverse data sets, including speech recognition data and data from a variety of psychoacoustic experiments. Is this were the case, it would be possible to prototype concepts for new or improved speech processing algorithms in simulation before time-consuming testing with cochlear implantees. Appropriate cochlear implant (CI) models are required to describe peripheral auditory neural excitation patterns, and in addition appropriate models of central auditory processing are required to investigate how the statistics of CI-mediated neural excitation (that differs considerably from normal acoustic stimulation) influences perceived sound. The research reported here considers modelling of central auditory processing.

A stochastic model to predict psychoacoustic data was created. This model has two processing steps. In the first, the model encodes an input signal (e.g., a pure tone) in space-time action potential trains derived from either acoustic or CI stimuli (the latter from a modelled Nucleus 24 cochlear implant). The second step is a model of central auditory nervous system (CANS) processing which decodes the action potential trains to estimate the original input signal and to predict the outcomes of discrimination tasks (e.g. frequency discrimination) using either type of stimulus. Using an optimal estimation mechanism, the CANS model interprets action potential trains by first estimating their instantaneous rates and then decodes these using state estimation methods. Two state estimation decoders were considered: maximum likelihood (ML) decoder and centre-of-gravity (COG) decoding.

Using these to predict frequency discrimination experimental outcomes, the COG decoder predicted smaller frequency discrimination thresholds than the ML decoder. Predictions were compared to normal-hearing (NH) and CI frequency discrimination data obtained in sound field. Although the trends of available data were predicted by the COG decoder, the predicted discrimination thresholds were superior to the experimentally obtained results. However, when using the ML decoder, the model predictions were similar in trend and magnitude to experimental results.

Predictions with this model were compared to the predictions of a phenomenological model of frequency discrimination in cochlear implants. Together, the results have implications in terms of (i) the processing mechanisms that the CANS may employ and (ii) the application to cochlear implants, and affirm the need to consider the processing mechanisms employed by the CANS when designing speech processing strategies for cochlear implants.

C26-b: Hemispheric Lateralization of Cortical Responses in Children Using Bilateral Cochlear Implants

Daniel D.E. Wong, Karen A. Gordon

The Hospital for Sick Children, Toronto, ON, Canada

We examined cortical activity evoked by right versus left ear stimulation in children using bilateral cochlear implants (CIs). CIs stimulate the auditory nerve using electrical pulses, promoting auditory development in children who are deaf. Because unilateral hearing is known to cause reorganization along the auditory pathways, we hypothesized that children using unilateral CIs and children who had long delays between their first and second CI would show abnormal lateralization of activity in the auditory cortex compared to children experiencing short or no periods of unilateral implant use.

Electroencephalographic responses were measured from 64 scalp locations in 17 children. Bilateral CI users were divided into three groups, corresponding to the time period between the activation of their first and second implant. The long delay group (n=10) consisted of children whose second implant was activated > 2 years after the first. The short delay group (n=8) consisted of children whose second implant was activated < 1 year after the first. Both CIs were activated at the same time in the simultaneous group (n=10). Responses from bilateral CI users were compared with those recorded from children using a single CI in the right ear (n=9). We measured the difference in activity between left and right auditory cortex hemispheres (cortical lateralization) for each evoked response.

Repeated measures ANOVA analysis revealed that in our group of children, responses evoked from a CI which was worn unilaterally for an extended period (unilateral and long delay groups) lateralized to the contralateral auditory cortex more strongly than responses from children with short or no periods of unilateral CI use (short delay and simultaneous groups) ($F=4.37(3,23)$, $p < 0.05$).

The differences in lateralization found in children receiving bilateral CIs after long delays could reflect a reduced ability of the pathways stimulated by the second CI to compete with the established pathways from the more experienced side, resulting in a system that is different from one in which bilateral pathways develop in tandem. If so, this suggests that there is a sensitive period for bilateral input in the developing auditory system

C27: The Effects Of Multiple, Very Early Refelctions On Vocoded Speech Perception

Sarah F. Poissant & Nathaniel A. Whitmal, III

University of Massachusetts Amherst, Amherst, MA, USA

Reverberation is likely to be the single-most detrimental characteristic of the natural listening environments in which cochlear implant (CI) recipients routinely converse and therefore deserves careful study. In our earliest work on the perception of reverberated, CI-processed speech we examined the integration of reflections of vocoded signals at source-listener distances that had either strong contributions from direct sound (small distances) or strong contributions from reflected sound (large distances). Results suggested that CI listeners may have some ability to utilize early reflections, but only in the presence of detectable direct sound arrival. The implication was that signals comprised largely of early reflections may be less intelligible for CI users than signals comprised largely of direct sound. In extending that work we set out to determine the specific difference in the temporal extent of reflections that can be integrated with the direct signal to provide additional useful information. We found vocoding shifts the boundary for early/late reflections from ~50 ms (depending upon reflection level) for natural speech to 20 ms and that even though reflections falling in this early period were not detrimental, they were not useful like they are for listeners with normal hearing.

The next logical step in our line of inquiry is to determine if vocoded speech perception is dependent on the relative reflection energy arriving in the early interval following the arrival of direct sound (as it is for normal hearing listeners) rather than on the arrival times and levels of individual reflections. It is possible that while a single, early reflection does not do enough to improve the perception of vocoded speech, that multiple early reflections might be of benefit provided the listener can fuse them into a single, perceptually louder signal. In the current experiment we compared perception of single- versus multi-reflection stimuli. Sentences were passed through idealized impulse responses containing two or more non-zero unit impulses. The first unit impulse in the response represented the direct arrival while subsequent impulses represented reflections, all of which arrived within the 20 ms early boundary for vocoded signals. Single reflection intensities were +3, 0, -6, and 12 dB relative to the direct sound. Intensities of the multiple reflections varied to provide differing amounts of relative reflection energy compared to the single reflection. Subjects listened to either natural or vocoded stimuli and produced speech reception thresholds in each experimental condition. Results further describe monaural echo fusion of vocoded speech and will be discussed in light of whether future efforts to increase very early room reflections would be of potential benefit to speech understanding in CI users.

C28: Better Acoustic Simulation Of Cochlear Implants

Diane S Lazard[1,2], Jeremy Marozeau[1] and Hugh McDermott[1,3]

1. Bionic Ear Institute, Melbourne, Australia
2. AP-HP, Hôpital Beaujon, Service d'ORL et Chirurgie Cervico-Faciale, Clichy, France.
3. Department of Otolaryngology, The University of Melbourne, Melbourne, Australia.

Channel vocoders have often been used as acoustic simulators of CI sound processing. Although such simulations may predict CI speech recognition moderately accurately under certain conditions, it is unclear whether the sensations perceived by CI recipients are similar to those perceived by people with normal hearing when listening to simulations. The aim of the present study is to develop an improved acoustic simulation of CI stimulation.

Five unilateral CI users with sufficient residual hearing in the contralateral ear participated in the experiments. They were asked to vary an acoustic signal presented to the non-implanted ear to match it to the sensation of the electric stimulation generated by the CI. The following stimuli were used: i) a white noise filtered through a bandpass filter in which the center frequency and Q factor were varied; ii) a 10-harmonic complex sound, varied in terms of spectral centroid and spectral spread; and iii) a 10-component complex sound in which inharmonicity was varied. Because this experiment consisted of subjective adjustments, the results may have been influenced by non-sensory biases. In order to minimize such effects, a multidimensional scaling dissimilarity judgment was also carried out. Subjects were asked to compare pairs of signals, comprising the electric stimulation and each of the different sounds obtained during the first experiment. The MDS analysis indicated graphically the independent perceptual dimensions associated with the stimuli, enabling us to identify the sound that was most similar perceptually to the electric stimulation.

The results helped us to reach a more realistic acoustic simulation of electric stimulation. They will be used to develop a new simulator that will help us to better understand peripheral and central sound processing in relation to cochlear implants.

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C29: The Influence of Linguistic Skills on Speech Recognition in Noise in Cochlear Implant Users

Marre W. Kaandorp[1], Annette M. B. de Groot[2], Joost M. Festen[1], S. Theo Goverts[1]

[1]ENT/audiology, VU University Medical Center, Amsterdam, The Netherlands
[2] Faculty of social and behavioural sciences, University of Amsterdam, Amsterdam, The Netherlands

In patient counselling, judgment of candidacy, and evaluation of the rehabilitation progress there is need for a more detailed understanding of the factors that determine the success of cochlear implantation. Speech recognition abilities vary considerably among Cochlear Implant (CI) users and knowledge of the underlying factors (except: duration of deafness, electrode position, or stimulation rate) is still limited. In general both auditory factors and non-auditory factors (e.g. working memory and linguistic skills) contribute to speech perception in noise. For CI users these contributions and there balance will be different because complex cochlear processing is ruled out and linguistic skills may be reduced due to speech deprivation. During rehabilitation speech recognition skills will continue to change mainly as a consequence of habituation to the processed signals.

The primary objective of this study is to examine how non-auditory, especially linguistic, factors influence speech recognition abilities in noise in CI users.

Outcome measures for speech understanding in noise are: recognition of monosyllables in quiet, digit-triplets in noise, and sentence keywords in noise. Thirty CI users participate in this study. All participants are post-lingually deaf adults. We use a Lexical Decision Task and a part of the Groningen Intelligence Test (GIT-2) to measure lexicon size and verbal processing abilities. These tests are selected because they both focus on words as the primary elements of language. The Text Reception Threshold (TRT) test, the visual analogue of the Speech Reception Threshold (SRT) test, is included as a measure of performance on processing sentences in an adverse condition without auditory processing.

Correlations between speech recognition scores and cognitive scores will be presented. Regression analysis on speech recognition in noise with linguistic scores, age, duration of deafness, and age of deafness as independent variables will be discussed. Knowledge of the influence of linguistic skills on speech understanding in noise in CI users, helps targeting the multidisciplinary rehabilitation program of CI users.

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C30: Auditory Training in Adult Cochlear Implant Listeners using Spectrally-Rippled Noise Stimuli in an Adaptive, Single-Interval, Paradigm

Kathleen F. Faulkner[1], Kelly L. Tremblay[1], Jay T. Rubinstein[2,3], Lynne A. Werner[1], Kaibao Nie[2]

[1]*Dept. of Speech and Hearing Sciences, University of Washington, Seattle, WA, USA*
[2]*VM Bloedel Hearing Research Center, Dept. of Otolaryngology, Head and Neck Surgery, Seattle, WA, USA*
[3]*Dept. of Bioengineering, University of Washington, Seattle, WA, USA*

Cochlear implant (CI) listeners commonly report difficulties when listening to music and understanding speech in the presence of background noise. While these deficits are likely a product of many factors, the ability to resolve frequency information is thought to be a contributor. Here we examine the use of auditory training exercises aimed at improving the perception of spectral information. To do this, we trained listeners to detect a change in the spectrum of a noise with a rippled spectrum. In the “change” condition, the spectrum of the second half of the ripple stimulus was an inverted version of the first half, while the “no-change” stimulus had no inversion. The task was to identify if a “change” was present in the ongoing signal. Thresholds were determined using an adaptive yes/no paradigm that tracked number of ripples per octave (RPO). Performance on four outcome measures (speech-in-quiet, speech-in-noise, music perception, and perceived hearing handicap) was also assessed before, during and following training.

Sixteen adult CI listeners participated in this experiment. Using a single-subject staggered baseline design, participants in the training group (n=8) participated in ~25 hours of spectral ripple testing/training over the course of six months. The control group (n=8) did not participate in training but completed the outcome measures. To evaluate retention, listeners were asked to return for follow-up testing sessions at one and three months post-training.

Results and Conclusions: 1) Spectral ripple thresholds can be improved with focused auditory training with a mean change of 3 RPO. 2) Improvements were also seen on outcome measures (CNC words in quiet, spondee detection in noise, pitch discrimination, and melody and timbre identification). Changes in outcome measures were significantly greater for the trained group compared to the control group. 3) Improved ripple threshold and outcome measures were retained for a period of three months. Individual performance patterns, suggesting who responds best to training, will be discussed.

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C31-a: Forward Masking To Evaluate Place Specificity Using Monopolar and Tripolar Stimulation

Claire A Fielden, Karolina Kluk, Idrick Akhoun, Colette M McKay

University of Manchester, UK

In recent years, much emphasis has been placed upon providing a greater number of discriminable channels in cochlear implants. Current Steering strategies have been highly successful in allowing the discrimination of a greater number of channels than determined by the actual physical electrode sites. However, without the ability to resolve different frequencies, challenging listening situations such as listening in the presence of competing noise or appreciating melody remain difficult. Furthermore use of a monopolar mode of stimulation has the added disadvantage of a wide path of excitation between active and reference electrodes. A large spread of current results inevitably in channel interactions and poor frequency selectivity.

This study examined whether use of a tripolar mode of stimulation produces a narrower pattern of activation when compared directly with monopolar mode at the same loudness. Place specificity was evaluated using a dual-masker psychophysical forward masking paradigm with a short masker-probe delay at two different levels of loudness. Probe threshold shift was the measurement of interest. 10 Advanced Bionics cochlear implant users were recruited to this study. The design was repeated measures, with fixed level masker and variable level probe. Masker stimuli were either monopolar or tripolar, whereas the probe stimulus was always tripolar. The dual maskers were interleaved symmetrically on electrodes either side of the probe electrode at varying distances away from the probe. Effects of residual masking, or masking decay on the measures of specificity from forward masking were also examined by determining probe threshold shift with a longer masker-probe delay.

Results showed that tripolar and monopolar modes produce similar place selectivity at louder levels, as measured by the width of the masking function. At a softer level of masker, preliminary results show that the monopolar masking function is wider than the tripolar function implying that levels of current may have an effect on place selectivity. Furthermore, the results show that the extent of residual masking may have important implications for the interpretation of forward making patterns in relation to place specificity.

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C31-b: The Dynamic Range Involved In Accessing Temporal Fine Structure In The Presence Of A Modulated Masker

Michael A. Stone[1], Brian C.J. Moore[1], Christian Füllgrabe[1,2]

[1]Auditory Perception Group, University of Cambridge, UK.
[2]MRC Institute of Hearing Research, Nottingham, UK.

Both the carrier (the temporal fine structure, TFS) and the modulation (original envelope, EO) in different frequency bands carry information that is useful for decoding speech in difficult listening situations. The ability to extract target speech from a modulated masker is attributed to the ability to “listen in the dips”. The experiments reported here explored dip-listening abilities when both EO and TFS were available. Signals were analysed with a 30-channel filterbank, each filter being one-ERBN wide.

Based on the instantaneous level of a rate-limited version of each channel envelope, a channel signal was formed by dynamically cross-fading between the original band-pass signal (EO+TFS) and a vocoded version produced using the extracted envelope, E’. The vocoder used either tone, noise or narrowband low-noise noise (LNN) carriers. The timing of the cross-fade was determined by comparing the envelope magnitude to a parametrically varying switching threshold to select either EO+TFS or the vocoded signal. The switching threshold was expressed relative to the long-term channel RMS. The output signals either contained E’ information near the channel peaks and EO+TFS in the channel valleys or vice versa. Speech intelligibility was measured for normal-hearing listeners using a competing-talker task.

For a target-to-background ratio (TBR) of 0 dB, when EO+TFS was present in the peaks, intelligibility started to decrease when the switching threshold exceeded –12 dB relative to the channel mean, and reached a minimum for levels above +5 dB. When E’ was present in the peaks, intelligibility started to increase when the switching threshold exceeded –9 dB, and reached a maximum for levels above +9 dB. This asymmetric performance indicates that listeners make better use of low-level EO+TFS cues when there are some related EO+TFS cues near the peaks. This result implies that low distortion reproduction of the peaks in a channel signal is important. When the TBR was negative, listeners attached less importance to the higher levels, and extracted proportionately more information from the lower levels of the channel signal.

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C32: The Effects of Pulse Rate On Detection Thresholds And Maximum Comfortable Loudness Levels In Humans With Cochlear Implants

Ning Zhou[1], Li Xu[1, 2], Bryan E. Pfingst[1]

[1]Kresge Hearing Research Institute, University of Michigan, Ann Arbor, MI
[2]School of Rehabilitation and Communication Sciences, Ohio University, Athens, OH

Electrical pulse trains are the carrier signal for most modern cochlear implant stimulation strategies. Loudness of these signals increases and maximum comfortable loudness (C level) and detection threshold level (T level) decreases, as a function of pulse rate. Evidence from electrophysiology studies of the auditory cortex (Middlebrooks, JASA, 2004) as well as animal psychophysics studies (Kang et al., JARO, 2010) suggest that two mechanisms underlie the effects of pulse rate on detection thresholds. Slopes of T-level versus pulse rate functions below 1000 pps reflect a multipulse integration mechanism while slopes above 1000 pps reflect an additional mechanism of pulse interactions. Importantly, the rate of threshold decrease as a function of pulse rate below 1000 pps varies across animals and is correlated with the health of the implanted cochlea (Kang et al., 2010). In the current study we examined the slopes of the T and C level versus pulse rate functions in human subjects to determine if the characteristics of these functions were similar to those of the T-level versus pulse rate functions seen across animals with various degrees of cochlear health.

Pulse trains of 600 ms duration with pulse rates of 156, 313, 625, 1250, 2500, to 5000 pps were used. Pulses were 40 μs/phase with an interphase gap of 8 μs. The measurements of T and C levels were obtained using a method of adjustment. T and C levels were measured for three sites (basal, middle, and apical) at each of the six stimulation rates using both bipolar and monopolar electrode configurations. Conditions were tested in random order three times and means and ranges of T and C levels were determined. The slopes of the T and C level versus pulse rate function were calculated separately based on a linear least-square fit for pulse rates below and above 1000 pps.

In the human subjects, the magnitudes of the slopes of the T level versus pulse were comparable to those found in animals. The slopes for T-level functions below 1000 pps were shallower than those above 1000 pps, consistent with the two mechanisms suggested by the previous studies in guinea pigs. Moreover, the slopes of T level versus pulse rate functions were overall steeper than those for the C level functions, resulting in an increased dynamic range at higher pulse rates, which was also consistent with previous findings (Kreft et al., JASA, 2004). The slopes of the T-level functions however were not correlated with those of C-level functions. The slopes of T-level and C-level functions varied across stimulation sites, but did not change systematically along the tonotopic axis, nor did they vary systematically as a function of electrode configuration. Neither T levels nor C levels were significantly correlated with slopes of level versus pulse rate functions, suggesting that different mechanisms might be responsible for the slopes and the levels of these functions.

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C33-a: Cochlear Implant Optimized Gain Function for SNR Based Noise Reduction

Stefan J. Mauger[1], Adam A. Hersbach[1] & Pam W. Dawson[1,2]

[1]Cochlear Limited, East Melbourne, Victoria 3002, Australia
[2]The HEARing Cooperative Research Centre (CRC), University of Melbourne, VIC, Australia

Cochlear Implants (CIs) are able to provide substantial speech intelligibility in quiet, but performance decreases significantly in noisy environments. Noise reduction (NR) has been used to significantly improve speech intelligibility in noise, achieving 24% improvement in speech shaped white noise, but only 7% improvement in babble scenarios. A number of gain functions have been developed through statistical optimization, which aims to minimize the total distortions created. Psychoacoustic studies with normal listeners have suggested that speech distortions and noise distortions affect speech quality independently, and should not be treated equally. This has lead to psychoacoustically motivated gain functions which typically limit speech distortions. Ideal binary masking studies have also suggested that statistically optimized functions may not be most appropriate for normal listeners. Although many studies have looked at optimizing the gain function for normal listeners, no studies have systematically investigated the most suitable gain function for CI recipients with respect to speech perception and speech quality.

This study assesses CI recipient speech perception outcomes using a binary mask for a range of gain thresholds. Additionally, smooth gain functions were used to investigate CI recipient's quality outcomes. A real-time computer system was used to emulate the commercial ACE stimulation strategy and a signal to noise ratio (SNR) based NR algorithm. The NR algorithm used an input of the noise alone, averaged over the previous second, as the noise estimate. This differs from real NR estimates, but has the same temporal characteristics without method specific underestimation errors in dynamic noise types. SNR estimation was performed by maximum likelihood estimation. Ten Nucleus CI recipients were tested using an adaptive speech reception threshold (SRT) test in competing noise.

The first study compared the ACE stimulation strategy alone to the ACE strategy with NR using five mask threshold conditions; -10, -5 0 5 and 10 dB. A SRT was first found for each recipient in the ACE condition. Fixed level testing was then performed with the five NR conditions at an SNR of 1 dB less than recipients SRT. Percent of morphemes correct was used to test speech intelligibility. Performance in speech weighted white noise and 20-talker babble were tested in two separate sessions approximately one week apart. Results showed that improvements in white noise of 27% in babble noise of 24% morphemes correct above the ACE condition were achieved with a non 0 dB binary mask gain threshold.

The second study assessed quality preference in 20-talker babble using a smooth gain curve; the parametric Weiner function. Continuous target speech and 20-talker babble were presented to CI recipients. By moving a cursor around an axis on a touch screen, recipients were able to manipulate the gain functions threshold and slope in real-time. Recipients were asked to find the position on the axis which was most comfortable and natural sounding. The most preferred gain function was found to be very similar in absolute gain threshold to the binary gain function which provided the most speech perception in the first study. Findings of this study will significantly improve single channel noise reduction outcomes.

C33-b: Evaluation Of F0 Extraction Algorithms For Better F0 Coding In Future Cochlear Implant Processors

Matthias Milczynski, Jan Wouters, Astrid van Wieringen

ExpORL, Dept. Neurosciences, K. U. Leuven, Leuven, Belgium

Enhanced fundamental frequency (F0) coding in electric hearing (EH) was recently demonstrated to be beneficial to tonal language and music perception. However, accurate F0 extraction was assumed also in adverse signal-to-noise (SNR) conditions. In the present study, the performance of four F0 extraction approaches was evaluated. The set of algorithms encompasses (1) a straight-forward autocorrelation-function (ACF) approach, (2) an ACF-based F0 extraction algorithm implemented in the PRAAT software in conjunction with a custom on-line F0 path-finder, (3) an algorithm employing harmonic modeling and (4) a Gaussian mixture model (GMM) method together with a speech enhancement component based on spectral subtraction. The four above mentioned algorithms provide a voiced/unvoiced decision as well as a F0-estimate. Conditions in quiet and at SNRs of +20, +15, +10, +5, 0 and -5 dB were evaluated. Steady-state, speech-weighted noise and multi-talker babble noise were used as maskers. The Keele database as well as the database developed by Paul Bagshaw (PB database) served as F0 references. Standard error measures were considered in the evaluation namely the voiced-error (miss-rate), unvoiced-error (false-alarm rate), gross-error (more than 20 % deviation from ground-truth) and mean F0 deviation. The results indicate that in particular the algorithms utilizing path-finding and GMMs can provide acceptable voicing error rates at tolerable gross-error rates for speech-weighted noise. Thereby, voiced- and unvoiced-error rates below 10 % were achieved by both algorithms for SNRs as low as +5 dB for the PB database. In all approaches, the error-rates dramatically increased for multi-talker babble noise. In conclusion, F0 extraction in adverse conditions is challenging primarily for ecologically relevant noise maskers. However, more sophisticated processing such as F0 path-finding and pattern recognition in the form of GMMs may serve as a reasonable basis for further optimization in hearing instruments.

C34: The Enhancement Of Onsets In The Speech Envelope Increases Speech Intelligibility In Noise Vocoder Cochlear Implant Simulations

Raphael Koning, Jan Wouters

ExpORL, Department of Neurosciences, K.U.Leuven, Leuven, Belgium

Speech understanding with cochlear implants (CIs) can be good in quiet, but very poor in more adverse listening conditions. One objective of speech enhancement algorithms is to improve the intelligibility of noisy speech signals. Recent studies showed that the transient parts of a speech signal contribute most to speech intelligibility in normal-hearing (NH) listeners. In this study, the influence of the enhancement of the onsets in the speech envelope on speech intelligibility in noisy conditions using an eight channel CI signal processor vocoder was investigated.

Sentences and consonant-vowel-consonant (CVC) words were processed with modified versions of the enhanced envelope continuous interleaved sampling (EECIS) and the transient emphasis spectral maxima (TESM) CI strategies relative to the standard CIS reference. Both strategies emphasize speech elements containing much phonetic information by deriving an additional gain at transient parts of the signal in each frequency band. The signals were presented in speech-shaped noise to NH listeners at signal-to-noise ratios of 4 to -4 dB for sentences and at 12, 6 and 0 dB for CVC words.

The sentence recognition task showed a significant speech reception threshold (SRT) improvement of 2.5 dB for the EECIS and 1.5 dB for the TESM strategy. The difference in SRT between the two envelope enhancement strategies was also significant. In the CVC word test, significant effects between the EECIS and the CIS strategies were obtained for the initial and final consonant recognition. An information transmission analysis of the results showed that the transmission of the consonant features place, manner and voicing was improved.

The presented results indicate that the enhancement of onsets in the speech envelope can improve speech intelligibility for vocoded speech in noisy environments due to a better perception of the transient cues of the speech signal.

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C35: Model-based validation framework for coding strategies in cochlear implants

Michele Nicoletti, Werner Hemmert

Technische Universität München, Institute of Medical Engineering, Munich, Germany

Although modern cochlear implants (CI) are able to restore speech perception to a high degree there is still a large potential for improvements e.g. in music perception and speech discrimination in noise.

To evaluate and optimize novel coding strategies, we have developed a toolbox which codes sound signals into spike-trains of the auditory nerve. We have previously developed a model of the intact inner ear, which we have complemented with detailed models of a CI speech processor, the channel crosstalk and spiral ganglion neuron models. Here we use a model of spiral ganglion type I neurons with Hodgkin-Huxley type ion channels, which are also found in cochlear nucleus neurons (HPAC, Kht, Klt). Their large time constants might be responsible to explain adaptation to electrical stimulation (Negem & Bruce 2008). We corrected conductances and time-constants to a body temperature of 37° and solved the differential equations in the time domain with a exponential Euler rule. Depending on the task, we model the neurons at different levels of detail. The electrode was modeled as an array of 12 current point sources at a distance of 0.5 mm from the spiral ganglion neurons. The coupling between electrode and excitation of the neuron was described by the activation function (second derivative of the extracellular potential with respect to the neuron's path). Cannel cross-talk was implemented by a convolution of the activation function with a spread function (symmetric, slope: 1dB/mm).

