

XX IERASC BIENNIAL SYMPOSIUM



10–14 JUNE 2007
Bled, Slovenia



PROGRAMME & BOOK OF ABSTRACTS



ACKNOWLEDGEMENTS

The XX IERASG Symposium Organisers acknowledge the assistance granted by the following companies and institutions:

Bronze Sponsor



JANSSEN-CILAG

Sponsors



Boehringer
Ingelheim



ART Stanislav Osenjak s.p.

Financial Supporters

Slovenian Research Agency

Medistar d. o. o.

Novartis Pharma Services Inc., Branch Office Slovenia

Medis d.o.o.

Slovenian Tourist Board

Tourist Board of Bled

Exhibitors

(please see the interior of the last cover page)

Programme and Book of Abstracts

XX IERASG BIENNIAL SYMPOSIUM



**Bled, Slovenia
June 10–14, 2007**

www.ierasg2007.org

XX IERASG Biennial Symposium

Bled, Slovenia, June 10–14, 2007

Organised by:

Slovene Society for Clinical Neurophysiology of the Slovene Medical Association,
Institute of Clinical Neurophysiology at Division of Neurology, and
Dept. of Otorhinolaryngology and Cervicofacial Surgery of the University Medical Centre Ljubljana, Slovenia,
International Evoked Response Audiometry Study Group (IERASG),
and
Auditoria, Event Management, Ljubljana, Slovenia

CME value:

20 credit points

Programme and Book of Abstracts

Editor:

Dušan Butinar

Technical Editors:

Blaž Konec, Ignac Zidar, Tone Žakelj

Published by:

Slovene Society for Clinical Neurophysiology of the Slovene Medical Association

CIP - Kataložni zapis o publikaciji
Narodna in univerzitetna knjižnica, Ljubljana

616.8(063)
616.28-072.7(063)

INTERNATIONAL Evoked Response Audiometry Study Group. Biennial
Symposium (20 ; 2007 ; Bled)

Programme and book of abstracts / XX IERASG Biennial Symposium,
Bled, Slovenia, June 10-14, 2007 ; [organised by Slovene Society
for Clinical Neurophysiology of the Slovene Medical Association ...
[et al.] ; editor Dušan Butinar]. - Ljubljana :
Slovene Society for Clinical Neurophysiology of the Slovene Medical
Association, 2007

ISBN 978-961-6456-29-6

1. Butinar, Dušan 2. Slovensko zdravniško društvo. Sekcija za
klinično nevrofiziologijo
233215744

CONTENTS

WELCOME MESSAGE	5
SYMPOSIUM COMMITTEES AND ORGANISATION	6
PROGRAMME FRAMEWORK	7
PROGRAMME AT A GLANCE	8
DETAILED PROGRAMME	10
Sunday, June 10	10
Monday, June 11	10
Tuesday, June 12	15
Wednesday, June 13	16
Thursday, June 14	20
SOCIAL PROGRAMME	22
INFORMATION FOR PRESENTING AUTHORS	23
GENERAL INFORMATION	24
TOURIST PROGRAMME	26
ABSTRACTS	29
Invited Lectures and Free Communications*	29
Posters	113
AUTHORS INDEX	155

**Locations/pages of individual abstracts are given in the Detailed Programme.*

Welcome to the XX IERASG Biennial Symposium

We, Slovenian neurophysiologists and audiologists, are honoured with the opportunity to host the XXth International Evoked Response Audiometry Study Group Biennial Symposium and to welcome you, dear colleagues and friends, at the Alpine pearl of Bled.

We have had a perfect reply to our invitation for cooperation. We are proud that Arnold Starr will deliver this year Hallowell Davis lecture "Sensory Cortical Changes Accompany Aging, Mild Cognitive Decline, and Dementia", and that the three other key lectures will be given by eminent experts – "Neonatal hearing Screening – the choice of method in the first evaluations: TEOAE or AABR or something else?" by Einar Laukli, "Brainstem encoding of sound; implications for language and music" by Nina Kraus, and "Magnetoencephalography of auditory cortex" by Bernhard Ross. These lectures will introduce short free communications, 76 presented orally and 41 by posters, consisting of interesting research results and treatment or technical reports from the large field, spanning from peripheral cochlear problems, the auditory nerve pathology, brainstem speech encoding, to cortical sensory changes.

We hope that the beautiful natural background and the technical as well as accommodation facilities of the venue will provide an inspiring surrounding for a fruitful discussion on your interesting contributions, thus assuring a successful professional meeting.

Bled, the Postojna Caves and Lipica Stud Farm are among the most attractive scenic spots in Slovenia. As the majority of you are coming from afar, we have tried and shall try to show you all of them, while your spouses and companions will hopefully take the opportunity of visiting also some other places. Our goal is to make to you the XXth IERASG Symposium a memorable professional and social event.

We look forward to meeting you in Slovenia again,



Dušan Butinar
Chairman of the Organising and Programme Committee

SYMPOSIUM COMMITTEES & ORGANISATION

Scientific Programme Committee

(alphabetically)

Dušan Butinar, Slovenia, *Chairman*
Tone Gros, Slovenia
Tomaž Pogačnik, Slovenia
Hillel Pratt, Israel
David R. Stapells, Canada
Arnold Starr, USA
Majda Špindler, Slovenia
Roger Thornton, United Kingdom
Jagoda Vatovec, Slovenia
David B. Vodusek, Slovenia
Janez Zidar, Slovenia
Miha Žargi, Slovenia

Organising Committee

Dušan Butinar, *Chairman*
Karin Keber
Blaž Konec-Pinki
Nika Kosmač
Jagoda Vatovec
Tone Žakelj

IERASG Council

Roger A. Thornton, United Kingdom, *Chairman*
John D. Durrant, USA, *Vice-Chairman*
Manuel Don, USA, *Treasurer*
Roger Ruth, USA, *Secretary*
Herbert Jay Gould, USA, *Newsletter Editor*
David L. McPherson, USA, *Membership Sec.*
Jose Juan Barajas de Prat, Spain
Dušan Butinar, Slovenia
Jean-Louis Collet, France
Monica Chapchap, Brazil
Barbara Cone-Wesson, USA
Ferdinando Grandori, Italy
Kimitaka Kaga, Japan
Lee-Suk Kim, Korea
Krzysztof Kochanek, Poland
Einar Laukli, Norway
Maria Cecilia Perez-Abalo, Cuba
Hillel Pratt, Israel
Suzanne Carolyn Purdy, Australia
Yvonne S. Siningher, USA
David R. Stapells, Canada
Georgy A. Tavartkiladze, Russia
Martin Walger, Germany

Scientific Secretariat

Institute of Clinical Neurophysiology
University Medical Centre, Ljubljana
Zaloška 7, SI-1525 Ljubljana, Slovenia
Phone +386 1 522 15 00
Fax: +386 1 522 15 33

Dr. Dušan Butinar, *Chairman*
Organising and Programme Committee
Phone: +386 1 522 15 14
E-mail: dusan.butinar@kclj.si

Mr. Tone Žakelj
Scientific Secretary
Phone: +386 1 522 15 09
E-mail: tone.zakelj@kclj.si

Symposium Secretariat

Ms. Karin Keber
Auditoria d.o.o.
Malnarjeva 10, SI-1000 Ljubljana, Slovenia
Phone: +386 1 244 56 76
Fax: +386 1 244 56 75
E-mail: karin.keber@auditoria.si

XX IERASG Symposium web site:
www.ierasg2007.org

PROGRAMME FRAMEWORK

Hours	Sunday, June 10	Monday, June 11	Tuesday, June 12	Wednesday, June 13	Thursday, June 14
8:00	14:00 Registration	Opening Ceremony & Hallowell Davis Lecture	Keynote Lecture I	Keynote Lecture II	Keynote Lecture III
9:00		Oral Session I	Oral Session VI	Oral Session VIII	Oral Session XII
10:30		Coffee Break sponsored by Pfizer	Coffee Break sponsored by Pliva	Coffee Break sponsored by Widex	Coffee Break sponsored by Eli Lilly
11:00		Oral Session II	Oral Session VII	Oral Session IX	Summary of IERASG 2007
12:30		Lunch	Lunch	Lunch	Lunch
13:30		Poster Session I	Excursion to Lipica & Postojna Caves & Dinner	Poster Session II	
15:15		Oral Session III		Oral Session X	
17:00		Coffee Break		Coffee Break sponsored by Widex	
17:30		Oral Session IV		Oral Session XI	
18:35		Oral Session V			
19:30		Free Evening			
20:00				Farewell Dinner	

PROGRAMME AT A GLANCE

Sunday, June 10	
14:00	Registration
18:00	Welcome Reception
Monday, June 11	
08:00	Opening Ceremony
08:15	Hallowell Davis Lecture <i>Chairperson: Roger Thornton</i>
09:00	Session I: Applications in Cognitive Neuroscience <i>Chairperson: Janez Zidar</i>
10:42	Coffee Break (sponsored by Pfizer)
11:00	Session II: CNS plasticity as Revealed by Evoked Potentials & Surgical Applications of Evoked Potentials <i>Chairperson: Dušan Butinar</i>
12:30	Lunch
13:30	Poster Session I <i>Chairperson: David Stapells</i>
15:15	Session III: Acoustically and Electrically Evoked Potentials (Part 1) <i>Chairperson: Jose Barajas</i>
17:00	Coffee Break
17:30	Session IV: Acoustically and Electrically Evoked Potentials (Part 2) <i>Chairperson: Maria Cecilia Pérez-Abalo</i>
18:35	Session V: Acoustically and Electrically Evoked Potentials (Part 3) <i>Chairperson: Hillel Pratt</i>
Tuesday, June 12	
08:00	Keynote Lecture I <i>Chairperson: Herbert Jay Gould</i>
09:00	Session VI: Newborn Hearing Screening and Diagnostic Evaluation (Part 1) <i>Chairperson: Jagoda Vatovec</i>
10:30	Coffee Break (sponsored by Pliva)
11:00	Session VII: Newborn Hearing Screening and Diagnostic Evaluation (Part 2) & Mechanisms and Site of Lesions in Auditory Neuropathy <i>Chairperson: Yvonne Sininger</i>
12:20	Lunch
13:20	Excursion to Lipica Stud Farm and Postojna Caves (dinner on the way back)

Wednesday, June 13	
08:00	Keynote Lecture II <i>Chairperson:</i> Manuel Don
09:00	Session VIII: Development of the Auditory System as Revealed by Evoked Responses & Physiological and Pathophysiological Bases of Auditory Evoked Potentials (Part 1) <i>Chairperson:</i> Martin Walger
10:30	Coffee Break (sponsored by Widex)
11:00	Session IX: Quantitative and Statistical Evaluation of Responses & Technology: Instrumentation and Data Processing <i>Chairperson:</i> George Tavartkiladze
12:30	Lunch
13:30	Poster Session II <i>Chairperson:</i> Barbara Cone-Wesson
15:15	Session X: Otoacoustic Emissions: TEOAE, DPOAE, SOAE <i>Chairperson:</i> Lee-Suk Kim
17:10	Coffee Break (sponsored by Widex)
17:30	Session XI: Physiological and Pathophysiological Bases of Auditory Evoked Potentials (Part 2) <i>Chairperson:</i> Ferdinando Grandori
20:30	Farewell Dinner
Thursday, June 14	
08:00	Keynote Lecture III <i>Chairperson:</i> Terence Picton
09:00	Session XII: Physiological and Pathophysiological Bases of Auditory Evoked Potentials (Part 3) <i>Chairperson:</i> Krzysztof Kochanek
10:30	Coffee Break (sponsored by Eli Lilly)
11:00	Summary of IERASG 2007 Symposium <i>Rapporteur:</i> John Durant
12:30	Lunch

DETAILED PROGRAMME

Sunday, June 10

14:00 Registration

18:00 Welcome Reception

Monday, June 11

08:00 Opening Ceremony

08:15 Hallowell Davis Lecture

Chairperson: Roger Thornton

Arnold Starr, Edward J. Golob, Rie Irimajiri, Henry J. Michalewski:
Sensory Cortical Changes Accompany Aging, Mild Cognitive Decline, and Dementia

Abstract on
Page

30

09:00–10:30

Session I: Applications in Cognitive Neuroscience

Chairperson: Janez Zidar

09:00 Yvonne S. Sininger:

Lateral Asymmetry in the Human Auditory System Evidence from Otoacoustic Emissions and Electrophysiology

31

09:13

David Purcell, Bernhard Ross, Terence Picton, Christo Pantev:
Cortical Responses to the 2f1-F2 Combination Tone

32

09:26

Anthony T. Cacace, Dennis J. McFarland, Earl Zimmerman, Dzintra Celmins:
Time and Frequency Domain Comparisons of Event-Related Potentials and Oscillations in Normal Aging and Individuals with Minimal Cognitive Impairment: Application of the Auditory Oddball Paradigm

33

09:39

Anthony T. Cacace, Dennis J. McFarland, Earl Zimmerman, Dzintra Celmins:
Electrophysiological Correlates of Auditory and Visual Recognition Memory in Normal Aging and Individuals with Minimal Cognitive Impairment

34

09:52

Ulrich Hoppe, Torsten Wohlberedt, Frank Digeser, Horst Hessel:
Cortical Auditory Evoked Potentials Evoked by Speech in Cochlear Implant Subjects are Affected by Acoustic Preprocessing

35

10:05

Curtis W. Ponton, Elais M. Ponton:
Driving while Listening - Multi-Tasking Mayhem: Analysis of Event-Related Potentials

36

10:18

Curtis W. Ponton, Elais M. Ponton:
Driving While Listening - Multi-Tasking Mayhem: Analysis of Spectral Data

37

Monday, June 11, continued		
10:30	Roger Thornton: <i>Selective Attention Increases the Temporal Precision of the Auditory N100 Event-Related Potential</i>	38
10:42	Coffee Break (sponsored by Pfizer)	
11:00–12:30	Session II: CNS plasticity as Revealed by Evoked Potentials Chairperson: Dušan Butinar	
11:00	Niels Christian Stenklev, Karine Faucher, Øyvind Aas-Hansen, Torgrim Fuhr, Børge Damsgård, Einar Laukli: <i>ABR and Regeneration of Inner Ear Hair Cells in Gentamicin-Treated Cod (<i>Gadus Morhua</i>)</i>	39
11:13	Kelly Tremblay, Bernhard Ross, Terence Picton: <i>Auditory Training and the P1-N1-P2 Complex: Age and Stimulus Effects</i>	40
11:26	Kevin J. Munro, Nataliya Y. Pisareva, David J. Parker, Suzanne C. Purdy: <i>Auditory Brainstem Response Asymmetry Following Monaural Long-Term Hearing Aid Experience: Evidence of Brainstem Plasticity In Adults?</i>	41
11:39	Martin Walger, Peter Igelmund, Hartmut Meister, Anke Brockhaus-Dumke, Dirk Fuerstenberg, Hasso von Wedel: <i>Objective Evaluation of Sound Discrimination of CI-Patients in Noise</i>	42
11:52–12:30	Surgical Applications of Evoked Potentials	
11:52	Norbert Dillier: <i>Application of Electrically Evoked Compound Action Potential Recordings for Patients with Cochlear Implants</i>	43
12:05	Branka Geczy, Jagoda Vatovec, Dušan Butinar: <i>Electrophysiologic Monitoring of the Auditory Nerve before and during Cochlear Implantation</i>	44
12:18	Krzysztof Morawski, Kazimierz Niemczyk, Jorge Bohorquez, Fred Telischi: <i>Various Models of Intraoperative Monitoring of Auditory Function in Patients with Cerebello-Pontine Angle Tumor</i>	45
12:30	Lunch	
13:30	Poster Session I Chairperson: David Stapells	
No. 1	Sung Wook Jeong, Woo Yong Bae, Soo Yong Ahn, Lee-Suk Kim: <i>Electrically Evoked Middle Latency Response in the Cat: Effect of Stimulation Rate and Pulse Duration</i>	114

Monday, June 11, continued

No. 2	Siobhán Brennan, Paul Bacon, John Stevens: <i>Effect of Ear Muff Placement on the Click Stimulus Waveform and Implications for ABR Threshold</i>	115
No. 3	Stanislav Bronyakin, Oleg Belov, George Tavartkiladze: <i>Technical Aspects of Stimulus Presentation through the Hearing Aid for ASSR Recording</i>	116
No. 4	Rafael E. Delgado, Nuri Açıkgoz, Linda Hood, Özcan Özdamar, Jorge Bohórquez: <i>Fast Infant Audiogram Determination Using an Intensity-Ramping ASSR Technique</i>	117
No. 5	Abreena I. Tlumak, Elaine Rubinstein, John D. Durrant: <i>Meta-Analysis of Variables that Affect Accuracy of Threshold Estimation via Measurement of the Auditory Steady-State Response</i>	118
No. 6	Kirsty Gardner-Berry, Suzanne Carolyn Purdy, Harvey Dillon, Simon Carlisle: <i>The Measurement of Gap Detection in Adults with Normal Hearing Using Cortical Auditory Evoked Potentials (CAEPs)</i>	119
No. 7	Herbert Jay Gould, Sarah Hay, Monique Pousson: <i>Late Evoked Potential Tracking of Time Compressed Speech</i>	120
No. 8	W. Wiktor Jedrzejczak, Krzysztof Kochanek, Lech Sliwa, Adam Pilka, Katarzyna J. Blinowska: <i>Time-Frequency Analysis of Auditory Steady State Responses</i>	121
No. 9	Krzysztof Kochanek, Jan Žera, Adam Pilka, Rafał Młyński, Henryk Skarżyński: <i>Evaluation of Hearing Protector Attenuation by Auditory Brainstem Responses</i>	122
No. 10	Doris R. Lewis, Daniela B. Calil: <i>Auditory Steady-State Responses in Hearing Impaired Children</i>	123
No. 11	Marcin Masalski, Stefan Giżewski, Maria Zalesska-Kręcicka: <i>Effect of the Post-Auricular Muscle Response on ASSR Detection</i>	124
No. 12	Krzysztof Morawski, Jorge Bohorquez, Katarzyna Pierchala, Fred Telischi, Ozcan Ozdamar, Kazimierz Niemczyk: <i>Assessment of Deconvolved Transtympanal Electrocochleography Obtained at High Stimulus Rates in Patients with Meniere's Disease and Acoustic Tumor</i>	125
No. 13	Patricia J. Muir, Carrie J. Scarff, Rachel M. Martin, Angela D. Reynolds, Jos J. Eggermont: <i>What Can /pa/-/pa/ Tell us about Temporal Processing?</i>	126
No. 14	Pavel Prado-Gutiérrez, Armando Alvaré-Jaramillo, Francisco A. Gonzalez-Marrero, Francisco Martín-Gonzales: <i>Effect of Repetition Rate on Both Acoustic and Electrically Evoked Auditory Potentials of Guinea Pigs</i>	127
No. 15	Mridula Sharma, Suzanne C. Purdy, Kevin J. Munro: <i>Reference Electrode Position for Single Ear Cortical Auditory Evoked Potential (CAEP) Recording. Does It Really Matter?</i>	128

Monday, June 11, continued

No. 16	Kate M. Autin, Edward J. Golob: <i>Auditory Event-Related Potentials and Perceptual Judgments of Speech</i>	129
No. 17	Torsten Rahne, Hellmut von Specht, Martin Böckmann: <i>Visual Cues Can Modulate the Automatic Organization of Auditory Streams</i>	130
No. 18	Martin Boeckmann: <i>Effects of Discrimination Training on the MMN Elicited by Pitch Modulation Direction Changes</i>	131
No. 19	Kiyoko Kobayashi, Maiko Mishina, Shinya Kobayashi: <i>Application of Phase Spectral Analysis for Cortical Auditory Evoked Potential Detection in Adults</i>	132
No. 20	Lee-Suk Kim, Sung Wook Jeong, Soo Yong Ahn, Jae Ryong Kim: <i>Comparison of ECAP Amplitude Growth Function between the Children with Auditory Neuropathy and those with Non-Neuropathic Sensorineural Hearing Loss. Preliminary Report</i>	133
No. 21	Emma Reichman, Karen Boyle, Michael Bradnam, Ruth Hamilton, Jim Harrigan, Juan Mora, Vivien Thorpe: <i>Normative ASSR, ABR and High-Frequency Tympanometry Data for Two-Month Old Infants</i>	134
No. 22	Ruth Brooke, Siobhán Brennan, John Stevens: <i>Reduction of Bone-Conduction Artefact when Recording ASSR</i>	135
15:15–17:00	Session III: Acoustically and Electrically Evoked Potentials (Part 1) Chairperson: Jose Barajas	
15:15	Matthew G. Evans: <i>An Attempt to Use Click ABR to Predict Uncomfortable Loudness Levels</i>	46
15:28	Wendy D'haenens, Ingeborg Dhooge, Bart Vinck: <i>Auditory Steady-State Responses in Normal Hearing Adults: A Test-Retest Reliability Study</i>	47
15:41	Christoph van der Reijden, Lucas Mens, Ad Snik: <i>Improving Recording and Stimulus Conditions of ASSRs in Infants and Adults</i>	48
15:54	Ann Iren Hugstmyr, Einar Laukli: <i>ASSR and Tone-Burst Evoked ABR. A Comparison</i>	49
16:07	Siobhán Brennan, John Stevens: <i>How Does the ASSR Response Amplitude Vary with Modulation Rate for Individual Babies?</i>	50
16:20	Maria Cecilia Pérez-Abalo, Maria C. Hernández, Jose Gaya, Lidia Charro, Ernesto Rodríguez, Lilian Rioja, Maribel Ponce de León, Sandra Bermejo: <i>Clinical Usefulness of the MSSR to Air and Bone Conducted Stimuli in Normal Hearing and Hearing Impaired Children</i>	51

Monday, June 11, continued

16:33	Lech Śliwa, Krzysztof Kochanek, Anna Piotrowska, Adam Piłka, Henryk Skarżyński: <i>Evaluation of Differences between Audiometric and ASSR Thresholds</i>	52
16:46	Michael Sasha John, Terence Picton: <i>RAMPER: Effects of Intensity Ramp Duration on Threshold Estimation</i>	53
17:00	Coffee Break	
17:30–18:35	Session IV: Acoustically and Electrically Evoked Potentials (Part 2) Chairperson: Maria Cecilia Pérez-Abalo	
17:30	Jane Alaerts, Heleen Luts, Jan Wouters: <i>Evaluating Speech Understanding by Means of Suprathreshold ASSR</i>	54
17:43	Alberico Bojano, Tiziana Cotecchia, Vincenzo Pastore, Antonio Della Volpe, Nicola Mansi, Raffaele Izzo: <i>Estimating Bimodal Hearing Gain Using Auditory Steady-State Responses in Cochlear Implanted Children</i>	55
17:56	Mridula Sharma, Katie Swaya, Suzanne C. Purdy, Andrea S. Kelly, Kevin J. Munro: <i>Effects of Broadband Noise on Speech Evoked Auditory Responses in Young Adults</i>	56
18:09	Andrew Dimitrijevic, John-Yuhan Bai, Henry Michalewski, Fan-Gang Zeng, Hillel Pratt, Arnold Starr: <i>Auditory Event-Related Responses to Single Feature Changes in Continuous Stimuli I: Temporal and Place Coding with Frequency Change</i>	57
18:22	Andrew Dimitrijevic, Brenda Lolli, Henry Michalewski, Arnold Starr: <i>Auditory Event-Related Responses to Single Feature Changes in Continuous Stimuli II: Temporal and Place Coding with Intensity Change</i>	58
18:35–19:26	Session V: Acoustically and Electrically Evoked Potentials (Part 3) Chairperson: Hillel Pratt	
18:35	Curtis J. Billings, Kelly L. Tremblay, Pamela E. Souza: <i>Cortical Auditory Evoked Potentials Recorded with and Without Hearing Aids: Effects of Stimulus Intensity and Amplification</i>	59
18:48	Harvey Dillon, John Seymour, Maryanne Golding, Richard Katsch, Suzanne Purdy: <i>Statistical Analysis of Cortical Waveforms Using MANOVA and Hotelling's t^2</i>	60
19:01	Lendra M. Friesen, Kelly L. Tremblay: <i>Speech-Evoked Auditory Potentials in Cochlear Implant Listeners</i>	61
19:14	Maryanne Golding, Harvey Dillon, John Seymour, Lyndal Carter: <i>The Sensitivity of Hotelling's T^2 in the Detection of Obligatory Cortical Auditory Evoked Potentials (CAEPs)</i>	62

Tuesday, June 12

08:00	Keynote Lecture I <i>Chairperson: Herbert Jay Gould</i> Einar Laukli: <i>Neonatal Hearing Screening. The Choice of Method in the First Evaluations: TEOAE or AABR or Something Else?</i>	63
09:00–10:30	Session VI: Newborn Hearing Screening and Diagnostic Evaluation (Part 1) <i>Chairperson: Jagoda Vatovec</i>	
09:00	David R. Stapells, Anna Van Maanen: <i>ASSRs to Multiple Simultaneous Air-Conducted Stimuli: Criteria for Normal Hearing in Infants</i>	64
09:13	Jennifer L. Hatton, David R. Stapells: <i>Effects of Single- vs. Multiple-Stimulus Presentation on 80 Hz ASSR Amplitudes and Threshold: Results in Young Infants</i>	65
09:26	John Stevens, Marian Brandreth, Paul Bacon: <i>Effects of Changing the OAE Screen Pass Criteria in Newborn Hearing Screening</i>	66
09:39	Guillermo Savio, Maria Cecilia Pérez-Abalo, Eleina Mijares, Didiesle Herrera, Agustin Lage: <i>Efficiency of the Automatic Detection of Multiple Auditory Steady State Responses Measured with ROC Methodology</i>	67
09:52	Jagoda Vatovec, Branka Geczy, Dušan Butinar: <i>Clinical Application of Auditory Steady-State Responses in Hearing Impaired Infants</i>	68
10:05	Ani Sahakian, Laura Booth, Andy Phillips, Katie Rutzler, Sarah Fancy, Nicky Armstead: <i>Home-Based Diagnostic Electrophysiology Following Referral From Community-Based Universal Newborn Hearing Screening</i>	69
10:18	Ljiljana Jelacic, Ksenija Ribaric-Jankes, Mirjana Sovilj, Aleksandar Ljubic: <i>The Examination of Fetal Brain Circulation Changes Caused by Defined Sound Stimulation</i>	70
10:30	Coffee Break (sponsored by Pliva)	
11:00–11:25	Session VII: Newborn Hearing Screening and Diagnostic Evaluation (Part 2) <i>Chairperson: Yvonne Sininger</i>	
11:00	Barbara Cone-Wesson, Angela Garinis, Sarah Varrichio, Aileen Wong: <i>Infant ASSR and the Detection of Amplitude Modulation</i>	71
11:13	Katie Rutzler, Laura Booth, Andy Phillips, Sarah Fancy, Nicky Armstead: <i>Comparison of Mixed Modulation Auditory Steady State Responses and Tone-Burst Auditory Brainstem Responses in Neonates with their Subsequent Behavioural Responses</i>	72

Tuesday, June 12, continued		
11:25–12:30	Mechanisms and Site of Lesions in Auditory Neuropathy	
11:25	Dušan Butinar, Arnold Starr, Janez Zidar, Jagoda Vatovec, Pantelitsa Koutsou, Kyproula Christodoulou: <i>Auditory Neuropathy is Asymptomatic in One of Two Different Point Mutations of the Neurofilament Light (NF-L) Gene</i>	73
11:38	Rosamaria Santarelli, Henry J. Michalewski, Edoardo Arslan, Arnold Starr: <i>Different Mechanisms in Temporal Processing Disorders Accompanying Auditory Neuropathy</i>	74
11:51	Zheng-min Xu: <i>Analysis in Infants with Hearing Disorder Using Auditory Techniques</i>	75
12:04	Catherine M. McMahon, Karen M. Bate, William P. R. Gibson, Halit Sanli: <i>Correlation between Speech Perception and Electrically-Evoked Auditory Potentials Measured in Subjects with Auditory Neuropathy after Cochlear Implantation</i>	76
12:20	Lunch	
13:20	Excursion to Lipica and Postojna Caves	
Wednesday, June 13		
08:00	Keynote Lecture II Chairperson: Manuel Don Nina Kraus: <i>Dynamic Sensory Encoding of Sound: Implications for Language and Music</i>	77
09:00–10:30	Session VIII: Development of the Auditory System as Revealed by Evoked Responses Chairperson: Martin Walger	
09:00	Lindsey Keogh, John D. Durrant, Diane Sabo, Randall Phelps: <i>Examination of an Abbreviated Stack-ABR Test in Newborns</i>	78
09:13	Susan A. Small, David R. Stapells: <i>Maturation of Bone-Conduction Auditory Steady-State Responses: Criteria for "Normal"</i>	79
09:26	Suzanne C. Purdy, Catherine Morgan, Mridula Sharma, Kevin J. Munro: <i>Effects of Stimulus Level on Speech Evoked Obligatory Cortical Auditory Evoked Potentials in Infants with Normal Hearing</i>	80
09:39	Krista L. Johnson, Steven G. Zecker, Nina Kraus: <i>Developmental Changes in Temporal and Spectral Brainstem Encoding of Speech in Early Childhood</i>	81

Wednesday, June 13, continued

09:52–10:30	Physiological and Pathophysiological Bases of Auditory Evoked Potentials (Part 1)	
09:52	Claus Elberling, Manuel Don, Mario Cebulla, Ekkehard Stürzebecher: <i>Chirp Stimuli Based on Cochlear Traveling Wave Delay</i>	82
10:05	Mario Cebulla, Ekkehard Stürzebecher, Claus Elberling, Wafaa Shehata-Dieler: <i>New Chirp Stimuli for Hearing Screening</i>	83
10:18	Manuel Don, Claus Elberling, Erin Maloff: <i>Stacked ABRs in Small Tumor Patients: Normal Peak Alignment vs. Mean Cochlear Delay Values Used in the Construction of Chirp Stimuli</i>	84
10:30	Coffee Break (sponsored by Widex)	
11:00–12:30	Session IX: Quantitative and Statistical Evaluation of Responses Chairperson: George Tavartkiladze	
11:00	Heleen Luts, Bram Van Dun, Jane Alaerts, Jan Wouters: <i>Objective Detection of ASSR: Do's and Don'ts</i>	85
11:13	Marcin Masalski: <i>Analysis of Statistic Value Fluctuation during ASSR Detection</i>	86
11:26	Steven L. Bell, Jing Lv, Alastair J. Manders, David M. Simpson: <i>A Bootstrap Approach to the Detection of Auditory Evoked Potentials</i>	87
11:39	Isaac Kurtz, Aaron H. Steinman, Yuri Sokolov: <i>Adaptive Filter Improves SNR in Auditory Evoked Responses: Method and Experimental Verification of Assumptions</i>	88
11:52	Isaac Kurtz, Aaron H. Steinman, Yuri Sokolov: <i>Adaptive Filter Improves SNR in Auditory Evoked Responses: Experimental Results</i>	89
12:05–12:30	Technology: Instrumentation and Data Processing	
12:05	Terence Picton, Sasha John: <i>Sweep Techniques for Recording Auditory Responses</i>	90
12:18	Bram Van Dun, Jan Wouters, Marc Moonen: <i>Improving ASSR Detection Using Multi-Channel Wiener Filtering</i>	91

Wednesday, June 13, continued

12:30	Lunch	
13:30–15:15	Poster Session II Chairperson: Barbara Cone-Wesson	
No. 23	Ieda Maria Ishida, Makoto Sugiura, Masaaki Teranishi, Naomi Katayama, Tsutomu Nakashima: <i>Otoacoustic Emissions, Ear Fullness and Tinnitus in the Recovery Course of Sudden Hearing Loss</i>	136
No. 24	Thomas Janssen, Jörg Müller: <i>DPOAE Fine Structure and Contralateral DPOAE Suppression in Human Ears Exposed to Noise in a Discotheque</i>	137
No. 25	Grazyna Lisowska, Grzegorz Namyslowski, Agata Hajduk, Stanislaw Kwiek, Jerzy Luszawski, Piotr Bazowski: <i>Contralateral Suppression of Click Evoked Otoacoustic Emissions in Patients with Cerebello-Pontine Angle Tumor and Multiple Sclerosis</i>	138
No. 26	Grazyna Lisowska, Grzegorz Namyslowski, Agata Hajduk, Stanislaw Kwiek, Jerzy Luszawski, Piotr Bazowski, Wojcich Scierski, Jan Pilch: <i>Hearing Improvement after Acoustic Neuroma Surgery</i>	139
No. 27	Grazyna Lisowska, Grzegorz Namyslowski: <i>Influence of Ageing and Gender on Contralateral Suppression of Click Evoked and Distortion Product Otoacoustic Emissions</i>	140
No. 28	Jörg Müller, Thomas Janssen: <i>Changes in DPOAE Fine Structure and Hearing Threshold due to Occupational Noise Exposure of One Day</i>	141
No. 29	Alessia Paglialonga,, Thomas Janssen, Gerhard Hoferer, Andre Lodwig, Peter Zoth: <i>A Novel Approach for Automated Hearing Threshold Estimation</i>	142
No. 30	Jennifer H. Horn, Sheila Pratt, John D. Durrant: <i>Study of Parameters to Optimize 2f2-f1 DPOAE Output</i>	143
No. 31	Krzysztof Morawski, Fred Telischi, Jorge Bohorquez, Kazimierz Niemczyk, Ozcan Ozdamar: <i>Morphology Changes in Elelctrocochleography Recorded during Reversible Ischemic Episodes. An Animal Model</i>	144
No. 32	Mona Mourad, Daa Ryad, Gada Malky: <i>Distortion Product Otoacoustic Emissions in Sensorineural Hearing Loss</i>	145
No. 33	Elaïs M. Ponton, Jennifer L. Hatton, David R. Stapells: <i>ASSR Measures of Binaural Processing: Effect of Dichotic Modulation Rate Separation on Brainstem (80 Hz) and Early Cortical (40 Hz) Auditory Steady-State Responses</i>	146
No. 34	Charles M. Fontaine, David R. Stapells: <i>Efficiency of Single Versus Multiple Stimuli for 40 Hz Auditory Steady-State Responses</i>	147

Wednesday, June 13, continued

No. 35	Maxine Armstrong, David R. Stapells: <i>Multiple-Stimulus Interactions in the Brainstem (80 Hz) and Cortical (14 & 40 Hz) Auditory Steady-State Responses</i>	148
No. 36	Guy Lightfoot, Adrian Cairns: <i>Masking</i>	149
No. 37	Saba Battelino, Dušan Butinar: <i>Electroaudiometry and Electric Evoked Auditory Brain-Stem Responses in Cochlear Implants Candidates Can be Compared</i>	150
No. 38	Lingyan Mo, Fan Zhang, Demin Han: <i>Research on Bone-Conducted Auditory Steady-State Responses in Adults with Normal Hearing</i>	151
No. 39	Zoran Rodi, Janez Zidar, Dušan Butinar: <i>Diagnostic Gain of a 75 dB HL as an Adjunct to a 70 dB SL BAEP</i>	152
No. 40	Ieda M. Ishida, David R. Stapells: <i>Does the 40-Hz ASSR show the Binaural Masking Level Difference?</i>	153
No. 41	Cynthia G. Fowler: <i>The Time Course and Reliability of P50 in Normal Adults</i>	154
15:15–17:00	Session X: Otoacoustic Emissions: TEOAE, DPOAE, SOAE Chairperson: Lee-Suk Kim	
15:15	Jeffrey A. Marler, Frederic L. Wightman, Carolyn B. Mervis, Doris J. Kistler, Zsolt Urban: <i>Auditory Function and Sensitivity in Connective Tissue Disorders</i>	92
15:28	John D. Durrant, Sheila Pratt, Jill Roxberg, Amanda Ortman, Malcolm McNeil, Pat Doyle: <i>Observations on Otoacoustic Emissions and Other Auditory Evoked Responses in Cohorts of Aging Subjects with and without Aphasia</i>	93
15:41	Alessia Paglialonga,, Marta Parazzini, Gabriella Tognola, Federica Sibella, Steven L. Bell, Mark E. Lutman, Gyorgy Thuroczy, Ferdinando Grandori, Paolo Ravazzani: <i>Time Frequency Analysis of Otoacoustic Emissions to Study the Effects of Exposure to GSM Radiofrequency Fields</i>	94
15:54	Jacek Smurzynski, Krzysztof Kochanek, Adam Pilka, Henryk Skarzynski: <i>Relationship between Hearing Sensitivity and Distortion-Product Otoacoustic Emissions in Patients with Low-Frequency Sensorineural Hearing Loss</i>	95
16:07	Johann A. Oswald, Thomas Janssen: <i>Calibration Effects on Optimal Stimulation of Distortion Product Otoacoustic Emissions</i>	96
16:20	Oleg Belov, George Tavartkiladze: <i>An Attempt to Decompose the Signal of the Transient Evoked Otoacoustic Emission to Primary Components</i>	97

Wednesday, June 13, continued		
16:33	Ossama A. Sobhy, Ahmed R. Koutb, Fathi Abdel-Baki, Tarek M. Ali, Iman Z. El-Raffa, Alaa H. Khater: <i>Study of Otoacoustic Emissions in Temporo-Mandibular Joint Dysfunction</i>	98
16:46	Günter Reuter, Svenja Beinroth, Thomas Janssen, Thomas Lenarz: <i>Correlation between Behavioural (Pure-Tone Audiogram) and Estimated Thresholds (Cochlea Scan)</i>	99
17:10	Coffee Break (sponsored by Widex)	
17:30–18:22	Session XI: Physiological and Pathophysiological Bases of Auditory Evoked Potentials (Part 2) <i>Chairperson: Ferdinando Grandori</i>	
17:30	Hillel Pratt, Arnold Starr, Henry J. Michalewski, Naomi Bleich, Nomi Mittelman: <i>The Auditory P50 Component to Onsets and Offsets of Gaps in Noise</i>	100
17:43	Özcan Özdamar, Jorge Bohórquez, Nuri Açıköz: <i>Generation Mechanisms of 40 Hz and 80 Hz ASSR Explained by Deconvolution Averaging</i>	101
17:56	Shaum P. Bhagat: <i>Effects of Monotic and Dichotic Interference Tones on the 40 Hz Auditory Steady-State Response</i>	102
18:09	Robert Burkard, Kathleen Szalda McNeerney, Michael Sasha John: <i>ASSR Input/Output Functions: Does Response Analysis Method Affect Response Properties?</i>	103
20:30	Farewell Dinner	
Thursday, June 14		
08:00	Keynote Lecture III <i>Chairperson: Terence Picton</i> Bernhard Ross: <i>Magnetoencephalography of Auditory Cortex</i>	104
09:00–10:45	Session XII: Physiological and Pathophysiological Bases of Auditory Evoked Potentials (Part 3) <i>Chairperson: Krzysztof Kochanek</i>	
09:00	Hiroaki Nishida: <i>Electrocochleography and Tinnitus</i>	106
09:13	Manuel Don, Betty Kwong, Chiemi Tanaka, Michael Waring: <i>ABR Evidence for a Dissociation between Symptoms and Underlying Pathological Changes in Meniere’s Disease Patients</i>	107

Thursday, June 14, continued

09:26	Kathleen C. M. Campbell, Larry Hughes, Robert Meech: <i>Preventing Noise and Drug Induced Hearing Loss with D-Methionine</i>	108
09:39	Helmut Riedel, Birger Kollmeier: <i>Challenging the Jeffress Model of Azimuthal Sound Localization in Humans with Binaural Auditory Evoked Potentials</i>	109
09:52	Stavros Hatzopoulos, Joseph Petrucci, Silvano Prosser, Giada Buzzoni, Alessandro Martini: <i>Hearing Threshold Estimation with CochleaScan and ASSR protocols</i>	110
10:05	Majda Spindler: <i>Second Stage of Universal Neonatal Screening With ABR. Results and Problems</i>	111
10:30	Coffee Break (sponsored by Eli Lilly)	
11:00	Summary of IERASG 2007 Symposium <i>Rapporteur: John Durant</i>	
12:30	Lunch	

SOCIAL PROGRAMME

Sunday, June 10, 2007

18:00–21:00 Welcome Reception

Bled Castle

Meeting point: In front of main entrance of Golf hotel Bled at **18:00**.

Bus transfer will be organised from Golf hotel Bled to the Castle at 18:00, as well as back at 21:00.

Sports foot-wear recommended (stairs & possibly slippery slope).

Included in the Fee for participants and accompanying persons.

Tuesday, June 12, 2007

13:30–22:30 Excursion to Lipica Stud Farm and Postojna Caves

Meeting point: In front of main entrance of Golf hotel Bled at **13:20**.

Bus transfer will be organised from Golf hotel Bled to Ljubljana Castle at 13:30.

Included in the Fee for participants and accompanying persons.

Highlights:

- Stud farm Lipica, home of the white Lipizzaner horses
- Spanish Riding School Performance
- world famous Postojna Caves
- spectacular rock and limestone formations
- guided inspection in the stunning underground world
- ride by the mini cave-train

Please note: The air in the caves is humid, the temperature is about 8° C. Passageways are paved and – though wet – not slippery. Sports jackets or sweaters and appropriate shoes are recommended.

The excursion will take you to two of the most famous Slovenian tourist attractions, the Postojna Caves and Lipica stud farm. Postojna and Lipica are located in the south-western part of Slovenia on the typical Karst landscape. Coaches will take you from the hotel directly to Lipica, where you will first enjoy a performance of the finest riding horses of the world, the Lippizaners. The show will be followed by a guided walk through the stables where you will get to know with the history of the stud farm and you will have a closer look to these intelligent, beautiful animals, as well. After the visit of the Farm, a drive to Postojna will follow. The Postojna Caves are European biggest and also one of the most beautiful caves in the world. Your guided tour will start by a ride with the mini cave-train and continue by walking in the most beautiful parts of the Caves, where many stalactites and stalagmites of different forms and colours have been created by nature through the millennia. After the ride back to the entrance, coaches will take you to a nearby nice inn called "Hudičevac", where the excursion will be concluded by dinner.

Wednesday, June 13, 2007

20:00–23:30 Farewell Dinner

Avsenik Inn, Begunje

Meeting point: In front of the main entrance of Golf hotel Bled at **19:50**.

Bus transfer will be organised from Golf hotel Bled to Avsenik Inn at 20:00, as well as back at 23:30 and at 24:00.

Included in the Fee for participants and accompanying persons.

INFORMATION FOR PRESENTING AUTHORS

Speaker Centre – Preview Room

The technical organiser will give you additional instructions concerning your session and the presentation of your paper in the Speaker Centre – Preview Room, located in the Foyer of Golf hotel Bled. Technical staff will be at your disposal on:

Sunday, June 10	from 14:00 to 18:00
Monday, June 11	from 07:00 to 20:00
Tuesday, June 12	from 07:00 to 13:30
Wednesday, June 13	from 07:00 to 19:00
Thursday, June 14	from 07:00 to 13:00

Oral Presentations

Technical equipment available for oral presentations:

- DATA projectors for computer presentation (native resolution: 1024 x 768 pixels)
- Computers with Microsoft Windows XP operating system and Microsoft Office 2003
- Slide and overhead projector will not be available.

Please make sure that your computer presentation is fully operational before your talk. Speakers are kindly asked to deliver their presentation on a CD or DVD media or USB Memory stick to the Speaker Centre. Only presentations in Power Point will be accepted. Version MS Power Point 2003 is recommended. If your presentation contains a video or an audio file, please bring all the files (audio, video, codec) with you.

We advise you to deliver your presentation and check computer presentation preferably in the morning of the day your talk is scheduled, but **not later than 2 hours in advance before the beginning of the session** or the **previous afternoon for the morning sessions**.

Oral presentations are limited to 10 minutes plus 2 minutes for discussion.

Check In

Please check-in with your session chairperson during the break (i.e., breakfast/poster session, coffee break, or lunch) preceding your session. Do not wait until the session begins to check-in. Check the IERASG Program/Abstract book for your session chairperson's name.

Poster Presentations

Poster boards have an available space of 0-95 m width and 2.50 m height. Double sided tape should be used.

Poster Session I

Authors are requested to have their posters displayed in the poster area by Monday, June 11 at 8:00 and to remove them by Tuesday, June 12 at 13:00.

Presenting authors are requested to be available for short discussion of their posters during the Poster Session I on **Monday, June 11 from 13:30 to 15:15**.

Poster Session II

Authors are requested to have their posters displayed in the poster area by Wednesday, June 13 at 8:00 and to remove them by Thursday, June 14 at 13:00.

Presenting authors are requested to be available for short discussion of their posters during the Poster Session II on **Wednesday, June 13 from 13:30 to 15:15**.

GENERAL INFORMATION

Official Language

The official language of the Symposium is English. No simultaneous translation is provided.