With our toolbox we present qualitative comparisons of neurograms elicited by different coding strategies with the situation in the healthy inner ear. Moreover, we conducted qualitative evaluations using two methods: With the framework of automatic speech recognition we evaluated speech discrimination using a noisy database. With the methods of information theory we are able to quantify the transmitted information coded in neuronal spike trains, which allows us to evaluate especially well how well temporal information is coded. The major advantage of our approach is that we are able to evaluate both spectral- and temporal aspects of novel coding strategies before we conduct long-lasting clinical studies.

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C36-a: Speech Perception in a Competing-Talker Background with Temporal Fine Structure

Daniel Visser, Andreas Krenmayr, Reinhold Schatzer, Paul A. Bader, Andreas Griessner, Matthias Zangerl, Christian Neustetter, Clemens M. Zierhofer

C. Doppler Laboratory for Active Implantable Systems, Institute of Ion Physics and Applied Physics, University of Innsbruck, Austria

The importance of temporal fine structure has been demonstrated by vocoder simulations for the perception of music, tonal languages and for segregation of male and female competing talkers. In the CIS strategy, pitch is encoded to a limited extent in the temporal code of the channel envelopes.

To improve the perception of pitch of CI users, the concept of Channel Specific Sampling Sequences (CSSS) represents within-channel temporal fine structure (FS) information on apical electrodes, whereas Coherent Fine Structure (CFS) presents coherent temporal FS in the voice pitch range across multiple electrodes. In both implementations FS is presented on apical channels only, while middle to basal channels carry CIS stimulation.

Speech Reception Thresholds (SRTs) for German OLSA sentence in a female competing-talker background have been measured in acute settings to compare both fine structure strategies with CIS. Nine MED-EL implant users with standard electrode arrays participated in this study. CFS configurations included 2, 3, 4, and 6 FS channels. The CSSS configuration was based on four FS channels.

In most subjects, speech test performance was best with one of the FS configurations. Group results show a trend for better results with CSSS as compared to CFS and CIS. For CFS stimulation, the optimum number of FS channels varied between 2 and 4 across subjects, with CFS6 consistently yielding the lowest speech perception levels.

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C36-b: Performance of CI Subjects Using Time-Frequency Masking Based Noise Reduction.

Obaid ur Rehman Qazi[1,2], Bas Van Dijk[1], Marc Moonen[2], Jan Wouters[2]

[1] Cochlear Technology Centre Belgium, Mechelen, Belgium.
[2] Katholieke Universiteit Leuven (K.U.Leuven), Leuven, Belgium.

Cochlear implant (CI) users report severe degradation of performance in noisy conditions, especially in a cocktail party environment where multi-talker babble noise overlaps in time and frequency with the target signal. CI recipients can require up to about 10-20 dB higher signal-to-noise ratio than normal hearing (NH) listeners in order to achieve similar speech intelligibility performance. In recent years significant emphasis has been put on binaural algorithms for bilateral input, which not only make use of the 'best ear' signal, but also have two or more microphone signals at their disposal to generate an output for both left and right ear. It has been reported that the phase error variance between two microphones is a function of input SNR. The binaural phase error filtering algorithm tries to minimize the phase error variance utilizing different time-frequency masking functions for noise reduction. The performance of the algorithm is evaluated under different mask functions for normal hearing and cochlear implant subjects assuming that Time Difference of Arrival (TDOA) is known.

Four different kinds of mask functions were evaluated, namely a Binary Mask (BMASK), Soft Mask (SMASK), Ternary Mask (TMASK) and Gaussian mask (GMASK). Theoretically BMASK introduces more distortions but also provides more noise rejection, whereas SMASK tries to minimize the distortions, but also offers less noise rejection. Speech Reception Threshold (SRT) was used as perceptual measure. Eight normal hearing and five cochlear implant subjects participated in this study with test and retest. Three spatial scenarios namely S0N90, S0N90/180/270 and S0N135/225/315 were simulated with the real room impulse responses, which were measured with Cochlear™ Nucleus 5 BTE devices worn by a KEMAR manikin in moderate reverberation.

All four defined mask functions provide significant improvement ($p<0.001$) in SRT over the unprocessed condition in the S0N90 scenario. BMASK is significantly better than TMASK and GMASK ($p<0.05$) for cochlear implant subjects, whereas for normal hearing subjects SMASK provides significantly better results. Mean SRT improvement provided by BMASK is 7.1 dB in S0N90 scenario as compared to 5.1 and 5.5 dB in GMASK and TMASK respectively. BMASK and SMASK also provide significant improvement ($p<0.05$) in S0N90/180/270 scenario. It is concluded that the binaural phase error filtering algorithm provides considerable improvement in intelligibility for both normal hearing and cochlear implant subjects. It is also found that same masking functions have significant differences in performance when tested with normal hearing and cochlear implant subject groups. The study also suggests that cochlear implant subjects can accept higher levels of distortions than normal hearing subjects, and therefore, more aggressive noise reduction for CI users is possible.

This work is supported by the EU ITN-project AUDIS and Cochlear Technology Centre Belgium.

C37: How Does Phantom Electrode Stimulation Produce A Lower Pitch Sensation Than The Most Apical Electrode In Cochlear Implants?

Aniket A. Saoji[1], David Landsberger[2], Monica Padilla[2], Leonid M. Litvak[1]

1. Advanced Bionics, Valencia, CA 91355
2. House Ear Institute, Los Angeles, CA 90057

Phantom electrode stimulation consists of out-of-phase stimulation of two electrodes. When presented at the apex of the electrode array, phantom stimulation is known to produce a lower pitch sensation than monopolar stimulation on the most apical electrode. The ratio of the current between the primary electrode (PE) and the compensating electrodes (CE) is represented by the coefficient σ, which ranges from 0 (monopolar) to 1 (full bipolar). The difference in pitch sensation produced by phantom and monopolar stimulation indicates differences in the current fields associated with the two modes of stimulation. However, the exact mechanism by which phantom stimulation produces a lower pitch sensation has not been reported.

In the present study, unmasked and masked thresholds were obtained using a psychophysical forward masking paradigm to estimate the spread of current for monopolar and phantom ($\sigma = 0.5$) stimulation. Masked thresholds were measured for two phantom electrode configurations (1) PE = 4, CE = 5 (lower pitch phantom electrode) & (2) PE = 4, CE = 3 (higher pitch phantom electrode). The monopolar and the phantom electrode maskers were 400 ms in duration, and were carefully balanced in loudness using a double-staircase adaptive procedure. Masked thresholds were obtained for 20 ms phantom ($\sigma = 0.75$) electrodes probes for a range of electrodes (1 to 10 electrodes). The unmasked thresholds were subtracted from the masked thresholds to obtain masking patterns for the two modes of stimulation.

Masking patterns revealed differences between the spread of excitation associated with monopolar and phantom stimulation. As compared to monopolar stimulation the lower pitch phantom electrode stimulation limits the spread of excitation towards the basal part of the electrode array and the higher pitch phantom electrode limits the spread of excitation towards the apical part of the electrode array. Some masking patterns also revealed a shift in the peak of the masking pattern as compared to monopolar stimulation. These results indicate that phantom electrode stimulation can be used for current shaping by which one can change the pitch sensation produced by phantom stimulation. Also, phantom stimulation can be potentially used to limit the spread of current in cochlear implants.

C38: Spread-Of-Excitation Measurements Using Masker and Probe Electrodes Which Are Both Current Steered

Lutz Gärtner[1], Andreas Büchner[1], Thomas Lenarz[1], Waldo Nogueira[2]

[1] Medizinische Hochschule Hannover,
[2] Advanced Bionics European Research Center GmbH Hannover

Current steering strategies stimulate pairs of adjacent electrodes simultaneously. By doing so, intermediate pitches can be elicited between the stimulating electrodes and studies have shown that some subjects are able to discriminate even more than 10 different pitches between two neighboring contacts. On the other hand, one could hypothesize that by using current steering the neural excitation in the cochlea might broaden and therefore compromise spatial selectivity. The aim of this pilot study is to analyze the effects of channel interaction between current steering stimuli by means of electrophysiological measures.

So far data from five subjects were collected, all using the HiRes90K or CII implant system with the current steering strategy "HiRes with Fidelity 120". We included only subjects in whom a clear NRI response could be recorded at comfortable loudness levels. Spread of excitation measures were taken with the research software BEDCS (Bionic Ear Data Collection System, Advanced Bionics). The forward masking paradigm was chosen with the recording always done on electrode 6. Additional artifact reduction was performed using the alternating polarity paradigm. Both the probe and the masker were generated by the current steering method. The probe location was steered between electrode 3 and 4 at the following positions: {3, 3.125, 3.25, 3.375, 3.5}. For each of these positions, the masker was also steered roving the following sites: {3, 2.875, 2.75, 2.625, 2.5}. The stimuli were presented at a comfortable loud level with equal loudness.

In 3 subjects the NRI amplitude decreased when moving the probe towards the base of the cochlea for a fixed masker. In 4 subjects the NRI amplitude decreased when moving the masker towards the apex for a fixed probe. For one subject, the responses did not show any systematic order.

Our pilot data indicate that current steering may help to shift the excitation patterns along the electrode array. Since the probe electrode shifts but the recording electrode is fixed the distance between probe and recording electrode varies during the measurement. This may have an influence on the recorded NRI amplitudes and also the excitation pattern. So far we did not investigate the effect of changing the recording electrode. Future measurements will include a second apical recording site.

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C39: Investigating the Auditory Nerve Fiber Response through Numerical Modeling of the Cochlea to Compare Current Shaping Strategies

Nicolas Veau[1], Jessica Falcone[2]

[1]MXM - Neurelec, Vallauris, France
[2]Georgia Institute of Technology, Atlanta, GA, USA

Cochlear implants restore hearing to individuals suffering from sensorineural hearing loss. Improving the hearing resolution of cochlear implant patients is a driving goal in the research community. Of particular interest is evaluating the effect of current steering and current focusing on auditory nerve fibers (ANFs). Current steering stimulates previously inaccessible ANFs located between two adjacent electrodes through current manipulation of two electrodes. This results in the patient hearing an intermediate pitch. Current focusing produces a more precise stimulation of the ANFs through current manipulation of three electrodes. Neurelec's next-generation cochlear implants will have the ability to stimulate multiple electrodes simultaneously using complex waveforms. With countless stimulation combinations, modeling tools are required to establish effective default parameters for patient use.

A graphical user interface (GUI) was developed to evaluate the effects of electrical stimulation on the ANFs. A simplified 3D model of the cochlea and the Neurelec electrode array was generated in OpenMEEG, a boundary element method (BEM) modeling software. A plane of ANFs situated within the cochlea was developed using NEURON, an empirically based neural simulator. Using the BEM, OpenMEEG calculated the generated potentials and currents through the cochlea when the electrodes were stimulated. The generated potentials were then inputted into NEURON, and returned the activating potentials counter, which records the binary response of each ANF.

The results of the numerical model for current steering revealed a clear correlation between the shifts in the stimulation of the ANFs to the shifts of the weighted currents. The results of the numerical model for current focusing revealed a clear correlation between the narrowing of the ANF stimulation range with the increase of the weighted currents. The results obtained by the numerical model mimicked those found in clinical trials and were also validated by an analytical model defined by the Rattay's activating function and Litvak's auditory neural probability model.

The successful verification of the numerical model is the first step towards a realistic simulation of electrode stimulation of the ANFs. Future work will include building a more realistic cochlea, Neurelec electrode array, and ANF population. The data obtained from the numerical model will be used to pre-configure Neurelec cochlear implants, providing default parameters that will minimize the time required for patient modifications.

C40-a: The Use Of A Cochlear Implant And Cell-Based Therapies To Promote Nerve Survival

Andrew K. Wise[1,2], James B. Fallon[1,2], Alison J. Neil[1], Lisa N. Pettingill[1], Marilyn C. Geaney[3], Robert K. Shepherd[1,2]

[1]The Bionic Ear Institute, Melbourne, Australia
[2]The University of Melbourne, Australia
[3]Living Cell Technologies Limited, New Zealand.

Spiral ganglion neurons (SGNs) in the deafened cochlea undergo continual degeneration ultimately resulting in cell death. The exogenous application of neurotrophins (NTs) can prevent SGN degeneration, with the survival effects enhanced by chronic intracochlear electrical stimulation (ES) from a cochlear implant. However, previously described techniques to administer NTs to the cochlea have limited clinical applicability, thus restricting the use of NTs in treating neurodegenerative diseases.

We have used a cell-based technique to provide NTs in a clinically viable manner that can be combined with cochlear implant use. Neonatal cats were ototoxically deafened systemically and at two months of age were unilaterally implanted with encapsulated NT-producing cells and a scalar tympani electrode array to deliver environmentally-derived ES. Animals received chronic ES only (n=5), NTs without chronic ES (n=6) or NTs in combination with chronic ES (n=6) for up to 7 months. In all cases the contralateral ear served as a deafened, un-implanted control.

Chronic ES alone did not result in greater SGN survival when compared to the contralateral cochlea. NT treatment alone resulted in significant SGN survival in the upper basal cochlear region ($p<0.05$). Importantly, chronic ES in combination with NT provided significant SGN survival throughout the basal and lower middle regions ($p<0.05$). NT treatment, with or without chronic ES, resulted in a significantly greater density of peripheral fibers within the osseous spiral lamina, compared to the contralateral cochlea ($p<0.01$). Furthermore, resprouting peripheral fibers were observed in the scala tympani and the scala media compartments of cochlea irrespective of treatment condition. There was not difference in the extent of fibrous tissue response to cochlear implantation between the experimental groups supporting the clinical viability of this approach.

We conclude that cell-based NT delivery is clinically viable and effective in preventing SGN degeneration and preserving peripheral fibers over extended durations of deafness. These findings have important implications for therapies that deliver therapeutic drugs safely to the cochlea.

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C40-b: Long Term Hearing Protection In The Guinea Pig Model Of Cochlear Implantation With Locally Delivered Dexamethasone.

Hayden T Eastwood[1], Andrew Chang[1], Jason C Lee[1], Stephen J O'Leary[1,2]

[1]University of Melbourne, Melbourne, Australia.
[2] Royal Victorian Eye and Ear Hospital, Melbourne, Australia.

Cochlear implant patients with residual hearing in the implanted ear can combine both electrical and acoustic stimulation to improve speech perception. Consequently the preservation of hearing in the implanted ear has become a goal of cochlear implant surgery. While it has been previously determined that the level of short term (1 week) hearing protection could be increased by either increasing the initial dose of dexamethasone or by increasing the time the dexamethasone is placed on the round window before cochleostomy, in a guinea pig model of cochlear implantation. It was not known whether this increased protection was permanent and which parameter, time or concentration, was more important for maximizing long term protection.

Dexamethasone at various concentrations was placed on the round window at either 30 minutes or 2 hours before a basal turn cochlear implantation was performed. Hearing levels were then measured through frequency specific thresholds for up to 3 months post implantation.

Results indicated that pre-treatment with locally delivered dexamethasone produces increased levels of residual hearing for up to three months after implantation and that the length of time the drug is applied to the round window before the cochleostomy is the most significant factor determining the extent of protection.

This work was supported through Grants from the NHMRC and Garnett Passé and Rodney Williams Memorial Foundation.

C41: High-Resolution Cone-Beam CT: A Potential Tool To Improve Atraumatic Electrode Design And Position

Sharon L. Cushing[1,2], Michael J. Daly [3,4], Claudiu G. Treaba[5], Harley Chan[3], Jonathan C. Irish[2,3,6], Blake C. Papsin[1,2], Karen A. Gordon[1,2]

[1]Archie's Cochlear Implant Laboratory, The Hospital for Sick Children, Toronto, ON, Canada
[2]Dept. of Otolaryngology-Head & Neck Surgery, University of Toronto, Toronto, ON, Canada
[3]Ontario Cancer Institute, Princess Margaret Hospital, Toronto, ON, Canada
[4]Institute of Medical Science, University of Toronto, Toronto, ON, Canada
[5] Cochlear, Denver Research and Technology Labs, Colorado, USA
[6]Dept. of Surgical Oncology, Princess Margaret Hospital, Toronto, ON, Canada

Optimizing cochlear implant electrode array design and insertion techniques has become a priority, particularly in light of mounting evidence that outcomes, including hearing preservation, can be improved by electrode design and position. Evaluating design and placement requires a method of in-vivo examination of array position, trajectory and behaviour used preferably at the time of implantation. Our aim is to examine the fidelity and utility of cone-beam computed tomography (CBCT) for characterising cochlear implant electrode insertion using custom 3D visualization software for surgical guidance ("X-Eyes Imaging Platform", University Health Network).

Twelve human temporal bones were implanted with the 'Straight Research Array'(SRA) manufactured by Cochlear Limited, using a variety of insertion techniques (contacts lateral, contacts medial, round window versus standard cochleostomy). Post-insertion, temporal bones were imaged with a conventional diagnostic CT and a prototype mobile C-Arm for intraoperative CBCT. Post-acquisition processing of low-dose CBCT images (1/6th dose of conventional CT) produced high-resolution 3D volumes with sub-mm spatial resolution (isotropic 0.2 mm3 voxels). The bones were resin impregnated and sectioned for light microscopic examination. Parallel sections starting perpendicular to the electrode lead entering the cochlea were achieved with grinding technique, and captured at regular intervals. Dimensional electrode characteristics visible in section images were compared with corresponding images available using X-Eyes software.

CBCT demonstrated adequate resolution to detect: 1) ideal insertion 2) perforation of the basilar membrane with the electrode fully inserted in the Scala Vestibuli and 3) distal kinking of the electrode when inserted via the round window 4) minor fluctuations of the electrode (rippling) and 5) proximity of to various structures (modiolus). CBCT did not demonstrate adequate resolution to detect anti-modiolar rotation of the array.

Data from the present study supports the use of the CBCT with the X-Eyes imaging platform to assess the implanted cochlear implant array. This is essential to determine specific effects of electrode design and surgical innovations on outcomes in cochlear implantation. The CBCT is a non-invasive and cost-effective approach yielding similar data to histo-pathologic analyses with encouraging potential for use in surgical and clinical settings.

C42: Development of a Steerable Cochlear Implant Electrode and a Robotic Insertion System.

J. Thomas Roland Jr., Spiros Manolidis, Jian Zhang, Nabil Simaan.

New York University School of Medicine and Vanderbilt University School of Engineering

Robots excel at performing tasks that require exact correlation between speed and position. Hence, robotic insertion of cochlear electrode arrays promises to provide more accurate and safer placement. To date, there are no commercial robotic systems that can manage the insertion of various types of commercial electrode arrays and future steerable electrode arrays. The talk presents our ongoing progress on the design of a tele-robotic slave that meets this need.

Recent study results suggest that cochlear implant electrode position and atraumatic electrode insertion are significant variables in overall cochlear implant performance. The current surgical procedure relies on primitive instrumentation, little or no tactile feedback and results in a great deal of variation in intracochlear position and trauma.

A collaboration was developed between the authors to develop and evaluate the feasibility of designing a reliable, efficient and relative inexpensive steerable electrode and robotic insertion system. A robotic system has been developed and the steerable electrode is under continuous evaluation and modification. The poster will outline the state of development and experimental results with the system including the effects of insertion speed, insertion degrees of freedom and outcomes in both cochlear models and human cadaveric temporal bones. Pre-programmed path planning based on imaging data, force sensors and impedance measurement guidance systems are under consideration.

The favorable results obtained to date are encouraging with regard to future development and refinement of the system and its application to human cochlear implantation.

C43: Pharmacological and electrical stimulus responses of spontaneously active spiral ganglion neurons on CNT electrode arrays

Kenneth H. Lee[1], Walter E. Voit[2,3], Taylor H. Ware[2,3], Edward W. Keefer[1,4]

[1]The University of Texas Southwestern Medical Center, Dallas, TX USA
[2]The University of Texas at Dallas, Materials Science and Engineering Department, Richardson, TX USA
[3]Syzygy Memory Plastics, Atlanta, GA, USA
[4]Plexon, Inc., Dallas, TX USA,

We have cultured mouse spiral ganglion neurons on carbon nanotube (CNT) coated multi-electrode arrays (MEAs). The CNT coating was deposited using electrochemical techniques with flexible methods that allowed us to produce high quality CNT coatings on a variety of electrode shapes and metals. This coating decreases the impedance of MEA electrodes 30-50 fold at 1kHz, an effect that benefits neural recordings by increasing the signal-to-noise ratio. Importantly for applications such as cochlear implants, the benefits of CNT coatings can be even greater when the electrodes are used for electrical stimulation. Because of the increased surface area on coated electrodes, charge transfer from electrode to electrolyte can be 2-3 orders of magnitude greater than uncoated electrodes. Increased capacitances permit higher charge transfer at shorter pulse durations while minimizing voltage excursions during electrical stimulation, a requisite for long-term stability of the electrode/tissue interface. This efficient charge transfer can benefit cochlear implants in at least two ways: lowered voltage at the electrode/tissue interface increases the safety factor by minimizing tissue trauma due to the electrical stimuli; and lowered power consumption required to drive the stimulator increases battery life. A third potential benefit we are exploring is that the highly convoluted nanoscale electrode surface may be neurotrophic, yielding enhanced spiral ganglion cell/electrode coupling.

Our experiments have demonstrated that neural networks formed by dissociated spiral ganglion cells begin to elicit spontaneous electrical activity after 7-10 days in culture. The level of activity is initially sparse, with approximately 10% of the electrode sites recording infrequent neural firing. However, once spontaneous activity begins, development is rapid and within 2-3 days, 30-80% of electrode sites record neural firing, which transiently synchronizes across multiple electrodes. In our preliminary work, we have shown that spiral ganglion networks respond to glutamate, GABA, glycine, acetylcholine and dopamine receptor drugs. By addition of specific receptor antagonists to modulate network activity, we have shown that spiral ganglion networks produce both glutamate and GABA endogenously. Our experiments suggest that this spontaneous spiral ganglion activity is dependent upon voltage gated Na^+ channels, as it can be blocked with the addition of 1 μM tetrodotoxin. On average, we found a 3.6-fold increase in single unit potentials when recording on CNT coated electrodes compared to non-coated electrodes. With CNT coated electrodes, stimulus response curves demonstrated that the cultured spiral ganglion neurons reach maximum activation efficiency at 20% of the current required for non-coated electrodes. These results reveal the potential of low impedance/high charge capacity electrodes to improve the function of neural interface devices such as cochlear implants. Current work seeks to couple the use of CNT coated electrodes with a manipulation of the underlying substrate to improve electrode adhesion, increase electrode flexibility and optimize the functional outcomes in cochlear implant users.

C44: Effects Of Brain-Derived Neurotrophic Factor (Bdnf) On The Cochlear Nucleus In Cats Deafened As Neonates

Cherian Kandathil, Olga Stakhovskaya, Gary Hradek, Patricia Leake

Epstein laboratory, Dept. of OHNS, UCSF, San Francisco, CA, USA

Many previous studies have shown significant neurotrophic effects of intracochlear delivery of BDNF in promoting improved survival of cochlear spiral ganglion (SG) neurons in rodents, and our laboratory has shown similar results in developing cats, deafened prior to hearing onset. This study examined the morphology of the cochlear nucleus (CN) in a group of neonatally deafened animals in which significant BDNF neurotrophic effects on the SG were previously reported. Cats were deafened by systemic administration of neomycin sulfate (60mg/kg, SQ, SID) starting three days after birth, for 16-21 days until ABR testing demonstrated profound hearing loss. Five cats were implanted unilaterally at 26-36 days of age using custom-designed electrodes with a drug-delivery cannula connected to an osmotic pump. BDNF (94µg/ml; 0.25µl/hr) was delivered for 10 weeks, and the animals were studied at 14-15 weeks of age.

Frozen sections of the brainstem were cut in a coronal plane at 50 µm thickness. Two sets of sections were utilized for the analyses. Every third section was stained with toluidine blue. Total CN volume and individual volumes of the three major CN subdivisions were measured in these sections. Another third of the sections were post-fixed with osmium tetroxide, embedded in epoxy, sectioned at 5 µm and counter-stained with toluidine blue. These sections were used for measurements of cross-sectional areas of spherical cell somata and numerical cell density in the anteroventral CN (AVCN). All measurements were made with the observer blinded to the experimental manipulations. Statistical comparisons were made between the CN ipsilateral and contralateral to the implant, and values were also compared to CN volume data for normal adult cats (n=4).

CN volumes were markedly smaller than normal (BDNF, 61% of normal; contralateral, 55%). Consistent with the neurotrophic effects of BDNF on SG survival in these animals, the total CN volume was significantly larger on the BDNF-treated side than on contralateral side (p=0.016; student's t-test, paired). Data from the three major CN subdivisions (DCN, PVCN and AVCN) showed a significant difference only for the AVCN volume (p=0.022; 2-way ANOVA, Tukey test). Spherical cell areas were significantly larger in the AVCN ipsilateral to the implant than on the contralateral side. The numerical density of spherical cells in the AVCN was significantly lower in the AVCN ipsilateral to the implant than on the contralateral side, consistent with the differences in AVCN volume observed. Together, findings indicate a significant neurotrophic effect of BDNF on the developing cochlear nucleus.

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D1-a: Exploring The Benefit From Enhancing Envelope Itds For Listening In Reverberant Environments

Jessica J. M. Monaghan and Bernhard U. Seeber

MRC Institute of Hearing Research, Nottingham, NG7 2RD, UK

Reflections in rooms alter the temporal envelope of the direct (target) sound: the modulation depth of the sound received at the ears is reduced, onsets are made less steep and binaural ear signals are decorrelated. Our previous work indicated that envelopes must have a minimum modulation depth, gradient and coherence in order to achieve good discrimination of interaural time differences (ITDs) from envelopes. ITD discrimination thresholds, therefore, increase greatly in the presence of reverberation. This is particularly relevant for cochlear implant (CI) listening since most current devices transmit ITDs only in the sound envelope, leading to impaired sound localization in rooms.

The aim of the present project is to ameliorate the detrimental effect of reverberation on envelope ITD discrimination by selectively enhancing envelope characteristics. The problem is to enhance only those parts of the reverberant sound envelope that are perceptually relevant for correct localization of the direct sound while not increasing the salience of the reverberation nor impairing speech understanding. These parts are likely the onsets when the direct sound is dominant, and a number of methods for onset selection were explored: 1) using explicit knowledge of the position of onsets in the direct sound, 2) using explicit knowledge of the instantaneous direct-to-reverberant ratio (DRR) of the signal, 3) using explicit knowledge of the ITD of the direct sound to identify the moments with matching instantaneous ITD in the reverberant signal. Reverberant sounds were processed with a sine-wave vocoder modified to steepen selected envelope onsets and discrimination thresholds for ITDs in the direct sound were measured in normal-hearing listeners.

Preliminary results indicate that selective sharpening of envelope onsets can improve envelope ITD discrimination thresholds in reverberation when compared to standard processing. The possible threshold reduction depends on the DRR and generally on the number of onsets processed. Possible detrimental effects of envelope sharpening on speech understanding will be ascertained.

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D1-b: Restoration of Binaural Hearing With A Cochlear Implant In Single Sided Deaf Subjects

Rolf-Dieter Battmer, Dietmar Basta, Ingo Todt, Arne Ernst

Department of Otolaryngology at ukb, University of Berlin, Germany

Recent treatments for the restoration of binaural hearing in single sided deaf subjects (SSD) are very limited. If treated at all, acoustic signals are only picked up from the deaf side and routed to the hearing side either as an electrical signal (CROS) or through bone conduction (Baha).Both methods use for the transmission of auditory signals the contralateral hearing cochlea and do not utilize the peripheral auditory pathways on both side. This implies that a true binaural hearing is not possible. However, through electrical stimulation via a cochlear implant the deaf side could be used. However, this would mean a cochlear implant in the non-hearing side.

Binaural hearing can be demonstrated for instance by speech in noise testing and lateralization tasks. Far more interesting from our point of view is the recording of the binaural interaction component (BIC) which represents an objective correlate of binaural hearing ability.

The aim of our present study is to develop an objective measurement (registration of BIC) to show and quantify the binaural interaction postoperatively in SSD-subjects with a cochlear implant. Five SSD subjects have been implanted with a Nucleus CP512 device and 2 of them are already first fitted with their CP810 speech processor. In the meantime, we have measured BIC acoustically in a group of 28 normal hearing adults to assure that our measurement equipment is working correctly. In all subjects BIC responses could be recorded. For the combination of both, electrical and acoustical stimulation, we use the Cochlear fitting system together with Custom Sound EP (CS EP) software (for triggering and stimulate electrically) and a Nicolet Viking system (for stimulating acoustically, recording and averaging). A trigger delay in CS EP compensates for the different timing of the electrical and acoustical brain stem responses. To achieve nearly equal amplitudes in both side of the recording we loudness balanced the acoustical and electrical stimuli. At the moment we only have the results of one subject were we could record successfully a BIC response. However, at the time of the conference we will have collected the data of all five subjects.

The future aim is to use this method preoperatively to have a predictor for the binaural interaction of acoustical and electrical signals. This is important not only for SSD subjects, but also for bilateral and bimodal patients.

Cochlear GmbH Germany supported this study.

D2-a: Binaural Benefits With and Without a Bilateral Mismatch in Acoustic Simulations of Cochlear Implant Processing

You-Ree Shin, Yang-soo Yoon, and Qian-Jie Fu

House Ear Institute, Los Angeles, CA, USA

In normal hearing (NH), binaural perception depends strongly on spectrally-matched stimulation patterns from each ear. In bilateral cochlear implants (CIs), there is likely a spectral mismatch between the electric stimulation patterns from each ear, due to differences in electrode position and neural survival. This bilateral mismatch most likely limits the benefits of bilateral implantation. In this study, sentence recognition was measured in noise with NH subjects listening to acoustic CI simulations with or without a bilateral mismatch.

Ten NH subjects participated in the study. Bilateral CIs were simulated using 8-channel sine-wave vocoders. The input frequency range was 200-7000 Hz; the output range was fixed at 16 mm (i.e., the length of a typical Nucleus electrode array). This 16-mm output was shifted in one or both ears to simulate a 22- or 25-mm electrode insertion depth: L22/R25 or L25/R25. IEEE sentence recognition was measured at two signal-to-noise ratios (SNRs): +5 dB and +10 dB. Subjects were tested while listening with headphones; head-related transfer functions were applied before the CI processing to preserve natural inter-aural level and timing differences. Speech was always presented from the front (S0); noise was presented from either left (N270), front (N0) or the right (N90). Each noise condition was tested for each speech processor condition.

Results showed significant binaural benefits (summation and squelch) for the bilaterally matched simulation (L25/R25), but not for the bilaterally mismatched simulation (L22/R25). Head shadow benefits were observed for both simulations, although the benefit was significantly smaller for the mismatched simulation (L22/R25).These suggest that spectrally patterns from each ear must be matched for CI users to receive binaural benefits from bilateral implants. Head-shadow effects, while still strong with the bilateral mismatch, also benefited from spectral matching across ears. Clinical fitting should reduce bilateral mismatches to provide the greatest binaural benefit of two implants.

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D2-b: The Benefits of Acoustic Cues For Cochlear Implant Users In Reverberation

Kate Helms Tillery, Christopher A. Brown, William A. Yost and Sid P. Bacon

Arizona State University, Tempe, AZ, USA

Cochlear implant (CI) users, given temporal envelope cues across a few frequency bands, demonstrate high levels of speech recognition in quiet. Poor spectral detail in the electric signal severely impacts their performance in noise, however. Those with residual acoustic hearing can improve intelligibility in noise by combining the electric and acoustic stimulation (EAS). Previous research in our laboratory has demonstrated that this benefit is due largely to variations in the fundamental frequency (F0) and amplitude envelope of the target speech. When combined with the electric signal, an acoustically presented tone, frequency-modulated (FM) to track F0 variation, significantly improved intelligibility in noise over electric-only stimulation. When the FM tone was also amplitude-modulated (AM) with the speech envelope, intelligibility improved further. Thus, both envelope and F0 cues presented acoustically provide significant EAS benefit in noise.

Another problematic environment for CI users is reverberation, which smears envelope cues. Although little is known about the benefits of EAS in this background, we hypothesized that F0 was more beneficial because it might be partially preserved in reverberation, whereas temporal smearing might limit the benefits of voicing and amplitude modulation, both envelope cues. Simulation studies in our laboratory generally agreed with this hypothesis. In simulated EAS, the FM cue provided substantially more benefit than the AM cue, while the voicing cue was unhelpful.

The purposes of the present study were to determine the benefit of low-frequency acoustic cues to actual EAS users in reverberation, and examine the individual contributions of voicing, amplitude envelope, and F0 variation to the intelligibility of reverberant speech. CI users with residual hearing repeated aloud sentences in simulated reverberation, using electric-only stimulation or EAS. The acoustic component comprised either reverberated broadband speech (filtered by each individual's audiometric configuration), or a reverberated tone. Prior to being reverberated, the tone was gated to coincide with voicing and modulated in frequency and/or amplitude to represent F0 and/or envelope variations. Sentence intelligibility scores indicate large individual variability, both in the benefit obtained from the acoustic component, and in the contribution of individual cues. On average, standard EAS provided considerable benefit, while the AM and FM cues combined were more helpful than either cue alone. This suggests that simulation studies may not capture the individual benefits of AM and FM cues in actual EAS.

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D3: Speech Intelligibility in Quiet And in Noise And Sound Localization Abilities For Digisonic® SP Binaural Cochlear Implant Users

Nicolas Verhaert[1,2], Diane Lazard[3], Dan Gnansia[4], Jean-Pierre Bébéar[5], Philippe Romanet[6], Eric Truy[1,7]

[1]Edouard Herriot hospital, ENT Department, Lyon, France.
[2]Department of Otorhinolaryngology, Head and Neck Surgery, University Hospital, Leuven, Belgium.
[3]AP-HP, Beaujon hospital, ENT Department, Clichy, France.
[4]MXM-Neurelec, Vallauris, France.
[5]Pellegrin Hospital, Bordeaux, France.
[6]General Hospital, Dijon, France.
[7]Claude Bernard University, CNRS UMR 5020, Lyon, France.

A critical aspect of cochlear implantation in the future will be the extent to binaural hearing, in order to improve spatial hearing abilities. However, although potential benefits of binaural hearing have been recognized for implanted listeners, current proposals remain “bilateral” (two implants), rather than “binaural” (two ears) in concept. Moreover, bilateral implantation is an expensive practice that is not systematically funded. In order to address these issues, a cochlear implant that allows electrical stimulation in both ears within a single device was developed by Neurelec, the Digisonic® SP Binaural. The implant is composed of a receiver with two electrode arrays, and external part is a single processor with deported microphone. The purpose of this study was to evaluate whether this new approach for implanting both ears could offer similar benefits as bilateral implantation for a lower cost.

Fourteen postlingually deafened adults implanted with in a Digisonic® SP binaural device were evaluated after 12 months of use. Speech perception testing was performed using French disyllabic words in quiet and speech-shaped noise (10dB SNR). Head-shadow, squelch and summation effects were also evaluated. Sound localization was tested using pink noise on 5 loudspeakers, from -90° to +90° along the azimuth. All tests were conducted in unilateral (one side activated) and binaural (two sides activated) conditions.

Speech scores, both in quiet and noise, were significantly higher in binaural than in unilateral condition: at twelve months interval, a mean difference of 14% was noted both in quiet and in noise. Significant summation, head-shadow and squelch effect were noted. Squelch effect was on average as good as head-shadow (mean value of 13.6% for squelch, 11.8% for head-shadow). Sound localization accuracy was significantly better in binaural condition. No explantation, hard or soft failure was described during this study.

These results collected on binaurally-implanted patients are quite consistent with previous studies on bilateral implantation. Specific “binaural” signal processing and stimulation strategy should now be implemented on this device to improve listening abilities.

Work supported by MXM – Neurelec Corporation.

D4: Effect of Head Movement On Sound Localization In Unilateral, Bimodal And Bilateral Cochlear Implantees

Kassandra-Anne H. Birtch, Ioan A. Curca, Ewan A. Macpherson

National Centre for Audiology
University of Western Ontario, London, Ontario, Canada

Cochlear implant (CI) users face several challenges in utilizing the acoustical cues for sound localization. Unilateral users lack access to interaural time and level difference cues. Bimodal (CI with contralateral hearing aid) users are likely affected by interaural differences in the mode, level, and timing of stimulation. Bilateral users can obtain balanced interaural stimulation, but acoustic-to-electrical compression and any envelope-based processing can compromise access to interaural level or timing difference cues. All CI users likely have reduced access to monaural spectral cues due to the typical placement of the microphone outside the pinna, the bandwidth of the processor, and limited spectral resolution of processing and stimulation. These factors can account for CI users' lateral biases and high rates of front/back reversal in sound localization tasks. Evidence from normal hearing listeners indicates that head movement is highly beneficial for reducing such localization errors.

We have investigated the effect of head movement on sound localization abilities in three unilateral, three bimodal, and three bilateral cochlear implant users. The subjects used a variety of MED-EL, Cochlear Corp., and Advanced Bionics implants, and were tested with their default program settings. Subjects localized wideband noise bursts presented from horizontal locations spanning 360 degrees under three head-movement conditions. In the static condition, 200-ms bursts were presented with the head stationary. In the free condition, participants were allowed to turn freely while the stimulus played continuously. In the controlled condition, the burst was presented over the central 40-degree portion of a single right-to-left head turn. Not all listeners were tested in the controlled condition.

All unilateral and bimodal subjects demonstrated lateral bias toward the side of the CI. That bias was typically reduced, but never eliminated, by either free or controlled head movement. All subjects exhibited frequent front/back confusions in the static condition. Those were typically reduced by head movement, but were nearly eliminated only for two bilateral subjects who did not exhibit static lateral bias. Head movement benefit was largest for bilateral subjects and smallest for unilaterals. Curiously, controlled head movement was typically more beneficial than free movement for listeners with large static lateral bias.

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D5: Tonotopic Symmetry Of ITD-Based Lateralization And Channel Interference

Bernhard Laback[1], Virginia Best[2], and Piotr Majdak[1]

[1] Acoustics Research Institute, Austrian Academy of Sciences, Austria
[2] School of Medical Sciences, University of Sydney, Australia

In acoustic hearing, sensitivity to interaural time differences (ITDs) in basal and apical frequency regions is asymmetric as a result of differences in peripheral processing in the two regions. In contrast, more symmetric sensitivity is observed when stimuli are used that account for the differences in peripheral processing. Similarly, electric hearing enables the presentation of exactly the same stimuli at basal and apical electrodes, and studies have found no evidence for a systematic effect of tonotopic stimulus place on ITD sensitivity.

Binaural interference refers to the degradation in sensitivity to spatial cues conveyed by a “target” stimulus in presence of a tonotopically remote and simultaneous “interferer” stimulus. The present work was aimed at investigating if an asymmetry of binaural interference observed in acoustic hearing (interference for high-frequency target and low-frequency interferer but not vice versa) also holds in electric hearing.

Six bilateral cochlear-implant (CI) listeners completed a series of experiments in which they judged the lateral position of a target pulse train lateralized via ITD in presence of an interfering diotic pulse train. The rate was 100 pulses/s. To minimize peripheral interactions, the target and interferer were presented at widely separated electrode pairs. Conditions with either basal or apical targets were tested.

Five listeners showed significant binaural interference. Across listeners, the amount of binaural interference did not systematically differ between basal and apical targets. Additional measurements of ITD lateralization discrimination thresholds, using the target stimulus in isolation, showed slightly better sensitivity in the basal region, possibly a result of peripheral effects.

Overall, the results do not support a tonotopic asymmetry in binaural interference. This suggests that the asymmetry reported in acoustic hearing studies is due to the different stimulus and/or peripheral-processing properties in the low and high frequency regions. Together with the ITD sensitivity observed at both apical and basal electrodes in electric hearing, these results suggest that ITD cues could be encoded across the entire tonotopic range in CI listeners.

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D6: Investigation of the Electric-Acoustic Stimulation (EAS) Cochlear Implant Alone Listening Condition and Speech Perception In Noise

Margaret T Dillon, English R King, Marcia C Adunka, Emily Buss, Harold C Pillsbury, Oliver F Adunka, Craig A Buchman,

University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

Subjects with greater than 12 months listening experience with Electric-Acoustic Stimulation (EAS) underwent further evaluation of their cochlear implant (CI) alone performance and speech perception abilities in noise. The FDA clinical trial on MED-EL's EAS system studies the CI alone listening condition with a novel, full-frequency map. Testing with the full-frequency map has the disadvantage of being unfamiliar, while testing in the truncated map used as part of the EAS configuration fails to represent low-frequency cues. In addition, the benefit of low-frequency cues provided by the hearing aid (HA) in the EAS system was evaluated in steady-state and fluctuating noise.

Subjects were assessed in listening configurations and with a test battery beyond the clinical trial protocol. Test materials were presented in sound field. Listening conditions included: EAS, CI alone (truncated map), and CI alone (full-frequency map). Test materials included: CNC words, HINT sentences in quiet and noise (SNR+10), CUNY sentences in noise (SNR+0), and BKB-SIN sentences.

Subjects performed at ceiling in each listening condition on HINT sentences in quiet. In CI alone conditions, better performance was achieved in the truncated, familiar map compared to the novel, full-frequency map. There was a trend for better performance in the EAS listening condition over the CI alone condition in both steady-state and fluctuating noise tests.

The finding of better performance in EAS than either CI alone condition suggests that loss of residual hearing in these patients could result in a decrement in performance. Including low-frequency cues in the novel, full-frequency map did not compensate for the absence of a HA, but it does not rule out the possibility that subjects could learn to use those cues with further practice.

D7: The Contributions Of Non-Integer Multiples Of F0 To The Benefits Of Electroacoustic Stimulation

Yi Hu[1,2], Christina Runge[2], David R. Friedland[2] and Julie Liss[3]

[1]Department of Electrical Engineering & Computer Science, University of Wisconsin-Milwaukee, Milwaukee, WI, 53211, USA
[2]Department of Otolaryngology and Communication Sciences, Medical College of Wisconsin, Milwaukee, WI, 53226, USA
[3]Department of Speech and Hearing Science, Arizona State University, Tempe, AZ 85287, USA

A recent innovation, electroacoustic stimulation (EAS), has shown great potential in improving speech recognition for cochlear implant (CI) patients with residual acoustic hearing. Several studies on the mechanisms underlying EAS benefits have shown that F0 cues are beneficial for improving speech intelligibility in noise for EAS listeners. Most of these studies, however, used lowpass filtering to isolate the F0 regions.

The major drawback in the previous studies on EAS benefits is that the generated stimuli contained two or more harmonics in the voiced segments, preventing a specific assessment of the contribution of the first harmonic (F0) to the observed EAS benefits. The current study employs a synthesis-driven approach based on harmonic modeling of voiced speech. This novel paradigm has the advantage of controlling the ways in which acoustic cues (including F0) in the acoustic portion of EAS stimuli are generated in the voiced speech. When used to study the contribution of different acoustic cues to EAS benefits, this approach is theoretically superior to the low-pass filtering techniques in that it is possible to introduce acoustic cues that do not exist in the original speech signals to determine their perceptual effects.

In the present study, we synthesized voiced speech using all harmonics above 600 Hz plus different configurations below 600 Hz. This way we were able to precisely control the target cues included in the generated stimuli. Four processing conditions were examined: all harmonics (All), the first harmonic (F0), a tone with a frequency of 1.2xF0 (1.2F0), and a tone with a frequency of 1.5xF0 (1.5F0). Synthesized IEEE sentences mixed with speech shaped noise at 4/7/10/13/infinite (clean) dB SNR were used as test materials. Results indicated that: 1) The All condition was significantly better than others at 4/7/10/13 SNRs; 2) for synthesized clean sentences, the average percent correct scores for F0/1.2F0/1.5F0/All were 80%, 87%, 93% and 95%, respectively; 3) similar to F0 condition, a tone signal with a frequency of 1.2xF0 or 1.5xF0 facilitated speech recognition in noise for EAS processing. This study demonstrated that tone signals with frequencies of non-integer multiples of F0 can contribute to EAS benefits, which has both practical and theoretical implications.

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D9: Pitch Perception In Bimodal Listeners

Chasity S. Moore, Anthony J. Spahr, Michael F. Dorman

Arizona State University – Tempe, Arizona

Cochlear implant users with residual hearing in the non-implanted ear provide a unique opportunity to examine pitch and sound quality conveyed by electrical stimulation. There has been significant interest in identifying the pitch provided by individual electrodes in order to estimate a frequency-to-place map for electrical stimulation. This study evaluated the pitch-matching and pitch-ranking abilities of bimodal listeners (BM). The goals of this study were (i) to identify a methodology that provides an accurate and reliable pitch estimate, (ii) to estimate the pitch provided by a single intra-cochlear electrode, and (iii) to compare pitch estimates of adjacent electrodes.

The first experiment was a comparison of methods for both normal-hearing (NH) and bimodal listeners (BM). Pitch estimates of acoustic tones were measured using a ranking and matching procedure. Both methods employed a two-interval, forced-choice procedure with a 240 Hz standard tone and 21 comparison tones from 80 to 640 Hz. Comparison stimuli were tested in three frequency blocks: low (80 – 204 Hz), mid (135 – 343 Hz), and high (251 – 640 Hz), with three repetitions of each frequency within each block. All presentations were randomized and all stimuli were matched in loudness prior to testing. In the matching procedure, listeners rated the pitch of the standard and comparison tone as “same” or “different”. In the ranking procedure, listeners rated the pitch of the comparison tone as “higher” or “lower” than the standard tone.

For both NH and BM listeners, the pitch matching procedure provided the most consistent results. Matching functions of both groups reveal a peak centered near the frequency of the standard tone, but BM users were more likely to report a match between standard and comparison tones. A true match was never actually presented.

The second experiment measured pitch matching functions of BM users when the standard tone was presented electrically through a single intra-cochlear electrode and comparison tones were presented to the non-implanted ear. Relative to acoustic pitch matching functions from the same listener, electric stimuli were matched to a wider range of comparison tone frequencies and were less likely to reveal a clear peak (pitch match) than acoustic functions. In cases where pitch estimates were collected on more than one electrode, there was significant overlap of the matching functions.

Overall, outcomes suggest pitch estimates based on the matching procedure are more reliable than those based on the ranking procedure and broad matching functions obtained from electric stimuli imply individual electrodes did not provide users with a clear pitch percept.

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D10: Spectral Processing and Speech Recognition In Bimodal Implant Users

Ting Zhang, Anthony J. Spahr, Michael F. Dorman

Arizona State University, Tempe, Arizona

It has been well documented that cochlear implant (CI) patients who have low-frequency acoustic hearing, either in the ear contralateral to the implant or in the same ear as the implant, benefit significantly from the combination of acoustic(A) and electric(E) stimulation (EAS). However, considerable variability in speech-perception benefit remains in patient outcomes.

Here, we report on a significant correlation between the spectral resolution of residual acoustic hearing and the speech-perception benefit in patients with a cochlear implant in one ear and low-frequency hearing in the other ear. Spectral modulation detection thresholds (SMDTs), defined as the smallest detectable spectral contrasts (the differences in amplitude between the peaks and valleys) in the spectral ripple stimuli, were measured in the A-alone condition. The recognition of CNC words in quiet and AzBio sentences in noise was also evaluated in the A-alone, E-alone, and combined EAS conditions. Results showed marked individual differences in the absolute SMDT and in the normalized gain in speech recognition (i.e., (EAS score-E score)/(100-E score)). Statistical analysis revealed a strong and significant correlation between the SMDT and the gain in both word ($r = -0.75$, $p<0.000$) and sentence-in-noise recognition ($r = -0.87$, $p<0.000$). These results suggest that the spectral resolution of residual acoustic hearing can account for a substantial portion of the variance for the improvement in speech recognition when the acoustic signal is added to the signal produced by the CI. In other words, the listeners with good spectral resolution for the acoustic signal are, on average, more able to benefit from the combined EAS. In correlating a basic psychophysical measure to EAS benefit, these results could provide important, clinical guidance for hearing care providers to make appropriate decision regarding the preservation of residual acoustic hearing in the non-implanted ear (i.e., bilateral implant stimulation vs. bimodal stimulation).

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D11-a: Estimating Behavioural Threshold from ECAP Variability: Comparison of Physiological Data With a Computational Model

Stephen D. Holmes[1] David M. Landsberger[2], Arthi G. Srinivasan[2] and Robert P. Morse[1]

[1]School of Life and Health Sciences, Aston University, Birmingham, UK
[2]House Ear Institute, Los Angeles, CA, USA

Electrical compound action potentials (eCAPs) are used for fitting cochlear implants when behavioural thresholds cannot be measured. Standard methods use either the alternating polarity or the masker-probe method to reduce the artefact. These artefact reduction techniques limit the pulse rate and the eCAP thresholds are therefore poor predictors of behavioural threshold to pulse rates used clinically.

We have proposed using the cross-trial variability of eCAPs to estimate threshold without artefact subtraction. For data collected using the Advanced Bionics HiRes90k implant, we found increased variability (above floor level) shortly after probe pulse offset. Variability in a narrow time window was found to be a non-monotonic function of level. At higher probe levels, however, even though the latency of N1and P1 peaks in the mean response reduced, the period of increased variability spread to later times. A key question was whether the variability changes had a neural rather than artefactual origin, and were therefore a potential predictor of behavioural threshold. We consequently simulated the physiological data.

We used the Chow and White (1996, Biophys. J., 71, 3013-3021) stochastic nerve model to simulate a population of 1000 cochlear nerve fibres; current spread was modelled as an exponential decay. Modelled eCAPs without artefact were obtained by convolving peri-stimulus time histograms, with contributions weighted by the return current spread, with a single unit function. This unit function was obtained from the optimal linear reconstruction of physiological data using the Wiener-Kolmogorov filter. The variability of the modelled eCAPs did not initially match those found physiologically. When, however, we also modelled the recording process with amplifier noise, variable DC offsets, and A-to-D converter quantization, the variance calculated from the model matched our physiological recordings. This suggests that the physiologically observed variability has a neural origin but the recording process is also a factor.

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D11-b: A Microelectrode Array for Chronic Recording Of Single-Unit Neuronal Activity In The Inferior Colliculus Of The Cat

Douglas B McCreery, Martin Han

Neural Engineering Program, Huntington Medical Research Institutes
734 Fairmount Avenue, Pasadena, CA (USA)

We have developed an implantable microelectrode array for chronic recording of single-unit neuronal activity in the central nucleus of the inferior colliculus (ICC) of adult cats. The array contains 16 recording sites, each with a surface area of 2000 μm^2, and sputter-coated with iridium oxide (SIROF). The linear array of electrode sites spans 5.5 mm, sufficient to sample the entire tonotopic gradient of the cat ICC.

The array is implanted with the cat's head mounted in a standard stereotaxic frame. To allow access to the entire rostrocaudal extent of the colliculus, the caudal pole of the cerebrum, with dura intact, is elevated from the tentorium, and a longitudinal slot of bone is removed from the tentorium. The cerebrum then is momentarily retracted to visualize the colliculus and the array inserter tool, mounted on a 4-axis stereotaxic positioner, is visually indexed to the array's entry point on the dorsal surface of the colliculus. The cerebrum is allowed to resume its normal position against the tentorium, and the array is inserted through the caudal pole of the cerebrum. After recovery from the general anesthesia, the animals have exhibited no detectable adverse effects from this procedure.