Venue

The symposium is held in the Golf Hotel, located right in the heart of Bled and surrounded by numerous majestic ancient trees. You can marvel at the splendour of the views across the lake, the island, the castle and the towering peaks of the Julian and Karavanke Alps. The Golf Hotel is a popular venue, whilst retaining a select atmosphere. The recent addition of a conference facility catering for up to 380 delegates and offering a fine view across the lake makes it the largest hotel convention centre in the region (www.hotel-golf-bled.com).

Registration and Fees

Registration is required for all Symposium participants and accompanying persons.

Full and Student Registration for participants includes:

- 2-year IERASG membership fee
- Admission to all scientific sessions
- Free entrance to the Exhibition
- Symposium material
- Coffee breaks and lunches
- Welcome Reception on Sunday, June 10
- Excursion to Lipica Stud Farm and Postojna Caves on Tuesday, June 12
- Farewell Dinner on Wednesday, June 13.

The registration fee for accompanying persons includes:

- Welcome Reception on Sunday, June 10
- Excursion to Lipica Stud Farm and Postojna Caves on Tuesday, June 12
- Farewell Dinner on Wednesday, June 13.

Registration and Information Desk

The Registration Desk, located in the Foyer of Golf hotel Bled, will be open:

Sunday, June 10	from 14:00 to 18:00
Monday, June 11	from 07:00 to 20:00
Tuesday, June 12	from 07:00 to 13:30
Wednesday, June 13	from 07:00 to 19:00
Thursday, June 14	from 07:00 to 13:00

Symposium Identification Badge

A symposium identification badge will be included in the congress material provided on registration. There will be no admittance to the scientific sessions without the symposium badge. Invitations for social events will be collected on entry. The symposium identification badges will be also most helpful in contacts with other participants.

Attendance Certificate and CME value

A certificate of attendance will be issued to all registered participants. The Symposium was accredited with 20 CME points by Medical Chamber of Slovenia.

Refreshments

During session breaks, coffee breaks and lunches will be served free of charge to participants wearing name badges.

No-Smoking Policy

Participants are requested to refrain from smoking in all parts of the Symposium venue except in specially designated areas.

Liability and Insurance

All participants are reminded that neither the Organising Committee nor the technical organiser Auditoria are liable for any losses, accidents or damage to persons or private property. Participants and accompanying persons are requested to make their own arrangements in respect of health and travel insurance.

Meeting Point/Message Desk

A meeting point is located in front of the main entrance to Golf hotel Bled.

Money Change

The Slovenian legal currency is Euro. Foreign currency may be exchanged at banks, exchange offices, travel agencies, hotels, airports and railway stations.

Automatic Cash Dispensers

Automatic cash dispensers, which enable cash withdrawal by credit card, are situated at main banks in Bled and also at Ljubljana Airport (Brnik). Cash may be withdrawn with the following credit cards: Maestro, Visa, Eurocard/Mastercard, American Express and Diners.

Credit Cards

All major credit cards, such as American Express, Visa, Eurocard/Mastercard, Diners, are widely accepted in hotels, restaurants and shops.

Time

European summer time, one hour ahead of Greenwich Mean Time.

Drinking Water

Tap water is safe to drink in Slovenia.

Shuttle bus Bled–Ljubljana Airport

Shuttle bus will be organised to drive participants from Bled to Ljubljana airport will be organised on Thursday, June 14 and Friday, June 15, 2007.

Please check your flight and shuttle bus departure. For any information and changes please contact the Registration desk.

TOURIST PROGRAMME

Sunday to Thursday, June 10–14, 2007, every day 09:00–12:30

Bled Sightseeing Tour

Bled is one of most beautiful parts of the Julian Alps and the most popular Slovenian tourist resort. It is adorned with three gems: the medieval castle, glacial lake, an island and a church in the middle of the lake. You will enjoy the view from the castle from the 11th century perched on a cliff over the lake. You will get to know some history of the Castle. Afterwards you will have a chance to make a wish in the St Mary's Church on the island by tolling a bell. There will be enough time to taste the local cake as well.

Price: 28 €

The price includes: entrance to Bled Castle and "pletna" boat ride to the Bled Island, a drive by bus around Bled, and a guided tour.

Monday, June 11, and Friday, June 15, 2007, 09:00–18:00

The Julian Alps: Great Alpine Adventure

Julian Alps are Slovenian largest mountain range with highest peaks, deepest valleys and beautiful views. You will be taken into the heart of the mountains over highest Slovenian mountain pass Vršič and into the Soča river valley, one of the most magnificent areas in Slovenia, where the crystal purity of the mountain waters are truly remarkable. The Triglav National Park is the only Slovenian National Park and covers a large area of the Julian Alps. You will admire its wonders on the way and visit the museum with the cultural and natural heritage of the National Park. In the small town of Bovec, famous ski resort and summer tourist resort, you will have lunch break and then you will ascend the Predil mountain pass, where you will cross the border with Italy and before returning to your resort there we will stop at Italian Lake of Lago del Predil.

Price: 35 €

The price includes: bus transport, local guide, Triglav National Park entrance fee.

Wednesday, June 13, 08:30–15:00

Ljubljana – City Tour with Highlights

Ljubljana is one of the smaller European capitals, but we are convinced that many bigger cities could be envious of all that, what Ljubljana has to offer. Its medieval city centre, mainly built in baroque manner, is squeezed between the hill with castle and the Ljubljanica River. The river banks and many other important buildings were designed by renowned Slovenian architect Jože Plečnik. Strolling through the city streets, one enjoys the pleasant view of the remnants of the Roman settlement Emona, the medieval old town, works by Plečnik, Baroque architecture and modern buildings specked with parks and squares.

Price: 27 €

The price includes: bus transport, guided walk.

Thursday, June 14, 2007, 08:00–19:00

Slovenian Vineyards Goriška Brda – Tastes, Beauty and History of Slovenian Premier Wine Region

This excursion will show you the natural as well as cultural diversity of Slovenia. From the alpine part of Slovenia we will take you through deep and narrow valleys to the hilly vineyards of the Mediterranean Slovenia, just on the border with Italy. You will not enjoy only the scenery, but you will taste some of the best local wines as well.

Goriška Brda (The Gorica Hills), the beautiful hilly wine region of the Mediterranean Slovenia with small villages standing on the top of hilly ridges, with stone houses, set among terraced vineyards and orchards offers special Mediterranean charm. After the lunch break you will visit the centre of this region on the Italian border, a small town of Nova Gorica, built after the WWII, today known as Slovenian Las Vegas.

Beside casinos you can also see the cultural and historical sights of Nova Gorica. You will be taken to Franciscan Monastery where you will see the tomb of the Bourbons and a wonderful old library.

Price: 56 €

The price includes: bus transport, guided tour, wine tasting, lunch, entrance fee.

Thursday, June 14, 2007, 09:00–13:00

Radovljica – Kropa: Cultural Treasures of Gorenjska

This half day excursion will take you to the scenic countryside of Gorenjska. You will get to know with cultural and historical heritage of this part of Slovenia as well. The small town of Kropa has been famous for its tradition in iron forgery; therefore you will visit an interesting Blacksmith Museum. The St. Mary's church in the village of Brezje is Slovenian famous pilgrimage church. In Radovljica you will learn something about the long beekeeping tradition of the area and you will enjoy a charming medieval old town as well.

Price: 27 €

The price includes: bus transport, guided tour, entrance fees, and snack.

Thursday, June 14, 2007, 13:30–18:00

Bohinj Lake with Savica Waterfall

This afternoon excursion takes you to one of the most beautiful parts of the Julian Alps. In Bohinj we offer you a walk up to the 60 meters high waterfall Savica and a ride by cable car up to 1530m high ski resort Vogel to enjoy the wonderful views over high peaks of the Julian Alps and a lake Bohinj beneath. On the way back we will make a stop on the lake shore to see church of St. John the Baptist, which has well preserved frescoes from 15th and 16th century and then we will continue the ride through upper valley of Bohinj, where typical rustic architecture can be admired.

Price: 27 €

The price includes: bus transport, guided tour, entrance fee for waterfall, *cable car ride is optional.

Friday, June 15, 2007, 07:00–22:30

Venice – The Pearl of Mediterranean

This excursion offers you a unique opportunity to visit the “floating city”, situated in a lagoon with 118 islets, city of thousands bridges and canals, and admire its marvellous architecture. You will have a chance to see the San Marco's Square, the mighty Doge's Palace, Rialto Bridge, Bridge of Sighs and other interesting sights of the city.

Price: 62 €

The price includes: luxury bus transport.

REMARKS

- Booking and payment is possible at the Symposium Registration Desk.
- Meeting point for all excursions is in front of Hotel Golf.
- The tours are subject to change. Organiser reserves the right to cancel the optional excursions should the minimum number of participants not be reached and change the programme due to weather or traffic conditions.

Abstracts

Invited Lectures & Free Communications

Hallowell Davis Lecture

Sensory Cortical Changes Accompany Aging, Mild Cognitive Decline, and Dementia

Arnold Starr, Edward J. Golob, Rie Imirijari, Henry J. Michalewski

University California Irvine, Irvine, California, USA

Normal aging, mild cognitive decline, and dementia are descriptive categories of domains accompanying longevity. We have been studying cortical processes during aging to define distinguishing features of normal and abnormal aging. The research focuses on both sensory and cognitive potentials to sensory stimuli with particular emphasis on the auditory modality. I will define the varieties of degenerative disorders that are accompanied by dementia and the myths of partial truths about "stuff" that increase and decrease the likelihood of becoming demented. Our physiological studies have concentrated on mild cognitive impairment (MCI) and on Alzheimer's disease (AD).

Mild cognitive impairment (MCI) patients have a high risk of converting to Alzheimer's disease (AD). The most common diagnostic subtypes of MCI have an episodic memory disorder (amnesic MCI) occurring either alone (single domain) or with other cognitive impairments (multiple domain).

Sensory cortical potentials to all modalities are enhanced in amplitude in aging compared to young controls. Their latency to suprathreshold intensities is typically not affected by aging. In contrast, the P300 cognitive potentials increase in latency at approximately 1.3 ms/year in a linear fashion as we age. P300 latency is a measure of speed of stimulus classification and it appears we are fastest at 13 years of age. The latency of this component also may be inversely related to wisdom.

Two of the studies I will present follow. The results suggest that changes of sensory cortex may be related to the clinical expression of specific forms of altered cognitive and behavior in MCI and AD.

1. We studied subjects with amnesic MCI ($n = 41$: 28 single domain, 13 multiple domain), AD ($n = 14$), and both younger ($n = 22$) and age-matched older controls ($n = 44$). Baseline auditory sensory (P50, N100) and cognitive potentials (P300) were recorded during an auditory discrimination task. MCI patients were followed for up to five years, and outcomes were classified as (1) continued diagnosis of MCI (MCI-Stable, $n = 16$), (2) probable AD (MCI-Convert, $n = 18$), or other outcomes ($n = 7$). Auditory potentials were analyzed as a function of MCI diagnosis and outcomes, and compared to young, older controls, and mild AD subjects. P50 amplitude increased with normal aging, and had additional increases in MCI as a function of both initial diagnosis (multiple domain > than single domain) and outcome (MCI-Convert > MCI-Stable). Treatment with Cholinesterase inhibitors (ChEIs) had no effects on the amplitudes of the cortical potentials. P300 latency increased with normal aging, and had additional increases in MCI but did not differ among outcomes. We conclude that auditory cortical sensory potentials differ among amnesic MCI subtypes and outcomes occurring up to five years later.
2. Somatosensory cortical potentials to median nerve stimulation and visual cortical potentials to reversing checkerboard stimulation were recorded from 15 older controls and 15 amnesic MCI subjects (single domain). Results were analyzed as a function of diagnosis (Control, MCI) and ChEIs treatment (Treated MCI, and Untreated MCI). Somatosensory and visual potentials did not differ significantly in amplitude in MCI subjects compared to controls. When ChEIs use was considered, somatosensory potentials (N20, P50) but not visual potentials (N70, P100, N150) were of larger amplitude in untreated MCI subjects compared to treated MCI subjects. Three individual MCI subjects tested while on and off ChEIs treatment showed increased N20 amplitude while off ChEIs compared to while on ChEIs. An enhancement of N20 somatosensory cortical activity occurs in amnesic single domain MCI and is sensitive to modulation by ChEIs.

Lateral Asymmetry in the Human Auditory System: Evidence from Otoacoustic Emissions and Electrophysiology

Yvonne S. Sininger

University of California, Los Angeles, CA, USA

A significant core of functional and brain imaging data as well as lesion studies have shown that the auditory regions of each hemisphere in humans are preferentially suited to processing of specific types of stimuli. Because of strong crossed neural connections, the contralateral ear also demonstrates preference for processing of like stimuli. The left auditory cortical regions (and the right ear) have high capacity for temporal precision to process stimuli that are rapidly changing or broadband including much of the content of human speech (Type I stimuli). The auditory regions of the right hemisphere (and the left ear) have particular spectral processing capacity best suited to slowly changing, narrow band stimuli such as pure tones or music (Type II stimuli). Information regarding lateralization of auditory information processing the auditory cortex is well accepted. Recently studies have shown that a similar side-specific processing of stimuli is evident at the level of ear and auditory brainstem. Specifically, stimulus guided laterality has been shown in the otoacoustic emissions of infants who demonstrate greater signal to noise ratio TEOAE in the right ear with short-duration, rapid, click stimuli (Type I) and a bigger (DPOAE) response to tones (Type II) in the left ear. Similar trends are seen in the auditory brainstem response and most recently in behavioral measures of gap detection. Significant differences in performance are noted based on ear/ stimulus interactions. In these instances as well, better performance is found with tonal stimuli when presented to the left ear and noise when presented to the right. A summary of work on lateral asymmetry in the auditory system will be presented.

Cortical Responses to the 2f1-f2 Combination Tone

David Purcell¹, Bernhard Ross², Terence Picton², Christo Pantev³

¹*National Centre for Audiology, University of Western Ontario, London, Canada*

²*Rotman Research Institute at Baycrest, Toronto, Canada*

³*Institute for Biomagnetism and Biosignalanalysis, University of Münster, Münster, Germany*

The simultaneous presentation of two tones with frequencies f_1 and f_2 causes the perception of several combination tones in addition to the original tones. The most prominent of these are at frequencies f_2-f_1 and $2f_1-f_2$. This study measured human physiological responses to the $2f_1-f_2$ combination tone at 500 Hz caused by tones of 750 and 1000 Hz with intensities of 65 and 55 dB SPL, respectively. Responses were measured from the cochlea using the distortion product otoacoustic emission (DPOAE), and from the auditory cortex using the 40-Hz steady-state magnetoencephalographic (MEG) response. The perceptual response was assessed by having the participant adjust a probe tone to cause maximal beating ("best-beats") with the perceived combination tone. The cortical response to the combination tone was evaluated in two ways: first by presenting a probe tone with a frequency 460 Hz at the perceptual best-beats level, resulting in a 40 Hz response because of interaction with the combination tone at 500 Hz, and second by simultaneously presenting two f_1 and f_2 pairs that caused combination tones that would themselves beat at 40 Hz. The $2f_1-f_2$ DPOAE in the external auditory canal had a level of 2.6 (SD 12.1) dB SPL. The 40-Hz MEG response in the contralateral cortex had a magnitude of 0.39 (SD 0.1) nAm. The perceived level of the combination tone was 44.8 (SD 11.3) dB SPL. There were no significant correlations between these measurements. These results indicate that physiological responses to the $2f_1-f_2$ combination tone occur in the human auditory system all the way from the cochlea to the cortex. The perceived magnitude of the combination tone is not determined by the measured physiological response at either the cochlea or the cortex.

Time and Frequency Domain Comparisons of Event-Related Potentials and Oscillations in Normal Aging and Individuals with Minimal Cognitive Impairment: Application of the Auditory Oddball Paradigm

Anthony T. Cacace¹, Dennis J. McFarland², Earl Zimmerman¹, Dzintra Celmins¹

¹*The Neurosciences Institute and Advanced Imaging Research Center, Department of Neurology, Albany Medical College, Albany, USA*

²*The Wadsworth Labs, New York State Health Department, Albany, USA*

The oddball paradigm was used to study two groups of individuals: normal aged without complaints of cognitive dysfunctions (5 males, 10 females, mean age 65 years) and individuals diagnosed with minimal cognitive impairment (MCI) (8 males, 4 females, mean age 67 years). Minimal cognitive impairment is considered a risk category or prodromal state that can convert to Alzheimer's disease (AD). Developing and validating biomarkers that may segregate individuals within these categories would be of considerable value in future investigations to ascertain who might convert to AD and who might be selected for or might benefit from early treatment. The study was approved by the Institutional Review Board of the Albany Medical College. Data were recorded from 19 electrodes over frontal, central, temporal, and occipital scalp locations using an electrode cap. Standard and target stimuli were randomly presented tones (standard: 250 Hz, 80% probability; target: 250 Hz base frequency +6 JNDs; 20% probability) 50 ms in total duration. Individuals used a button press to indicate target selection. Raw electroencephalographic (EEG) data were stored on a trial-by-trial basis over a 2 s period (1 s, prestimulus baseline, 1 s poststimulus interval) and were analyzed off-line in the time and frequency domains. Time domain averaging localized two main peaks: a negative peak between 80-200 ms and a positive peak between 250-600 ms, which were maximum over central/midline scalp locations (Fz, Cz, Pz). Spectral analysis assessed for event-related synchronizations (ERSs) and event-related desynchronization (ERDs) of locked and unlocked activity. A 3-way ANOVA (group x peak x channel) found that only latency values in the time domain were significantly different between groups. Discriminant analysis using latency values, stimulus conditions, and electrode locations as factors had a 17.4% error rate in classifying individuals as control or MCI (13/15 controls; 11/14 MCIs). Using the crossvalidate option in Statistical Analysis Systems (SAS) program, the error rate was 34.8%, suggesting that the classifier does not generalize well in this sample. The discussion will focus on the significant differences observed between normal aged and MCI groups, the implications of these results, and issues involved in crossvalidation.

Electrophysiological Correlates of Auditory and Visual Recognition Memory in Normal Aging and Individuals with Minimal Cognitive Impairment

Anthony T. Cacace¹, Dennis J. McFarland², Earl Zimmerman¹, Dzintra Celmins¹

¹*The Neurosciences Institute and Advanced Imaging Research Center, Department of Neurology, Albany Medical College, Albany, USA*

²*The Wadsworth Labs, New York State Health Department, Albany, USA*

In the earliest phases, Alzheimer's disease, related dementias and/or prodromal states impair the ability to encode and retain new events over time; a topic subsumed under the rubric of "episodic" memory. Accordingly, examining the electrophysiological correlates of episodic memory is a reasonable approach to detect and monitor change in these conditions. The differential effects of the disease state on cognition were assessed by examining the auditory and visual recognition memory (encoding and recognition) for concrete nouns using reactive changes of electroencephalographic (EEG) rhythms in the frequency domain. Two groups of individuals were studied: normal aged (mean age 65 years) without complaints of cognitive dysfunctions and individuals diagnosed with minimal cognitive impairment (MCI) (mean age 67 years). Data were recorded from 19 electrodes over frontal, central, temporal and occipital scalp locations. Raw EEG data were stored on a trial-by-trial basis over a 4 s period (2 s, prestimulus baseline, 2 s poststimulus interval). The study was approved by the Institutional Review Board of the Albany Medical College. The encoding stage required individuals to remember 25 concrete nouns presented sequentially. The recognition stage consisted of 50 additional words; 25 of which were new (never presented); 25 of which were old (retained from the initial list). The recognition task was to indicate by button press, if the words were old or new. The EEG was examined by means of an autoregressive spectral analysis, in 3 Hz spectral bands between 1 and 31 Hz. The analysis evaluated the encoding and recognition aspects of this task and considered interval prestimulus vs. poststimulus), modality (auditory vs. visual), electrode location, frequency band, and whether the words were old or new. The results indicated that EEG activity during encoding stage did not differentiate between groups. In contrast, during the recognition phase, individuals with MCI show a greater event related desynchronization of EEG activity to the words at approximately 7 Hz, an effect that was maximum at the central/midline scalp location, Pz. This effect was not specific to stimulus modality of presentation or to whether the word was old or new.

Cortical Auditory Evoked Potentials Evoked by Speech in Cochlear Implant Subjects are Affected by Acoustic Preprocessing

Ulrich Hoppe¹, Torsten Wohlberedt¹, Frank Digeser¹, Horst Hessel²

¹Department of Audiology, ENT Clinic, University of Erlangen, Erlangen, Germany

²Cochlear GmbH, Hannover, Germany

Cochlear Implant (CI) fitting is the optimization of speech perception by modification of a number of usually interdependent parameters. It is based upon the subjective statements of the patients about their hearing impression with respect to speech understanding, loudness perception and the sound quality. Several investigations have shown that cortical auditory evoked potentials (CAEP) can be elicited by speech syllables in cochlear implantees. Since CAEP allow the investigation of the auditory speech processing without the patients' collaboration they may be helpful for retrieving objective data. The aim of the study was to investigate the influence of acoustic preprocessing as syllabic compression on CAEP evoked by speech. CAEP were recorded in ten subjects provided with a nucleus ESPRIT3G speech processor and in five normal hearing subjects at four electrode locations on the scalp (Cz, Fz, Fc1, FC2). One sinus burst (1 kHz, 300 ms, 65 dB) and two speech syllables /ta/ and /da/ were presented at 65 dB SPL via loudspeaker. Both speech stimuli were presented with and without syllabic compression. Additionally, psychoacoustic discrimination tests were performed for the CVs. In all subjects CAEP were measured reliably with the known N1-P2 complex. Compared to the normal hearing listeners latencies were significantly prolonged in the CI group while peak-to-peak amplitudes did not differ significantly between the groups for all investigated stimuli. Syllabic compression decreases latencies of N1 and P2 of both normal hearing subjects and CI listeners. CAEP amplitudes however, are affected differently: While N1 and P2 amplitudes in the normal hearing group are increased by the syllabic compression, CI listeners exhibit slightly smaller amplitudes. Most of the CI subjects were not able to discriminate the speech syllables even when the syllabic compression was used. The study demonstrates that CAEP evoked by speech can be reliably recorded and that they are sensitive against the acoustic preprocessing in cochlear implant subjects. They may be used for evaluation of cochlear implant benefit and the selection of the appropriate preprocessing.

The study was supported by a grant from Cochlear GmbH, Hannover, Germany.