As of this writing, multiunit neuronal activity and on some channels, well-differentiated sortable single-unit activity has been recorded for at least 59 days. The neuronal responses are well tuned to acoustic tone bursts.

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D12-a: Effects of Amplitude Modulation of Pulse Trains and Pure Tones On Neuronal Activation Patterns Recorded In the Auditory Midbrain

Matthew C. Schoenecker[1], Ben H. Bonham[1], Olga A. Stakhovskaya[1], Russell L. Snyder[1,2], Stephen J. Rebscher[1], Alexander M. Hetherington[1], and Patricia A. Leake[1]

[1]University of California, San Francisco, CA, USA
[2]Utah State University, Logan, UT, USA

Previously, we reported similarity in the spread of activation along the tonotopic axis of the inferior colliculus for unmodulated acoustic pure tones and electrical pulse trains (Schoenecker et al., CIAP 2009). Here we extend those earlier studies by comparing spread of activation evoked by amplitude modulated tones and pulse trains. Amplitude modulated tones and pulse trains better model the spectral components of speech sounds than do their unmodulated counterparts.

We recorded responses to sinusoidally modulated (50 Hz and 125 Hz; 20% and 100% modulation depths) and unmodulated tones and pulse trains (1000 pulses per second, 40 us/phase) in the central nucleus of the inferior colliculus (ICC) of guinea pigs and cats. Responses (single- and and multi-units) were recorded using a 32-channel silicon probe, and response widths (i.e., spread of activation along the tonotopic axis) were compared among stimuli with matched peak response rates.

Modulation at 50 Hz (100% modulation depth) consistently increased the response width of strongest activation across the tonotopic axis for both acoustic and electrical stimulation (as compared to unmodulated stimuli), but had a less-pronounced effect on the response width of sustained activation. When the modulation frequency was increased to 125 Hz, the response widths of both the maximum and sustained activation were less in most cases. When the modulation depth was decreased to 20%, response widths of both the maximum and sustained activation were decreased. Preliminary analyses indicate that, as previously reported for unmodulated acoustic tones and electrical pulse trains, the response widths of modulated tones and pulse trains are comparable when stimuli are matched re: peak response rates.

These physiological studies in the central nervous system would predict that the maximum interaction between interleaved cochlear implant channels (or between simultaneously-presented acoustic tones) would be greater for modulated than for unmodulated stimuli, but that central neural processes – by reducing the spread of the response – are able to at least partially compensate for the increased spread of activation caused by modulation and thereby decrease interaction during sustained stimulation.

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D12-b: Electroporation of adherent cells with cochlear implant stimulation

Andrew Farrington[1], Carrie J Newbold[1, 2]

[1]Department of Otolaryngology, University of Melbourne, Carlton, Australia
[2]The HEARing CRC, Carlton, Australia

Electroporation is the formation of microscopic pores in the membranes of electrically stimulated cells. It is used in laboratories to deliver genes and drugs to cells, and in the clinic to lesion tumours and deliver cancer treatments. Typically, the electrical stimulation used for electroporation is monophasic, voltage-controlled, high voltage (kV) and very short pulses (ns). Cochlear implants aim to electrically stimulate neurons at a distance (mm) from the active electrodes using biphasic, current-controlled, low voltage (V) and relatively long pulses (µs). However, there are indications that electroporation may be occurring with cochlear implant electrical stimulation in the fibrous tissue matrix that grows over the electrodes after implantation. This has been tested using an in vitro model. Adherent epithelial cells were grown on planar gold electrodes, and electrically stimulated at clinically relevant levels. A large-molecule dye (propidium iodide) that can only enter the cell if the membrane was disrupted was applied to the solution during or after electrical stimulation. Dye uptake was recorded for the cells over the stimulated electrodes, indicating electroporation was occurring. While this work needs to be verified in an in vivo or ex situ environment, it may explain the transitory reduction in electrode impedance measured clinically following onset of electrical stimulation. When electrical stimulation is commenced, some of the charge applied travels through the adherent cells by way of pores in the cell membrane. This would create a drop in electrode impedance that remains while stimulation is taking place, but increases once finished as the pores close.

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D13: ECAP Signals: Sigmoidal Fitting Functions for Amplitude Growth Sequences

Konrad E. Schwarz[1], Philipp Spitzer[1], Stefan B. Strahl[1]

[1]Research and Development, MED-EL GmbH, Innsbruck, Austria

Evoked compound action potential (ECAP) amplitude growth functions (AGFs) reflect the coherence of increasing stimulation pulses and the corresponding ECAP signals. The ECAP-amplitude (measured, “y”) is usually analyzed as a linear function (“y=f(x)=x*k + y0”, 2 parameter) of the stimulation amplitude (“x”) above the ECAP threshold and below any saturation effects. The intersection of the interpolated straight line with the x-axis subsequently yields to the ECAP-threshold.

Models show that the ECAP amplitude is approximately proportional to the number of excited nerve fibers except for high stimulation levels, where these models predict a decay of the ECAP amplitude [1]. Additionally, an artificial upper limit may be the compliance limit of the implant used. Stimulation near threshold shows a shallow increase of the ECAP amplitude compared to the slope of the linear model. Physiologically, regarding the potential distribution as well as the excitation of single nerve fibers in terms of probabilities, the resulting shape of the AGF can be seen as cumulative distribution function. Thus, a sigmoidal shape (“y=g(x)= c/(1+exp(-k(x-x0)) – y0”, 4 parameter) appears to be more suitable than a linear model. For the sigmoidal model, the intersection of the tangent at the inflection point of the sigmoid function (at its steepest point) with the x-axis can be used to calculate the ECAP-threshold.

This posters compares the determination of the ECAP-threshold based on a linear model as well as on a sigmoidal model using data derived from >20 Patients provided with MED-EL implants at different electrodes in the apical, middle and basal region. Preliminary results show systematically higher ECAP thresholds for the sigmoidal model, which is in line with the shallow slope for lower stimulation levels.

In summary, the physiological motivated sigmoidal fit of the AGF results in a more robust and straight forward analysis with the advantage of a higher information content due to the 4 parameters.

[1] Briaire, J.; Frijns, J. “Unraveling the electrically evoked compound action potential”. *Hearing Research*, **205**, pages 143–156, 2005.

D14: Spread of Excitation in Bipolar Mode of Different Pulse Shapes

Jaime A. Undurraga[1], Robert P. Carlyon[2], Olivier Macherey[2], Jan Wouters[1], Astrid van Wieringen[1]

[1] ExpORL, Department of Neurosciences, Katholieke Universiteit Leuven (KULeuven), Herestraat 49 bus 721, B-3000 Leuven, Belgium.
[2] MRC Cognition and Brain Sciences Unit, 15 Chaucer Road, Cambridge CB2 7EF, UK.

Bipolar stimulation (BP) has been suggested as a method to reduce the spread of current along the cochlea and increase the number of effective cochlear implant (CI) channels. However, behavioral measurements in BP mode have shown either similar or worse performance than in monopolar mode (MP). One possible limitation of BP stimulation is the bimodal spatial excitation that it may produce, with two main peaks at the sites of the stimulating electrodes. Here, we estimate and compare excitation patterns produced by different pulse shapes, presented in BP mode from 5 human users of the CII or HiRes90K CI (Advanced Bionics). The spread of excitation (SOE) was estimated by means of ECAP responses obtained with the masker-probe paradigm. Four types of maskers were used: symmetric (SYM), pseudomonophasic (PS), reverse pseudomonophasic (RPS) and symmetric with inter-phase gap (2 ms) (SYM-IPG) pulses. Maskers were presented at a comfortable level in BP+9, BP+3 and MP (only SYM) mode on fixed electrodes. In one condition the leading phase of the masker was anodic on the more apical electrode of the channel and in a second condition it was cathodic. The probe was a SYM pulse presented in MP mode to one electrode. Results to date indicate that SOEs obtained in BP mode depend on the leading polarity and the pulse shape. BP+9/SYM maskers result in two peaks close to each electrode of the masker. BP+9/SYM-IPG maskers show a single main peak near the electrode for which the masker's second phase (responsible for the masking) is anodic. BP+3 maskers show more complex patterns. SOE's centroids for SYM-IPG shape, are closer to the masker electrode where the second phase is anodic. BP+3/PS centroids are closer to the masker electrode where the high-amplitude phase is anodic. BP+3/SYM centroids are closer to the middle point between the masker electrodes. The SOEs for MP maskers show a main excitation peak closer to the masker electrode and the widths of their excitation patterns do not differ significantly from those obtained with maskers presented in BP+3 mode. These results are in agreement with our previous finding that the anodic polarity is the most effective one. These results also suggest that SOEs obtained with BP+3/SYM maskers are not significantly more selective than those ones obtained with MP maskers.

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D15: Auditory Steady State Responses to High-Rate Stimuli In Cochlear-Implant Users

Michael Hofmann and Jan Wouters

ExpORL, Dept. Neurosciences, K.U.Leuven, Leuven, Belgium

Electrically Auditory Steady State Responses (EASSRs) are EEG potentials in response to periodic electrical stimuli presented through a cochlear implant (CI). For slow rate pulse trains in the 40 Hz range, electrophysiological thresholds derived from response amplitude growth functions correlate well with behavioral thresholds at these rates.

The aims of this study were: (1) to show that auditory steady state potentials can be reliably evoked by modulated high-rate pulse trains with clinical carrier rates and modulation frequencies in the 40 Hz range, (2) to demonstrate that stimulus artifacts for such stimuli can be completely removed from the recording, (3) to analyze the properties of the resulting responses with regards to amplitude, phase and apparent latency, and (4) to examine the predictive value of electrophysiological thresholds derived from such responses for behavioral thresholds at these high rates.

For six users of a Nucleus cochlear implant, EASSRs to symmetric biphasic bipolar pulse trains were recorded with seven scalp electrodes. Responses to six different stimuli were analyzed: two slow rate pulse trains with pulse rates in the 40 Hz range as well as two amplitude-modulated (AM) and two pulse-width-modulated (PWM) pulse trains with a carrier rate of 900 pps and modulation frequencies in the 40 Hz range. Measurements were done at eight stimulus intensities. Artifacts due to the electrical stimulation were removed from the recordings. To determine the presence of a neural response, improved robust statistics based on Hotelling's T-square test were used that could cope with the presence of limited remaining artifact components. Measurements from different recording electrodes and adjacent stimulus intensities were combined to increase statistical power.

The results show that EASSRs can be evoked by AM and PWM high-rate pulse trains in CI users. In the recorded EEG, these responses can be completely separated from the artifacts generated by the electrical stimulation. At lower intensities, the obtained response amplitudes for AM and PWM stimuli are higher than for slow-rate stimuli, while apparent latencies are similar for all three stimuli. Electrophysiological thresholds derived from responses to AM and PWM high-rate stimuli are significantly lower than for slow-rate stimuli and correlate well with behavioral thresholds.

Support provided by IWT-Vlaanderen project 080304 and Cochlear.

D16: Language Production in Prelingual and Postlingual Hearing Impaired Adults: an fMRI Study.

Berit M Verbist[1,2], Ilya M Veer[1,3], Jeroen J Briaire[4],Johanneke HT Journee[1], Daan van de Velde[5], Mark A van Buchem[1], Niels O Schiller[3,5], Serge ARB Rombouts[1,3], Johan HM Frijns[4]

[1]Dept. of Radiology, Leiden University Medical Center (LUMC) and
[2]University Medical Center Nijmegen (UMCN), the Netherlands
[3]Leiden Institute for Brain and Cognition (LIBC), the Netherlands
[4] Dept. of ORL-HNS, LUMC, the Netherlands
[5]Dept of Psychology, Leiden University (Social Sciences), the Netherlands

An increasing level of function can be achieved with present-day cochlear implants (CIs), but the outcome in terms of speech comprehension still remains highly variable. Although largely unpredictable, certain subgroups of CI candidates have been identified as poor performers. Our research group focuses on the central (retro-cochlear) aspects of hearing loss. This can be studied by means of functional MRI. The goal of this study was to evaluate cortical organization of language production in expected good performers versus poor performers. Prelingually deafened people (PRE) generally show a poorer outcome than postlingually deafened people (POST). We performed an fMRI study to investigate differences in brain activation patterns during phonological processing in 9 PRE, 11 POST and 10 normal hearing controls (HC). Three tasks at different linguistic levels were presented to the participants: (1) a covert picture naming task assumed to evaluate conceptual preparation, lexical access and word form encoding, (2) a categorization task to evaluate phonological awareness for phonemes, and (3) a rhyming task to evaluate phonological awareness for rhymes.

All results reported are cluster corrected for multiple comparisons ($p<.05$). Activation in the inferior frontal gyrus (IFG; Broca's area) was left-lateralized in HC and bilateral in the PRE and POST group. A between-groups difference was found in the right IFG between PRE and HC during the rhyming task. Activation was located in the IFG's pars triangularis in all groups. The POST group showed additional activation in the pars opercularis during the picture naming task. Lastly, increasing fronto-parietal activity, implicated in attention and cognitive control, was observed in the right hemisphere in both the PRE and POST group compared with HC as task difficulty increased.

These results suggest differences in phonological processing and cognitive control between deaf people and HC. Activation in certain target areas may reflect differences between good and bad performers, respectively represented by the POST and PRE-group, and become useful in preoperative identification of good performers and postoperative guidance of auditory rehabilitation strategies.

D17: Lexical Organization In Children With Cochlear Implants

Deena Wechsler-Kashi[1,2], Yoed N. Kenett[2], Dror Y. Kenett[3], Eshel Ben-Jacob[3], Miriam Faust[2,4]

[1]Department of Communication Sciences and Disorders, Ono Academic College, Kiryat Ono, Israel
[2]Gonda Multidisciplinary Brain Research Center, Bar Ilan University, Ramat Gan, Israel
[3]School of Physics and Astronomy, The Raymond and Beverly Sackler Faculty of Exact Sciences, Tel Aviv University, Tel Aviv, Israel
[4]Department of Psychology, Bar Ilan University, Ramat Gan, Israel

Language skills of deaf children significantly improve after they receive a cochlear implant (CI). Nevertheless, although implanted children show significant improvement, many do not achieve age-appropriate language skills. The nature and specific neuro-linguistic mechanisms underlying these varying language outcomes are not fully understood.

Limited information is available on the nature and architecture of lexical networks in children, and in children with CIs in particular. In this study we analyzed responses on a Verbal Fluency (VF) experiment in order to identify differences in word retrieval processes that elucidate the organization of words in the mental lexicons of children with CIs.

In the VF experiments, subjects are typically asked to say, in one minute, as many words as possible, that belong to a certain category or that begin with a given sound. We used the sounds /t/, /l/, and /f/ in the phonological VF experiment and the categories animals and food for the semantic VF experiment.

Responses of thirty two children with CIs (14 females, 18 males) and 34 children with normal-hearing (NH) (22 females, 12 males) age 7-12 on both phonological and semantic VF experiments were recorded and digitized. We performed qualitative analyses examining word clustering and shifting in the children's response. Furthermore, we performed quantitative analyses via correlation and network theory methodologies in order to investigate the differences between the semantic and phonological networks of children with CIs compared to NH children.

Results will be discussed in terms of their implications for lexical development in children with CIs.

D18-a: Musical Experience and Quality Of Life In Cochlear Implant Recipients

Christina D Fuller[1], Rolien H Free[1], Bert Maat[1], Deniz Başkent[1,2]

[1]University Medical Center Groningen, Groningen, The Netherlands
[2]School of Behavioural and Cognitive Neuroscience, University of Groningen, The Netherlands

The perception of music and speech in noise continue to be challenges for cochlear implant (CI) users, and many CI recipients are less satisfied with their music perception post-implantation. To increase the quality of life (QoL) for this population, further research is needed on perception and enjoyment of music while using implants. Additionally, recent research has indicated that musical experience modulates auditory functions in normal hearing listeners, leading to easier perception of speech in difficult listening situations. This finding implies that musical experience can positively affect the ability of understanding speech in noise. We have hypothesized that 1) a more profound musical background may be associated with higher QoL and better speech intelligibility; 2) enjoyment of music with the CI may be positively associated with QoL.

Adult CI users with more than one year of CI experience were sent packages containing a translated and adjusted version of the Musical Background Questionnaire and two validated QoL questionnaires, the Nijmegen Cochlear Implant Questionnaire (NCIQ) and the Speech Spatial and Qualities questionnaire (SSQ). Word recognition scores in quiet were obtained from internal patient records.

It was observed that the musical listening habits of the CI recipients declined after implantation. 29% of the respondents, who were deafened at a younger age ($p=0.002$), stated that music sounds as pleasant as before. Five CI recipients played an instrument after implantation. NCIQ and SSQ scores were highly correlated. Against hypothesis 1, no association was found between the musical background and QoL, speech perception and music appreciation. There was also no association between the speech perception scores and the subjective musical scores. Supporting hypothesis 2, the quality of the sound of music and the speech perception were positively associated with QoL.

The study showed that the musical background is not associated with QoL in our patient population. However, better quality of the sound of music and better speech perception are associated with higher QoL. The CI users who enjoy music are deafened at a younger age. We hypothesize the lack of a musical auditory memory as a contributing factor. The findings imply that either CI users with a high QoL also enjoy listening to music because their devices work better, or enjoying music contributes to better QoL. If latter, a musical therapy program enabling CI users enjoy music again may improve their QoL.

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D18-b: A Psychophysical Method For Measuring Spatial Resolution In Cochlear Implants

Mahan Azadpour and Colette M. McKay

University of Manchester, Manchester, UK

A novel psychophysical method was developed for quantifying spatial resolution in cochlear implants. Spectrally-flat and non-flat pulse-train stimuli were generated by interleaving pulses on eleven sequentially activated electrodes. Spectrally-flat stimuli used loudness balanced currents and spectrally-non-flat stimuli had a single spatial ripple consisting of a middle peak and adjacent valleys with various peak-to-valley distance. The currents on peak and valley electrodes were adjusted to balance the overall loudness with the spectrally-flat stimulus, while keeping the currents on flanking electrodes fixed. The monotonically increasing psychometric functions obtained from percent correct discrimination of non-flat and flat stimuli versus the distance between peak and valley electrodes were used to quantify spatial resolution for each of eight subjects.

In a second experiment current level difference limens were measured for the peak electrode in the same subjects. The majority of the variability in spatial resolution was explained by the ability to detect current level changes on the peak electrode, suggesting that detection of a spatial ripple is more affected by the ability to detect changes in level across the cochlea than the degree of current spread The results were consistent with a hypothesis that a factor other than spread of excitation, such as variance in neural response, might underlie much of the variability in spatial resolution.

Speech perception performance was also measured in the same subjects. Spatial resolution ability was not correlated with phoneme perception in quiet and sentence recognition in quiet and background noise, suggesting that the ability to resolve spectral components is not a major factor underlying variance in speech understanding. This finding is consistent with the hypothesis that implantees use global spectral changes more than fine spectral structure to identify speech (Saoji et al., 2009).

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D19: Cortical Processing Of Musical And Speech Sounds in Early-Implanted Children – Role Of Musical Activities

Ritva Torppa[1,2], Tommi Makkonen[1,2], Hannu Loimo[1,2], Jari Lipsanen[1], Andrew Faulkner[3], Minna Huotilainen[1,2,4]

[1]Cognitive Brain Research Unit,
[2]University of Helsinki, Finland
[3]Speech, Hearing and Phonetic Sciences, University College London, UK
[4]Finnish Institute of Occupational Health, Helsinki, Finland

Musical experience has been shown to enhance auditory cortical functioning in normal hearing (NH) children. In our behavioural experiments we have found connections from musical activities to auditory perception in CI children. The aim of the present study was to find out if such effects are evident at the neural level, and if the processing of musical or spoken stimuli differs between implanted and normal hearing children. ERP responses were recorded in a multi-feature change-detection paradigm from early-implanted children with unilateral CIs aged 4 to 13 years and age-matched NH children. Nine of the implanted children had participated in musical activities outside of the home. Changes in pitch, timbre/vowel, duration, intensity and presence of a temporal gap were presented amongst repeating standards of 295 Hz piano tones or spoken pseudo-words /tatata/. CI artefacts were removed by ICA. ERPs were measured twice, 14 to 18 months apart.

ERP waveforms to piano tones and deviants from these were similar in CI and NH groups across all perceptual dimensions except for intensity increments. CI children had smaller and earlier P1 responses compared to NH controls, and their MMN responses showed less accurate discrimination of musical instrument timbre, sound duration, and temporal gaps, but MMNs for pitch and intensity decrement deviants did not differ between groups. P3a responses suggested less accurate attention switching to changes in timbre. The similarities of neurocognitive processing in music instrument tones are surprising and may indicate that early-implanted children are better able to process some musical features than has previously been thought. For spoken stimuli, in contrast to piano tones and consistent with our behavioural data, CI and NH groups differ markedly in their ERPs to pitch changes. The impact of musical activities on neurocognitive mechanisms of sound feature perception in CI children will be discussed further in this poster.

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D20-a: Optical and Electrical Co-Stimulation in the Cochlea.

Michael J. Jung[1], Suhrud M. Rajguru[1], Ken Zhao[1], Claus-Peter Richter[1-3]

[1]Dept. of Otolaryngology, Northwestern University, Chicago, IL, USA
[2]Dept. of Biomedical Engineering, Northwestern University, Evanston, IL, USA
[3]The Hugh Knowles Center, Dept. of Communication Sciences and Disorders, Northwestern University, Evanston, IL, USA

Infrared neural stimulation (INS) via pulsed infrared laser radiation has been demonstrated in the peripheral nerves, and more recently in the vestibular and auditory systems. In the sciatic nerve, simultaneous presentation of a sub-threshold electric current pulse with the infrared laser pulse has been shown to reduce the threshold for INS. If this interaction holds in the cochlea, the heat delivered to the tissue with each pulse could be substantially reduced with co-stimulation and can guide the design of INS-based cochlear implants.

In this study, we present results quantifying the effects of optical and electrical co-stimulation in the auditory system of guinea pigs. The cochleae were surgically exposed and two cochleostomies were created to access the scala tympani. An optical fiber was advanced through the more basal opening and a silver ball electrode through the second opening. A craniotomy was made to insert a 16-channel electrode array into the central nucleus of the inferior colliculus (ICC). ICC neural responses evoked by INS in the cochlea were recorded. For selected channels, evoked field potentials were used to quantify the responses. The amplitude of the optical and the electrical stimuli were varied systematically; the radiant energy was between 0-100 µJ, and the current amplitude was between 0-500 µA. Optical pulses were 100 µs in duration and electrical pulses were biphasic pulses 250 µs per phase. Stimuli were presented at a rate of 4 Hz. The time of the optical stimulus was changed systematically between –5 and 5 ms at steps of 1 ms, referenced to the electrical pulse which was always at 0 ms.

Responses varied for stimuli at threshold level and at levels above threshold. At threshold or sub-threshold levels for electrical stimulation, the responses were synergistic if optical and electrical stimuli were presented at the same time and they were antagonistic if the stimuli were presented with an inter-stimulus delay. For electrical and optical stimulus levels above threshold, synergistic effects could be seen if the optical stimulus occurred 1-3 ms before the electrical stimulus. The response decreased if electrical stimuli occurred before the optical stimulus. The data suggest non-linear interaction between the two stimuli.

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D20-b: Enhanced Auditory Neuron Survival Following Cell-Based BDNF Treatment In The Deaf Guinea Pig

Lisa N. Pettingill[1], Andrew K. Wise[1,2], Marilyn S. Geaney[3] and Robert K. Shepherd[1,2]

[1]The Bionic Ear Institute, East Melbourne, Victoria, Australia
[2]Department of Otolaryngology, The University of Melbourne, Parkville, Victoria, Australia
[3]Living Cell Technologies Limited, Auckland, New Zealand

The cochlear implant (bionic ear) provides auditory cues to patients with a severe-to-profound sensorineural hearing loss by electrically stimulating the auditory neurons (ANs) of the cochlea. However, ANs undergo progressive degeneration in deafness. While exogenous delivery of neurotrophins such as brain-derived neurotrophic factor (BDNF) supports AN survival in animal models of deafness, a clinically applicable means of providing neurotrophin treatment is required.

This study investigated the potential of cell- and gene-based therapies to support AN survival in deafness, using encapsulated BDNF-expressing Schwann cells (eBDNF-SCs) in the deaf guinea pig.

Schwann cells from P3 rat sciatic nerve were lipofected to express BDNF, and were then encapsulated in a biocompatible alginate matrix. Normal hearing guinea pigs were systemically deafened using kanamycin and frusemide, and five days post-deafening either eBDNF-SCs or empty (control) capsules were implanted into the scala tympani of the left cochlea. AN survival was quantified two or four weeks post-implantation.

The cell-based BDNF treatment resulted in significantly greater AN survival, in comparison to controls, at both time points. Two weeks post-implantation, AN survival in the cochleae treated with eBDNF-SCs (975.37 ± 127.02 ANs/mm2; mean ± SEM) was significantly greater ($P < 0.05$) than in the cochleae that received empty capsules (770.97 ± 27.20 ANs/mm2). After four weeks, a significant ($P < 0.05$) rescue effect was also observed in the eBDNF-SC cohort (637.02 ± 98.55 ANs/mm2) in comparison to the control group (447.8 ± 23.27 ANs/mm2).

These findings suggest that cell-based neurotrophin treatment provides a clinically transferable therapeutic option for the delivery of neurotrophic factors to reduce or prevent AN degeneration in deafness. Long-term studies investigating the combined application of cell-based neurotrophin treatment and chronic electrical stimulation from a cochlear implant may further enhance these outcomes.

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D21: Infrared Neural Stimulation of the Cat Cochlea

Ken Zhao[1], Suhrud M. Rajguru[1] and Claus-Peter Richter[1, 2, 3]

[1]Department of Otolaryngology, Northwestern University Feinberg School of Medicine, Chicago, IL, USA
[2] Department of Biomedical Engineering, Northwestern University, Evanston, IL, USA
[3] Hugh Knowles Center, Department of Communication Sciences and Disorders, Northwestern University, Evanston, IL, USA

Infrared neural stimulation (INS) does not require a physical contact with neural tissue, and has been shown to produce spatially precise stimulation in the cochlea. We have demonstrated the efficacy of INS in gerbil, guinea pig, and cat auditory systems. In the present report, we evaluated the parameter space of infrared pulses delivered to spiral ganglion cells in normal hearing, acutely deafened, and chronically deafened cats. We investigated the changes in compound action potentials (CAP) evoked by the infrared pulses of varying pulse lengths, pulse shapes, and radiation wavelengths. Pulses were delivered by an optical fiber inserted in the basal turn of the cochlea and oriented toward the spiral ganglion. No acoustic responses could be evoked in the chronically deafened animals, while the INS was always effective in stimulating the spiral ganglion neurons. Results suggest that infrared pulses with shorter wavelengths and corresponding longer penetration depths were more effective. The results also suggest that pulse durations between 50-100 μs evoked the largest CAPs in both normal hearing and deaf animals. The variations in rise times of pulses, for four different pulse shapes (square, ramp-up, ramp-down and triangular), did not significantly affect the evoked responses. Additionally, we utilized micro computed tomography (microCT) to visualize the orientations and locations of the optical fiber within the cat cochleae. The fibers were located between 300-900 μm from the target spiral ganglion neurons. The results from this study will optimize the design of a cochlear implant utilizing INS as its mode of neural stimulation.

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D22: Modeling Of Peripheral Factors That Affect Neural Excitation In The Electrically Stimulated Cochlea

Tania Hanekom, Tiaan K Malherbe, Robert Jönsson, Johan J Hanekom

University of Pretoria, Pretoria, South Africa

Sound perception among cochlear implant users varies significantly and is affected, among others, by factors such as electrode insertion depth, neural survival profiles and electrode to neural proximity. The research presented here is directed at the development of models of peripheral neural excitation of the electrically stimulated auditory system. The models consist of detailed volume conduction (VC) models of the cochlear structures and surrounding tissues to describe current distributions within the cochlea which are subsequently applied to computational neural models to predict neural excitation characteristics. The models aim to include parameters describing peripheral factors that cause inter-subject variability so that variance in performance caused by these factors may be identified and quantified.

To study inter-subject variability in hearing performance, subject-specific models are required. Development of a subject-specific model of a guinea-pig was used to investigate modeling techniques that would be applicable to the development of similar models for human subjects. A method was devised by which the dimensions of the cochlear structures and the intra-cochlear location of the electrode contacts, estimated from CT image data, could be used to construct a model. Guinea pig model results were verified by comparing predicted neural excitation profiles with measured EABR data collected from the IC of the modeled animal. Initial results showed that electrode to neural proximity alone cannot account for neural excitation profiles observed via physiological measurements. Additional factors that have since been implemented include insertion damage to the basilar membrane and neurons and an improved description of the current path from the monopolar return electrode.

Models for human subjects showed that psychoacoustic thresholds are not suitable to verify model integrity and that a more central measure of neural activation is required. NRT data was thus selected to evaluate model integrity. Data collection and interpretation are still on-going.

Work on the neural side of the peripheral model used neural populations implemented through interacting single fiber models to investigate phenomena that could affect hearing performance. One important phenomenon that was discovered as a potential parameter that could partly account for inter subject variation in pitch perception is ephaptic excitation, since it could cause significant cross-turn stimulation.

This modeling work provides a theoretical basis for investigating specific factors that affect neural excitation at the periphery of the auditory system and could aid the future development of a sophisticated auditory neural interface.

D23: The Effect Of Enhanced Temporal Pitch Cues On Perception Of Mandarin Chinese In Real And Simulated Electric Hearing

Matthias Milczynski, Jan Wouters, Astrid van Wieringen

ExpORL, Dept. Neurosciences, K. U. Leuven, Leuven, Belgium

Mandarin Chinese is the most spoken native language worldwide and is characterized by four tones that are additional determinants of lexical meaning. Mandarin tones are primarily distinguished by their corresponding fundamental frequency (F0) contour. Recent studies demonstrated significantly worse lexical tone perception in Cochlear Implant (CI) users compared to normal hearing (NH) listeners. Diminished lexical tone perception in electric hearing (EH) is mainly attributable to impaired pitch perception. We have evaluated a new CI processing strategy called F0mod in a Mandarin word and sentence recognition test in comparison to the standard Advanced Combination Encoder (ACE). Four Nucleus Freedom CI users and sixteen NH listeners were tested. In experiments involving CI subjects, electrical stimulation patterns were generated off-line and directly streamed to the subjects' implant using the Laura 34 (L34) research processor. The NH subjects were presented with noise-band vocoder CI-simulations using either 22 or 8 spectral channels. In the word test, the subjects' responses were further segmented into phoneme and tone scores. Conditions in noise were tested using steady-state, speech-weighted noise. The results indicate a significantly better tone perception performance in both groups using F0mod relative to ACE ($p<0.05$). Moreover, the NH group performed significantly better on word recognition with 8 channels using F0mod compared to ACE using 8 and 22 channels. Only a small but significant improvement in word recognition was demonstrated in the CI group ($p<0.05$). This is indicates a translational effect of improved lexical tone perception on speech recognition. No significant differences between strategies in sentence recognition were shown. In conclusion, F0mod provides (1) a significant improvement in Mandarin lexical tone perception and (2) no degradation in word and sentence recognition in EH. These benefits motivate a promising application of F0mod to a continuously growing tonal language speaking CI population. This study was partially supported by IWT-Vlaanderen and Cochlear Ltd.

D24-a: Hemispheric Lateralization of Cortical Responses in Children Using Bilateral Cochlear Implants

Daniel D.E. Wong[1], Karen A. Gordon[1]

[1]The Hospital for Sick Children, Toronto, ON, Canada

We examined cortical activity evoked by right versus left ear stimulation in children using bilateral cochlear implants (CIs). CIs stimulate the auditory nerve using electrical pulses, promoting auditory development in children who are deaf. Because unilateral hearing is known to cause reorganization along the auditory pathways, we hypothesized that children using unilateral CIs and children who had long delays between their first and second CI would show abnormal lateralization of activity in the auditory cortex compared to children experiencing short or no periods of unilateral implant use.

Electroencephalographic responses were measured from 64 scalp locations in 17 children. Bilateral CI users were divided into three groups, corresponding to the time period between the activation of their first and second implant. The long delay group (n=10) consisted of children whose second implant was activated > 2 years after the first. The short delay group (n=8) consisted of children whose second implant was activated < 1 year after the first. Both CIs were activated at the same time in the simultaneous group (n=10). Responses from bilateral CI users were compared with those recorded from children using a single CI in the right ear (n=9). We measured the difference in activity between left and right auditory cortex hemispheres (cortical lateralization) for each evoked response.

Repeated measures ANOVA analysis revealed that in our group of children, responses evoked from a CI which was worn unilaterally for an extended period (unilateral and long delay groups) lateralized to the contralateral auditory cortex more strongly than responses from children with short or no periods of unilateral CI use (short delay and simultaneous groups) ($F=4.37(3,23)$, $p < 0.05$).

The differences in lateralization found in children receiving bilateral CIs after long delays could reflect a reduced ability of the pathways stimulated by the second CI to compete with the established pathways from the more experienced side, resulting in a system that is different from one in which bilateral pathways develop in tandem. If so, this suggests that there is a sensitive period for bilateral input in the developing auditory system.

D24-b: Front-End Noise Suppression for Bilateral Cochlear Implants Using Estimated Binary Masks

Sara I. Duran, Leslie M. Collins and Chandra S. Throckmorton

Duke University Department of Electrical and Computer Engineering, Durham, NC

Bilateral implantation is becoming more common and is generally accepted by the research community as beneficial to implanted individuals. Research has demonstrated that sound localization is greatly improved with bilateral implants; however, a similar level of benefit has not been observed for tasks requiring the segregation of a target speaker from interfering sources. Research suggests that bilateral implants should be pitch matched in order to maximize perception of the cues necessary for auditory scene analysis (e.g. Long et al., 2006); however, recent work by Lu et al. (2010) suggests that in some cases accurate pitch matching may not be possible or may not improve perception to a normal-hearing range. Therefore, bilateral CI users might benefit from a preprocessing stage that isolates the target from the interfering sources for them.

Previously proposed denoising methods often tend to not be robust in reverberant conditions, limiting their efficacy in real-world listening environments; however, one denoising method that has been demonstrated to perform well with convolutive mixtures is the ideal binary mask (Roman et al., 2006). The source mixture is broken into time-frequency (T-F) segments, and the mask is used to attenuate the segments that are dominated by interferers while leaving the segments dominated by the target unaffected. However, since the signal and noise cannot be independently accessed in real-world environments, the mixed signal must be used to estimate the binary mask.

In this study, an estimate of the noise signal is obtained by cancelling the target using an adaptive filter, which requires microphone input from both of the bilateral CI listeners' implants. The noise approximation is then compared to the mixture to determine the estimated value of the binary mask corresponding to each T-F unit (Roman et al., 2006). This mask is applied to noisy speech before processing it with each subject's clinical processing algorithm. In order to evaluate this method, speech recognition tests were conducted with bilateral CI users under three different conditions-- unprocessed mixture, mixture processed using the ideal binary mask and the mixture processed using the estimated binary mask. The results of this study could indicate a benefit to implementing a speech processing algorithm that has access to binaural information.

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D25: Audiovisual Crossmodal Plasticity in Adult Cochlear Implant Users

Yun Gong[1], Emily A. Tobey[1, 2], Michael Devous, Sr.[1, 2], Thomas S. Harris[2], Peter S. Roland[2]

[1] University of Texas at Dallas, Dallas, TX, USA
[2] University of Texas Southwestern Medical Center, Dallas, TX, USA

There are numerous studies investigating speech perception in cochlear implant (CI) users from different aspects. However, only few studies provide insight into the variability of speech perception by focusing on crossmodal plasticity. This cross-sectional study explored the neural basis for speech perception and lipreading performance in a group of adult CI users. The study examined the relationship between regional cerebral blood flow (rCBF) generated during a visual presentation of connected speech and other factors (such as auditory deprivation, lipreading comprehension, and auditory speech perception) of 43 adult CI users. Eight highly correlated auditory speech perception measures were reduced to a single score for analysis. Each subject was scanned by single photon emission computed tomography to measure the rCBF response to a visual-only condition of connected speech. Lipreading comprehension scores were measured during the imaging sessions. Voxel-based analyses were used to examine rCBF response relationships to other factors. Higher rCBF within bilateral auditory cortices, especially the left hemisphere, was associated with more serious auditory deprivation (earlier onset of deafness and longer duration of deafness). Higher rCBF within auditory areas was also associated with better lipreading comprehension and poorer auditory speech perception of CI users. Further covariance analyses indicated auditory deprivation might be the main confounding factor for the relationship between higher rCBF within auditory cortices and poorer auditory speech performance. One possible explanation for the relationships between rCBF generated by a visual stimulus and speech perception (or lipreading) may be crossmodal plasticity. It appears earlier onset of deafness and longer duration of deafness induced more visual-related synapses in auditory cortices. More visual-related synapses colonized in auditory cortices may provide the neural basis for better lipreading comprehension and poorer auditory perception of CI users. Such visual conditions may serve as an objective method to estimate the influence of audiovisual crossmodal processing on speech perception in adult CI users.

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D26: Pitch-related Perception by Bilateral and Bimodal Cochlear Implant Users

Tianhao Li, Qian-Jie Fu

House Ear Institute, Los Angeles, CA U.S.A

Due to limited spectral and temporal resolution provided by cochlear implants (CIs), pitch-related perception of CI users rely largely on spectral and temporal envelope information. CI users with residual hearing in contra-lateral ear may also use low-frequency acoustic information for pitch-related perception. Thus, pitch-related perception of bilateral and bimodal CI users involves not only binaurally spectral and temporal interaction, but also binaural interaction between electric hearing and acoustic hearing. The present study investigated binaural interaction of spectral and temporal information and binaural interaction of electric hearing and acoustic hearing for pitch-related perception in bilateral and bimodal CI users.

Voice gender discrimination (VGD) was measured with four vowel stimulus sets, in which the inter-gender fundamental frequency (F0) difference, spectral and temporal cues were systematically manipulated. Vowel and consonant recognition was measured in quiet and in noise at a 5dB signal-to-noise ratio (SNR). Melodic contour identification (MCI) was also measured as a control condition. All perception tasks were observed under three listening modes (left CI/HA alone, right CI/HA alone, and both) with seven bilateral CI users and five bimodal CI users so far. There was no significant difference in performance on any tasks between the two groups. While some individual subjects showed binaural benefits under certain test conditions, the significant binaural benefit was found only for VGD measured with the stimulus set with the smaller inter-gender F0 difference in the bimodal CI group. Better ear was dominant for all phoneme recognition tasks and VGD tasks using more temporal cues within both groups. There was a slight binaural improvement in VGD performance tested with spectral cues only for both groups. These results suggest that (1) spectral information can be integrated to some degree across ears in bilateral and bimodal CI users; (2) temporal periodicity processing is better ear dominant for pitch-related perception in bilateral and bimodal CI users; (3) the improvement of pitch perception with acoustic hearing is not necessarily transferred to phoneme recognition in noise in bimodal CI users. Detailed analysis further disclosed the mechanisms underlying binaural interaction of spectral and temporal information processing and binaural interaction of acoustic and electric hearing for pitch-related perception.

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D27-a: Stimulation Levels and Subjective Ratings

Anthony J. Spahr[1], Leonid M. Litvak [2], Sarah Cook[1], and Michael F Dorman[1]

[1]Arizona State University, Tempe, AZ, USA
[2]Advanced Bionics Corporation, Valencia, CA, USA

Introduction: Cochlear Implant users typically have a short window to assess the acceptability of a new program. This initial impression often determines if the program will be appropriate for chronic use. The objective of this study was to determine the effect of stimulation level adjustments on the initial acceptability impression of the user.

Methods: Eleven users of the Advanced Bionics cochlear implant system participated in this study. For each listener, a baseline program was created using the minimum pulse width setting allowed by the programming software. Additional maps were created by increasing the pulse width setting of the baseline program to 30, 60, 90 and 120 µS. Most comfortable stimulation levels (M-levels) in each new program were set using (i) the stimulation level estimated by the programming software, and (ii) a global adjustment so that sentences presented at 60 dB SPL (0 degrees azimuth) were comfortably loud with a volume control (VC) setting of 0%.

During testing, maps were selected in random order and listeners were asked to rate the acceptability of the program after hearing 5-10 recorded sentences presented at 60 dB SPL. In one-half of the trials, sentences were presented with the VC set to 0% and in the other half of the trials listeners adjusted the VC so that sentences were “comfortably loud”. The acceptability of each map was rated on a scale of 1 (completely unacceptable) to 5 (completely acceptable).

Results: Generally, users were less accepting of wider pulse width settings. In conditions where m-levels were underestimated by the programming software, ratings were significantly higher when users were allowed to globally adjust m-levels during fitting and when they were allowed to adjust the VC setting during testing. No differences were observed between fitting methods when the VC was adjusted by the user.

Conclusions: Differences in stimulation level have the potential to significantly affect the listener’s initial impression of a program. Failure to compensate for loudness differences could cause listeners to reject otherwise acceptable programs.

D27-b: Cochlear Implant Stimulating Strategy Incorporating Current Steering Scheme and Psychoacoustic Model

Charles T. M. Choi[1], Wen-Ya Tsai[1], Yi-Hsuan Lee[2]

[1]National Chiao Tung University, Hsinchu, Taiwan, R.O.C.
[2]National Taichung University of Education, Taichung, Taiwan, R.O.C.

Cochlear implant (CI), which has been commercial products for almost thirty years, provides the only opportunity for people with profoundly hearing impairment to recover partial hearing. Meanwhile, stimulating strategy plays an extremely important role in maximizing the CI user's overall communicative potential, and many strategies have been developed over the past two decades. Until recently the main thrust in CI research is to improve the hearing ability in quiet environment. However, the most challenging problems currently are how to improve the CI users' ability to listen to music, tonal languages, and in noisy environment. New stimulating strategies can be used to tackle these problems.

In this study, we propose a novel hybrid stimulating strategy based on virtual channel technique to increase the perceptual quality of CI users. Psychoacoustic model is further incorporated, which is beneficial to reduce the number of activated electrodes for saving power but maintain similar hearing performance for CI users. We designed a CI vocoder and conducted hearing tests to evaluate the proposed strategies using normal hearing test subjects. The experiment results show that the proposed hybrid strategy without psychoacoustic model incorporated achieves consistently higher recognition rates when compared to commercial strategies CIS and HiRes120, especially in a relatively noisy environment (e.g. SNR = -5 dB). After incorporating psychoacoustic model not only the number of activated electrodes is actually reduced, the speech is heard almost the same, and the test subjects can still correctly recognize as many sentences as before.

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D28: Neurotrophin Induced Ectopic Growth Of Peripheral Processes Does Not Compromise The Cochleotopic Organization Of The Implanted Cochlea

T. G. Landry[1,2], A. K. Wise[1,2], J. B. Fallon[1,2] & R. K. Shepherd[1,2]

[1]Bionic Ear Institute and [2]University of Melbourne, Melbourne, Australia

Spiral ganglion neurons (SGNs), undergo progressive degeneration in deafness. In animal models, exogenous delivery of neurotrophic factors, including brain-derived neurotrophic factor and neurotrophin-3, exhibit pronounced survival effects on SGNs, resulting in significant reductions in electrically-evoked thresholds. However, neurotrophin treatment has been shown to promote ectopic growth of peripheral processes[1], potentially compromising cochleotopic organization and therefore reducing the ability of cochlear implants to convey place pitch. We have used single fiber tracing of SGN peripheral processes and multichannel electrophysiological recordings in the inferior colliculus (IC) to evaluate the extent and functional effects of chronic neurotrophin treatment combined with intracochlear electrical stimulation in adult-deafened guinea pigs (n= 26).

Following two weeks of deafness, animals received a scala tympani electrode array and drug delivery system. A 2×2 treatment design was used for neurotrophin treatment and electrical stimulation with appropriate controls. After a four week treatment period, a neural tracer was injected into the auditory nerve trunk in an acute experiment in order to trace single SGN peripheral processes in cochlear surface preparations. Neurotrophin treatment resulted in significant increases in both the length of traced processes (two-way ANOVA, $p = 0.006$), and in their lateral deviation along the cochlea ($p < 0.0005$) – a measure relevant to the cochleotopic organization of SGNs as extensive lateral deviation has the potential to reduce electrode selectivity and increase the spread of excitation in the auditory nerve. To determine if responses in the central auditory pathway were significantly affected by these morphological effects, multi-unit neural activity to intracochlear electrical stimulation was recorded along the cochleotopic map of the IC using a 32-channel recording array. Notably, we observed no effect of neurotrophin treatment on the spread of activation to bipolar cochlear stimulation (two-way ANOVA, $p > 0.05$).

Although neurotrophin treatment increases ectopic SGN peripheral process growth, this does not significantly impact on the spread of activation using conventional scala tympani electrode arrays. This is likely due to the large differences in scale between the ectopic peripheral process growth (tens of microns) and the relatively broad excitation patterns produced by intracochlear electrical stimulation. Therefore, the beneficial effects of neurotrophin treatment on SGN survival and function can be obtained with a negligible effect upon the cochleotopic organization of SGNs.

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[1] Wise AK, Richardson R, Hardman J, Clark G, O'Leary S (2005). J Comp Neurol 487: 147-165.

D29: Neurotrophic Effects Of BDNF and Electrical Stimulation In Cats Deafened At Birth

Patricia A. Leake, Gary T. Hradek, Alexander Hetherington,
Olga Stakhovskaya and Ben H. Bonham

Epstein Laboratory, Dept. of OHNS, UCSF, San Francisco, CA USA

Postnatal development and survival of cochlear spiral ganglion (SG) neurons likely depend upon both neurotrophic support and neural activity. Our earlier studies demonstrated that electrical stimulation (ES) partially prevents SG degeneration after early deafness in cats, and neurotrophic agents may further enhance neural survival. Recently, we have studied intracochlear BDNF infusion in this animal model of congenital deafness. Kittens were deafened prior to hearing onset (neomycin, 60 mg/kg SQ SID, 16-21d) and implanted at 4-5 weeks of age using custom-designed electrodes with a drug-delivery cannula connected to an osmotic pump. BDNF (94□atal devel□atal development and survival of cochlear spiral gangli

After BDNF infusion, SG cell soma areas were 34% larger, and SG density was 25% higher as compared to the contralateral side (P<0.001). In further studies, the BDNF treatment was combined with 6-7 months of ES. After BNDF+ES, significantly larger cell size (17% increase) and markedly greater SG survival (56% increase; P<0.001) were maintained; but both size and density were reduced (by 14% and 9%, respectively; P<0.05) from values seen immediately after BDNF infusion. In this animal model, combined BNDF+ES was not significantly more effective than ES alone and only modestly more effective than BDNF alone (preliminary data) with these prolonged durations of stimulation and deafness. Other potentially important findings after combined BDNF+ES included higher density of radial nerve fibers in the osseous spiral lamina compared to both contralateral and ES only, ectopic sprouting of fibers into the scala tympani above the implant, increased vascularity of the SG compared to contralateral, and thicker fibrotic encapsulation of the electrode array compared to both ES only and passive implantation.

Functionally, a clear reduction in EABR thresholds relative to initial thresholds was seen after BDNF alone and also after BDNF+ES on the two chronically stimulated bipolar channels of the implant, but not on the inactivate control channel. Electrophysiology experiments recording with multichannel probes in the inferior colliculus (IC) showed that the fundamental cochleotopic organization of the central auditory system was maintained, at least to the level of the midbrain, both in chronically stimulated animals and also in naïve neonatally deafened control subjects. IC thresholds were well-correlated with EABR thresholds. Interestingly, IC thresholds were correlated with 2-dB activation widths in all other groups, but not in BDNF-treated animals in which greater variability was observed.

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D30: The potential benefits of combining intracochlear current focusing techniques with dual electrode stimulation: a computational study

Randy K. Kalkman, David M.T. Dekker, Jeroen J. Briaire
and Johan H.M. Frijns

Leiden University Medical Centre, Leiden, The Netherlands

Current focusing techniques in cochlear implants aim at decreasing the spread of neural excitation. Typically, multiple electrodes are used simultaneously to attenuate the field of a single electrode, e.g. in the case of (partial) tripolar stimulation and, as explored more recently, phased array stimulation. In the technique known as dual electrode stimulation (DES), simultaneous stimulation of two electrode contacts is used in an attempt to excite neurons in the area between two principal excitation areas, rather than to diminish the spread of excitation. The present study investigates the effects of combining current focusing techniques and DES using a realistic computational model of the implanted human cochlea.

Excitation patterns of dually stimulated monopoles, (partial) tripoles and phased array channels in lateral and perimodiolar electrode arrays were simulated and compared. Pitch percepts, loudness levels and excitation densities (the percentage of fibers excited at a specific location) were predicted as a function of current level. Excitation density plots revealed that focused DES can create a more confined excitation region compared to conventional DES. However, this focusing effect was more prominent in lateral wall insertions than it was in perimodiolar insertions. It was found that DES with partial tripoles and phased array stimulation produces shifting pitch percepts similar to that of conventional DES with two monopoles at the same location. Due to the presence of side lobes in their excitation patterns, full tripoles induce a non-monotonic shift in pitch when gradually shifting the balance from one tripole to the other. As expected, focused DES requires more current to achieve the same loudness as conventional DES, with the difference factor depending on stimulation type, loudness level, electrode array position and insertion depth of the main contacts.

The study indicates that combining DES with current focusing strategies can create intermediate pitch percepts as well as conventional DES can, while maintaining a high spatial selectivity. This is achieved at the expense of a higher power consumption and the need for more sophisticated means to control loudness

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D31: Sparse Stimuli Benefit Cochlear Implant Users In Noisy Environment

Guoping Li, Mark E Lutman

Institute of Sound and Vibration Research, University of Southampton, UK

Improving speech recognition performance in noise for cochlear implant (CI) users remains a challenging task. One of the main reasons for lack of significant improvement in real life for CI users is due to the physical limitation of cochlear implants. Cochlear implants have a much smaller dynamic range available to encode the acoustic signals compared to normal auditory system. The limited dynamic range leads to an information bottle neck for cochlear implants to encode acoustic information with limited dynamic range of electrical pulses. Such encoding is not efficient in noisy situations because the limited communication bandwidth is used not only by the essential part of speech, envelopes, but also by noise.

This paper proposed a SPARSE strategy, aiming to achieve efficient encoding of speech signals by applying information theory to reduce the information bottle neck constrain of cochlear implants. According to information theory, an efficient encoding can be achieved even with a narrow communication bandwidth if the redundancy of signal to be encoded can be reduced and the most essential information can be extracted. The SPARSE strategy is also based on the sparse coding theory, suggesting that only few auditory neurons fire at the same time to encode natural acoustic signals. The SPARSE strategy aims to identify the most information-bearing components of speech signals and reduce the redundant components. As a result, noise tends to be suppressed, but also some (unimportant) components of speech may be removed beneficially. A sparse representation of speech signals can thus be achieved before being sent through to the auditory neurons, with reduced noise and reduction of redundant components. Previous experiments confirmed SPARSE can significantly improve Signal-to-Noise-Ratio (SNR) in 10 and 5 dB SNR compared with the ACE strategy, one of the strategies commercially available in current cochlear implants.

SPARSE strategy was tested with 13 cochlear implant (CI) users listening to BKB sentences in babble noise with 3 different signal-to-noise ratios (SNR): Quiet, 10 dB, 5 dB. The results showed significant improvement for 5 dB ($p<0.05$) compared to ACE, one of the current encoding strategies used in cochlear implants. The improvement is not significant for 10 dB ($p=0.055$). Further experiments will be conducted to investigate take home device with cochlear implant users to evaluate SPARSE strategy in a wider range of noisy situations.