Driving while Listening – Multi-Tasking Mayhem: Analysis of Event-Related Potentials

Curtis W. Ponton¹, Elais M. Ponton²

¹Compumedics Neuroscan, University of Texas at El Paso, El Paso, Texas, USA

²Human Auditory Physiology Laboratory, University of British Columbia, Vancouver, British Columbia, Canada

Due to the rapid evolution of technology, complex behaviors, such as listening to conversation on a cellular phone while driving, are often combined. The technological advances that allow multi-tasking at times outstrip the human brain's capacity for attending to and performing simultaneous complex behaviors proficiently. When, for example, cellular phone use and driving are combined, the deterioration in driving performance can have serious and potentially fatal consequences. Over a four year period, we examined the processes underlying this form of multi-tasking, both behaviorally and neurophysiologically. Data present at the IERASG Tenerife conference (2003) examined multi-tasking by simulating simultaneous driving and hands-free cellular phone use. Results showed that for auditory ERPs to categorization of isolated words, longer latency potentials associated with higher cognitive processes like memory were attenuated when the driving simulation was performed concurrently. The latest studies assessed continuous auditory processing using a seven number, digit-span task performed in isolation, while listening to music, while driving, or all simultaneously. Like earlier studies, this experiment demonstrated impaired driving performance with multi-tasking. However, pronounced decrements were also found in behavioral memory function as well as with many measures of neurophysiological activity while multi-tasking. Behaviorally, the concurrent presentation of music had little impact on digit span recall, while the driving task significantly reduced recall at every serial position in the digit span list. Electrophysiologically, music significantly attenuated the early sensory evoked potentials (< 150 ms) but had only a minor impact on later cognitive potentials. In contrast, simultaneous driving had little impact on the sensory potentials but resulted in a large, significant reduction in later cognitive potentials. The results of these experiments confirm the negative impact of multi-tasking and divided attention interference and provide new insights into changes in brain activity observed when performing complex tasks in isolation and simultaneously.

Driving While Listening – Multi-Tasking Mayhem: Analysis of Spectral Data

Curtis W. Ponton¹, Elais M. Ponton²

¹*Compumedics Neuroscan, University of Texas at El Paso, El Paso, Texas, USA*

²*Human Auditory Physiology Laboratory, University of British Columbia, Vancouver, British Columbia, Canada*

In this study of multi-tasking, not all experimental conditions generate evoked potentials. Unlike discrete auditory events, conditions based on continuous stimulation such as navigating simulated driving environments are unsuitable for evoked measures of brain activity that require time and phase locking to stimulus onset. Even within the auditory domain, certain aspects of cognitive processing may be more evident within induced spectral changes rather than evoked brain activity. Such oscillatory or spectral activations may be enhanced or suppressed by task-induced cognitive processing. In this study of multi-tasking with simulated driving and cell phone use, possible changes in induced cortical activity were recorded for the primary tasks performed in isolation and in combination. For analysis, the EEG was divided spectrally into the traditional 5 bands of delta (0.5–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), beta (13–29 Hz) and gamma (30–50 Hz). Results demonstrated that brain states or cortical oscillation patterns observed with optimal performance when completing the digit span task alone (high theta/alpha and beta) or the driving simulation alone (high beta and gamma), were altered substantially when were performed simultaneously. Most notably, the oscillatory activity bordering the theta/alpha frequency range, which was often visible in real time EEG recording during the digit span task, was strongly suppressed when the driving task was performed concurrently. Suppression of the “optimal” states of brain activity observed during multi-tasking was correlated with degraded behavioral performance on the simultaneously performed driving and digit span tasks. These results strongly demonstrated that induced as well as evoked cortical activity along with behavioral performance is disrupted or sacrificed when multi-tasking. In conclusion, these data provide clear evidence that current efforts to limit or ban cellular phone use while driving are justified, not only by accident statistics, but also by controlled scientific measures of performance and brain activity

Selective Attention Increases the Temporal Precision of the Auditory N₁₀₀ Event-Related Potential

Roger Thornton

MRC Institute of Hearing Research, Southampton, United Kingdom

Selective attention increases the amplitude of the averaged N₁₀₀ event-related potential (ERP). This increase may result from more neurons responding to the stimulus or from the same number of neurons better synchronised with the stimulus, or both. We investigated the synchronization mechanism using a new response latency jitter measurement algorithm that performed well for all the signal-to-noise ratios obtained in the experiment. We found that the significantly increased N₁₀₀ amplitude is accounted for by a significantly decreased latency jitter variance for the attended stimuli.

ABR and Regeneration of Inner Ear Hair Cells in Gentamicin-Treated Cod (*Gadus Morhua*)

Niels Christian Stenklev¹, Karine Faucher², Øyvind Aas-Hansen², Torgrim Fuhr¹,
Børge Damsgård², Einar Laukli¹

¹ENT Department, Institute for Clinical Medicine, Faculty of Medicine, University of Tromsø, Tromsø, Norway

²Norwegian Institute of Fisheries and Aquaculture Research, Tromsø, Norway

Background. The ABR on the Atlantic cod can be done in a reproducible manner using a standardized setup, which can be used to study environmental influences of cod inner ear hair cells.

Method. 32 adult animals in the 1–2 kg size were included in the study. They were stratified into four groups (n = 8 in each): one group receiving a bath of gentamicin and streptomycin, one receiving two intravenous injections of gentamicin 40 mg/kg, and two control groups. The fishes were sedated and fixated at approximately 5 centimeters' depth in a 32-liter tank. The stimuli were series of 2000 five-cycle (2-1-2) 250 Hz tonebursts delivered from a Brüel & Kjær loudspeaker. Responses were measured using a filter setting of 30–3000 Hz and a gain of 100,000. Responses were visually interpreted using the Bio-Logic AEP software. Stimulus level was reduced until threshold was attained. Scanning electron microscopic studies from some of the fishes' inner ears were done at different intervals after the intervention. All groups were studied at 10 and 16–20 days after the intervention.

Results/Discussion. Hearing thresholds at 10 days after the intervention were not significantly different between the drug bath group and the control groups. The intravenous gentamicin group, however, had significantly increased 250 Hz hearing thresholds at 10 days after the intervention, compared to other groups. One fish in the intravenous gentamicin group returned to normal hearing thresholds at 17 days post-intervention. Scanning electron microscopy showed evidence of inner ear hair cell destruction and regeneration of the intravenous gentamicin-treated fish. The ABR reflects inner ear function, not lateral line response, in the cod. The destruction and regeneration of the inner ear in cod can be studied by the ABR.

Auditory Training and the P1-N1-P2 Complex: Age and Stimulus Effects

Kelly Tremblay ¹, Bernhard Ross ², Terence Picton ²

¹*University of Washington, Seattle, Washington, USA*

²*Rotman Research Institute, Toronto, Ontario, Canada*

In a series of past experiments, we and others examined the effects of auditory training on P1-N1-P2 cortical evoked responses recorded in young normal hearing listeners. A consistent finding was that P2 amplitude increased following training. A typical interpretation of this result was that auditory training alters the physiological representation of the acoustic cue being trained. However, it is also possible that training-related changes in P2 amplitude reflect other, non auditory specific processes that are associated with training; such as stimulus exposure and task execution. In this experiment we examined the effects of auditory training on the P1-N1-P2 complex for younger ($n = 10$) and older ($n = 10$) listeners. Using simultaneously EEG/MEG recordings, we recorded two pre-training baseline measures as well as one post-training measure (following five days of training). Compared to the older adults, younger adults showed greater perceptual improvements with training. Older adults showed fewer changes in P2 amplitude as well. Three additional findings were: 1) Modulations in P2 amplitude were not limited to the stimuli being trained; increased P2 amplitudes were observed in response to a noise burst stimulus that was not used during training. 2) The morphology of the evoked responses appeared different for younger and older adults, pre- and post-training. 3) Each age group was differentially affected by repeated stimulus exposure. Collectively, these results suggest that modulations in P2 amplitude are not specifically related to the perception of the trained cue, and that auditory experience/exposure affects younger and older listeners differently.

Auditory Brainstem Response Asymmetry Following Monaural Long-Term Hearing Aid Experience: Evidence of Brainstem Plasticity In Adults?

Kevin J. Munro¹, Nataliya Y. Pisareva¹, David J. Parker¹, Suzanne C. Purdy²

¹*School of Psychological Sciences, University of Manchester, Manchester, United Kingdom*

²*Department of Psychology, University of Auckland, Auckland, New Zealand*

A number of studies have reported perceptual changes in adult humans following long-term hearing aid experience. These perceptual changes are consistent with reorganization within the central auditory system; however, few studies have directly measured neurophysiological changes following provision of a hearing aid. This study measured the auditory brainstem response in 17 adults with an acquired, symmetrical hearing-impairment, 8 of whom were experienced users of a monaural hearing aid. The stimulus was a 0.1 ms rarefaction click presented at 70, 80 and 90 dB nHL. Wave V amplitude of the auditory brainstem response was significantly larger in the ear with hearing aid experience. Thus, the 'passive' auditory training provided by a hearing aid is sufficient to induce reorganization at the level of the brainstem in adult humans. This finding is consistent with behavioural studies that show perceptual changes in adult humans following experience of a monaural hearing aid. Therefore, hearing aids may be a useful tool for modifying and exploring the central auditory system in adult humans.

Objective Evaluation of Sound Discrimination of CI-Patients in Noise

Martin Walger^{1,2}, Peter Igelmund¹, Hartmut Meister², Anke Brockhaus-Dumke³,
Dirk Fuerstenberg¹, Hasso von Wedel¹

¹ENT Department and Cochlear Implant Center,

²Jean-Uhrmacher-Institute for Clinical ENT Research, and

³Department of Psychiatry and Psychotherapy, University of Cologne, Cologne, Germany

For CI patients, hearing in noise is a general problem. Evaluation of hearing and understanding in noise is usually evaluated with subjective audiological tests. Our project aims at establishing cortical auditory evoked potentials (CAEP), especially event-related potentials (ERP), as objective measures of auditory discrimination ability in noise. The results of the study are intended to establish a basis for objective evaluation of auditory skills in non-cooperative patients such as infants and patients with multiple handicaps. CAEP's were recorded from postlingually deafened CI patients under different signal to noise ratios with two EEG systems: a 32 channel Neuroscan 32 (Neuroscan) working with electrode impedances below 5 kOhms and 2) a 128 channel GES 250 (Electrical Geodesics) working with electrode impedances in the range of 50 kOhms. We used an oddball paradigm with tonal stimuli and speech sounds. Stimuli were presented via free field loudspeaker at 30 dB SL using the software 'Presentation' (Neurobehavioral Systems). For direct comparison of CAEP parameters with discrimination abilities, the subjects also underwent psychophysical experiments. A major problem in recording CAEPs from CI patients are electrical artefacts resulting from the activity of the implant which appear in the averaged responses from electrodes near the device. In spite of the short stimulus duration (80 ms for the tonal stimuli), the artefacts lasted for more than 1 s. With the GES 250 system, the amplitudes of the artefacts were severalfold higher as compared to the Neuroscan system. In addition, the spatial distribution of artefact-contaminated electrodes differed between the two systems. Contralateral to the device we could record N1/P1 and P300 components in all patients. First results are presented and discussed.

Supported by the Marga und Walter Boll Foundation and Cochlear Europe Ltd.

Application of Electrically Evoked Compound Action Potential Recordings for Patients with Cochlear Implants

Dillier Norbert

University of Zurich, Zurich, Switzerland

Recent advances of electrically evoked compound action potential (ECAP) recordings in patients with cochlear implants which can be obtained either intraoperatively or postoperatively in short time using a variety of stimulus conditions have provided more detailed information about the status and variability of the auditory nerve elements and thereby assisted the speech processor fitting process especially for very young children. In addition to using ECAP measurements for threshold profile determination, these electrophysiological measurements also allow monitoring of long term changes in stimulation conditions, investigations of electrode and field interactions and optimization of stimulation rate and selection of stimulation electrodes. It has been shown in a number of studies that different implant users prefer different settings for rate of stimulation and other parameters of coding strategies. One possible conclusion of these observations is that for higher stimulation rates, neural adaptation and fatigue effects should be considered and may play an important role in the observed differences and variations between objective performance results and subjective preferences.

Electrophysiologic Monitoring of the Auditory Nerve before and during Cochlear Implantation

Branka B. Geczy¹, Jagoda Vatovec¹, Dušan Butinar²

¹Department of Otorhinolaryngology and Cervicofacial Surgery and

²Institute of Clinical Neurophysiology, Division of Neurology, University Medical Centre Ljubljana, Ljubljana, Slovenia

Background. Electrical auditory brainstem response (EABR) is an electrophysiologic measure used for pre-operative evaluation of candidates for cochlear implantation. Direct responses of the auditory nerve to electric stimuli are recorded. Neural response telemetry (NRT) is an indirect measurement of electrically evoked action potentials of the auditory nerve through the cochlear implant. It is performed in the operating room or after surgery.

Methods. Results of EABR and NRT measures performed in cooperation with a neurophysiologist are reviewed. In the period of 2002–2006, 42 children received *Nucleus implant* which allowed NRT measurement. There were 17 boys and 25 girls, aged 8 month to 14 years.

Results. EABR were recorded in 52% of tested patients, responses were mostly unilateral (91%). NRT reviewed a stimuable auditory nerve in 86% of tested patients.

Conclusions. EABR provide the clinician with a valuable tool for selecting the most appropriate ear for implantation. NRT provides information for the initial fitting of the speech processor, especially in small children who are unable to cooperate during the fitting. The results of this measurement are especially valuable in cases where stapedius reflex during surgery is absent. NRT also provide reassurance that the implant is functioning and enable us the follow-up of auditory nerve response changes during rehabilitation.

Various Models of Intraoperative Monitoring of Auditory Function in Patients with Cerebello-Pontine Angle Tumor

Krzysztof Morawski¹, Kazimierz Niemczyk¹, Jorge Bohorquez², Fred Telisch^{2,3}

¹Department of Otolaryngology, Medical University of Warsaw, Poland

²Department of Biomedical Engineering and

³Department of Otolaryngology Ear Institute, University of Miami, Miami, Florida, USA

Three strategies of intraoperative monitoring (IM) of auditory function during cerebello-pontine angle tumor (CPAT) surgery: transtympanic electrocochleography (TT-ECoChG), auditory brainstem responses (ABR), and distortion product otoacoustic emissions (DPOAEs).

Methods and Measures. Patients with CPAT were monitored intraoperatively using TT-ECoChG, ABR, and DPOAEs. ABR and TT-ECoChG were elicited acoustically by clicks (75–85 dB nHL) and DPOAEs were obtained using two primary tones (L1,L2 – 60 to 70 dB SPL; F1,F2 – 2.0 to 5.0 kHz). In all TT-ECoChG monitored patients the following components of compound action potential (CAP) were analyzed: N1-amplitude, N1-latency, summation potential (SP). In ABR subjects waves III and V were analyzed. Amplitude and phase of DPOAE were monitored as a measure of cochlear status intraoperatively.

Results. Clear and repeatable CAPs in TT-ECoChG strategy were obtained after 64–128 samples averaged. TT-ECoChG morphology, including N1-amplitude, N1-latency and SP, were displayed and sufficiently analyzed on-line every 3–6 s. Interpretable ABR waveforms required at least 256 (and frequently more) samples during critical moments of tumor removal. DPOAE phase fluctuations were quicker to change at the onset of changes in cochlear function while amplitude measures were better in evaluation of recovery of cochlear function. DPOAE strategy reflecting cochlear activity also needed ABR as a supporting tool for effective IM of hearing.

Conclusions. TT-ECoChG and DPOAE effectively recorded even minimal changes in peripheral part of auditory function in real time but needed to be supported by ABR when dissection involved the more distal parts of cochlear nerve and brainstem. Clinical Significance of Study: TT-ECoChG/ABR or DPOAE/ABR strategy may serve as the most effective tool for intraoperative monitoring of auditory function during CPAT surgery.

Support. KBN – Poland, Grant No 4 P05C 056 17.

An Attempt to Use Click ABR to Predict Uncomfortable Loudness Levels

Matthew G. Evans

Audiology Department, Royal Berkshire NHS Foundation, NHS Trust, Reading, Berkshire, United Kingdom

The Uncomfortable Loudness Level (ULL) is an important measure for use in hearing aid fitting to set maximum output levels preventing aided discomfort to loud sounds. In current clinical practice, ULL's are obtained subjectively. This method is known to have a high degree of inter- and intra-subject variability and may not be suitable for use in some subject populations, such as young children. Many researchers have attempted to determine an objective method for ULL prediction, which is suitable for use in clinical practice. Thornton et al., 1989 used the Auditory Brainstem Response (ABR) wave V latency-intensity function slope to predict ULL to within ± 6 dB for 90% of subjects. The present study aimed to further investigate the use of ABR waveform parameters to predict ULL. The utility of wave amplitude, latency and input/output function slope for waves I, II, IV and V were examined. Click-evoked ABRs were recorded from 15 normally hearing subjects, using an ear canal electrode at intensities relative to their subjectively measured ULL. This type of electrode was used in order to enhance ABR wave I. Four waves were consistently identified (waves I, II, IV and V), and their parameter values recorded. The results were applied to the model established by Thornton (1989) to predict subjective ULL. In this study, the ULL could be predicted to within ± 5 dB for 16.67% of subjects. The results were then used to construct parameter slope-intensity functions. Those functions which showed a statistically significant Pearson correlation between parameter values and intensity were used to predict ABR derived estimates of ULL for individual subjects. Comparison of ABR derived estimates and subjectively measured ULL values showed that best predictive ability was obtained using the wave IV latency slope-intensity function. This was able to predict ULL to within ± 10 dB of measured values for 76.67% of subjects, with a maximum error of 28.69 dB, much inferior to that obtained by Thornton et al., (1989). In contradiction to the work of Thornton (1987, 1989) we were unable to reliably predict ULL with sufficient accuracy for use in clinical practice. However, the results do warrant further development of an extratympanic EcochG technique explore the potential ability to predict ULL.

Auditory Steady-State Responses in Normal Hearing Adults: A Test-Retest Reliability Study

Wendy D'haenens, Ingeborg Dhooge, Bart Vinck

Ghent University, Ghent, Belgium

The auditory steady-state response (ASSR) has emerged as a useful diagnostic tool to assess hearing sensitivity in a frequency specific manner. The accuracy of ASSR threshold estimations and the test-retest reliability of ASSR are two important issues when clinical implementation is considered. However, the latter has received only limited attention in the published ASSR literature. The purpose of the present study is therefore to assess the test-retest reliability of the multiple ASSR technique in normal hearing adults. A total of 29 participants (15 females, 14 males) between the ages of 18 and 30 years contributed to 2 sessions (test/retest). Exponential envelope AM²/FM stimuli were offered binaurally at multiple carrier frequencies (CF) of 500, 1000, 2000, and 4000 Hz with modulation frequencies ranging from 82–110 Hz. ASSR thresholds were estimated with a descending search protocol using a 10-dB precision. The test-retest reliability was assessed via Pearson product-moment correlation analysis. The mean correlation coefficients across all intensities were high for response amplitude ($r = 0.94$) and lower for EEG noise ($r = 0.67$). The correlations for pure-tone audiometric thresholds ranged from 0.36 to 0.73 for each single octave frequency from 250 to 8000 Hz. The correlation coefficients for ASSR thresholds were 0.55 for 1000, 2000, 4000 Hz CF and 0.34 for 500 Hz CF. The difference between ASSR and behavioural thresholds were calculated and demonstrated no significant difference between the test and retest session. The mean (± 1 SD) difference thresholds were 19 ± 12 , 14 ± 10 , 11 ± 9 , 14 ± 9 dB for 500, 1000, 2000, and 4000 Hz CF, respectively. Determining the difference in ASSR thresholds between test and retest is important to establish the normal variability between test sessions. Therefore, ASSR thresholds obtained during test and retest were subtracted and the absolute values of these differences were used for descriptive analysis. The mean differences (± 1 SD) were 9 ± 8 , 7 ± 6 , 6 ± 5 , 6 ± 6 dB for 500, 1000, 2000, and 4000 Hz CF, respectively. This investigation shows that the multiple ASSR technique produces clinically acceptable test-retest reliability for normal hearing adults.

Improving Recording and Stimulus Conditions of ASSRs in Infants and Adults

Christoph van der Reijden, Lucas Mens, Ad Snik

Radboud University, Nijmegen Medical Centre, Nijmegen, The Netherlands

Objective. To reduce recording time by identifying stimulus conditions and EEG derivations that yield Auditory Steady-State Responses (ASSRs) with high signal to noise ratios (SNRs) in adults that were awake or asleep and in infants aged 0 to 5 months that were asleep.

Method. ASSRs were recorded with ten-channel EEG registration. Stimuli were tones of 500 Hz or 2 kHz that were 100% amplitude modulated with 40 Hz or 90 Hz, and 20% frequency modulated (MM stimulus). A second type of stimulus used multiple carriers at a distance of twice the modulation frequency (ES stimulus). The presentation level was 20 dB SL in adults and 65 dB SPL in the infants.

Results. In infants, the 2 kHz ES-stimulus amplitude modulated with 90 Hz, produced significantly larger responses than those produced by the MM stimulus. However, with 500 Hz, the MM stimulus produced significantly larger responses than the ES stimulus. Large SNRs were obtained from ipsilateral mastoid referenced to Cz, Pz or inion. In awake adults, responses to the 2 kHz ES stimulus amplitude modulated with 90 Hz, were significantly larger (60–80%) than those that were evoked with the MM stimulus. Responses to the 500 Hz ES-stimulus improved systematically (about 10–15%) but not significantly compared to responses to the 500 Hz MM stimulus. ES stimuli of 500 Hz and 2 kHz amplitude modulated with 40 Hz, produced on average 1.8 times larger SNRs than with 90 Hz amplitude modulation (AM). These improvements were significant for the 2 kHz stimulus but not for the 500 Hz stimulus. The inion-Cz, neck-Cz and ipsilateral mastoid-Cz derivations produced these large SNRs significantly more frequently than other derivations. In sleeping adults SNRs of the responses to ES stimuli (500 Hz and 2 kHz) were significantly larger (on average 1.7 times) with 40 Hz AM than with 90 Hz AM.

Conclusions. Well-selected stimulus and recording parameters produced ASSRs with high SNRs. These parameters differed between the adults and the infants. Significance: Stimuli can only be improved if the responses are large enough to detect significant differences between stimulus conditions. Recording time of ASSRs can be reduced significantly using improved stimuli.