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D32-a: Acoustic Landmark Detection: Realising A New N-Of-M Speech Processing Strategy For Cochlear Implants

Cherith M. Webb

University of Southampton, United Kingdom

Speech processing in a cochlear implant (CI) should preserve as many of the acoustic cues required for good speech reception as possible. “Peak-picking” strategies, also known as “N-of-M” are one method employed by CI coding schemes and base channel selection on spectral maxima (bands with greater than a certain, defined amplitude). Although these strategies often yield average scores of 70-80% correct for sentences in quiet, even the best performing CI users do not hear as well in background noise as their normal hearing peers. The current study looks to address whether we can develop a new N-of-M strategy based on evidence from speech perception models. In particular, this project draws on research relating to so called “acoustic landmarks” and their importance for normal speech perception, both in quiet and in noise. Landmarks can be considered as locations in the acoustic signal which are rich in information relating to the manner of articulation of speech sounds. According to the Lexical Access from Features (LAFF) model of speech perception, detecting these landmarks within the signal is the initial processing stage involved in speech perception, and allows for further acoustic analysis of the signal; locating regions within the signal where important cues tend to be concentrated.

Automatic Speech Recognition (ASR) systems developed based on the principle of detecting and identifying acoustic landmarks from within the speech signal have shown that algorithms can be trained to accurately and robustly identify these perceptually important landmarks. Consequently, the question then is whether an ASR-based landmark detection algorithm can be adapted/applied to channel selection in an N-of-M CI strategy? A peak-picking CI strategy incorporating landmark detection would base channel selection on the probability of the corresponding frequency bands containing an acoustic landmark, rather than on simple amplitude.

Ultimately, the aim of the current project is to determine whether a landmark based N-of-M strategy can in fact improve speech recognition for CI users. This will be evaluated in three stages and preliminary results from the first two stages shall be discussed. The first stage is to compare the transmission of landmark cues through the ASR models with the transmission of those cues in a CI system. The second stage is to develop an off-line landmark-based peak-picking algorithm, which could be achieved by marrying ASR landmark detection and CI processing systems. The third and final stage of the project is to compare the performance of the landmark-based algorithm with performance of current CI processing strategies using both normal hearing subjects (via an acoustic model) and CI users (using direct electrical stimulation). If this new approach is found to be beneficial, it could then be translated into an on-line application in a real CI device.

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D32-b: A Dual-Microphone Algorithm For Improving Speech Intelligibility In Competing-Talker Listening Situations

Nima Yousefian and Philipos C. Loizou

Department of Electrical Engineering, University of Texas at Dallas, Richardson, TX, USA

The level of speech intelligibility by cochlear implant (CI) users is highly dependent on the type of background interference, i.e., whether it is stationary noise (e.g., car noise, speech-weighted noise) or competing talker(s). The majority of existing noise reduction algorithms do not perform well in competing-talker situations due to the inherent difficulty in discriminating between the target and masking talkers. Recently, dual-microphone noise reduction algorithms have received wide attention as they exhibit better performance than single-microphone techniques, both in terms of speech intelligibility and quality. Beamforming is the most popular technique used in cochlear implant devices because of the ease of implementation and acceptable performance in various noise conditions. However, sensitivity to microphone mismatch, degradation in performance in reverberant environments and poor results in multiple and competing-talker scenarios are among the main drawbacks of beamforming techniques.

In the present study we examine the performance of a new dual-microphone noise reduction technique capable of operating in single- and multiple-talker scenarios. The proposed method utilizes the coherence function, computed from the input signals received at the two microphones, as a means for signal-to-noise ratio (SNR) estimation at each band. The estimated SNR is subsequently used as a criterion for channel selection. Envelopes corresponding to channels with SNR above a preset threshold are retained while envelopes with SNR falling below the threshold are discarded. The proposed strategy was implemented in the ACE strategy by replacing the maximum channel selection criterion with the SNR channel selection criterion, and tested with Nucleus implant users. Speech Intelligibility tests (in terms of SRT) were carried out in several testing configurations which included either a single competing talker originating from 45^o or 90^o, or two competing talkers originating from (90^o, 180^o) or (90^o, 270^o) (target talker was at 0^o). Compared against the conventional beamforming strategy, the proposed strategy yielded 5-10 dB improvement in most conditions.

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D33-a: Speech Perception Based On Acoustic Temporal Fine Structure In Cochlear Implant Listeners

Jong Ho Won, Kaibao Nie, Xing Li, Elyse M. Jameyson, Ward R. Drennan, and Jay T. Rubinstein

V.M. Bloedel Hearing Research Center, Departments of Otolaryngology & Bioengineering, University of Washington, Seattle, WA, USA

Previous studies using the Hilbert vocoder processing have demonstrated that normal-hearing listeners can understand speech using the recovered envelope (E) cues from temporal fine structure (TFS). Cochlear implant (CI) sound processing uses E information to modulate pulse trains, hence acoustic TFS information is largely discarded during this processing. However, there is a possibility that acoustic TFS can be transmitted through the CI sound processor in a form of the recovered E cues as a result of implant processing. More specifically, when speech signals containing only Hilbert TFS cues are presented through the CI sound processor, speech E cues could be reconstructed at the output of the sound processor filters, which will be modulated with pulse trains. If this recovered envelope cues can be used by CI listeners to understand speech, we hypothesized that CI listeners' performance would increase as more recovered E cues become available for them. To test this hypothesis, consonant recognition was evaluated in 8 CI users with stimuli having intact information (i.e. E+TFS), only E cues, or only TFS cues. The subjects were fitted with a 8-channel CIS map. For the TFS condition, four different number of analysis bands (1, 2, 4, and 8) were used to create TFS-stimuli. The intact and E conditions were only tested with 8 bands to determine if CI users perform better with the intact speech. The cutoff frequencies for the analysis filters were matched to the cutoff frequencies of the CIS map. Results showed that a consistent improvement in performance was observed as the band number decreased from 8 to 1, which is consistent with the pattern observed in normal-hearing listeners. Electrode outputs were analyzed to assess correlations between outputs response to original stimuli and to TFS-stimuli. This analysis showed that the degree of similarity increased as the number of analysis bands was decreased, supporting the recognition data. Taken together, the present study demonstrated that the CI sound processor generates the recovered E cues out of broadband acoustic TFS and CI users can use the recovered E cues for speech perception.

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D33-b: Evaluation Of A New Signal Processing Strategy Including A Partial Bipolar Channel To Transmit Low Frequency Information

Waldo Nogueira[1], Alexander Foerstel[2], Aniket Saoji[3], Leonid Litvak[3], Volkmar Hamacher[1], Tobias Rottmann[2], Thomas Lenarz[2], Andreas Buechner[2]

[1] Advanced Bionics European Research Center GmbH Hannover
[2] Medical University of Hannover, Department of Otolaryngology, Hannover, Germany
[3] Advanced Bionics LLC, Valencia, USA

This work presents the evaluation of a new signal processing strategy for the CII/HR90k implant of Advanced Bionics. The new strategy is based on HiRes 120 but makes use of an additional virtual channel which presents signal components below 250 Hz. For representation of this new channel a virtual electrode is created by partially bipolar stimulation producing a lower pitch sensation than the most apical electrode contact. The transmitted frequency spectrum is expanded by about 2 octaves to capture the fundamental frequency of speech and music.

The new strategy, called Phantom, was evaluated in 15 HiRes90k cochlear implant users. The fitting procedure of the new low frequency channel was investigated prior to evaluating speech and music perception with the new strategy. Speech was evaluated using the HSM sentence test in noise and the adaptive OlSa sentence test after one month of experience with the new strategy. Music perception was assessed in a controlled comparison condition via a questionnaire. Finally, psychophysical measures were performed to further investigate the effect of the Phantom channel.

The fitting was crucial for the performance. The performance with F120 and Phantom was similar in both speech perception tests (HSM: 43.43% with F120 and 49.6% with Phantom; OlSa: -1.86dB SNR with F120 and -1.98dB SNR with Phantom).With both strategies, music was easy to follow, with a small advantage for Phantom. With Phantom music was perceived slightly more natural than with F120. The sound balance with Phantom was rated to be more neutral than with F120. Finally, the overall impression of music with Phantom was significantly better than with F120. However, current results of psychophysical measures do not show a correlation to the music perception.

Our results indicate a benefit of the Phantom strategy for music perception. Further research is currently ongoing to understand the underlying mechanisms and to investigate whether a further iteration may also bring advantages for other situations.

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D34: Suppressing Reverberation in Cochlear Implants Using a Channel-Selection Based Strategy

Oldooz Hazrati, Kostas Kokkinakis and Philipos C. Loizou

Department of Electrical Engineering, University of Texas at Dallas, Richardson, TX, USA

Most cochlear implant (CI) users can identify words and sentences with high accuracy in quiet and anechoic environments. However, their performance degrades significantly in reverberant environments. Previous attempts to develop reverberation suppression (dereverberation) algorithms that would improve speech intelligibility have been partially successful in low-to-moderate reverberation times and mostly by the use of dual- or multi-microphone setups.

A different approach for dereverberation, based on channel selection, which has been previously found to improve the intelligibility of noise-masked speech, is investigated in this study. In our previous study, this new channel selection criterion was found to yield substantial improvements in intelligibility by CI users even in highly reverberant environments (T60 = 1 s). In this case, channels were selected based on the signal-to-reverberant ratio, which to some extent reflected the ratio of the energies of the signal originating from the early (and direct path) reflections and the signal from the late reflections. That study demonstrated the full potential of the proposed channel selection criterion (performance was comparable to that obtained in anechoic conditions), which was estimated under ideal conditions.

Identifying the channels that need to be selected in non-ideal scenarios is a challenging task, as we have neither access to the room impulse response nor we have access to the clean (uncorrupted) speech signal. In the present study, we investigate a new speech coding strategy capable of accurately estimating the channel selection criterion from the reverberant stimuli. Only envelopes corresponding to channels satisfying the proposed criterion are selected and used for stimulation (remaining channels are discarded). To evaluate the potential of the proposed dereverberation strategy, speech intelligibility is assessed in CI users using IEEE sentences at two reverberation times (T60 = 0.6 s and 0.8 s), wherein most of the existing dereverberation techniques fail to improve intelligibility. Results indicate substantial improvements in speech intelligibility in both reverberant conditions tested.

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D35: Clinical Fitting of Cochlear Implant Guided by Electrode Discrimination

Shaza Saleh[1], Debi Vickers[1], Leah Meerton[2] and Shakeel Saeed[1,2].

[1] UCL Ear Institute, London, UK.
[2] Royal National Throat Nose and Ear Hospital, London, UK.

Cochlear implants (CI) are designed to provide maximal place pitch information on the premise that each electrode creates a distinct pitch at discrete-spectral locations in the cochlea. However, “holes” in hearing may affect speech perception for the cochlear implant user (Shannon et al., 2001). Smith and Faulkner (2006) in a simulation study showed that it was significantly poorer for speech perception when dropping the information in a simulated hole as compared to two conditions where that information was redirected around the hole. This highlights the importance of locating possible holes in hearing among CI recipients and programming appropriately around them. One way to accomplish that could be electrode discrimination (ED).

Our study used a clinically viable protocol to assess (ED) based on pitch ranking which was used to guide re-mapping, by switching off indiscriminable electrodes. 9 adult cochlear implantees were recruited, 3 from each of Med-EL, Cochlear and Advanced Bionics (AB) had ED tested. In a cross-over study 2 experimental maps (EM) based on ED were provided to each participant and used for 1 month each. Efficacy was assessed with speech perception (BKB Sentences) in quiet at 70dBSPL and in noise at a signal-to-noise ration of +10dB. Testing took place at baseline with the original clinical map (CM) and with each EM. EM options were: (1) allowing the stimulation-rate (SR) per channel to increase in AB & Med-El or increasing it manually in Cochlear, or (2) maintaining the baseline SR.

Results were: (1) 2 of 3 Med-El participants showed significant benefits in speech perception with at least one EM, (2) 1 of 3 AB subjects showed significant improvement in noise when maintaining baseline SR & (3) 1 of 3 Cochlear subjects showed significant improvement in quiet (18%) and in noise (23%) while maintaining SR. The Wilcoxon signed ranks test was carried out on the BKB results to compare the best EM with CM and it revealed significant improvements in noise ($z= -2.023$, $p< .05$) but not in quiet ($z= -1.547$, $p= .122$).

In summary, 4 of 9 subjects demonstrated significant improvements. Preliminary results are encouraging and suggest that ED can be used to guide fitting. More subjects will be tested to establish the best approach to take for each device and strategy.

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References:

Smith M, Faulkner A: Perceptual adaptation by normally hearing listeners to a simulated ‘hole’ in hearing. J Acoust Soc Am 2006; 120:4019-4030
Shannon RV, Galvin JJ, Baskent D: Holes in hearing. J Assoc Res Otolaryngol 2001; 3:185–199.

D36: A New Research Implementation Of Mp3000 To Improve Intermediate Pitch Percept Between Electrode Contacts

Andreas Büchner, Mark Schüssler, Thomas Lenarz

Medical University of Hannover, Department of Otolaryngology, Hannover, Germany

MP3000 is the first commercial signal processing strategy for cochlear implants making use of a psychoacoustic masking model derived from normal hearing listeners. It reduces the number of electric stimuli inside the cochlea thus lowering channel interaction and power consumption without compromising speech understanding. However, due to the intrinsic behavior of psychoacoustic masking models, stimuli generated by MP3000 are relatively isolated compared to stimulation patterns created by peak-picker strategies like ACE. Therefore the perception of “virtual pitches” between neighboring electrode contacts may be reduced when using MP3000. To avoid this potential problem, a research variant of MP3000 named V- PACE (virtual psychoacoustic advanced combination encoder) is currently under investigation. This strategy still uses the psychoacoustic masking model, but instead of selecting isolated channels, pairs of neighboring channels are always being selected for sequential stimulation, such that the principle of intermediate pitch percept between physical electrode contacts should be maintained.

Three conditions shall be evaluated in an ABCCBA cross-over study: MP3000 (5 channels selected), V-PACE-half (5 channel-pairs selected, half stimulation rate per electrode) and V-PACE-full (5 channel-pairs selected, full stimulation rate per electrode). The two conditions for V-PACE were chosen to account for possible stimulation rate effects introduced by the doubled overall stimulation rate of the pairwise stimulation associated with the new strategy. Each condition is being used by the subjects for a period of 3 weeks to allow acclimatization to the new strategy. Speech perception tests in noise (HSM in CCITT and competing talker), pitch discrimination tasks and melody recognition tests are performed to evaluate the different conditions. In addition, sound quality ratings will be assessed by the APHAB questionnaire. 9 Nucleus Freedom users were enrolled so far, five of them passed the first cycle; 12 are planned in total.

Preliminary results indicate equal speech perception performance with both strategies. Preference seems to be equally distributed between MP3000 and V-PACE. Also, results of the pitch discrimination task do not reveal differences between V-PACE and MP3000. Detailed results from a larger sample size will be presented at the conference.

D37-a: The Benefit of Residual Acoustic Hearing to Auditory and Auditory-Visual Cochlear-Implant Consonant Perception

Benjamin M. Sheffield, Gerald Schuchman, Joshua G. Bernstein

Walter Reed Army Medical Center, Washington, DC, USA

As cochlear implant (CI) acceptance increases and candidacy criteria are relaxed, these devices are increasingly recommended for patients with less than profound hearing loss. As a result, many patients who receive a CI also retain some residual hearing in the non-implanted ear (i.e., bimodal hearing) that can benefit CI performance. However, guidelines for clinical decisions pertaining to cochlear implantation are largely based on expectations for post-surgical speech reception performance with the CI alone in auditory-alone conditions. A more comprehensive prediction of post-implant performance would include the expected effects of residual acoustic hearing and visual cues on speech understanding. An evaluation of auditory-visual (AV) performance might be particularly important due to the complementary interaction between the speech information relayed by visual cues and that contained in the low-frequency auditory signal. The goal of this study was to characterize the benefit provided by residual acoustic hearing to consonant identification under auditory and AV conditions.

Consonant identification was measured for conditions involving combinations of electric hearing (via the CI), acoustic hearing (via the non-implanted ear) and lipreading (visual cues). Identification data were expressed as confusion matrices and analyzed to determine how consonant features are relayed and combined across stimulus modalities. Results suggest that the bimodal benefit to CI consonant identification was enhanced when visual cues were also present, because the voicing cues provided by the residual acoustic hearing complemented the mainly place-of-articulation cues provided visually.

These findings suggest the need for a comprehensive prediction of post-implant speech reception performance incorporating the influence of acoustic, electric and visual modalities to inform implantation decisions. Furthermore, the increased importance of residual acoustic hearing under AV conditions should also be considered when evaluating the candidacy of a current bimodal CI user for a second CI. Because a traditional full-length CI often destroys residual acoustic hearing in the implanted ear, the likely loss of benefits from this acoustic hearing should be weighed against the potential benefits from bilateral implantation. Finally, the consideration of AV listening situations highlights an even greater need for hybrid CI technology that can reliably preserve low-frequency acoustic hearing.

D37-b: Modeling Speech Intelligibility by Cochlear Implant Users

Fei Chen and Philipos C. Loizou

Department of Electrical Engineering, University of Texas at Dallas
Richardson, TX, USA

While a number of intelligibility indices, such as the articulation index (AI) and speech transmission index (STI), are available for predicting speech intelligibility by normal-hearing and hearing-impaired listeners, no reliable index exists for predicting speech intelligibility by cochlear implant (CI) listeners. The challenge faced with developing such an index is that a number of patient-specific factors (e.g., electrode insertion depth and placement, duration of deafness, surviving neural pattern, etc.) may affect their performance in quiet and noisy conditions. A patient-specific intelligibility index would thus be more appropriate. Such an index could be used for instance to optimize the fitting parameters of individual patients or to optimize speech coding strategies.

The present study takes the first step in developing a patient-specific intelligibility index for predicting speech intelligibility by CI patients in noisy conditions. Given that most speech coding strategies convey primarily envelope information, a speech-based STI measure was chosen. In particular, the normalized covariance metric (NCM) was evaluated. Parameters taken from the patient's MAP (e.g., frequency spacing, stimulation rate, threshold and most comfortable levels, number of active electrodes, etc.) were used for computing the envelopes in each channel. To simulate channel interaction effects, an electrode excitation spreading model was employed to generate the "spread" envelopes. The overall excitation pattern among electrodes was expressed by a spreading matrix. The "spread" envelopes along with the parameters taken from the patient's MAP were used as input into the computation of the NCM measure. The average NCM index values were correlated with the mean intelligibility scores obtained by each of the seven cochlear implant listeners tested in 24 noisy conditions. A modestly high (r=0.77 on average) correlation was found. The intelligibility model was further extended to account for the fact that CI users receive only a limited number of effective channels of information. The number and set of effective channels were assumed to be different across subjects. After accounting for the existence of "non-effective" channels into our model, the correlations of our model with individual subject's scores improved to an average of r=0.84.

Overall, the proposed intelligibility model incorporated factors such as channel interaction, limited dynamic range and limited number of channels. These factors have been found to account for much of the variance in the intelligibility scores of cochlear implant users.

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D38-a: Effects of Environmental Sound Training on the Perception of Speech and Environmental Sounds In Cochlear Implant Listeners

Valeriy Shafiro[1], Stanley Sheft[1], Sejal Kuvadia[1], Kim Ho[1] & Brian Gygi[2],

[1] Rush University Medical Center, Chicago, IL
[2] Veterans Affairs Health Systems of Northern California, Martinez, CA

Environmental sound perception plays an important role in daily living and constitutes a major concern for cochlear implant (CI) patients. Environmental sounds can alert listeners to immediate dangers and contribute to one's sense of awareness and well being. Recent studies demonstrate considerably reduced environmental sound perception even in experienced CI patients with adequate speech performance. Extending previous work that demonstrated positive effects of short-term training with spectrally degraded environmental sounds in normal hearing (NH) listeners, the present project (1) examined potential benefits of an extended environmental sound training program for both speech and environmental sounds in CI and CI-simulated NH listeners, and (2) evaluated the role of central factors and peripheral spectro-temporal processing abilities in the perception of complex meaningful sounds.

All participants received two pretests (one week apart) prior to beginning a week-long environmental sound training program, which was followed by two posttest sessions, separated by another week without training. Stimuli, processed with a four-channel vocoder for NH listeners, consisted of a 160-item environmental sound test, and word and sentence tests (i.e., CNC, SPIN). In addition, listeners were tested with a battery of cognitive tests which included measures of inhibition, closure, working memory and executive function, and a battery of psychoacoustic tests of spectral and temporal processing.

Results indicated that following training, environmental sound perception improved significantly in both CI and NH listeners, while speech perception measures improved significantly for NH listeners only. Speech and environmental sound performance was also differentially correlated with tests of spectral and temporal-fine-structure processing abilities, while working memory and executive function were correlated with speech, but not environmental sound perception. These findings indicate that successful perception of acoustically complex meaningful sounds involves joint contribution of specific peripheral factors and central processes, and suggest directions for improving listener performance through training.

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D38-b: More Insights Into Cochlear Morphology And The Development Of An Insertion Model

Kim S. van der Marel[1], Jeroen J. Briaire[1], Ron Wolterbeek[1]
Berit M. Verbist [1,2], Johan H.M. Frijns[1]

[1] Leiden University Medical Center, Leiden, the Netherlands
[2] Radboud University Nijmegen Medical Center, Nijmegen, the Netherlands

Clinical and modeling studies suggested that CI performance can be improved by gathering more knowledge and control over the position of the electrode array, and thereby minimalizing the insertion trauma during the placement. The array position not only depends on the placement by the surgeon, but also on the anatomical variations of the cochlea. These two factors, combined with electrode design determine (linear and angular) insertion depth and distance between the contacts and modiolus. This study analyzes the morphometry of the cochlea and its variability to produce a preoperative predictor for the final electrode.

In the cochlear implant program of the Leiden University a pre- and post-operative CT-scan is obtained in all patients. For this study a data set of 646 ears was analyzed, from which 323 are implanted with a HiFocus electrode array. Using multiplanar reconstructions all cochleae were aligned and measured in accordance with the recent consensus for cochlear coordinates. The position of the inner and outer walls of the basal turn of the cochlear duct was measured on 8 angles. In the postoperative images the position of the individual electrode contacts of the array was determined, including their distances to the modiolus.

The preoperative data were evaluated using principal component analysis (PCA), curve fitting (logarithmic spiral) and linear mixed models. The postoperative predictors were determined using curve fits and linear regression models.

The morphometry of the cochlea showed a significant size difference depending on gender (male 4% larger cochlea). With PCA it is possible to describe 80% of the variance of the cochlear geometry with four components. The surgical variation (contact 16 position) explained 56% of variation in insertiondepth. With a linear regression model it was possible to predict 78% of the final angular electrode position with only cochlear size and surgical insertion depth as input parameters. The performance of the insertion model based on curve fitting was assessed by simple linear regression with true insertiondepth as outcome (R^2=0.63). The absolute deviations from the true outcome were in 95% below 1.89 mm.

It was concluded that a few parameters are sufficient to both describe the shape and size of all (non-dysplastic) cochleas and to predict the final implant trajectory with high accuracy.

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D39: Recognition of Synthetic and Natural Speech by Normal-Hearing Listeners and Cochlear Implant Users

Caili Ji[1,2], Anting Xu[1], Qian-Jie Fu[2]

[1]QiLu Hospital, Shandong University, Jinan, China
[2]House Ear Institute, Los Angeles, CA, U.S.A.

Text-to-speech (TTS) synthesis converts arbitrary text into audible speech. Applications of TTS involve communications in many areas, such as telephony voice service, car navigation information, and audio e-books, etc. One great advantage of TTS is that the speech rate can be modified for individual listeners. However, the TTS output must also be highly intelligible and natural sounding. Cochlear implant (CI) users regularly encounter synthetic speech. Given the current limits in CI signal processing, CI users may be susceptible to the degradations in speech intelligibility and quality associated with synthetic speech. In this study, recognition of synthetic and naturally produced sentences was measured in normal-hearing (NH) listeners and CI users.

IEEE sentence recognition was measured in quiet. IEEE sentences were either naturally produced (1 male and 1 female) or synthesized using AT&T Labs' Natural Voices TTS engines (1 male and 1 female). Both TTS and natural speech were played at three different rates, including slow rate (half-speed), normal rate (as recorded), and fast rate (double-speed). For natural speech, the slow and fast speech stimuli were generated with Adobe Audition. Performance was assessed in terms of percent correct words in sentences. CI subjects were tested while listening with their clinical speech processors. NH subjects were tested while listening to unprocessed speech and to an 8-channel acoustic CI simulation. Sentence materials and speaking rates were randomized and counterbalanced across subjects.

Results showed that NH listeners performed very well (>90%) with unprocessed natural or synthetic speech; there was no significant difference in performance with between synthetic and natural speech. For the CI simulation, mean NH performance was moderately poorer with synthetic speech than with natural speech at the slow and normal rates, and much poorer at the fast rate. CI subject performance was similar to NH performance with the CI simulation at the slow and normal rates (i.e., poorer with synthetic than with normal speech), but much poorer than the simulation at the fast rate.

The present data suggests the limited spectral resolution may limit CI users' understanding of synthetic speech. While current TTS engines may deliver high quality speech for NH listeners, TTS system may need to be optimized for hearing impaired listeners. The present data also showed that CI users were much more susceptible to fast speaking rates than were NH subjects listening to similarly degrades speech signals, suggesting potential deficits in CI users' cognitive processing.