ASSR and Tone-Burst Evoked ABR. A Comparison

Ann Iren Hugstmyr, Einar Laukli

Department of Otorhinolaryngology, University of Tromsø, Tromsø, Norway

Objective threshold evaluations using electrophysiological methods have been suffering from the lack of frequency specificity. There is a great need for an objective audiogram when fitting hearing aids in the youngest children. The development of ASSR has been promising, but more studies are needed to control for the actual frequency specificity in different cases of hearing loss with variation in degree and configuration. The conventional ABR has a lower degree of frequency specificity even with the use of tone-bursts, and more or less the frequency range around 2–4 kHz is evaluated even with tone-bursts outside this area. We have used a 4 kHz conventional 2-1-2 tone-bursts and made comparison with ASSR at frequencies 2 and 4 kHz. The two methods were compared in a clinical setting measuring children with a suspected hearing loss. The ASSR included all four frequencies 0.5–4 kHz, but only the results of the two upper frequencies will be presented here. The results of 37 children, one measured twice, altogether 76 ears show a slightly lower response threshold for the conventional ABR. There may be different explanations for this discrepancy. We have not searched for thresholds lower than 20 dB nHL, and the quite complex ASSR stimuli may introduce some factors related to stimulus level control. The mean difference in threshold of 5–10 dB must be taken into consideration when making the choice of method for the higher frequency measurements. The situation in the lower frequency range has also to be evaluated.

How Does the ASSR Response Amplitude Vary with Modulation Rate for Individual Babies?

Siobhán Brennan, John Stevens

Department of Medical Physics and Clinical Engineering, Royal Hallamshire Hospital, Sheffield, United Kingdom

The ASSR amplitude varies with modulation rate. In a study on adults (Foster 2003) it was shown that this variation in amplitude with modulation rate differs between subjects. The variation was such that the choice of a suboptimum modulation rate could extend the recording time to achieve a set level of significance by several times. In earlier work, Dobie and Wilson (1998) also noted that individuals' optimum rates were quite variable and were not particularly consistent between trials. The duration of the test is critical to the application of ASSR in assessing the hearing threshold in babies. The selection of the optimum modulation rate for each individual baby is therefore also critical. The study on adults was therefore extended to look at the variation in ASSR amplitude with modulation rate between babies. The ASSR response was measured at modulation rates of 70, 75, 80, 85, 90, and 95 Hz to amplitude and frequency modulated 1 kHz and 2 kHz carrier frequencies using the MASTER (John and Picton 2000) research system. Although the study was limited compared to the study in adults, due to the shorter test times possible in babies, the results so far have shown that the relationship between response amplitude and modulation rate is variable between babies. This variation is sufficiently great to significantly effect test time. The lower modulation rates tended to give larger responses but there was no consistent pattern.

References:

- Foster MR. A comparison of auditory steady state responses and tone-pip auditory brainstem response in the measurement of hearing. MSc Project, University of Sheffield, UK, 2003.
- Dobie RA, Wilson MJ. Low-level steady-state auditory evoked potentials: Effects of rate and sedation on detectability. *J Acoust Soc Am* 1998; 104: 3482-8.
- John MS, Picton TW. MASTER: a Windows program for recording multiple auditory steady-state responses. *Comput Meth Prog Bio* 2000; 61: 125.

Clinical Usefulness of the MSSR to Air and Bone Conducted Stimuli in Normal Hearing and Hearing Impaired Children

Maria Cecilia Pérez-Abalo, Maria C. Hernández, Jose Gaya, Lidia Charro, Ernesto Rodríguez, Lilian Rioja, Maribel Ponce de León, Sandra Bermejo

Cuban Neuroscience Center, Havana, Cuba

The accuracy of multiple auditory steady state responses (MSSR) to estimate frequency-specific hearing thresholds for both air (AC) and bone conducted (BC) stimuli was evaluated. A second aim of this study was to examine the possibility of artefactual responses elicited by AC and BC stimuli (at moderate to high intensities) in the AUDIX system. Three groups of children (between 3–14 years old) were tested: G1) Normal hearing children N = 15; G2) Children with conductive hearing losses N = 15; G3) Cochlear implant candidates with severe to profound hearing losses N = 15. The behavioural audiometric thresholds (BHT) and the frequency specific ASSR thresholds (RTH) elicited by single and multiple AC (and BC) stimuli were determined in all children. Also the test/retest reliability of the AC-MSSR audiometry (after one year elapsed) was examined in a subset of G3. In all, a reasonable close correspondence was found between the behavioural and the physiological thresholds to both AC and BC stimuli in normal and hearing impaired children. On average the MSSR thresholds were 12–19 dB above the corresponding behavioural thresholds for AC-stimuli and 10–13 for BC-stimuli in normal hearing children. These differences (RTH-BTH) were smaller in the hearing impaired group: 6–10 for the AC-stimuli and 5–12 for the BC stimuli. Also in both groups the ASSR air-bone gap correlated significantly with the corresponding behavioural estimate. Although most children in G3 showed absent responses at high intensities (AC 100–110 dB, BC 55–60 dB) there were very few artefactual responses in the recordings to the AC-stimuli and none for BC stimuli. In conclusion the MSSR technique can provide reliable estimates of the AC and BC hearing thresholds, and the air-bone gap in normal and hearing impaired children.

Evaluation of Differences between Audiometric and ASSR Thresholds

Lech Śliwa, Krzysztof Kochanek, Anna Piotrowska, Adam Piłka, Henryk Skarżyński

Institute of Physiology and Pathology of Hearing, Warsaw, Poland

Clinical application of Auditory Steady State Responses (ASSR) has widened in recent years due to technological advances and growing availability of instrumentation. However, accuracy and reliability of the method still need to be investigated. The aim of the study was to determine the differences between audiometric and ASSR thresholds and assess threshold variability in groups of normal subjects and patients with sensorineural hearing loss. Three different devices were used in the tests: GSI Audera, BioLogic MASTER, and GN Otometrics Chartr EP. ASSRs were measured at four audiometric frequencies using procedures recommended by manufacturers. Additionally, ASSR thresholds were compared against ABR thresholds. The investigation showed that the average difference between actual and estimated thresholds can be made low, provided test conditions are adequately controlled. However, significant differences between PTA and ASSR thresholds may appear in individual cases irrespective of the applied measuring system. Intra- and intersubject variability of the ASSR thresholds is also meaningful. The estimation of audiometric threshold based on ASSR measurement must take into account the specificity of the patients' population and the applied signal detection method. Threshold variability must be considered as a factor limiting estimation accuracy.

RAMPER: Effects of Intensity Ramp Duration on Threshold Estimation

Michael Sasha John, Terence Picton

The Rotman Research Institute, Toronto, Canada.

This study investigated performance of a novel technique for assessing frequency specific hearing thresholds. The technique used RAMP-Evoked Response (RAMPER) data of 10 normal hearing adults which were elicited by four amplitude-modulated (exponential envelopes) tones (0.5, 1, 2, and 4 kHz). Similar to the MASTER technique, the tones were each modulated at a unique rate between 80 and 110 Hz and were simultaneously presented to each ear. The intensity of the amplitude-modulated tones followed a continuously rising linear (dB) ramp function which spanned from 20–70 dB over a period of N seconds, and which was followed by a falling ramp function (forming a symmetrical ramp function spanning $2N$ seconds). Because the intensity of the stimuli changes over time the technique uses time-frequency analysis: in this case a spectrogram derived using Short-Time Fourier Transforms of a moving 1.024 second window. We investigated the effects of setting N at 2, 4 and 8 seconds. Slopes of the amplitude-intensity functions (and phase-intensity functions) were not found to be statistically different for any of the ramp durations, or between RAMPER data collected to rising and falling intensity ramps. Hearing threshold values predicted from the 3 different RAMP durations were not found to be significantly different, although threshold estimates at 500 Hz tended to slightly higher for 8-second ramps compared to the 4-second ramps. The differing ramp durations therefore did not seem to alter the test results much. However, inter-subject threshold estimates, and intra-subject phase variance, were both found to be smaller for the shorter ramp. While shorter ramp durations provide a smaller number of discrete responses for a given intensity range, the SNR of these responses will be improved compared to responses derived by longer duration ramps. It is proposed that this characteristic of shorter duration ramps may be advantageous for test performance.

Evaluating Speech Understanding by Means of Suprathreshold ASSR

Jane Alaerts, Heleen Luts, Jan Wouters

ExpORL, Dept. Neurosciences, K. U. Leuven, Leuven, Belgium

Auditory steady-state responses (ASSRs) have proved their importance in the neonatal population as an objective technique to assess hearing thresholds. Recent studies have shown that ASSR is correlated with the discriminability of speech, but this application has not been implemented in clinical practice. However, an objective test that gives useful information about suprathreshold hearing abilities is needed. Up till now, speech understanding skills can only be assessed by means of behavioral speech audiometry, but this is not feasible in children before the age of 3 to 4 years. As ASSRs reflect the ability of the brain to detect changes in frequency and amplitude, recordings of ASSRs to modulated suprathreshold stimuli may provide an objective measurement of the processes needed in the initial stages of speech perception. As modulation frequencies below 50 Hz are highly important for speech perception, a pilot study was performed in order to assess the feasibility to record ASSRs within this range. To this end, a speech-weighted noise was modulated at 15 different modulation frequencies between 4 Hz and 32 Hz and ASSRs were recorded for every modulation frequency in adults. Although results revealed strong inter-subject variability, responses were consistently larger in the 10-Hz and 20-Hz region in all subjects. Subsequently, a second study was conducted in order to simulate behavioral speech-in-noise tests. The sensitivity of the brain to detect slowly amplitude-modulated noise signals (S) embedded within a stationary background noise (N) was investigated. Four modulated speech-weighted noise signals were created, with modulation frequencies of 4 Hz, 10 Hz, 20 Hz and 38 Hz. The modulated noise and the stationary noise were then unilaterally presented at different signal-to-noise ratios (SNR) between -15 dB and + 15 dB. Amplitude, noise and SNR of the ASSRs were calculated for every presented SNR of the input. The ASSR-results were then compared with results from psychophysical speech perception tasks. In this way, the relation between electrophysiological recordings and behavioral speech perception was evaluated. At the conference, results will be presented in more detail and the relevance of suprathreshold ASSR in a clinical setting will be discussed.

Estimating Bimodal Hearing Gain Using Auditory Steady-State Responses in Cochlear Implanted Children

Alberico Bojano¹, Tiziana Cotecchia¹, Vincenzo Pastore¹,
 Antonio Della Volpe², Nicola Mansi², Raffaele Izzo¹

¹Department of Audiology and Phoniatry, "Santobono Pausilipon" Children Hospital, Napoli, Italy

²Department of Otorhinolaryngology, "Santobono Pausilipon" Children Hospital, Napoli, Italy.

The aim of this study was to evaluate in an objective way the binaural-bimodal auditory gain in children users of unilateral cochlear implant (CI) with residual hearing in the opposite ear, in which they use a hearing aid (HA). Ten children (2 males and 8 females) suffering from bilateral, sensorineural, severe/profound hearing impairment of congenital origin were examined. All of them wear an unilateral cochlear implant and at the same time a digital behind-the-ear hearing aid in the non implanted ear. Per each patient the assessment was carried out using the auditory steady-state evoked potentials in free field mode (ASSR FF). Hearing gain was evaluated in 3 conditions during spontaneous sleep: cochlear implant alone, hearing aid alone, and cochlear implant in conjunction with hearing aid in the other ear. ASSR responses were evoked presenting the four amplitude-modulated carrier tones ranging from 50 to 100 dB HL per each ear. Only responses with a residual noise level < 0.1 were considered effective. The test evaluation indicated that cochlear implant use presented a complete hearing gain, comparable to a regular hearing activity of tested ear. The use of the alone hearing aid showed a limited gain on the only low frequencies. Study results allow one to suppose the presence of an additional effect derived by the simultaneous gain of both devices. Our findings suggest that binaural redundancy obtained by the additional effect of simultaneously wear of CI and HA may contribute to an improvement of speech intelligibility.

Effects of Broadband Noise on Speech Evoked Auditory Responses in Young Adults

Mridula Sharma^{1,2}, Katie Swaya¹, Suzanne C. Purdy^{1,2}, Andrea S. Kelly¹, Kevin J. Munro³

¹*The University of Auckland, Auckland, New Zealand*

²*Macquarie University, Sydney, New South Wales, Australia*

³*University of Manchester, Manchester, United Kingdom*

Young adults with normal hearing and no history of auditory processing disorder were tested to examine the speech evoked (/da/) obligatory cortical auditory evoked potentials (CAEP), P1-N1-P2, in the presence and absence of noise at three different loudness levels (soft, comfortable and loud). Latency was significantly increased by the presence of noise for N1–P2 at all three levels of loudness, compared to the quiet condition. Loudness level had a variable effect on amplitudes of different CAEP peaks. Latencies were more consistent, with generally increased latencies in noise. At the loudest presentation level, P1 was significantly larger when there was no noise (quiet condition) and this effect was also seen at softer levels. In contrast, N1 was larger for the quiet condition than in noise, but only at the two softer levels. Thus the effects of masking noise and stimulus presentation level on the CAEP waveform are complex and not simply additive. This has implications for studies exploring the effects of noise on evoked potential waveforms, for example as an objective index of auditory processing ability. Further examination of broadband noise effects on obligatory CAEPs is required, particularly in children for whom developmental effects may add additional complexity.

Auditory Event-Related Responses to Single Feature Changes in Continuous Stimuli I: Temporal and Place Coding with Frequency Change

Andrew Dimitrijevic, John-Yuhan Bai, Henry Michalewski, Fan-Gang Zeng, Hillel Pratt, Arnold Starr

University California Irvine, Irvine, California, USA

Previous work in auditory event-related potential (ERP) research has used stimuli that change in several features. For example, tone bursts in silence change in both intensity and frequency. In this experiment we examined ERPs that were elicited using stimuli that changes in only one feature – frequency. Stimuli were continuous pure tones with periodic changes in frequency lasting 100 ms. We used 2 sets of pure tones, both low (250 Hz) and high (4000 Hz) frequencies to examine cortical differences associated with sudden changes in temporal and place coding. The frequency changes varied in magnitude ranging from 0, 2, 4, 10, 25, to 50% increases from the base frequency. For example, a 10% change with the 250 Hz base frequency would represent stimulus change from a constant 250 to 275 Hz. We also examined conditions with continuous noise masking. Psychoacoustic thresholds for detection of frequency changes were also measured. A 64-channel recording system was used to measure ERPs that were elicited by the frequency change. Subjects were normal-hearing young controls. Changes in frequency resulted in N100s whose peak latencies were maximal at midline electrodes FCz and Cz. For the 250 Hz stimuli, N100s became smaller and later with decreasing frequency changes, however, with 4000 Hz, N100s became smaller in magnitude with minimal changes in latency. The use of a novel stimulus change, embedded in an otherwise continuous pure tone shows correspondence between physiological and psychophysical measures. ERP differences between 250 and 4000 Hz base frequencies suggest that low and high frequencies are differentially processed in the brain. Results are discussed in terms of spectral and temporal processing in the brain.

Work supported by NIH DC-02618.

Auditory Event-Related Responses to Single Feature Changes in Continuous Stimuli II: Temporal and Place Coding with Intensity Change

Andrew Dimitrijevic, Brenda Lolli, Henry Michalewski, Arnold Starr

University California Irvine, Irvine, California, USA

Previous work in auditory event-related potential (ERP) research has used stimuli that change in several features. For example, tone bursts in silence change in both intensity and frequency. In this experiment we examined ERPs that were elicited using stimuli that changes in only one feature – intensity. Stimuli were continuous pure tones with periodic changes in intensity lasting 100 ms. We used 3 sets of pure tones, 250, 1000 and 4000 Hz to examine cortical differences associated with sudden changes in temporal and place coding. The intensity changes varied in magnitude ranging from 0, 2, 4, 6, to 8 dB above the continuous pure tone which was presented at 80 dB SPL. A 64-channel recording system was used to measure ERPs that were elicited by the intensity change. Subjects were normal-hearing young controls. Changes in intensity resulted in N100s whose peak latencies were maximal at midline electrodes FCz and Cz. Smaller intensity changes with the low frequency (250 Hz) stimulus were associated with N100 changes in both amplitude and latency, whereas with 1000 and 4000 Hz stimulus frequency, N100 changes were seen with predominately with amplitude. The use of a novel stimulus change, embedded in an otherwise continuous pure tone shows correspondence between physiological and psychophysical measures. ERP differences between high and low frequencies suggest that low and high frequencies are differentially processed in the brain. Results are discussed in terms of spectral and temporal processing in the brain.

Work supported by NIH DC-02618.

Cortical Auditory Evoked Potentials Recorded with and Without Hearing Aids: Effects of Stimulus Intensity and Amplification

Curtis J. Billings, Kelly L. Tremblay, Pamela E. Souza

University of Washington, Seattle, Washington, United States of America

Hearing aid amplification can be used as a model for studying the effects of auditory stimulation on the central auditory system (CAS). However, to date, little is known about the effects of amplification on the neural representation of auditory stimuli. For the unaided ear, increasing the intensity of a stimulus results in increased peak amplitudes and decreased peak latencies. Whether or not these changes occur when stimuli are presented through a hearing aid is currently unknown. Therefore, we examined the effects of stimulus presentation level on the physiological detection of sound in unaided and aided conditions. We set out to determine if: (1) increasing stimulus intensities resulted in decreased latencies and increased amplitudes in both unaided and aided conditions, and if (2) aided and unaided intensity functions differed from each other. P1, N1, P2, and N2 cortical auditory evoked potentials (CAEPs) were recorded in sound field from 13 normal-hearing young adults in response to a 1000 Hz tone presented at seven stimulus intensities (30–90 dB in 10 dB steps). These stimuli were presented under unaided and aided conditions (approximately 20 dB of hearing aid gain was provided). A repeated-measures ANOVA revealed a main effect of intensity; that is, regardless of condition (unaided or aided), amplitudes increased and latencies decreased with increases in stimulus intensity. However, there was no main effect of amplification and no intensity x amplification interaction, suggesting that aided and unaided intensity functions did not differ significantly. These results raise new questions about the effects of amplification on CAEPs. Hearing aids increase the intensity of a signal; therefore, when compared with unaided responses, we might have expected to see larger amplitudes and shorter latencies in the aided conditions. These results demonstrate that 20 dB of hearing aid gain affects neural responses differently than 20 dB of stimulus intensity change. Hearing aid signal processing is discussed as a possible contributor to these results. This study demonstrates (1) the importance of controlling for stimulus intensity when evoking responses in aided conditions, and (2) the need to better understand the interaction between the hearing aid and the CAS.

Statistical Analysis of Cortical Waveforms Using MANOVA and Hotelling's t^2

Harvey Dillon¹, John Seymour¹, Maryanne Golding¹, Richard Katsch¹, Suzanne Purdy²

¹*National Acoustic Laboratories, Sydney, New South Wales, Australia*

²*University of Auckland, Auckland, New Zealand*

Assessment of whether an evoked cortical response is present can be difficult because the shape of the waveforms can vary markedly from person to person, from time to time for the same person, and with age until people reach adulthood. This paper describes a technique for determining statistically whether a response is present and a closely related technique for determining whether two cortical responses collected under different conditions are significantly different. The first step is the reduction of each recorded epoch to a small number of values that are sufficiently spaced in time that each value has some information not highly predictable from the other values. Typically we average all waveform amplitudes falling within adjacent time bins of duration 50 ms. The arrays from all epochs are then combined into a matrix, with one row per epoch and one column per time bin. To detect whether the average epoch for one condition is different than the average epoch for another condition, the two matrices are submitted to a standard MANOVA analysis in which the time bins (columns) form the variables, and the epochs (rows) form the repeated observations. MANOVA calculates whether there is any linear combination of the variables for which the mean value for the first response differs significantly from the mean value for the second response. No assumptions need be made about the specific shape, polarity or location of prominent peaks. The analysis automatically puts the greatest weight on those time bins in which the two responses are most reliably different from each other. The result of the calculation is the probability that the observed difference between the linear combinations of the variables arose from chance alone. To detect whether a response is present, the same pre-conditioning of the signal occurs, but the single matrix of values is subjected to the Hotelling's t^2 analysis. This statistic can be viewed as calculating the probability of any linear combination of the variables being significantly different from zero. For neither MANOVA nor Hotelling's t^2 , is it necessary that the variables be statistically independent.

Speech-Evoked Auditory Potentials in Cochlear Implant Listeners

Lendra M. Friesen¹, Kelly L. Tremblay²

*Sunnybrook & Women's College, HSC, Toronto, Canada
University of Washington, Seattle, Washington, USA*

The purpose of this study was to examine the effect of cochlear implant (CI) channel number on the neural representation of acoustic changes contained in speech. Eleven normal hearing monolingual English speaking adults were tested. Unprocessed naturally spoken syllables, containing medial vowels, as well as processed versions (simulating 2, 4, 8, 12, and 16 implant channels) were used for behavioral and electrophysiological testing. Behavioral results: Similar to our previously published findings, perception improved as a function of channel number (Friesen et al., 2001); however, the effect of channel number was not the same for all stimulus tokens. The perception of 'heed' for example was remarkably better than the perception of 'hid' with only 2 channels of information. Physiological results: Neural response patterns differed as a function of channel number. Evoked neural activity, in response to the acoustic changes contained in the speech signal, increased in amplitude and decreased in latency as the number of channels increased.

The Sensitivity of Hotelling's T2 in the Detection of Obligatory Cortical Auditory Evoked Potentials (CAEPs)

Maryanne Golding^{1,2}, Harvey Dillon^{1,2}, John Seymour^{1,2}, Lyndal Carter^{1,2}

¹National Acoustic Laboratories, Sydney, New South Wales, Australia

²The Cooperative Research Centre for Cochlear Implant and Hearing Aid Innovation, Melbourne, Australia

Obligatory CAEPs may vary widely in morphology between and within participants, particularly in infants. This makes the rigid application of a waveform template to aid in response detection ineffective. The clinician's decision making process for cortical response detection therefore takes place in the presence of some uncertainty, especially when the stimulus presentation level is close to threshold. The application of an appropriate statistic to determine the probability that a response is detected is therefore appealing. In a recent experiment, cortical responses were recorded from adults and infants in response to speech segments presented at sensation levels (relative to behavioural thresholds) ranging from +30 to -10 dB as well as non-stimulus trials. Each cortical response consisted of 100 to 200 artefact-free epochs and there were in total 200 cortical responses generated from the presentation of two speech stimuli, multiple presentation levels and combined participant groups. Each cortical response was wholly exported to MATLAB for statistical analysis using Hotelling's T2 and response detection was determined using multiple levels of statistical significance. In a second analysis, a sub-sample of artefact-free epochs from each cortical response was also exported to MATLAB for analysis. Averaged waveforms that were generated from the complete set of epochs and the sub-set of epochs for each cortical response were also presented to human experts for evaluation. Their task was to determine if a cortical response to auditory stimulation was evident or not, and to rate their degree of certainty in making their decision. The sensitivity and specificity of both methods of cortical response detection (i.e. statistical versus human expert), for complete and subsets of epochs, were compared by generating Receiver Operating Curves (ROC) from which discriminability index (d') values, which estimate various hit rate and false alarm rate combinations, were calculated. Hotelling's T2 was more accurate in discriminating a cortical response from no response, than the expert human observers.

Keynote Lecture I

Neonatal Hearing Screening. The Choice of Method in the First Evaluations: TEOAE or AABR or Something Else?

Einar Laukli

Department of Otorhinolaryngology, University of Tromsø, Tromsø, Norway

Neonatal hearing screening programmes have now been implemented in several countries all over the world. The very beginnings of these programmes are many years back in time, but there are still new countries starting up with national procedures for the early identification of hearing loss. Among them are the Nordic countries where we have been rather late in the introduction of these measurements. There are as we know different techniques to be used. In the USA, the dominating procedure as far as I know is the AABR, possibly based on the fact that the AABR is a US development. In Europe, the OAE, and in particular the TEOAE have a dominating position. The DPOAE is used to a less extension. I will in this presentation look at these most commonly used screening methods with a weight on the AABR and the TEOAE. I will go through the principle of measurements and refer some reports on the efficiency of the methods. Cost-benefit has to be considered since these programmes covering all live births require a great deal of resources from the government. A crucial point in the choice of method is the actual precision in detecting a hearing loss. A high rate of infants being referred for a follow-up will put a major burden on the audiological sections responsible for the measurement of the actual hearing losses, i.e. performing the clinical threshold measurements. Parents are worried, and this is also a negative factor which should be considered. So a low rate of false positives is recommended. A low rate of false negatives is also a must since the major goal of these screening programmes is to find the actual infants with a hearing loss. The time required for each measurement and the economical resources involved both regarding cost of equipment, articles of consumption and personnel resources are all factors to be considered carefully. There are pros and cons for each method, and it is of great importance to analyse the different factors before making a choice regarding what method to be taken into use.

ASSRs to Multiple Simultaneous Air-Conducted Stimuli: Criteria for Normal Hearing in Infants

David R. Stapells¹, Anna Van Maanen^{1,2}

¹University of British Columbia School of Audiology & Speech Sciences, Vancouver, Canada

²British Columbia Children's Hospital, Vancouver, Canada

Multiple auditory steady-state responses (ASSRs) to stimuli modulated at ~80 Hz are a promising technique for threshold estimation in infants, but more infant data are required. We obtained multiple-ASSRs to air-conducted (AC) stimuli in 34 infants (average age 13.6 months) in two age groups: greater than 6 months (N = 17, mean age 25.1 months), and 6 months and under (N = 17, mean age 3.2 months). All infants had normal hearing in both ears confirmed by normal tone ABRs (i.e. ABR present: ≤ 35 dB nHL @ 500 Hz; ≤ 30 dB nHL @ 2000 Hz; ≤ 25 dB nHL @ 4000 Hz). Two-channel ASSRs were recorded to multiple simultaneous stimuli presented to both ears using insert earphones. Stimuli were calibrated in dB HL and were cosine-cubed-windowed tones with a duration of about one modulation cycle, with different modulation rates for each carrier frequency and ear.

Results. ASSR thresholds, estimated from the 50% point on cumulative percent-present distributions, were 38, 29, 24, and 18 dB HL at 500, 1000, 2000 and 4000 Hz, respectively. Most (90%) of the infants showed present ASSRs at 49, 44, 36, and 35 dB HL at 500, 1000, 2000 and 4000 Hz, respectively. There were no significant differences in thresholds between the two age groups (i.e. on average within 1 dB). When responses were present for all stimuli for both ears (40–50 dB HL), the median recording time was 3 min, with most infants (78%) showing all 8 responses within 10 minutes. Compared to ipsilateral responses, ASSRs in the contralateral EEG channel were significantly smaller and often absent at 40–50 dB HL. Based upon these data and the literature, normal AC-ASSR “screening” levels (i.e. the levels at which most normal infants should show a response) would be 50 dB HL at 500 Hz, 45 dB HL at 1000 Hz, and 40 dB HL at 2000 and 4000 Hz. ASSR absence in the contralateral EEG channel is common in infants and should not be considered abnormal nor elevated. Using the multiple ASSR, most infants with normal hearing referred for diagnostic evoked potential testing can now be quickly confirmed as having normal thresholds for 4 frequencies in both ears.

Research supported by CIHR.

Effects of Single- vs Multiple-Stimulus Presentation on 80 Hz ASSR Amplitudes and Threshold: Results in Young Infants

Jennifer L. Hatton, David R. Stapells

University of British Columbia, School of Audiology & Speech Sciences, Vancouver, British Columbia, Canada

Previous research in adults has shown reduced ASSR amplitudes when multiple stimuli are presented simultaneously at 75–80 dB SPL, but not for 60 dB SPL or lower (e.g. Herdman & Stapells, 2001; John et al., 1998; Lins & Picton, 1995). Although multiple-stimulus ASSR results in infants are promising, we do not currently know whether the multiple-ASSR technique, in infants, is more efficient than single stimuli. Using the Rotman MASTER research system, we carried-out two studies to assess this in normal young infants:

Study 1. ASSR amplitudes were obtained from 15 normal infants (mean age = 5 months) in response to 60 dB SPL single or multiple (4 or 8 stimuli) air-conduction AM tones [500–4000 Hz; 77–105 Hz modulation rates]. Mean amplitude (pooled over four carrier frequencies) was 40 nV in the single-stimulus condition. Amplitudes in the multiple-stimulus conditions were significantly reduced compared to the single-stimulus condition: 4 stimuli to one ear resulted in a 16% reduction ($p < 0.03$); 8 stimuli to two ears (4 in each ear) resulted in a 26% reduction ($p < 0.01$). The difference between monotic and dichotic multiple stimuli did not quite reach significance ($p = 0.11$). Infants therefore show greater multiple-stimulus ASSR interactions compared to adults. The larger interactions in infants may reflect cochlear and/or brainstem immaturity (especially with dichotic presentation), or may simply reflect a higher stimulus intensity at the infant eardrum.

Study 2. (currently in progress; 11 normal infants; mean age = 5 months) investigated this further by determining 500-Hz ASSR thresholds for the single and dichotic-multiple (8 stimuli) conditions. Results thus far indicate a trend ($p = 0.06$) for slightly higher ASSR thresholds in the dichotic-multiple condition. On average only 5-dB higher than the single-stimulus condition, this is not likely a clinically significant difference, and does not explain the greater interactions in infants. In summary, infant ASSRs show greater interactions than adults, but as with adults, multiple-stimulus presentation in infants is more efficient than single AM tones [i.e. multiple-stimulus amplitudes are greater than single-stimulus amplitudes divided by ($M^{0.5}$), where M is the number of stimuli].

Work supported by CIHR and NSERC-Canada.

Effects of Changing the OAE Screen Pass Criteria in Newborn Hearing Screening

John Stevens, Marian Brandreth, Paul Bacon

*Department of Medical Physics and Clinical Engineering, Royal Hallamshire Hospital, Sheffield, United Kingdom
in conjunction with MRC Hearing and Communication Group, University of Manchester, Manchester, United Kingdom*

A study is being carried out for the English newborn hearing screening program to investigate the effects of changing the OAE screen pass criteria on the pass rate and the number of cases that would be missed by the screen. TEOAE is used as the primary screen in the English newborn hearing screening program for well babies. The current pass criteria is for a minimum of two half octave bands from 1.5, 2, 3 and 4 kHz to have a signal to noise ratio of greater than 6 dB. Screening data has been collected from six sites for a period of two years to provide a database on which the effects of varying the screen pass criteria can be investigated. Preliminary analysis has been carried out on the data from one of the major sites involving 12,000 screening records and around 40 cases of hearing impairment. This has involved looking at the effects of reducing the signal to noise criteria and/or reducing the number of bands from two to one as well as the benefits or otherwise of including the 1 kHz band. Initial analysis implies that the two band criteria is robust as it is possible to reduce the number of bands to one with minimal effect on the number of bilateral hearing impaired cases detected. The effect on pass rate and cases missed for a wide range of criteria will be presented with preliminary conclusions on what the results indicate for the choice of an optimum OAE screen pass criteria.

Efficiency of the Automatic Detection of Multiple Auditory Steady State Responses Measured with ROC Methodology

Guillermo Savio, Maria Cecilia Pérez-Abalo, Eleina Mijares, Didiesle Herrera, Agustin Lage

Cuban Neuroscience Center, Havana, Cuba

We have been evaluating comparatively, using Receiver Operating Characteristics (ROC) curves, the efficiency of the automatic detection of Multiple Auditory Steady State Responses (MSSR) with an established methodology such as click Auditory Brainstem Responses (cABR). For the automatic detection of cABR two statistics were calculated: the Standard Deviation Ratio (SDR) between the signal and the background noise and the Correlation Coefficient Ratio (CCR) between two replicates, whereas for the MSSR the statistics in the frequency domain Hotelling T2 (HT2) and circular T2 (CT2) were used. The ROC curves were computed over 138 recordings (69 without response y 69 with response) obtained at a fixed intensity of 40 dB nHL within a sample of 35 newborn. Although these evoked responses (cABR and MSSR) could be identified efficiently by the different statistics, the MSSR showed better efficiency with higher areas under the ROC curve (HT2: 0.98 for 1 and CT2: 0.96–0.99 for 0.5 and 2 KHz) compared to the cABR (0.92 for CCR and 0.92 for the SDR). However, the MSSR had lower time-efficiency than the cABR (MSSR: 5.2 ± 3.2 minutes, cABR: 2.5 ± 1.6 minutes). We conclude that the MSSR technique shows significant advantages for the automated detection of near threshold responses over cABR and, further improved, could be valuable within a newborn screening context.

Clinical Application of Auditory Steady-State Responses in Hearing Impaired Infants

Jagoda Vatovec¹, Branka Geczy¹, Dušan Butinar²

¹Department of Otorhinolaryngology and

²Institute of Clinical Neurophysiology, Division of Neurology, University Medical Centre Ljubljana, Ljubljana, Slovenia

Background. Neonatal hearing screening is the first step in early intervention programs. For exact quantification of hearing loss and appropriate intervention the neonates are referred to diagnostic centres. Measurement of auditory steady-state responses (ASSR) is an electrophysiologic method that can be used for frequency-specific threshold estimations in infants and children with hearing impairment.

Methods. There were 40 ears of 20 infants who failed neonatal hearing screening tested, first by pure tones in sound field and tympanometry. Otoacoustic emission measurements (OAE), click-evoked brainstem responses (ABR), and ASSR were performed under sedation with chloral hydrate or in natural sleep. Relationship between the average of 500–4000 Hz thresholds of the pure-tones, OAE, ABR estimations and ASSR-based thresholds was evaluated.

Results. All infants had normal function of the middle ear according to tympanograms. OAE was registered in 14 ears. There was close relationship found between ABR and ASSR test results. The results of behavioural measurements and ASSR were not in such a good correlation.

Conclusion. There is a good correlation for the ASSR versus ABR and OAE comparisons. The possibilities to obtain frequency specific hearing thresholds in the mid and low frequencies are advantage of ASSR over ABR testing.

Home-Based Diagnostic Electrophysiology Following Referral from Community-Based Universal Newborn Hearing Screening

Ani Sahakian, Laura Booth, Andy Phillips, Katie Rutzler, Sarah Fancy, Nicky Armstead

Royal Berkshire NHS Foundation Trust, Reading, United Kingdom

Here we present the diagnostic electrophysiological test protocol we have devised for audiological assessment following referral from our community based Newborn Hearing Screening Programme. The coverage for neonatal screening is over 99% and the referral rates into the department from the screening program have consistently been less than 1% for the 4 years that the program has been live. We have accurately and authoritatively diagnosed over 40 children with permanent hearing loss, many within 3 weeks of birth. We discuss the referral rates into the department and how as a team we have produced a family friendly approach offering a full home based service for electrophysiological testing and subsequent early habilitation. We show comparative information that addresses the differences found in providing a hospital based service and a domiciliary service and the problems found with testing in each setting together with trouble shooting ideas for electrical interference. The domiciliary service allows parents the flexibility of their child being tested in their home environment, and reduces need for child care, allows both parents to be present and consequently abolishes do not attend (DNA) problems. Parental anxiety is considerably reduced if children are tested at home when both parents can be present. We show video footage of testing in these settings and of parent's opinions relating to the service. Our data shows that we have been able to accurately collect air-conduction steady state and both air-conduction and bone-conduction tone burst ABR at four frequencies for each of our children. In the home, we have been able to record thresholds down to 20 dB nHL for both TBABR and ASSR. We consider that this is due to children being in an optimal attentional state for testing, with low myogenic artefact.

The Examination of Fetal Brain Circulation Changes Caused by Defined Sound Stimulation

Ljiljana Jelacic¹, Ksenija Ribaric-Jankes², Mirjana Sovilj¹, Aleksandar Ljubic³

¹*Institute for Experimental Phonetics and Speech Pathology, Belgrade, Serbia*

²*Neurological Department and*

³*Institute for Obstetrics and Gynecology, Clinical Center of Serbia, Belgrade, Serbia*

Recent researches in the field of fetal auditory perception give us reliable demonstratives about auditory perception developed in prenatal period: there are obvious evidences that fetus reacts to sounds from external surroundings from which he constantly receives sound stimuli as well as from the mother womb. The aim of this research was to examine fetal circulation changes in aa. cerebri media (ACM) caused by defined sound stimulus. We conducted examination using the procedure of prenatal hearing screening (PHS), for early detection of the degree of hearing development in a fetus. The introduction of PHS procedure is given in the paper. The sample comprised 80 pregnant women, divided into two groups: control group (C = 22) consisted of pregnant women with low risk pregnancies, while the experimental group (E = 58) consisted of pregnant women with high risk pregnancies. The examination of fetal reaction to defined sound stimulus was performed in the period from 27th to 31st gestation week. Defined stimulus is a digitally generated sound with the intensity of 90 dB, frequency range of 1500–4500 Hz, and duration of 0.2 seconds. Doppler analysis of blood flow was performed on the ultrasound apparatus Aloka SSD 1700, with Doppler and color Doppler features. We used convex and sector probe with frequency of 3.5 MHz. Brain circulation changes caused by defined sound stimulation were registered in the first third of artery cerebri media (ACM). The Doppler waves analysis in observed artery was performed by registering the values of pulsatility index (Pi) before and after the defined sound stimulation. Analysis of the results showed that fetuses from high risk pregnancies demonstrated significantly higher circulation changes in ACM caused by defined sound stimulation, which are expressed through absolute and relative changes of Pi values, in relation to fetuses from low risk pregnancies. Two types of psychophysiology reactivity were noticed in both observed samples: a) positive reactivity direction characterized by the increase of Pi values (blood flow decrease in ACM), and b) negative reactivity direction characterized by the decrease of Pi values (blood flow increase in ACM).

Infant ASSR and the Detection of Amplitude Modulation

Barbara Cone-Wesson, Angela Garinis, Sarah Varrichio, Aileen Wong

University of Arizona, Department of Speech, Language and Hearing Sciences, Tucson, Arizona, USA

Beyond their application for estimating auditory thresholds, ASSRs may also provide a method for evaluating supra-threshold hearing abilities. The Canadian Group led by Picton has shown that ASSR amplitude and phase may be related to psychophysical abilities such as word recognition and in the estimation of temporal modulation transfer functions. Such abilities are difficult to evaluate in very young infants, although they would likely be related to speech perception and thus have diagnostic implications. The purpose of this study was to evaluate the effect of amplitude modulation depth on ASSRs evoked by tones in infants (< 12 months) and in adults. The participants were also tested for amplitude modulation detection using observer-based psychophysical methods. Fifteen adults and 20 infants participated in this study. ASSRs were obtained in response to four simultaneously presented carrier frequencies: 500, 1000, 2000 and 4000 Hz. Modulation rates for the carriers were 78, 83, 88, 93 and 98 Hz, respectively. Amplitude modulation depths tested were 100, 50, 20, and 10%. ASSRs were obtained using stimuli at 70 dB SPL and then at 10 dB decrements for each modulation depth condition until no statistically significant responses were detected by the response spectrum algorithm (F-test). Psychophysical tests of modulation detection were carried out using stimulus levels of 60 dB SPL. Participants were trained to detect the presence of the modulated stimuli presented in a train of un-modulated stimuli. The percentage of correct detections of the modulated tones was measured as a function of modulation depth. Infant ASSR thresholds were elevated with respect to those of adults, and amplitudes were smaller. The effect of modulation depth and carrier frequency on ASSR threshold and amplitude were similar in infants and adults, although far fewer ASSRs in infants were apparent for modulation depths < 100% than in adults. Adults were able to detect the tones modulated at 10%, but infants had poor performance for detection of modulation depths < 50%. ASSR threshold and psychophysical detection of modulation depth appear to be related in young infants. ASSRs may be used to indicate maturity of brainstem mechanisms involved in temporal processing (modulation detection).

Comparison of Mixed Modulation Auditory Steady State Responses and Tone-Burst Auditory Brainstem Responses in Neonates with their Subsequent Behavioural Responses

Katie Rutzler, Laura Booth, Andy Phillips, Sarah Fancy, Nicky Armstead

Audiology Department, Royal Berkshire NHS Foundation Trust, Reading, United Kingdom

This study presents data collected from newborns within West Berkshire, UK. Tone-burst auditory brainstem responses (presented at a stimulus rate of 39.1 Hz) and mixed modulation auditory steady state responses (with modulation default rates between 82 and 99 Hz) were recorded in a total of 15 neonates left ears and 13 right ears. Air-conduction thresholds were recorded at 0.5, 1, 2 and 4 kHz from newborns where the degree of hearing was classified from normal to profound loss. To optimise recording conditions, the testing was carried out in the parents' home. Under these test conditions, average noise levels of less than 10 nV were achieved. The thresholds were compared where possible to those subsequently obtained using visual re-inforcement audiometry (VRA). The responses obtained from air-conduction TB ABR and MM ASSR show high statistical correlation across the octave frequencies 0.5–4 kHz ranging from 0.82–0.92, independent of degree of hearing loss. Subsequent comparison of these responses to behavioural thresholds, obtained from VRA, again show high correlations ranging from 0.75–0.96. Our data shows that we have been able to accurately collect air-conduction steady state and both air-conduction and bone-conduction tone burst ABR at four frequencies for each of our children. In the home, we have been able to record thresholds down to 20 dB nHL for both TBABR and ASSR. We consider that this is due to children being in an optimal attentional state for testing, with low myogenic artefact. The results presented indicate that it is possible to reliably record air-conduction frequency specific hearing levels using the mixed modulation auditory steady state response which are comparable to tone-burst auditory brainstem response levels in the neonatal population across the range of hearing loss. Furthermore the results from the two techniques show good correlation to subsequent behavioural hearing levels suggesting that electrophysiological methods can be used to accurately predict an infant's hearing threshold at specific frequencies and calculate prescription targets on which to base hearing aid fitting. The question continues however regarding consistency of calibration of the stimulus level for the different test techniques and specifically their relation to the growing ear canal size of an infant. This area of research, to measure sound pressure level of stimuli at the ear-drum, is currently underway within the department.

Auditory Neuropathy is Asymptomatic in One of Two Different Point Mutations of the Neurofilament Light (NF-L) Gene

Dušan Butinar¹, Arnold Starr², Janez Zidar¹, Jagoda Vatovec³,
 Pantelitsa Koutsou⁴, Kyproula Christodoulou⁴

¹*Institute of Clinical Neurophysiology, University of Ljubljana, Ljubljana, Slovenia*

²*Department of Neurology, University California Irvine, Irvine, California, USA*

³*Department of Otorhinolaryngology and Cervicofacial Surgery, University of Ljubljana, Ljubljana, Slovenia;*

⁴*The Cyprus Institute of Neurology and Genetics, Nicosia, Cyprus*

Objective was to define auditory nerve and cochlear functions in two families with autosomal dominant axonal Charcot Marie Tooth disorder localized to two different point mutations in the neurofilament-light gene (Pro22Ser mutation in family 1 and Glu397Lys mutation in family 2). We quantified neurological, peripheral nerve, audiological, and vestibular functions in affected members of two families. Both families were without symptoms of audiological or vestibular dysfunction. Neurological and nerve conduction studies showed an axonal neuropathy affecting distal muscular and sensory functions equivalently in both families. Three members of family 2 also had evidence of pyramidal tract involvement. Auditory brainstem responses (ABRs) and stapedial muscle reflexes were absent or abnormal in affected members of family 2 but not in family 1. The audiograms, otoacoustic emissions, speech comprehension, and thresholds for detecting brief silent intervals in noise (gap detection) were normal in both families. The disorder of ABRs in affected members of family 2 was consistent with both altered synchrony and slowed conduction in both auditory nerve and brainstem auditory pathway. Vestibular nerve functions were unaffected. Auditory neuropathy is asymptomatic in one of two families with CMT disorder with different point mutations of the NFL gene.

Different Mechanisms in Temporal Processing Disorders Accompanying Auditory Neuropathy

Rosamaria Santarelli¹, Henry J. Michalewski², Edoardo Arslan¹, Arnold Starr²

¹University of Padua, Padua, Italy

²University California Irvine, Irvine, California, USA

Auditory neuropathy (AN) is a recently identified disorder of auditory nerve characterized by prominent auditory temporal processing deficits. Both auditory nerve and brainstem activities recorded as far-field potentials are typically undetectable whereas cochlear outer hair activities (otoacoustic emissions and/or cochlear microphonics) are normal. We have recorded both receptor (summing potential [SP]; cochlear microphonics [CMs]) and auditory nerve (compound action potential [CAP]) activities by transtympanic electrocochleography (ECoChG). We studied cochlear potentials bilaterally from eight children and adults with AN by an electrode placed on the promontory. Test stimuli were 0.1 ms clicks which were presented in free-field from 60 to 120 dB SPL. The results were compared with the ECoChG results from 16 children who were tested because of a suspected hearing loss but were found to have normal thresholds of CAPs. Cochlear potentials were identified in all AN subjects and were prolonged in duration and reduced in amplitude compared to controls. CAPs were identified in 4/16 AN cochlea only to high intensity stimuli. In the remaining ears it was difficult to separately identify the CAP and the SP within the broad cochlear potential. In contrast, CMs were identified in all AN subjects and did not differ significantly in amplitude from controls. Also SPs when identified were of normal amplitude. We used rapid stimulus rates in six of the AN subjects to help distinguish the generator sources of the prolonged cochlear potentials by taking advantage of different amount of adaptation involving CAP and SP. We identified the presence of several different physiological abnormalities including preserved receptor and CAPs, preserved receptor and attenuated CAPs, and absence of CAPs. Adaptation studies were accompanied by a reduction of duration of cochlear potentials to control values consistent with their being atypical neural events. There are several mechanisms active in AN disrupting the function of synapses of inner hair cells, generation of nerve action potentials by auditory nerve, and transmission of nerve impulses centrally.