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D40: Free-Field Assessment of Temporal Auditory Processing and Speech Recognition in Cochlear Implant Users

Dan Gnansia[1], Diane Lazard[2], Claude Fugain[2], Denis Lancelin[3], Bernard Meyer[2], Christian Lorenzi[3]

1 MXM – Neurelec, Vallauris, France.
2 AP-HP, Beaujon hospital, ENT Department, Clichy, France.
3 UMR LPP 8158 CNRS - Univ Paris Descartes - Ecole normale supérieure; DEC, Paris, France

Although speech recognition in cochlear implantees has steadily improved over the years, considerable variability remains in patient outcomes. Previous work (e.g., Fu, Q.-J., "Temporal processing and speech recognition in cochlear implant users", 2002, Neuroreport 13, 1635-1639) showed that auditory temporal processing abilities (i.e., modulation detection thresholds) was strongly correlated with speech intelligibility in quiet for cochlear implantees, suggesting that the success of cochlear implantation is driven by the ability of implantees to use temporal-envelope cues. Importantly, modulation detection was measured using direct electrical stimulation (bypassing the implant' speech processor), and stimuli were carefully adjusted to the reduced electrical dynamic range of each patient. The goal of the present study was to extend this initial study by measuring speech identification and temporal processing abilities in free field (speech and non-speech stimuli being passed through the patient's processor). In addition, speech intelligibility was measured both in quiet and in noise.

Twenty implanted patients (Neurelec Digisonic® SP implant with Saphyr® processor) were included. Nonsense syllables identification was measured in quiet and in the presence of a steady (+6, 0 and -3dB signal-to-noise ratio) and fluctuating (8Hz sine amplitude modulation, 100% modulation depth, -3dB signal-to-noise ratio) speech-shaped noise masker. Modulation detection thresholds were measured using sine amplitude-modulated white noise carriers at modulation rates of 8 and 128Hz, in a 2-down 1-up adaptive forced-choice procedure.

Overall, modulation-detection thresholds measured in free field were much poorer than those reported by Fu (2002). Detection thresholds ranged from 7 to 61% at 8Hz, and 75 to 89% at 128Hz. In comparison, Fu (2002) reported detection thresholds between 0.4 and 10% for a 100-Hz modulation rate. Speech identification scores in quiet ranged between 43 and 72% for consonants, and between 34 and 66% for vowels. These results are relatively similar to those reported by Fu (2002) (consonants: 26-83%; vowels: 21-83%). But inconsistently with Fu (2002), no significant correlation was found between speech identification scores and modulation-detection thresholds.

These results are not consistent with the idea that modulation reception is a predictor of speech intelligibility in cochlear implantees. They will be discussed in light of additional experiments investigating the effects of implant' speech processor on modulation transmission.

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D41: Stability of Clinically Meaningful, Non-Linguistic Measures of Hearing Performance with a Cochlear Implant

Ward R. Drennan, Jong Ho Won, Elyse M. Jameyson, Jay T. Rubinstein

University of Washington, Department of Otolaryngology, VM Bloedel Hearing Research Center, Seattle, WA

Clinical outcomes with a cochlear implant (CI) are typically measured using linguistic measures. When evaluating novel CI sound processing strategies, linguistic measures pose difficulty because it typically takes new implant users 6 months or more to acclimate to speech (e.g. Ruffin et al. 2007). This can make evaluating innovative sound processing strategies time consuming and costly. Using traditional psychoacoustic methods, three tests of hearing acuity have been developed in our lab for the evaluation of clinical hearing performance with a CI. These include a test of spectral resolution, the spectral ripple test designed to measure spectral resolution adapted from Henry and Turner (2005), the Schroeder-phase tests designed as a temporal-spectral test adapted from Dooling et al. (2002), and the determination of the temporal modulation transfer function designed to evaluate sensitivity to temporal modulations adapted from Bacon and Viemeister (1985). These tests are time efficient, lasting about 30 minutes each. They have been shown to be reliable and clinically relevant, i.e., predictive of clinical CI performance (Won et al. 2007; Drennan et al., 2008; Won et al., 2009 CIAP, 2011 submitted) and also could work with any native language. The tests have been shown to be acutely reflective of engineering changes in CI sound processing strategies (Drennan et al. 2010). It is hypothesized that these tests will demonstrate minimal acclimatization over a 12-month period thus being valuable for acute testing of performance. Further, later speech perception ability might be predictable based on early psychoacoustic test scores.

Eight cochlear implant users have enrolled in the study, five of which have completed the study. Each was or will be tested at 1, 3, 6, 9 & 12 months post activation with the 3 non-linguistic measures and also tested at 1 and 12 months with CNC words and a spondee-in-noise (SRT) test. Initial results indicated the ripple and temporal modulation tests yielded nearly the same average performance tested at these time points, suggesting good stability. Individual results showed some variability, but no overall improvement trend has been observed to date. Average Schroeder-phase results showed improvements of up to several percentage points over 12 months. This appeared to be driven by a few listeners, whereas others were stable. The results support the notion that for a group of listeners roughly the same size, at least the ripple and temporal modulation tests would be useful for evaluating CI processing strategies acutely without an extensive acclimatization period.

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D42: Speech Perception in Music Backgrounds by Cochlear Implant Users and Normal Hearing Listeners

Elizabeth N. Eskridge, John Galvin III, Qian-Jie Fu, Justin M. Aronoff

House Ear Institute, Los Angeles, CA, USA

Cochlear implant (CI) users regularly encounter background music in restaurants, movies, sporting events, etc. For CI users, background music may interfere with speech understanding, similar to background noise or competing speech. Because of poor pitch perception and difficulty 'listening in the dips', CI users may be much more susceptible to music maskers than normal hearing (NH) listeners. In this study, we measured CI and NH subjects' HINT sentence recognition in the presence of different music, speech and noise maskers.

Eleven CI subjects (using their clinical processors and settings) and nine NH subjects listened to unprocessed speech and various speech, music and noise maskers, including musical excerpts, multi-talker babble, steady noise filtered by the music or speech spectrum, and filtered noise modulated by the music temporal envelopes. Speech reception thresholds (SRTs) were adaptively measured by adjusting the masker level according to subject response.

NH performance was significantly better than CI performance for all conditions. Mean NH SRTs were -4.2 dB and -4.7 dB for the HINT-shaped steady noise and speech babble maskers, respectively. Mean NH SRTs were -11.2 dB, -9.4 dB and -10.7 dB for the musical excerpt, music-shaped steady noise, and music-modulated noise maskers, respectively. Mean CI SRTs were 3.7 dB and 6.0 dB for the HINT-shaped steady noise and speech babble maskers, respectively. Mean CI SRTs were 0.6 dB, -1.5 dB and -0.8 dB for the musical excerpt, music-shaped steady noise, and music-modulated noise maskers, respectively.

While the speech-related maskers generally produced more interference than the music-related maskers, NH subjects were better able to 'listen in the dips' of the speech babble, musical excerpt and music-modulated maskers. For both groups, there was greater energetic masking for the speech-shaped maskers than the music-shaped maskers. Performance was generally similar within each group for the musical excerpt and music-modulated noise. Because of reduced energetic masking, the availability of pitch cues in the musical excerpt maskers did not provide further release from masking. As always, improved spectro-temporal resolution will allow CI users to better understand speech and music, as well as separate speech in music backgrounds.

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D43: Effects of Speaking Styles on Speech Intelligibility by Mandarin-speaking and English-speaking Cochlear Implant Patients

Qian-Jie Fu[1], Xiaosong Wang[1], Yongxin Li[2], Hou-yong Kang[3], Guoping Zhang[2], Sha Liu[2], Deming Han[2]

[1]House Ear Institute, Los Angeles, California, USA
[2]Beijing TongRen Hospital, Capital Medical University, Ministry of Education of China, Beijing, P. R. China
[3]The First Affiliated Hospital, Chongqing Medical University Chongqing, P. R. China.

In general, normal-hearing (NH) listeners are able to understand speech regardless of variations in talker, speaking rate, and language context. Cochlear implant (CI) users are susceptible to the acoustic variability in speech signals, due to the limited spectral resolution of the implant device. Most CI speech studies have used clear speech samples in quiet or noise. Little is known about the effects of speaking rate or voice quality on CI users' speech understanding. The present study is to investigate the effects of speaking styles on speech intelligibility by adult and pediatric cochlear implant patients.

Sentence recognition was first measured in Mandarin-speaking cochlear implant patients and normal-hearing subjects with speech utterances representing six different speaking styles: slow, normal, fast, emotional, shouting, and whispering. Sentence recognition performance was comparable across all different speaking styles except that Mandarin-speaking cochlear implant patients' speech performance dropped dramatically when listening to the whispering speech. Cochlear implant performance was comparable to the recognition performance of normal-hearing subjects listening to 4-channel acoustic simulation of cochlear implant processing. Also, there was no significant difference between adult and pediatric cochlear implant patients. HINT sentence recognition was also measured in English-speaking adult cochlear implant patients with speech utterances representing two different styles: normal and whispering. Results showed relatively small difference between normal speech and whispering speech for English-speaking adult cochlear implant patients.

The results suggest that Mandarin-speaking cochlear implant patients are highly susceptible to the whispering speech because of the lack of pitch cues. The results from the present study further demonstrate the importance of pitch cues in speech understanding for Mandarin-speaking cochlear implant patients.

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D44: Predicting The Insertion Depth of the Hi Focus 1j Electrode Array Based On High Resolution CT Images.

Olga A. Stakhovskaya, Lawrence R. Lustig, Patricia A. Leake

University of CA San Francisco, Department of Otolaryngology-Head and Neck Surgery, Epstein Lab

Estimation of the optimum insertion depth of the electrode array prior to surgery can be an important tool in modern cochlear implantation. The angular depth of insertion for the same electrode array may vary substantially in different individuals due to differences in cochlear size. Measurements of anatomical dimensions of the cochlea obtained from computed tomography (CT) images can provide detailed information about the insertion depth required for an electrode to cover a specific frequency range. Control over the desired insertion depth also may be an important factor in preservation of residual hearing. Avoiding undesirable over-insertions can also reduce the extent of trauma caused during implantation.

Human temporal bones were harvested within 24 hours post-mortem and fixed with formalin. “Pre-operative” micro CT images were obtained using an isotropic nominal resolution of 18 μm. Two- and three-dimensional measurements of the outer/inner wall lengths and basal turn diameters were made directly on the CT images. The insertion depth required to reach 360º of rotation from the round window was estimated based on these measurements and specimens were implanted with HiFocus 1j array.

Measurements of cochlear dimensions obtained in CT images allowed prediction of the insertion depth to the desired point with an accuracy of 0.5 mm of the array length. The most accurate predictions were based on the direct 3-dimensional measurements of the distances from the round window to a given point along the outer wall of the cochlea after adjustment for electrode thickness using a “wrapping factor”. Values of the “wrapping factor” for a given array were based on the radiological studies in living subjects done by Dr. Charles Finley at the University of NC (personal communication), with a correction for the high resolution CT images available in this study. The accuracy of alternative anatomical landmarks (basal turn diameters, 2 dimensional measurements of the outer wall of the cochlea) in the prediction of the electrode array length required to place an electrode at the desired intracochlear position were also investigated.

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Attendee List

Abbas, Paul	University of Iowa, Iowa City, IA, USA	paul-abbas@uIowa.edu
Agrawal, Smita	Advanced Bionics, Valencia, CA, USA	smita.agrawal@advancedbionics.com
Ahmad, Faisal	Univ. of North Carolina, Med Sch, Chapel Hill, NC, USA	faisal_ahmad@med.unc.edu
Alkhamra, Rana	University of Jordan, Amman, Jordan	ranaalkhamra@gmail.com
Ardoint, Marine	Arizona State University, Tempe, AZ, USA	marine.ardoint@gmail.com
Aronoff, Justin	House Ear Institute, Los Angeles, CA, USA	jaronoff@hei.org
Azadpour, Mahan	University of Manchester, Manchester, UK	mahan.azadpour@Manchester.ac.UK
Bacon, Sid	Arizona State University, Tempe, AZ, USA	spb@asu.edu
Bader, Paul	University of Innsbruck, Innsbruck, Austria	paul.bader@uibk.ac.at
Baskent, Deniz	University Medical Center, Groningen, Netherlands	dbaskent@hotmail.com
Basta, Dietmar	University of Berlin,, Berlin, Germany	dietmar.basta@rz.hu-berlin.de
Battmer, Rolf-Dieter	Unfallkrankenhaus Berlin, Berlin, Germany	rolf-dieter.battmer@UKb.de
Beitel, Ralph	UCSF, San Francisco, CA, USA	rbeit99@yahoo.com
Benard, Ruben	Audiologisch Centrum Zwolle, Zwolle, Netherlands	m.r.benard@med.umcg.nl
Bernstein, Joshua	Walter Reed Army Medical Center, Washington, DC, USA	joshua.G.bernstein@us.army.mil
Bhargava, Pranesh	University Medical Center, Groningen, Netherlands	praneshbhargava@gmail.com
Bhattacharya, Aparajita	University of California, Irvine, Irvine, CA, USA	abhattac@uci.edu
Bierer, Julie	University of Washington, Seattle, WA, USA	jbierer@u.Washington.edu
Birtch, Kassandra-Ann	University of Western Ontario, London, ONT, Canada	kbirtch@uwo.ca
Boermans, Peter-Paul	Leiden University Medical Center, Leiden, Netherlands	p.p.b.m.boermans@lumc.nl
Boisvert, Isabelle	Macquarie University, Sydney, NSW, Australia	isabelle.boisvert@mg.edu.au
Bonham, Ben	UCSF, San Francisco, CA, USA	ben@phy.ucsf.edu
Boons, Tinne	ExpORL, Leuven, Belgium	tinne.boons@med.kuleuven.be
Bowling, Sara	University of Michigan, Ann Arbor, MI, USA	bowlings@med.umich.edu
Boyle, Patrick	Advanced Bionics, Valencia, CA, USA	patrick.boyle@advancedbionics.com
Braun, Susanne	Med-El,	susan.braun@medel.com
Briaire, Jeroen	Leiden University Medical Center, Leiden, Netherlands	j.j.briaire@lumc.nl
Brickman, Daniel	Oregon Health and Science University, Portland, OR, USA	brickman@ohsu.edu
Brill, Stefan	University of Würzburg, Würzburg, Germany	stefan.brill@uni-wuerzburg.de
Brown, Carolyn	University of Iowa, Iowa City, IA, USA	CArolyn-brown@uIowa.edu
Brown, Christopher	Arizona State University, Tempe, AZ, USA	c-b@asu.edu
Brownen, Mike	Advanced Bionics, Keller, TX, USA	mbrownen@advancedbionics.com
Bruce, Ian	McMaster University, Hamilton, ONT, Canada	ibruce@ieee.org
Büchner, Andreas	Medizinische Hochschule Hannover, Hannover, Germany	buechner@hoerzentrum-Hannover.de
Büchner, Carolin Frohne	Medizinische Hochschule Hannover, Hannover, Germany	buechner@hoerzentrum-Hannover.de
Busby, Peter	Cochlear Ltd, E Melbourne, Australia	pbusby@Cochlear.com
Buyens, Wim	Cochlear Technology Centre Europe, Mechelen, Belgium	wbuyens@Cochlear.be
Calixto, Roger	Hannover Medical School, Hannover, Germany	CAlixto.roger@mh-Hannover.de
Carlyon, Robert	mrc cbu, Cambridge, UK	bob.carlyon@mrc-cbu.cam.ac.UK
Cartee, Lianne	North Carolina State University, Raleigh, NC, USA	lacartee@ncsu.edu
Carter, Paul	Cochlear Ltd, Lane Cove, NSW, Australia	pcarter@Cochlear.com.au
Chandan, Kirpa	University of Manchester, Manchester, UK	Kirpa.chandan@postgrad.manchester.ac.uk
Chang, Diane	Advanced Bionics, Valencia, CA, USA	diane.chang@advancedbionics.com
Chatterjee, Monita	University of Maryland, College Park, MD, USA	mchatterjee@hesp.umd.edu
Chen, Fei	University of Texas at Dallas, Richardson, TX, USA	fchen@utDallas.edu
Chien, Sunny	University of Sydney, Sydney, Australia	sunnychien.pyro@gmail.com
Choi, Charles	National Chiao Tung University, Hsinchu, Taiwan, R.O.C.	ctchoi@cs.nctu.edu.tw
Chowdhury, Shibasis	Univ. of Southampton, Southampton, UK	sc7c08@soton.ac.UK
Chung, Yoojin	Boston University, Boston, MA, USA	yjchung@bu.edu
Churchill, Tyler	University of Wisconsin at Madison, Madison, WI, USA	tchurchill@wisc.edu
Cohen, Yale	University of Pennsylvania, Philadelphia, PA, USA	vcohen@mail.med.upenn.edu
Colesa, Deborah	University of Michigan, Ann Arbor, MI, USA	djmorris@umich.edu
Collins, Leslie	Duke University, Durham, NC, USA	lcollins@ee.duke.edu
Cone, Barbara	University of Arizona, Tucson, AZ, USA	conewess@arizona.edu
Cook, Sarah	Arizona State Univerity, Tempe, AZ, USA	sjcook2@asu.edu
Cowan, Robert	CRC Hear, East Melbourne, Australia	r.cowan@unimelb.edu.au
Crew, Joseph	House Ear Institute, Los Angeles, CA, USA	jcrew@hei.org
Culling, John	Cardiff University, Cardiff, UK	cullingj@cardiff.ac.uk
Curca, Ioan	University of Western Ontario, London, ONT, Canada	ioan@nca.uwo.ca
Cushing, Sharon	University of Toronto, Toronto, Canada	s.cushing@utoronto.ca
Dasika, Vasant	FDA, White Oak, MD, USA	vasant.dasika@gmail.com
Dawson, Pam	Cochlear Ltd, East Melbourne, Australia	bsheridan@Cochlear.com
Deeks, John	MRC Cognition and Brain Sciences UN, Cambridge, UK	john.deeks@mrc-cbu.CAm.ac.UK
Dekker, David	Leiden University Medical Centre, Leiden, Netherlands	d.m.t.dekker@lumc.nl
Delgute, Bertrand	Harvard University, Boston, MA, USA	bertrand_delgutte@meei.harvard.edu
Delreux, Marieke	Univeersitair Audiologisch Centrum, Amsterdam, NL	m.delreux@vumc.nl
Deshpande, Aniruddha	Univ. of Cincinnati, Cincinnati, OH, USA	deshpaak@mail.uc.edu

Desmond, Jill	Duke University, Durham, SC, USA	jill.desmond@duke.edu
Dillier, Norbert	University Hospital, Zurich, Switzerland	norbert.dilier@usz.ch
Dillon, Margaret	UNC School of Medicine, Chapel Hill, NC, USA	mdillon@med.unc.edu
Ding, Nai	University of Maryland, College Park, MD, USA	gahding@umd.edu
Donahue, Amy	NIDCD, Rockville, MD, USA	donahuea@nidcd.nih.gov
Donaldson, Gail	University of South Florida, Tampa, FL, USA	gdonalds@cas.usf.edu
Dorman, Michael	Arizona State University, Tempe, AZ, USA	michael.dorman@asu.edu
Drennan, Ward	University of Washington, Seattle, WA, USA	drennan@u.Washington.edu
Duran, Sara	Duke University, Durham, NC, USA	sara.duran@dUKe.edu
Edwards, Brent	Starkey, Berkeley, CA, USA	brent_edwards@starkey.com
Emadi, Gulam	Advanced Bionics,	gulam.emadi@advancedbionics.com
Etler, Christine	University of Iowa, Iowa City, IA, USA	christine-etler@uiowa.edu
Fallon, James	Bionic Ear Institute, East Melbourne, Australia	james.fallon@ieee.org
Faulkner, Andrew	UCL Speech Hearing and Phonetic Sci, London, UK	a.faulkner@ucl.ac.UK
Faulkner, Katie	University of Washington, Seattle, WA, USA	katieff@Washington.edu
Fielden, Claire	University of Manchester, Manchester, UK	claire.fielden@postgrad.manchester.ac.uk
Finley, Charles	Advanced Bionics, Valencia, CA, USA	charlesfinley@advancedbionics.com
Firszt, Jill	Washington University, St. Louis, MO, USA	firsztj@ent.wustl.edu
Fitzgerald, Matthew	NYU School of Medicine, New York, NY, USA	matthew.fitzgerald@nyumc.org
Fitzpatrick, Douglas	University of North Carolina, Chapel Hill, NC, USA	dcf@med.unc.edu
Forge, Andrew	University College London, London, UK	a.forge@ucl.ac.uk
Francart, Tom	K.U.Leuven, Exporl, Leuven, Belgium	tom.francart@med.kuLeuven.be
Franz, Darla	Med El,	darla.franz@medel.com
Fredelake, Stefan	Universitat Oldenburg, Oldenburg, Germany	stefan.fredelake@uni-oldenburg.de
Free, Rolien	University Medical Center Groningen, Groningen, NL	r.h.free@kno.azg.nl
Friesen, Lendra	Sunnybrook Health Sciences Centre, Toronto, Canada	lendra.friesen@sunnybrook.ca
Frijns, Johan	Leiden University Medical Centre, Leiden, Netherlands	j.h.m.frijns@lumc.nl
Fu, Qian-jie	House Ear Institute, Los Angeles, CA, USA	qfu@hei.org
Fuller, Christina	University Medical Center Groningen, Groningen, NL	c.d.fuller@student.rug.nl
Gaertner, Lutz	Medizinische Hochschule h, Hannover, Germany	gaertner@hoerzentrum-Hannover.de
Galvin, John	House Ear Institute, Los Angeles, CA, USA	jgalvin@hei.org
Garadat, Soha	University of Michigan, Ann Arbor, MI, USA	garadat@umich.edu
Garnham, Carolyn	Med-El, Matlock, UK	carolyn.garnham@medel.com
Gaudrain, Etienne	MRC Cognition and Brain Sciences UN, Cambridge, UK	etienne.gaudrain@mrc-cbu.cam.ac.uk
Gifford, René	Vanderbilt Bill Wilkerson Center, Nashville, TN, USA	rene.h.gifford@Vanderbilt.Edu
Gillis, Steven	University of Antwerp, Antwerp, Belgium	steven.gillis@ua.ac.be
Gnansia, Dan	MXM-Neurelec, Vallauris, France	dgnansia@neurelec.com
Goldberg, Sarah	Advanced Bionics, Sylmar, CA, USA	sgoldberg@bionics.com
Goldsworthy, Ray	Sensimetrics Corporation, Malden, MA, USA	raygold@sens.com
Gomersall, Philip	MRC Cognition and Brain Sciences UN, Cambridge, UK	philip.gomersall@mrc-cbu.cam.ac.uk
Gong, Yun	University of Texas at Dallas, Dallas, TX, USA	yxg038000@Utdallas.edu
Gordon, Karen	University of Toronto, Toronto, Canada	karen-a.gordon@sickkids.ca
Goupell, Matthew	University of Wisconsin at Madison, Madison, WI, USA	goupell@waisman.wisc.edu
Grayden, David	University of Melbourne, Parkville, Australia	grayden@unimelb.edu.au
Green, Tim	UCL, London, UK	tim.green@ucl.ac.UK
Greisiger, Ralf	Oslo University Hospital, Oslo, Norway	falfg@student.matnat.uio.no
Griessner, Andreas	Med El,	andreas.griessner@medel.com
Hamacher, Volkmar	Phonak Ag, Staefa, Switzerland	volkmar.hamacher@phonak.com
Hamilton, Tara	University of New South Wales, Sydney, NSW, Australia	t.hamilton@unsw.edu.au
Hanekom, Johan	University of Pretoria, Pretoria, South Africa	johan.hanekom@up.ac.za
Hanekom, Tania	University of Pretoria, Pretoria, South Africa	tania.hanekom@up.ac.za
Hartley, Douglas	Oxford University, Oxford, UK	douglas.hartley@dpag.ox.ac.UK
Hartley, Lee	Advanced Bionics, Sylmar, CA, USA	jwiggins@advancedbionics.com
Haumann, Sabine	Hörzentrum Hannover hzh, Hannover, Germany	haumann@hoerzentrum-Hannover.de
Hawks, John	Kent State University, Kent, OH, USA	jhawks@kent.edu
Hazrati, Oldooz	University of Texas at Dallas, Dallas, TX, USA	hazrati@utdallas.edu
He, Shuman	University of North Carolina, Chapel Hill, NC, USA	shuman_he@med.unc.edu
Heasman, John	Cochlear Ltd, East Melbourne, Australia	bsheridan@Cochlear.com.au
Heerlein, Markus	Advanced Bionics,	markus.heerlein@advancedbionics.com
Heinz, Michael	Purdue University, West Lafayette, IN, USA	mheinz@purdue.edu
Helmi, Irvan	MedEl,	irvan.helmi@medel.com
Hemmert, Werner	Technical University Munich, Garching, Germany	werner.hemmert@tum.de
Hernandez, Victor	University of Goettingen, Goettingen, Germany	victor.hernandez@medizin.uni-goettingen.de
Hersbach, Adam	Cochlear Ltd, East Melbourne, Australia	ahersbach@cochlear.com
Hess, Christi	University of Wisconsin at Madison, Madison, WI, USA	christi.hess@gmail.com
Hight, Eddie	House Ear Institute, Los Angeles, CA, USA	ahight@hei.org
Hochmair, Erwin	University of Innsbruck, Innsbruck, Austria	erwin.hochmair@uibk.ac.at
Hoepner, Lucas	Medical University of Hannover, Hannover, Germany	lucas.hoepner@googlemail.com
Hofmann, Michael	K.U. Leuven, Exporl, Leuven, Belgium	michael.hofmann@med.kuLeuven.be
Holden, Laura	Washington University School of Med, St. Louis, MO, USA	holdenl@wustl.edu

Holmberg, Paul	Cochlear Ltd., Sydney, NSW, Australia	pholmberg@Cochlear.com.au
Holmes, Stephen	Aston University, Birmingham, UK	s.d.holmes@aston.ac.uk
Horn, David	Seattle Children's Hospitalqq, Seattle, WA, USA	david.horn@seattlechildrens.org
Hose, Bernd	Cochlear ag, Basel, Switzerland	bhose@Cochlear.com
Hu, Hongmei	Jiangsu University, Zhenjiang, China	huhongmei.hu@gmail.com
Hu, Yi	University of Wisconsin-Milwaukee, Milwaukee, WI, USA	huy@uwm.edu
Huang, Juan	Johns Hopkins University, Baltimore, MD, USA	jhuang7@jhu.edu
Humes, Larry	University of Indiana, Bloomington, IN, USA	humes@indiana.edu
Irwin, Colin	Cochlear Europe, Basel, Switzerland	cirwin@Cochlear.com
Iskandar, Andi	Med El,	andi.iskandar@medel.com
Ito, Rindy O	regon Health and Science University, Portland, OR, USA	ito@ohsu.edu
Jackson, Kim	Med-El Corporation, Durham, NC, USA	sUSAnne.stoops@medel.com
Johnson, Luke	Johns Hopkins University, Baltimore, MD, USA	lukejohnson07@gmail.com
Johnson, Will	Advanced Bionics,	william.johnson@advancedbionics.com.
Jolly, Claude	Med-El, Innsbruck, Austria	claude.jolly@medel.com
Jones, Gary	VM Bloedel Hearing Research Center, Seattle, WA, USA	jonesgl@u.Washington.edu
Jones, Heath	Waisman Center Wisconsin, Madison, WI, USA	godar@waisman.wisc.edu
Joshi, Manohar	Advanced Bionics	manohar.joshi@advancedbionics.com
Kaandorp, Marre	Univeersitair Audiologisch Centrum, Amsterdam, NL	MW.Kaandorp@vumc.nl
Kabot, Ernst	Med El,	ernst.kabot@medel.com
Kalkman, Randy	Leiden University Medical Center, Leiden, Netherlands	r.k.kalkman@lumc.nl
Kals, Mathias	University of Innsbruck, Innsbruck, Austria	mathias.kals@uibk.ac.at
Kan, Alan	UCSF, San Francisco, CA, USA	Ckandathil@ohns.ucsf.edu
Karumasiti, Tissa	Advanced Bionics,	tissak@advancedbionics.com
Kawabata, Yuko	Advanced Bionics,	yuko.kawabata@advancedbionics.com
Keefer, Edward	UT Southwestern Medical School, Dallas, TX, USA	
Keppler, Hannah	University of Gent, Gent, Belgium	hannah.keppler@ugent.be
Kerber, Martin	Med-El, Innsbruck, Austria	martin.kerber@medel.com
Khing, Phyu	University of New South Wales, Sydney, NSW, Australia	phyu.khing@gmail.com
Killian, Matthijs	Cochlear, Mechelen, Belgium	mkillian@Cochlear.com
Kim, Sung June	Nanobioelectronics & Systems Research, Seoul, Korea	kimsj@snu.ac.kr
Kirby, Benjamin	University of Iowa, Iowa City, IA 52242, IA, USA	benjamin-kirby@uiowa.edu
Kirk, Karen	University of Iowa, Iowa City, IA, USA	karen-kirk@uiowa.edu
Kishon-Rabin, Liat	Tel-Aviv University, Tel-Hashomer, Israel	lrabin@post.tau.ac.il
Kleine Punte, Andrea	Med El, Antwerp, Belgium	andrea.kleine-puente@medel.com
Kluk de kort, Karolina	University of Manchester, Manchester, UK	karolina.kluk@manchester.ac.uk
Koch, Dawn	Advanced Bionics, Evanston, IL, USA	dawnk@advancedbionics.com
Koning, Raphael	ExpORL, Leuven, Belgium	raphael.koning@med.kuleuven.be
Kral, Andre	Institue of Audioneurotechnology, Hannover, Germany	a.kral@uke.de
Krawczyk, Elizabeth	Med El,	elizabeth.krawczyk@medel.com
Krishnamoorthi, Harish	Cochlear,	hkrishnamoorthi@cochlear.com
Kulkarni, Abhi	Advanced Bionics,	abhijit.kulkarni@advancedbionics.com
Kumar, Shaun	Cochlear,	skumar@cochlear.com
Kuvadia, Sejal	Rush University Medical Center, Chicago, IL, USA	skuvadia@gmail.com
Kwon, Bomjun	University of Utah, Salt Lake City, UT, USA	bjkwon@gmail.com
Laback, Bernhard	Austrian Academy of Sciences, Vienna, Austria	bernhard.laback@oeaw.ac.at
Lai, Wai Kong	University Hospital, Zurich, Switzerland	waikong.lai@usz.ch
Landsberger, David	House Research Institute, Los Angeles, CA, USA	dlandsberger@hei.org
Launer, Stefan	Phonak, Staefa, Switzerland	stefan.launer@phonak.com
Lazard, Diane	Ecole Normale Superieure, Paris, France	dianelazard@yahoo.fr
Leake, Patrica	UCSF, San Francisco, CA, USA	pleake@ohns.ucsf.edu
Leander, Anna	Med El,	anna.leander@medel.com
Leavons, Jason	Cochlear,	jleavens@cochlear.com
Lee, Ho Sun	Nurobiosys Corporation, Suwon, Korea	
Lee, Kenneth	University of Texas, Dallas, TX, USA	kenneth.lee@utsouthwestern.edu
Lenarz, Thomas	Medizinische Hochschule, Hannover, Germany	lenarz.thomas@mh-hannover.de
Lenssen, Anneke	K.U.Leuven, Exporl, Leuven, Belgium	anneke.lenssen@med.kuLeuven.be
Li, Tianhao	House Ear Institute, Los Angeles, CA, USA	tli@hei.org
Liberman, Charles	Harvard University, Boston, MA, USA	charles_liberman@meei.harvard.edu
Lim, Hubert	University of Minnesota, Minneapolis, MN, USA	hubertlim@aol.com
Lin, Payton	UC Irvine, Irvine, CA, USA	paytonl@uci.edu
Lineweaver, Sean	Cochlear, Centennial, CO, USA	slineaweaver@Cochlear.com
Litovsky, Ruth	University of Wisconsin, Madison, WI, USA	litovsky@waisman.wisc.edu
Locher, Maiko	Leiden University Med. Center, Leiden, Netherlands	m.locher@lumc.nl
Loiselle, Louise	Arizona State Univ., Tempe, AZ, USA	lloisell@asu.edu
Loizou, Phillip	University of Texas at Dallas, Richardson, TX, USA	loizou@utDallas.edu
Long, Christopher	Cochlear Research and Applications, Centennial, CO, USA	clong@Cochlear.com
Lotfi, Atossa	Advanced Bionics,	atoosa.lofti@advancedbionics.com
Lovett, Rosemary	UCL, London, UK	r.lovett@ucl.ac.uk
Lunner, Thomas	Oticon A/S, Denmark	tlu@oticon.dk

Luo, Xin	Purdue University, West Lafayette, IN, USA	luo5@Purdue.edu
Lupin, Alan	Royal B.C. Museum, Victoria, B.C., Canada	alanlupin@telus.net
Maarefvand, Mohammad	Bionic Institute, East Melbourne, Australia	mmaarefvand@bionicear.org
Macherey, Olivier	MRC Cognition and Brain Sciences UN, Cambridge, UK	olivier.macherey@mrc-cbu.CAm.ac.UK
Macpherson, Ewan	University of Western Ontario, London, Canada	ewan.macpherson@nca.uwo.ca
Majdak, Piotr	Austrian academy of Sciences / Acou, Wien, Austria	piotr@majdak.com
Maloff, Erin	University of Washington, Seattle, WA, USA	emaloff@u.washington.edu
Marimuthu, Vijay	Macquarie University, Sydney, Australia	vijay.marimuthu@mq.edu.au
Marozeau, Jeremy	Bionic Ear Institute, East Melbourne, VIC, Australia	JMAROZEAU@bionicear.org
Marzalek, Michael	Arizona State University, Tempe, AZ, USA	mike@mikemarz.com
Masaki, Kinu	Advanced Bionics,	kinuko.musaki@advancedbionics.com
Masterson, Megan	Purdue University, West Lafayette, IN, USA	memaster@purdue.edu
Matic, Agnella	Northwestern University, Chicago, IL, USA	a-izzo@northwestern.edu
Mauger, Stefan	La Trobe University, Victoria, Australia	smauger@cochlear.com
McAlpine, David	UCL, London, UK	d.mcalpine@ucl.ac.uk
McClannahan, Katrina	University of Washington, Seattle, WA, USA	kmccl@uw.edu
McCreery, Douglas	Huntington Medical Research Inst, Pasadena, CA, USA	dougmc@hmri.org
McDermott, Hugh	University of Melbourne, Carlton, VIC, Australia	hughm@unimelb.edu.au
McKay, Colette	University of Manchester, Manchester, UK	colette.mckay@Manchester.ac.UK
McLaughlin, Myles	UC Irvine, Irvine, CA, USA	mclaugmy@tcd.ie
Meister, Dirk	Med El,	dirk.meister@medel.com
Mens, Lucas	Radboud University Nijmegen Medical, Nijmegen, NL	l.mens@kno.umcn.nl
Meyer, Ted	Medical University of SC, Charleston, SC, USA	meyerta@musc.edu
Middlebrooks, John	UC Irvine, Irvine, CA, USA	j.midd@uci.edu
Milczynski, Matthias	Katholieke Universiteit Leuven, Leuven, Belgium	matthias.milczynski@med.kuLeuven.be
Miller, Roger	NIDCD/NIH, Bethesda, MD, USA	millerr@nidcd.nih.gov
Min, Kyou Sik	Seoul National University, Seoul, Korea	justhink1@gmail.com
Minehart, Elaine	CIAP Supreme Commander, La Canada, CA, USA	elaineminehart@gmail.com
Mishra, Lakshmi	Advanced Bionics, Sylmar, CA, USA	lakshmi.mishra@advancedbionics.com
Mistrik, Pavel	Med El,	pavel.mistrik@medel.com
Misurelli, Sara	University of Wisconsin at Madison, Madison, WI, USA	smisurelli@wisc.edu
Monaghan, Jessica	MRC Institute of Hearing Research, Nottingham, UK	jessica@ihr.mrc.ac.uk
Moore, Chasity	Arizona State University, Tempe, AZ, USA	chasity4@cox.net
Morris, David	University of Copenhagen, Copenhagen, Denmark	dmorris@hum.ku.dk
Morse, Robert	Aston University, Birmingham, UK	r.p.morse@aston.ac.uk
Muralimanohar, Ramesh	University of Colorado, Boulder, CO, USA	
Mussoi, Bruna	University of Iowa, Iowa City, IA, USA	bruna-mussoi@uiowa.edu
Nelson, Peggy	University of Minnesota, Minneapolis, MN, USA	nelso477@umn.edu
Nesselroth, Yuval	Cochlear,	ynesselroth@cochlear.com
Neuman, Arlene	NYU School of Medicine, New York, NY, USA	arlene.neuman@nyumc.org
Neustetter, Christian	Med El,	christian.neustetter@medel.com
Newbold, Carrie	Cochlear Ltd, Lane Cove, NSW, Australia	cnewbold@hearingcrc.org
Nicoletti, Michele	Technische Universität München, Garching, Germany	michele.nicoletti@tum.de
Nie, Kaibao	University of Washington, Seattle, WA, USA	niek@u.Washington.edu
Nittrouer, Susan	Ohio State University, Columbus, OH, USA	susan.nittrouer@osumc.edu
Noel, Victor	Massachusetts Eye and Ear Infirmary, Boston, MA, USA	victor_noel@meei.harvard.edu
Nogueira, Waldo	Advanced Bionics n.v., Niel, Belgium	waldon@abionics.fr
Nopp, Peter	Med-El, Innsbruck, Austria	peter.nopp@medel.com
Norton, Susan	Children's Hospital, Seattle, WA, USA	susan.norton@seattlechildrens.org
Nygard, Tony	Cochlear Ltd, Lane Cove, NSW, Australia	tnygard@Cochlear.com.au
Oba, Sandy	House Ear Institute, Los Angeles, CA, USA	soba@hei.org
Obaid, Gazi	Cochlear,	cbe-reception@cochlear.com
O'Leary, Stephen	University of Melbourne, East Melbourne, Australia	sjoleary@unimelb.edu.au
Opie, Jane	Med-El, Innsbruck, Austria	jane.opie@medel.com
Oplinger, Kenneth	Cochlear,	koplinger@cochlear.com
Oxenham, Andrew	University of Minnesota, Minneapolis, MN, USA	oxenham@umn.edu
Paasche, Gerrit	Medical University of Hannover, Hannover, Germany	paasche.gerrit@mh-Hannover.de
Padilla, Monica	House Ear Institute, Los Angeles, CA, USA	mpadilla@hei.org
Palmer, Logan	Advanced Bionics, Sylmar, CA, USA	logan.palmer@advancedbionics.com
Pals, Carina	University Medical Center Groningen, Groningen, NL	pals.carina@gmail.com
Pannu, Satinderpall	Lawrence Livermore National Lab, Livermore, CA, USA	pannu1@llnl.gov
Park, Min Hyun	University of Washington, Seattle, WA, USA	drpark@snu.ac.kr
Parkinson, Aaron	Cochlear Americas, Centennial, CO, USA	aparkinson@Cochlear.com
Patrick, James	Cochlear Ltd, Lane Cove, NSW, Australia	jpatrick@Cochlear.com.au
Peng, Shu-chen	University of Maryland, College Park, MD, USA	rbeasley@hesp.umd.edu
Perez, Ronen	,	
Perry, Trevor	The Ohio State University, Columbus, OH, USA	trevortperry@gmail.com
Pesch, Joerg	Cochlear gmbh, Hannover, Germany	jpesch@Cochlear.ch
Peskova, Olga	University of Texas, Dallas, TX, USA	olgapeskova@utdallas.edu
Peterson, Kathleen		kepeterson5@cox.net

Pettingill, Lisa	Bionic Ear Institute, Victoria, Australia	lpettingill@bionicear.org
Pfingst, Bryan	University of Michigan, Ann Arbor, MI, USA	bpfingst@umich.edu
Philips, Birgit	Ghent University, Gent, Belgium	birgit.philips@ugent.be
Poissant, Sarah	University of Massachusetts Amherst, Amherst, MA, USA	spoissant@comdis.umass.edu
Polak, Marek	Med El,	marek.polak@medel.com
Poppeliers, Jan	Cochlear,	cbe-reception@cochlear.com
Potts, Lisa	Washington University, St. Louis, MO, USA	pottsl@ent.wustl.edu
Prusick, Lindsay	University of Iowa, Iowa City, IA, USA	lindsay-prusick@uiowa.edu
Pu, Yvonne	Advanced Bionics,	yvonne.pu@advancedbionics.com
Rader, Tobias	Zhno/audiologische akustik, Frankfurt, Germany	tobias.rader@kgu.de
Ramanna, Guruprasad	Cochlear Ltd,	lramanna@cochlear.com
Ramanna, Lakshmish	Cochlear, Centennial, CO, USA	lramanna@Cochlear.com
Reiss, Lina	Oregon Health & Science, Portland, OR, USA	reiss@ohsu.edu
Reuter, Guenter	MHH, Hannover, Germany	reuter.guenter@mh-Hannover.de
Richter, Claus-Peter	Northwestern University, Chicago, IL, USA	cri529@northwestern.edu
Risi, Franco	Cochlear,	frisi@cochlear.com
Robert, Mark	House Ear Institute, Los Angeles, CA, USA	mrobert@hei.org
Rode, Thilo	Medizinische Hochschule Hannover, Hannover, Germany	rode.thilo@mh-hannover.de
Roehrlein, Gerhard	Advanced Bionics,	gerhard.roehrlein@advancedbionics.com
Roland, J Thomas	NYU Medical Center, New York, NY, USA	tom.roland@med.nyu.edu
Rosen, Stuart	UCL Speech Hearing and Phonetics, London, UK	stuart@phon.ucl.ac.UK
Rubinstein, Jay	University of Washington, Seattle, WA, USA	rubinj@u.washington.edu
Ruffin, Chad	Riley Hospital, Indianapolis, IN, USA	chad.ruffin@gmail.com
Russell, Benjamin	University of South Florida, Tampa, FL, USA	barussell@gmail.com
Sagi, Elad	NYU School of Medicine, New York, NY, USA	elad.sagi@med.nyu.edu
Saleh, Shaza	University College London, London, UK	shaza.saleh@ucl.ac.uk
Sanes, Daniel	New York University, New York, NY, USA	sanes@cns.nyu.edu
Sang, Jinqui	University of Southampton, Southhampton, UK	sangjinqiu@gmail.com
Schatzer, Reinhold	University of Innsbruck, Innsbruck, Austria	reinhold.schatzer@uibk.ac.at
Schleich, Peter	Med-El, Innsbruck, Austria	peter.schleich@medel.com
Schwarz, Konrad	Med-El, Innsbruck, Austria	konrad.schwarz@medel.com
Schwarzenbeck, Thomas	Med El,	thomas.schwarzenbeck@medel.com
Scott, Sophie	University College London, London, UK, UK	sophie.scott@ucl.ac.uk
Seeber, Bernhard	MRC Institute of Hearing Research, Nottingham, UK	bernhard@ihr.mrc.ac.UK
Shafiro, Valeriya	Rush University Medical Center, Chicago, IL, USA	valeriy_shafiro@rush.edu
Shannon, Robert	House Ear Institute, Los Angeles, CA, USA	bshannon@hei.org
Sheffield, Benjamin	Walter Reed Army Medical Center, Washington, DC, USA	benjamin.m.sheffield@us.army.mil
Shin, You-Ree	House Ear Institute, Los Angeles, CA, USA	yshin@hei.org
Silberer, Amanda	University of Iowa, Iowa City, IA, USA	ab-silberer@wiu.edu
Skoruppa, Katrin	University College London, London, UK	k.skoruppa@ucl.ac.uk
Skudowitz, Gila	Isreal	gila@steiner.co.il
Smith, Robert	Institute for Sensory Research, Syracuse, NY, USA	rlsmith@syr.edu
Smith, Zachary	Cochlear, Centennial, CO, USA	zsmith@Cochlear.com
Snyder, Russell	UCSF, San Francisco, CA, USA	rsnyder@ohns.ucsf.edu
Soede, Wim	Leiden University Medical Center, Leiden, Netherlands	w.soede@lumc.nl
Spahr, Tony	Arizona State University, Tempe, AZ, USA	tspahr@asu.edu
Spitzer, Philipp	MedEl,	philipp.spitzer@medel.com
Srinivasan, Arthi	House Ear Institute, Los Angeles, CA, USA	agsriniva@gmail.com
Stainsby, Thomas	Cochlear Technology Centre Belgium, Mechelen, Belgium	cbe-reeption@cochlear.com
Stakhovskaya, Olga	UCSF, San Francisco, CA, USA	ostakhovskaya@ohns.ucsf.edu
Stickney, Ginger	University of California, Irvine, CA, USA	stickney@uci.edu
Stohl, Joshua	Med-El Corporation, Durham, NC, USA	josh.stohl@medel.com
Stone, Michael	University of Cambridge, Cambridge, UK	mas19@CAm.ac.UK
Strahl, Stefan	Med-El, Innsbruck, Austria	stefan.strahl@medel.com
Su, Gina	University of Michigan, Ann Arbor, MI, USA	glsu@umich.edu
Svirsky, Mario	NYU, Langone Medical Center, New York, NY, USA	mario.svirsky@nyumc.org
Swaninathan, Jayaganesh	Massachusetts Inst. Of Technology, Boston, MA, USA	jswamy@mit.edu
Swanson, Brett	Cochlear Ltd, Lane Cove, NSW, Australia	bswanson@Cochlear.com.au
Tan, Chin-tuan	NYU School of Medicine, New York, NY, USA	chin-tuan.tan@med.nyu.edu
Tanaka, Chienni	The Ohio State University, Columbus, OH, USA	tanakach@ohsu.edu
Tarr, Eric	The Ohio State University, Columbus, OH, USA	tarr.18@buckeyemail.osu.edu
Taylor, Ruth	University College London, London, UK	ruth.taylor@ucl.ac.uk
Thenuwara, Chuladatta	Advanced Bionics,	chula.thenuwara@advancedbionics.com
Throckmorton, Chandra	Duke University, Durham, NC, USA	cst@ee.dUKe.edu
Tillein, Jochen	Johann-W.-Goeuniversitaet, Frankfurt, Germany	tillein@em.uni-frankfurt.de
Tillery, Kate	Arizona State University, Tempe, AZ, USA	ahelms@asu.edu
Tobey, Emily	University of Texas at Dallas, Dallas, TX, USA	etobey@utDallas.edu
Todd, Ann	University of Wisconsin, Madison, WI, USA	aetodd@wisc.edu
Toratani, Tomoki	Med El,	tomoki.toratani@medel.com
Torppa, Ritva	University of Helsinki, Helsinki, Finland	ritva.torppa@Helsinki.fi

Tran, Phillip	University of Sydney, Sydney, Australia	phillip.tran@sydney.edu.au
Treaba, Claudiu	Cochlear,	ctreaba@cochlear.com
Treadway, Jamie	House Ear Institute, Los Angeles, CA, USA	jtreadway@hei.org
Trehub, Sandra	University of Toronto, Mississauga, Canada	sandra.trehub@utoronto.ca
Tsay, Ishan	Cochlear Americas, Centennial, CO, USA	atsay@Cochlear.com
Twitchell, Kim	Med El,	kim.twitchell@medel.com
Tyler, Richard	University of Iowa, Iowa City, IA, USA	rich-tyler@uiowa.edu
Ubbink, Sander	Audiologisch Centrum Zwolle, Zwolle, Netherlands	s.w.j.ubbink@med.umcg.nl
Uchanski, Rosalie	Washington University, St. Louis, MO, USA	ruchanski@wustl.edu
Undurraga, Jaime	Exporl, KU Leuven, Leuven, Belgium	jaime.undurraga@med.kuLeuven.be
van den Hoek, Femke	Academic Medical Centre, Amsterdam, Netherlands	F.L.vandenHoek@amc.uva.nl
Van den Honert, Chris	Cochlear Research & applications, Centennial, CO, USA	cvdhonert@Cochlear.com
Van der Marel, Kim	Leiden University Medical Center, Leiden, Netherlands	k.s.van_der_Marel@lumc.nl
Van Dijk, Bas	Cochlear Technology Centre Europe, Mechelen, Belgium	bvandijk@Cochlear.be
Van Wieringen, Astrid	Exporl, KU Leuven, Leuven, Belgium	astrid.vanwieringen@med.kuLeuven.be
van Zanten, Bert G.	UMC Utrecht, Utrecht, Netherlands	G.A.vanZanten@umcutrecht.nl
Vandali, Andrew	Hearing CRC, Carlton, VIC, Australia	avandali@bionicear.org
Vanpoucke, Filiep	Advanced Bionics n.v, Niel, Belgium	filiepv@abionics.fr
Varsavsky, Andrea	University of Melbourne, Melbourne, Australia	ava@unimelb.edu.au
Veau, Nicolas	Neurelec, Vallauris, France	nveau@neurelec.com
Vellinga, Dirk	Leiden University Medical Center, Leiden, Netherlands	d.vellinga@lumc.nl
Verbist, Berit	Leiden University Medical Center, Leiden, Netherlands	b.m.verbist@lumc.nl
Verhoeven, Kristien	Cochlear Technology Centre Europe, Mechelen, Belgium	kverhoeven@Cochlear.be
Vermeire, Katrien	Universitair Ziekenhuis, Gent, Belgium	katrien.vermeire@uzgent.be
Vickers, Debi	UCL, London, UK	d.vickers@ucl.ac.uk
Visram, Anisa	University of Manchester, Manchester, UK	anisa.visram@Manchester.ac.UK
Visser, Daniel	University of Innsbruck, Innsbruck, Austria	daniel.visser @uibk.ac.at
Vogt, Gerhard	Med El,	gerhard.vogt@medel.com
Voit, Walter	The University of Texas at Dallas, Dallas, TX, USA	
Vollmer, Maike	University Hospital Würzburg, Würzburg, Germany	vollmer_m@yahoo.com
Wang, Ningyuan	University of Minnesota, Minneapolis, MN, USA	wang2087@umn.edu
Wang, Shuai	Arizona State University, Tempe, AZ, USA	swang102@asu.edu
Wang, Xiaosong	House Ear Institute, Los Angeles, CA, USA	xwang@hei.org
Webb, Cheritn	University of Southampton, UK	cmw506@soton.ac.uk
Werner, Lynne	University of Washington, Seattle, WA, USA	lawerner@u.washington.edu
White, Mark	North Carolina State University, Raleigh, NC, USA	Mark@markwhite.name
Wilson, Blake	Med-El Corporation, Durham, NC, USA	blake.wilson@duke.edu
Winn, Matthew	University of Maryland, College Park, MD, USA	mwinn83@gmail.com
Wise, Andrew	Bionic Ear Institute, Melbourne, Australia	awise@bionicear.org
Wolford, Bob	Med-El Corporation, Durham, NC, USA	Bob.Wolford@medel.com
Won, Jong ho	University of Washington, Seattle, WA, USA	jhwon@u.Washington.edu
Wong, Daniel	Hospital for Sick Children, Toronto, ON, Canada	ddewong@gmail.com
Wong, Paul	,	paul.wong88@gmail.com
Wouters, Jan	Exporl, KU Leuven, Leuven, Belgium	jan.wouters@med.kuLeuven.be
Wozny, David	Oregon Health and Science University, Portland, OR, USA	
Wu, Ching Chih	Purdue University, West Lafayette, IN, USA	wu94@purdue.edu
Xu, Li	Ohio University, Athens, OH, USA	xul@ohio.edu
Yang, Hsin-i	University of California, Irvine, Irvine, CA, USA	hsiniy@uci.edu
Yeo, Holly	Advanced Bionics,	holly.yeo@advancedbionics.com
Yoon, Yang-Soo	House Ear Institute, Los Angeles, CA, USA	yyoon@hei.org
Yuan, Meng	Chinese Academy of Sciences, Shanghai, China	ym@mail.ioa.ac.cn
Zangerl, Matthias	Med El,	matthias.zangerl@medel.com
Zhang, Ting	Arizona State University, Tempe, AZ, USA	Ting.Zhang@asu.edu
Zheng, Yi	University of Wisconsin at Madison, Madison, WI, USA	yzheng32@wisc.edu
Zhou, Ning	Ohio University, Athens, OH, USA	ningzhou_jo@yahoo.com

Author Index