Analysis in Infants with Hearing Disorder Using Auditory Techniques

Zheng-min Xu

Department of Otorhinolaryngology, Children's Hospital of Fudan University, Shanghai, China

Objective. To investigate the infants with hearing problem for differential audiology using auditory steady-state response (ASSR), vision reinforcement audiometry (VRA), auditory brain-stem response (ABR), otoacoustic evoked emissions (OAE), and acoustic reflect techniques.

Methods. Thirty cases (sixty ears) in control group were measured by the ABR latency, and ASSR, VRA and acoustic reflect thresholds. Based upon the etiology of this disorder, the 20 cases were divided into three groups; asphyxia (group I), jaundice (group II), and neonatal hyperbilirubinemia (group III). They were examined by the DPOAE, CM, ABR latency, ASSR, tympanometry and VRA. All data were analysed statistically by F test.

Results. In group I, DPOAE and CM were present. Tympanogram showed A type, whereas some cases displayed that the III–V peak latency of ABR was delayed, and in another case (two ears) the waves IV and V disappeared. Mean ASSR thresholds were higher than the mean VRA thresholds at 0.25, 0.5, 1, 2, and 4 kHz in which the mean correlation coefficient (r) ranges from 0.41 to 0.65. In group II and III, some patients (7 ears) had CM clearly, whereas DPOAE were not present. The wave V and wave I–III peak latency of ABR showed delay. In group II the ASSR thresholds were close to VRA thresholds ($r = 0.92\text{--}0.97$), and the correlation coefficient (r) ranges from 0.69 to 0.86 between group I and group II. Comparison of the mean threshold-differences between the ASSR and VRA thresholds for group I, group II, and group III for each frequency revealed significant difference (F test $P < 0.05$, $P < 0.01$, $P < 0.01$, $P < 0.05$, $P < 0.05$).

Conclusion. To study infants for the auditory neuropathy diagnosis and differential diagnosis using auditory techniques, we could make the standard evaluation for this disorder so as it is important how to intervene, and how to predict the outcome.

Correlation between Speech Perception and Electrically-Evoked Auditory Potentials Measured in Subjects with Auditory Neuropathy after Cochlear Implantation

Catherine M. McMahon¹, Karen M. Bate¹, William P. R. Gibson², Halit Sanli²

¹*Audiology Section, Macquarie University and*

²*Sydney Cochlear Implant Centre, Sydney, New South Wales, Australia*

Cochlear implantation is considered an effective management option for children diagnosed with auditory neuropathy. It is assumed that this is because, in most cases of auditory neuropathy, the lesion is located at the inner hair cells or the primary afferent synapse, rather than the auditory nerve per se. Previous studies reporting benefit in cochlear implantation in this population of subjects have assessed benefit using behavioural measures such as speech perception tests. In this study, we have assessed the benefit of cochlear implantation in subjects with AN using objective assessments including electrically-evoked auditory brainstem responses (ABR) and cortical auditory evoked potentials (CAEP) and have correlated this with subjective assessments of speech perception. Correlations between objective and subjective assessments demonstrate that the role of electrical stimulation in providing benefit is not simple. We show that there is no correlation between the electrically-evoked ABR and the electrically-evoked CAEP waveforms. Nor is there a correlation between the objective tests and speech perception abilities.

Keynote Lecture II

Dynamic Sensory Encoding of Sound: Implications for Language and Music

Nina Kraus

Northwestern University, Evanston, Illinois, USA

The auditory brainstem reflects acoustic characteristics of speech and music with remarkable fidelity¹. We have become increasingly convinced that brainstem neural encoding plays an enormous role in faithfully representing acoustic characteristics of sound in the normal system, that this precise encoding breaks down in clinical populations², and that it reacts to differing levels of expertise (music and language). For impaired systems (language-based learning disabilities, autism), we have demonstrated that brainstem encoding of speech can be used clinically as a biological marker of deficient auditory processing³. The expert system of the musician illustrates how extensive auditory expertise can enhance basic sensory circuitry. Our work supports the view that engaging high-level cognitive processes (language and music) facilitates tuning – better accuracy – of sensory processing, likely through cortico-fugal modulation of afferent function. Taken together, our research demonstrates that subcortical sensory encoding is more dynamic than previously thought; our data indicate that it is tuned by life-long, short-term, and real-time experience, and impacted by non-acoustic factors such as visual input. This malleability has theoretical, clinical and educational implications. The wide range of perceptual abilities commonly observed in normal and clinical populations can be explained, at least in part, by idiosyncratic (individual-specific) shaping of sensory function mediated by the auditory brainstem.

Supported by: NIH NIDCD R01-01510, NSF BCS-0544846.

References:

1. Johnson K, Nicol T, Kraus N. The brainstem response to speech: a biological marker. *Ear Hearing* 2005; 26 (5): 424–33.
2. <http://www.communication.northwestern.edu/brainvolts/clinicaltechnologies/>
3. Banai K, Nicol T, Zecker S, Kraus N. Brainstem timing: Implications for cortical processing and literacy. *J Neurosci* 2005; 25 (43): 9850–7.

Examination of an Abbreviated Stack-ABR Test in Newborns

Lindsey Keogh¹, John D. Durrant¹, Diane Sabo^{1,2}, Randall Phelps²

¹University of Pittsburgh and

²Children's Hospital of Pittsburgh, Pittsburgh, Pennsylvania, USA

In conventional ABR (auditory brain-stem response) testing, amplitudes have been of limited diagnostic value due to high variance, hence heavy reliance upon latency. Variance in the ABR waveform is exacerbated by the phase dispersion of the traveling-wave mechanism, an effect potentially compounded further by early developmental. An effective method to reduce variance of the wave-V magnitude is the stacked-ABR method of Don M et al. (1997, Am J Otol 18: 608–21). An alternative approach using tone bursts has been suggested by Philibert B et al. (2003, Int J Audiol 42: 71–81). Neither method has been explored in neonates. This study was a part of a larger interdisciplinary investigation of in-utero toxic exposures, giving us the opportunity to examine the efficacy of an abbreviated stacked-ABR method (to minimize collection time) and the statistical precision of the wave-V magnitude (V–V_n) in a large cohort of newborns (N > 125). Subjects were tested under natural sleep; electrodes were placed at high forehead (non-inverting input) and mastoids (inverted signal from the right/test ear and ground at left) in a single-channel recording. Four tone-pips, 1000–8000 Hz were used, as well as clicks. The stacked responses were computed [a] via alignment of waves V based upon visual selection and [b] referencing to the maxima of deflections of the integral of the ABR in the vicinity of wave V (M. Don, personal communication). The latter method averted subjective wave identification. The primary statistical analyses were descriptive, namely using parametric measures of central tendencies and graphical analyses of grand averages of conventional versus stacked responses. The coefficient of variation also was computed and compared for measures of amplitude for click, tone-burst, and stacked responses, providing a sense of statistical precision among measures. Preliminary results support expectations that the abbreviated stacked response achieves substantial enhancement of the wave V–V_n magnitude in neonates, by about 3-fold relative to the click ABR. It is anticipated that this approach may extend the utility of the stacked-ABR approach, per se, and may facilitate evaluation of neuro-integrity of neonates.

Maturation of Bone-Conduction Auditory Steady-State Responses: Criteria for “Normal”

Susan A. Small, David R. Stapells

University of British Columbia, Vancouver, Canada

The *objective* of this study was to compare bone-conduction (BC) auditory steady-state responses (BCASSR) for infants and adults with normal hearing to investigate the time course of maturation of BC hearing sensitivity and the criteria for normal BC hearing. BCASSR thresholds were obtained in groups of young (0–11 months, $n = 35$) and older (12–24 months, $n = 13$) infants and adults ($n = 18$). The multiple BC stimuli (Rotman MASTER; carrier frequencies: 500–4000 Hz; 77–101-Hz modulation rates; amplitude/frequency modulated) were presented simultaneously to a B-71 bone-oscillator placed on the temporal bone.

Results. Mean (1 SD) BCASSR thresholds were 14 (13), 5 (8), 26 (10), and 14 (11) dB HL in the young infants, 22 (11), 13 (6), 26 (9), and 13 (9) dB HL in the older infants, and 31 (15), 24 (14), 20 (8), and 16 (11) dB HL for the adults at 500, 1000, 2000, and 4000 Hz, respectively. For low frequencies, BCASSR thresholds worsen with age, whereas high frequencies are unaffected by age except for a slight improvement at 2000 Hz.

Discussion. Young infants are much more sensitive to low-frequency BC stimuli, and probably more sensitive to high-frequency BC stimuli, compared to adults. The differences between infants and adults decrease by 12–24 months of age; however, infants up to age 24 months are still more sensitive to 1000-Hz BC stimuli, indicating that BC hearing does not become adult-like at all frequencies until at least two years of age. These findings emphasize that different “normal levels” (i.e. BC hearing sensitivity is within normal limits when they have BCASSRs present at these levels) must be used for infants of different ages. For infants aged 0–1 months, we propose normal levels of 30, 20, 40, and 30 dB HL at 500, 1000, 2000, and 4000 Hz, respectively. For infants aged 12–24 months, proposed normal levels are 40, 20, 40, and 20 dB HL at 500, 1000, 2000, and 4000 Hz, respectively.

Work supported by CIHR and NSERC Canada.

Effects of Stimulus Level on Speech Evoked Obligatory Cortical Auditory Evoked Potentials in Infants with Normal Hearing

Suzanne C Purdy^{1,2,3}, Catherine Morgan², Mridula Sharma^{1,3}, Kevin J. Munro⁴

¹The University of Auckland, Auckland, New Zealand

²National Acoustic Laboratories and

³Macquarie University, Sydney, New South Wales, Australia

⁴The University of Manchester, Manchester, United Kingdom

The effect of stimulus level on speech-evoked CAEP amplitudes and latencies was investigated in infants with normal hearing. Infants (age range 3 to 8 months) with no risk factors for hearing loss, no parental concern and normal tympanograms and otoacoustic emissions participated. The online artifact rejection rate was set at ± 100 microvolts. Several very active infants with more than 50% artifact rejection rates were excluded and results for 16 infants were analysed. Stimuli were natural speech tokens /m/ and /t/ delivered at 30, 40, 50, 60, 70, and 80 dB SPL in the sound field via a centrally placed speaker (0 degrees azimuth) at a distance of 1.5 m from the infant. Stimuli were 78–79 ms in duration, presented at an inter-stimulus interval of 1125 ms. Infants were awake and seated on a caregiver's lap. A researcher distracted the infants with toys during testing. CAEPs were measured from three electrode positions, vertex midline (Cz), and left (C3) and right (C4) hemispheres, referenced to the mastoid. Infants were placed in two groups. One group was tested at levels of 30, 50, and 70 dB SPL while the other group was tested on 40, 60, and 80 dB SPL. Order of stimulus (/t/, /m/) and level was counterbalanced across participants. Responses were recorded at levels down to 30 and 40 dB in the majority of infants. Input-output functions show different effects of increasing sound level for the two stimuli. There were minimal changes in latency with increase in level for /t/. For /m/, there were more substantial CAEP latency increases (approximately 50–60 ms) at soft compared to loud levels. Amplitudes saturated at moderate-high levels (60–80 dB SPL) for both stimuli. These findings indicate that stimulus characteristics should be considered when evaluating the effects of audibility on CAEP characteristics in infants. This has relevance for the clinical use of CAEPs in infants for hearing aid and cochlear implant evaluation.

Developmental Changes in Temporal and Spectral Brainstem Encoding of Speech in Early Childhood

Krista L. Johnson, Steven G. Zecker, Nina Kraus

Northwestern University, Evanston, Illinois, USA

The human auditory brainstem response to tone and click stimuli is mature by 2 years of age. However, it appears that click and speech stimuli impose different encoding demands in the brainstem; some individuals with literacy disorders show abnormal neural encoding of speech but normal click-evoked brainstem activity (Banai et al., J Neurosci 2005). This study investigated the maturation of the neural encoding of the speech syllable /da/. Speech-evoked brainstem responses were collected from children between the ages of 3–5 and compared to existing norms from 8–12 year olds. Results reveal that the neural brainstem response to speech continues to develop until 5 years of age. Responses of children between the ages of 3–4 years exhibit distinct temporal and spectral differences compared to the older children. Specifically, timing of onset responses (speech-evoked waves V, A, and VA slope) are still developing between 3 and 5 years. Additionally, offset responses are not robust until age 5. In the frequency domain, the greatest age effects are apparent at higher frequencies (the upper limit of brainstem phase locking) and are consistent with a developmental progression from low-to-high frequencies (Rubel et al., Science 1983). The findings of this study challenge the notion that the human auditory brainstem is fully mature by the second year of life, and imply that brainstem neurons respond differently to simple and complex stimuli. Moreover, different components of the speech-evoked response (Kraus et al., Trends Neurosci 2005) mature at different rates, providing an opportunity to examine the developmental trajectory of different aspects of auditory processing.

Supported by the National Organization for Hearing Research (NOHR).

Chirp Stimuli Based on Cochlear Traveling Wave Delay

Claus Elberling¹, Manuel Don², Mario Cebulla³, Ekkehard Stürzebecher⁴

¹*Oticon A/S, Snekkersten, Denmark*

²*House Ear Institute, Los Angeles, California, USA*

³*Julius Maximilians-University, Würzburg, Germany*

⁴*WDH Denmark, c/o Petershagen, Germany*

In order to increase the temporal synchrony of neural excitation in the auditory periphery and the brain stem two different attempts can be applied: Output compensation by way of the Stacked ABR and Input compensation by way of using chirp-stimuli for the recording of the ABR. The present study investigates fundamental issues related to chirp-stimuli. The cochlea is approximated by a linear two-port system and the group and phase delay of this system are calculated using estimates of the cochlear traveling wave delay based on: (i) a cochlear model, (ii) tone-burst auditory brain stem response (ABR) latencies, and (iii) narrow-band ABR latencies. Simulations of the neural output demonstrate that when the delay functions are interpreted as group delays then the underlying activity for individual frequencies has a phase delay which corresponds to what can be calculated from the corresponding group delay. Based on this interpretation three chirps are constructed from the estimated delay functions. The clinical efficiency of the chirps is evaluated on a group of 49 normal-hearing young adults. The chirps are compared to a standard click stimulus by recording the auditory steady-state response (ASSR) at two relatively low presentation levels (30 and 50 dB nHL), and using a stimulus rate of 90/s. The main results are as follows: (i) at both levels, the chirps give significantly shorter detection time and higher signal-to-noise ratio (SNR) than the click; (ii) even at 30 dB nHL the chirps perform significantly better than the click at 50 dB nHL, which demonstrates that the higher efficiency of the chirps is equivalent to 20 dB or more in stimulus level; (iii) at 50 dB nHL the chirp that is based on the narrow-band ABR-latencies is significantly more efficient than the two other chirps. The results indicate that a chirp is a better choice than a click for the clinical recording of early auditory evoked responses.

New Chirp Stimuli for Hearing Screening

Mario Cebulla¹, Ekkehard Stürzebecher², Claus Elberling³, Wafaa Shehata-Dieler¹

¹ENT Clinic, Faculty of Medicine, Julius-Maximilians-University, Würzburg, Germany

²WDH Denmark, c/o Petershagen, Germany

³Oticon A/S, 'Eriksholm', Snekkersten, Denmark

The preferred transient click stimulus used for ABR recordings has an essential limitation because of the traveling wave delay in the cochlea, which leads to a poor synchronization of the neural excitation in the different parts of the cochlea. Therefore, the spatio-temporally summated response does not achieve the amplitude that would result from more synchronous excitations. As has been shown, a series of repetitive clicks can be represented by a series of cosines having fixed frequencies corresponding to whole number multiples of the repetition rate. This allows the phase of each cosine to be adjusted in order to compensate for the cochlea delay. In the present work, the compensation is based on normative latencies of narrow-band ABRs, which were used to calculate cochlea phase delay and to generate a chirp. When tested in normal-hearing adults (see Elberling et al., abstract), the chirp resulted in higher ABR amplitudes compared to those produced by a click. However, these positive chirp-findings in adults may not necessarily apply to ABR-recordings in newborns, although the cochlea is considered almost fully matured at birth. Therefore hearing screening was performed on 740 newborns. The chirp was presented at a level of 35 dB nHL, and with a repetition rate of 90/s. The error probability of the automated test procedure was 0.1%. The detection times were found to be significantly shorter than those obtained in a comparative study of 330 newborns using a click at 40 dB nHL. In addition to the chirp, two band-limited chirps (135–1500 Hz and 1500–8000 Hz), were applied simultaneously to 54 newborns. The results demonstrate that in newborns the chirp provides the same improvement in test efficiency compared to the click as found in adults. Therefore application of the chirp can significantly improve the AABR for newborn hearing screening. The results also demonstrate that a 'frequency-specific' hearing screening seems to be feasible. The substitution of the click by the new, broad-band or band-limited chirp stimuli can probably also improve the recording of ABRs in several other applications.

Stacked ABRs in Small Tumor Patients: Normal Peak Alignment vs. Mean Cochlear Delay Values Used in the Construction of Chirp Stimuli

Manuel Don¹, Claus Elberling², Erin Maloff³

¹*House Ear Institute, Los Angeles, California, USA*

²*Oticon A/S, 'Eriksholm', Denmark*

³*Vanderbilt University, Nashville, Tennessee, USA*

The Stacked ABR used in small tumor detection is an estimate of the total synchronized activity in response to click stimulation. Synchronization of the activity is accomplished by decomposing the ABR into octave-wide narrow-band responses using the high-pass masking technique, aligning the responses according to the wave V peak latencies, and summing them to form the Stacked ABR. This alignment process is an output compensation for the cochlear traveling wave delay. The approach of the Stacked ABR has the advantage of optimizing the activity for the individual but has the disadvantage of needing to record responses to six stimulus and noise masking conditions in order to estimate the cochlear delays. An alternate approach to recording the synchronized activity is to use a chirp stimulus that compensates for the cochlear traveling wave delay at the input (see Elberling et al., abstract). The input compensation approach using a chirp stimulus based on mean latency delays has the advantage of requiring only a single run recording but has the disadvantage of utilizing a compensation based on group mean instead of individual latency values. A chirp stimulus (Elberling et al., abstract) was developed based on the mean latencies of narrow-band ABRs. In this paper we compare the results of Stacked ABRs based on individual, actual latencies to the Stacked ABRs based on mean latencies from a group of normal-hearing subjects to detect the presence of a small acoustic tumor. While both methods in this comparison still use the output compensation approach, using the mean latency values may provide insight to results we might achieve using a chirp designed from these mean latency values. This comparison was carried out in 39 normal-hearing individuals and 17 small acoustic tumor patients. The results indicate that for a 95% sensitivity criterion, the Stacked ABR based on the mean latency values had a specificity that is only slightly worse than that achieved with the Stacked ABR based on the individualized latency values. Thus, it appears worthwhile to investigate the use of this chirp as an efficient method for detecting small tumors without sacrificing too much specificity.

Objective Detection of ASSR: Do's and Don'ts

Heleen Luts¹, Bram Van Dun^{1,2}, Jane Alaerts¹, Jan Wouters¹

¹ExpORL, Department of Neurosciences and

²SCD-SISTA, Department of Electrical Engineering (ESAT), K. U. Leuven, Belgium

The objective response detection of auditory steady-state responses (ASSRs) is an attractive feature of the technique. However, this 'objectiveness' has to be interpreted with care. The purpose of this study was to evaluate the risks of the uncontrolled use of an objective detection criterion in the recording of ASSRs. The influence of decisions like when to accept a response and stop the recording was assessed by analyzing the number of false and true detected responses. A large sample of 468 multiple-stimulus ASSR recordings (32 sweeps) of normal-hearing and hearing-impaired adults and babies was processed offline. Error rates were calculated for different detection paradigms at eight control frequencies. At the signal frequencies, detection rates and detection times were determined, keeping the error rates fixed. When a variable recording length was allowed (meaning the recording can be interrupted before the maximum number of sweeps is reached) and a significance level of $p = 0.05$ was applied, the error rate increased to unacceptable levels because of the problem of repeated testing. Therefore, the acceptance criterion of the statistical test needs to be adjusted to ensure an acceptable error rate. With an error rate of 5%, the highest detection rate was associated with a fixed recording length of 32 sweeps per intensity level combined with weighted averaging. There was a serious decrease in detection rate when less than 24 sweeps were recorded. With an error rate of only 1%, small responses could not be distinguished from the noise. The gain in detection time using a variable instead of a fixed recording length was very limited when a conventional multiple-stimulus approach was used. Test duration could considerably be shortened when the test set-up would allow an independent presentation and recording of the eight signals and responses. In conclusion, the detection rate and detection time can significantly improve or deteriorate, even with small adaptations of the detection paradigm. Although response detection is objective, the measurement protocol has to be well-considered and a critical approach is required when judging the responses.

Analysis of Statistic Value Fluctuation during ASSR Detection

Marcin Masalski

Wroclaw University of Technology, Wroclaw, Poland

Detection of ASSR is usually performed at the end of an examination. Evaluation of a response can be also carried out during an examination by a statistical testing of available parts of a recorded signal. In this case response is commonly considered to be present if statistic value exceeds a critical value. This study presents a benefit of the analysis of statistic value fluctuations during an examination. New statistic was constructed on the basis of the F-test with respect of number of consecutive statistic values that exceed a predefined critical value. Critical values for particular significance levels were calculated by extensive Monte Carlo simulations. Statistical power was evaluated offline on real life signals and generated signal sets. Real life signals were recorded during hearing threshold estimations by means of ASSR to multiple simultaneous stimuli. For different amplitudes of simulated responses different approaches turned out to have highest statistical power at the same average examination time. Comparison of average examination time was performed based on real life signal set. Maximal permitted examination time was adjusted to obtain equal ratio of detected responses. Time improvement of 19% was found in comparison to single response evaluation at the end of an examination. In comparison to response evaluation based on single critical value exceeding, time improvement was 8%.

A Bootstrap Approach to the Detection of Auditory Evoked Potentials

Steven L. Bell, Jing Lv, Alastair J. Manders, David M. Simpson

Institute of Sound and Vibration Research, University of Southampton, Southampton, United Kingdom

Auditory Evoked potentials are often evaluated subjectively (by visual inspection) and considerable differences between interpretations can occur. Objective, automated methods are normally based on calculating one or more parameters from the data, but only some of these techniques can provide statistical significance (p-values) for the presence of a response. The bootstrap method can be used to provide such p-values; it is based on randomly resampling (with replacement) the original data and gives an estimate of the probability that the response obtained is due to random variation in the data rather than a physiological response [1]. It can compare estimators for detecting responses and it can also estimate a criterion value for response detection corresponding to any chosen significance level, so avoiding the need for elaborate theoretical calculations of criterion values. We have applied the bootstrap approach to detect hearing thresholds with both the Auditory Brainstem Response (ABR) [2] and the Slow Vertex Response (SVR). For the ABR data, time-domain detection algorithms including (amongst others) the Fsp [3] and \pm difference [4] were compared. For the SVR data both time-domain and frequency-domain techniques (such as magnitude-squared coherence [5]) were compared. This paper summarises the findings of these analyses. The flexibility of the approach is illustrated, showing how it can be used with different parameters, numbers of stimuli and with user-defined false-positive rates. The bootstrap method provides a new, simple and yet powerful means of detecting evoked potentials, which is very flexible and readily adapted to a wide variety of signal parameters.

References:

1. Efron B. Bootstrap methods. Another look at the jackknife. *Ann Stat* 1979; 7: 1-26.
2. Lv J, Simpson DM, Bell SL. Objective detection of evoked potentials using a bootstrap technique. *Med Eng Phys* 2007; 29: 191-8.
3. Elberling C, Don M. Quality estimation of averaged auditory brainstem responses. *Scand Audiol* 1984; 13 (3): 187-97.
4. Wong PK, Bickford RG. Brain stem auditory evoked potentials: the use of noise estimate. *Electroencephalogr Clin Neurophysiol* 1980; 50 (1-2): 25-34.
5. Dobie RA, Wilson MJ. Analysis of auditory evoked potentials by magnitude-squared coherence. *Ear Hear* 1989; 10 (1): 2-13.

Adaptive Filter Improves SNR in Auditory Evoked Responses: Method and Experimental Verification of Assumptions

Isaac Kurtz, Aaron H. Steinman, Yuri Sokolov

Vivosonic Incorporated, Toronto, Ontario, Canada

Electrical noise generated by muscular activity during an auditory evoked response (AER) test masks the AER signal because EMG noise is many times greater than the AER. Artifact rejection (AR) eliminates the epochs that are most contaminated with EMG noise but is not helpful when the EMG noise is constantly present throughout the test. Furthermore, AR does not remove low-level EMG noise that is below the artifact rejection threshold yet many times greater than the AER of interest. Bandpass filtering may improve signal-to-noise ratio for the low frequency components of the middle and late latency responses, but is not helpful in the detection of auditory brainstem responses (ABR), since most of the ABR spectrum is contained within the same bandwidth as the EMG spectrum. For this reason, drug-induced sedation is usually required for ABR testing in babies and children from 6 months to 4 or 5 years of age. A new adaptive filtering technique that reduces the effect of EMG noise on ABR recordings is presented. The technique involves adaptively estimating the spectrum of the noise in the recording and comparing it with the spectrum of the signal-plus-noise contained in the averaged response. Each spectral component is then resolved into a correlated and uncorrelated subcomponent and weighted in proportion with its correlated subcomponent. This technique assumes that, although EMG and ABR share the same bandwidth, the magnitudes of their individual spectral components are different. Experimental verification of this assumption is presented.

Adaptive Filter Improves SNR in Auditory Evoked Responses: Experimental Results

Isaac Kurtz, Aaron H. Steinman, Yuri Sokolov

Vivosonic Incorporated, Toronto, Ontario, Canada

The clinical use of Auditory Brainstem Response (ABR) for the testing hearing thresholds in young children requires the clinician to recognize the presence of ABR when the stimulus is above threshold and the absence of ABR when the stimulus is below threshold. Distinguishing the two conditions is hindered by the presence of EMG noise which is much greater than ABR. For this reason, drug-induced sedation is usually required for ABR testing in babies and children from 6 months to 4 or 5 years of age. In the current preliminary investigation an adaptive filtering technique that takes advantage of the spectral differences between the ABR and EMG was combined with weighted averaging. Two experiments were performed to determine whether the distinction between the presence and absence of ABR may be enhanced despite significant EMG noise. The objective of the first experiment was to determine the effect of the adaptive filter on noise in ABR recordings when ABR is absent. The subject extended his neck and, with the assistance of a visual display, maintained a constant 20–30 μV (peak-to-peak) of noise in the recording. Signals from a typical ABR electrode montage were recorded, optimally weighted and averaged with no auditory stimulus in the subject's ear. Results showed a reduction in noise such that the number of sweeps required to achieve a desired level of residual noise, measured as the variance of the weighted average response, was 2.8 times greater for the conventionally filtered response compared to the adaptively filtered response. In the second experiment, the subject was stimulated with a 70 dB nHL click stimulus under two conditions: 1) 20–30 μV of noise generated by extending the neck and 2) 25–50 μV peak-to-peak of noise generated by biting. Correlation coefficient was 0.58 and 0.57 for the conventionally filtered and the adaptively filtered responses respectively, indicating no significant reduction in ABR. These preliminary results indicate that the adaptive filtering technique, combined with weighted averaging, may allow the clinician to distinguish between the presence or absence of an ABR signal in non-sedated subjects, even in the presence of significant EMG noise.

Sweep Techniques for Recording Auditory Responses

Terence Picton, Sasha John

Rotman Research Institute, Baycrest Centre and University of Toronto, Toronto, Ontario, Canada

Auditory steady-state responses are typically recorded by presenting a periodic stimulus, such as an amplitude-modulated tone, for a period of time and evaluating the brain's response, e.g. at the modulation frequency, using a Fourier Transform. Brain responses may also be recorded while some parameter of the stimulus changes over time (and the response is no longer truly steady-state). If the modulation frequency of the stimulus is constant, a short-time Fourier Transform spectrogram can be used. Sweeping stimulus intensity can estimate threshold by the appearance of a response above the EEG noise levels and can evaluate physiological recruitment by the amplitude-slope of the supra-threshold response. The spectrogram approach can also be used with a sweep of the carrier frequency to show the brain's response at different frequencies and possibly demonstrate islands of decreased hearing at particular frequencies. A sweep of the frequency of a masking stimulus (with a constant test stimulus) might be used to assess tuning curves. Changes in binaural parameters may be swept to give the perception of auditory motion and to follow the brain's response to such movement. If the modulation frequency of the stimulus is swept, the Fourier Transform cannot be used since it depends on the response having a constant frequency over the period of the transform. However, a Fourier analyser can track the instantaneous response provided the changing modulation frequency is available as a reference and the rate of change is within the analyser limits. A drawback of sweep techniques is that the residual EEG noise levels in the recording are higher than when recording truly steady-state responses. The EEG noise levels are reduced by the amount of time used to analyse the response. The sweep provides many more estimates of the response within a given period of time, but thereby allows for less noise reduction. However, if the amplitude and phase of the response change predictably with the swept parameter, the expected curve of the response over time might help to disentangle the response from the increased noise.

Improving ASSR Detection Using Multi-Channel Wiener Filtering

Bram Van Dun^{1,2}, Jan Wouters¹, Marc Moonen²

¹ExpORL, and

²ESAT-SCD, Katholieke Universiteit Leuven, Leuven, Belgium

The duration of ASSR measurements can be shortened significantly by a whole range of different techniques. A non-exhaustive list includes stimulus waveforms, averaging techniques, statistical tests, independent modification of intensities and electrode positioning. When using multi-channel measurements, the correlation of the noise between different EEG-channels can be exploited to lower this noise level and to increase the signal-to-noise ratio (SNR) of the ASSR signal. Increasing the SNR immediately lowers measurement duration. We propose a new multi-channel technique that basically: (1) estimates the ASSR and noise components in the available measurement channels; (2) uses these estimates to calculate a filter that theoretically maximises the SNR of the ASSR signal; (3) applies the calculated filter weighting coefficients to the available channels and thus recombines them to one channel that maximises the SNR. As the SNR-maximisation involves the use of a Minimum Mean Squared Error (MMSE) criterium, the technique is called Multi-channel Wiener Filtering (MWF). This technique is also commonly used in multi-microphone environments, e.g. hearing aids. Seven-channel measurements (nine electrodes) were conducted on eight normal-hearing subjects at intensities between 30 and 60 dB SPL, using stimuli with carrier frequencies at 0.5, 1, 2 and 4 kHz left and right. Results show a significant mean measurement time reduction of 10%, varying between a 50% decrease and a 15% increase, which indicates the great variability of the method. However, seven out of eight subjects show a measurement time decrease. According to theory, the MWF method performs better when using data that has an initially higher SNR. As a result, performance increases at higher intensities and for carrier frequencies that elicit higher responses. To reduce preparation time and improve clinical applicability, the influence of the number of recorded channels was investigated. Results show a near-optimal performance is already obtained at five channels for this data set. This indicates a trade-off is possible between the number of channels and the measurement time. The results above show that multi-channel techniques can reduce measurement duration significantly. It is expected that a well-considered choice of the processing algorithm and corresponding electrode placement can improve performance even more.

Auditory Function and Sensitivity in Connective Tissue Disorders

Jeffrey A. Marler¹, Frederic L. Wightman², Carolyn B. Mervis³, Doris J. Kistler², Zsolt Urban⁴

¹*Department of Communication Sciences & Disorders, James Madison University, Harrisonburg, Virginia, USA*

²*Heuser Hearing Research Center, and*

³*Department of Psychological & Brain Sciences, University of Louisville, Louisville, Kentucky*

⁴*Department of Pediatrics, Washington University, St. Louis, Missouri, USA*

The purpose of this research was to obtain tympanometry, audiometric thresholds, and distortion product otoacoustic emissions (DPOAEs) in individuals with Williams syndrome (WS, $n = 50$) and nonsyndromic supra-valvar aortic stenosis (SVAS, $n = 10$). WS is a genetic disorder, caused by a microdeletion of approximately 28 genes on chromosome 7q11.23 (including the elastin gene). Hypersensitivity to sound has long been a recognized phenotype in WS, and has recently been reported in a subset of individuals with non-syndromic SVAS, but quantitative studies of auditory function and sensitivity in these two genetic connective tissue disorders are few (see Marler et al., 2005 for a review). Seventy-two percent of children and 100% of adults with WS demonstrated mild or mild-to-moderate SHL (as determined by tympanometry, air- and bone-conduction). These results were also reflected in the DPOAEs. Interestingly, DPOAE levels were significantly decreased in children with WS who had normal hearing ($n = 11$). These findings indicate that the auditory systems in this subgroup were in fact, not normal. In addition, the DPOAE I/O function at 4000 Hz in this subgroup showed a loss of cochlear compression (in the absence of behavioral hearing loss). Effect size analyses indicated a clinically meaningful difference in audiometric and DPOAE data. We also report that individuals with point mutations of a single gene in the WS region (elastin) who do not have the WS genotype or phenotype (SVAS) have significantly depressed cochlear function (DPOAEs) but relatively preserved behavioral hearing sensitivity. Clinically, our data suggest that a large number of special needs, school-aged children with WS have undiagnosed SHL. Theoretically, WS ears may be an experimental model for what has been referred to as “fragile ears” (Maison & Liberman, 2000), or ears genetically pre-disposed to trauma from normal environmental noise.

Observations on Otoacoustic Emissions and Other Auditory Evoked Responses in Cohorts of Aging Subjects with and without Aphasia

John D. Durrant¹, Sheila Pratt^{1,2}, Jill Roxberg², Amanda Ortman^{1,2}, Malcolm McNeil^{1,2}, Pat Doyle^{1,2}

¹University of Pittsburgh, Pittsburgh, Pennsylvania, USA

²Geriatric Research Education & Clinical Center, VA Pittsburgh Healthcare System, Pittsburgh, Pennsylvania, USA

There appears to be a consensus that otoacoustic emissions (OAEs) diminish with longevity, somewhat independently of presbycusis hearing loss. An on-going study of aging subjects with and without histories of hearing loss or cerebral stroke associated with aphasia provided us the opportunity to examine whether this trend is manifest in DP-grams from our study cohorts. Electrophysiologic measures also were acquired in the subjects for analysis of basic auditory function from the ground up, namely tests of DPOAEs, ABRs, and ALLRs (auditory long-latency responses), in addition to routine pure-tone and speech audiometry. Comparisons were made within groups (by age) and across groups (controls with/without hearing loss and/or unilateral cerebral lesions). The subject samples consisted of 30 non-brain-damaged normal hearing adults, 30 non-brain-damaged adults with bilateral symmetric sensorineural hearing loss, and 15 adults with normal hearing and brain-damage resulting in aphasia. The groups were balanced for gender and age, with age varying from 38 to 82 years. The DP-grams were distortion-product-OAE isolevel plots for $f_2/f_1 = 1.2$; $L_1-L_2 = 10$ dB with $L_1 = 65$ dB SPL. The ABRs were click-evoked at 90 dB nHL. The ALLRs were assessed using tone-bursts of 500 Hz presented at 50 dB SL. Data acquisition and analyses are near completion, directed toward (among other issues of importance to the main study) scrutinizing the extent to which an independent aging effect was/was not manifested in the cohorts' data. In general, the results are being examined for the usefulness (or not) of OAEs and the other evoked responses per the objectives of the main study: ¹ to have a reasonably comprehensive over-view of the auditory status of subjects; ² to amass comparable cohorts relative to factors expected to be affected by aging (within groups), hearing loss (within and across groups), and/or measures not expected to be associated with aphasia alone (across groups).

Supported by a Rehabilitation Research and Development award from the U.S. Veterans Administration Office of Research and Development.

Time Frequency Analysis of Otoacoustic Emissions to Study the Effects of Exposure to GSM Radiofrequency Fields

Alessia Paglialonga^{1,2}, Marta Parazzini¹, Gabriella Tognola¹, Federica Sibella¹, Steven L. Bell³,
Mark E. Lutman³, Gyorgy Thuroczy⁴, Ferdinando Grandori¹, Paolo Ravazzani¹

¹CNR Institute of Biomedical Engineering, Milan, Italy

²Bioengineering Department, Politecnico di Milano, Milan, Italy

³Institute of Sound and Vibration Research, University of Southampton, Southampton, United Kingdom

⁴National Research Institute for Radiobiology and Radiohygiene, Budapest, Hungary

Mobile phones have become very commonly used throughout the world within a short period of time. To date there is only a limited knowledge about interaction between electromagnetic fields (EMFs) emitted by mobile phones and auditory function; moreover, there is widespread concern that there may be potential for harm. The aim of this study, performed in the framework of the European Commission Project GUARD was to assess potential changes in the cochlear function of normal subjects as a consequence of exposure to low-intensity EMFs emitted by GSM mobile phones. The within-subject study was performed on 27 healthy young adults (age 18–30 years) without any evidence of hearing or ear disorder. Participants attended two sessions, 10 minutes each: genuine and sham exposure to mobile phone radiation in a double-blind design. Transiently evoked otoacoustic emissions (TEOAEs) were recorded, only in the exposed ear, before and immediately after 10 minutes of real or sham exposure. Speech at a typical conversational level was delivered via an earphone to one ear, plus genuine or sham EMF exposure. A frequency specific analysis of TEOAE recordings that separates the contributions of each basilar membrane partition, based on the Wavelet Transform (WT), was used and relevant parameters (reproducibility, energy, and latency) of emissions were extracted and evaluated. This analysis seems likely to improve TEOAE sensitivity to detect even minute changes in outer hair cell function due to EMF exposure. No statistically significant changes were detected. Only isolated/sporadic variations were found when comparing exposure and sham conditions, but the observed shifts were markedly within physiological variability of the parameters under investigation. Considering their characteristics and type of appearance, these changes should be interpreted as due by chance and, in any case, considered as irrelevant with respect to a potential risk on health. It could be concluded that a 10-minutes close exposure of EMFs emitted from a mobile phone has no immediate after-effect on TEOAE frequency specific parameters in young human subjects.

This study was partially supported by the Project GUARD "Potential adverse effects of GSM cellular phones on hearing" (European Commission, 5FP, QLK4-CT-2001-00150, 2002–2004).

Relationship between Hearing Sensitivity and Distortion-Product Otoacoustic Emissions in Patients with Low-Frequency Sensorineural Hearing Loss

Jacek Smurzynski¹, Krzysztof Kochanek², Adam Pilka², Henryk Skarzynski²

¹East Tennessee State University, Johnson City, Tennessee, USA

²Institute of Physiology and Pathology of Hearing, Warsaw, Poland

The aim of the study was to assess the contribution of apical and basal regions of the cochlea to the generation of distortion-product otoacoustic emissions (DPOAEs) in patients with low-frequency sensorineural hearing loss (LFSNHL). Those individuals were evaluated with a battery of audiological tests, including otoscopy, pure-tone audiogram, tympanometry, ipsilateral and contralateral acoustic reflex measurements, and click-evoked ABRs. For some patients, the results of CT and/or MRI evaluations were also available. All patients had normal hearing thresholds for frequencies above 1–2 kHz and moderate to severe LFSNHL below 1–2 kHz. DP-grams were recorded by the Scout OAE system using the L1/L2 levels of 65/55 and 55/40 dB SPL, the f_2 frequency decreasing from 8 to 0.7 kHz in 1/4-octave steps, and $f_2/f_1 = 1.2$. The DPOAEs of patients were compared to the baselines obtained for a group of young normally-hearing adults. The working hypothesis was that DPOAEs might be reduced or absent in the low-frequency region but within a normal range for frequencies corresponding to normal hearing sensitivity. In general, there was a modest correspondence between the configurations of the pure-tone audiograms of the patients and their DP-grams expressed relative to the normal range. However, the lowest f_2 frequency at which normal or near-normal DPOAEs were recorded was lower than its counterpart on the audiogram. That trend was more evident for the primary levels of 65/55 than for the 55/40 dB SPL condition. The results indicate that: 1) to some extent, the DP-gram reflects the configuration of the pure-tone audiogram; 2) DPOAEs measured in the ear canal result from complex generation processes involving multiple sources that are widely spread along basilar membrane; 3) the most basal region of the cochlea contributes to the generation of DPOAEs evoked by primaries corresponding to more apical regions, and 4) the role of that basal region contribution increases with an increase of the level of the primaries. For patients who are at risk for the progression of LFSNHL, monitoring cochlear function with DPOAEs may provide additional clinical objective information about the status of the peripheral hearing.

Calibration Effects on Optimal Stimulation of Distortion Product Otoacoustic Emissions

Johann A. Oswald¹, Thomas Janssen²

¹*Institute for Real-Time Computer Systems, Technische Universitaet Muenchen, Munich, Germany*

²*ENT-Department, Technische Universitaet Muenchen, Munich, Germany*

Distortion product otoacoustic emissions (DPOAEs) and therefrom derived input/output (I/O) functions suffer from interindividual variability in humans. Consequently, further processing of data, like estimation of hearing threshold, maintains notable inaccuracy. By using a model based calibration method (ear canal compensated calibration, ECCC), the interindividual variability of optimal DPOAE measurements is to be reduced significantly. The individual, optimal path in the primary tone level space (L1, L2 space) for evoking DPOAEs basing on ECCC is notably less frequency dependent compared to other calibration methods like “in the ear” (ITE) calibration. For a proof of concept, both calibration methods, ITE and ECCC, were applied for DPOAE measurements in 13 normal hearing humans at test frequencies $f_2 = 1, 2, 3, 4, 6,$ and 8 kHz with fixed frequency ratio $f_2/f_1 = 1.2$. The combinations of primary tone levels L1 and L2 were not fixed as the settings for recording maximal $2f_1-f_2$ DPOAE amplitudes was to be estimated individually. The stimulus range L2 reached from 25 to 75 dB SPL in steps of 10 dB and L1 varied in steps of 3 dB in a vast range in order to record individually maximal levels of DPOAE in L1, L2 space. Basing on the same data of the same pool of normal hearing subjects, the optimal primary tone settings were determined individually and in mean dependent on the calibration methods ECCC and ITE respectively. Using ECCC, the optimal path in L1–L2 stimulus-space over all subjects and frequencies was $L1 = 0.5 L2 + 39$ [dB SPL]. Using ITE, the optimal path was $L1, ITE = 0.5 L2, ITE + 42$. When using the same restrictions to stimulus levels ($L2 < 65$ dB SPL) like in comparable studies in literature, the optimal stimulus paradigm using ITE evolved to $L1, ITE = 0.42, L2 ITE + 45$ [dB SPL]. Using ECCC the optimal stimulus path is less frequency dependent and not as influenced by the standing wave problem in the outer ear canal. Therefore DPOAE measurements and derived I/O-functions can be post-processed in a physiologically correct way with respect to hearing threshold or loss of compression.

An Attempt to Decompose the Signal of the Transient Evoked Otoacoustic Emission to Primary Components

Oleg Belov, George Tavartkiladze

National Research Centre for Audiology and Hearing Rehabilitation, Moscow, Russia

An attempt to decompose the signal of the transient otoacoustic emission to primary components using the transform to logarithmic time scale and the method of predictive deconvolution is described. All methods for estimation of some parameters of a signal in noise use certain assumption regarding the properties of the signal. For example, widely used FFT is appropriate for signals composed of continuous tones, which leads to some misinterpretations in more complex cases. A minimal set of assumptions about the TEOAE structure was used with consequent built up of the appropriate numeric algorithm for parameters estimation. Three assumptions were under consideration: first, the TEOAE signal consists of a small number of primary components; second, all primary components have a similar shape, initially unknown, but its time scale and latency are tied in accordance with a scale invariance of the cochlea; and third, the shapes of primary components for at least all subjects with normal hearing are similar, although positions and amplitudes of these components are distinct. A set of TEOAE recordings from normal hearing subjects was converted to a logarithmic time scale. In this scale all signals governed by the above assumptions could be expressed as a convolution of the unified component image with an individual set of pulses or 'events'. The first approximation to the component image by the cepstrums of data was calculated. In the next stage, the predictive deconvolution technique was used to obtain a better approximation. An attempt to refine and to compensate the cochlear delay also was made. This algorithm was tested on the modelled signal. The shape of the modelled component was successfully recovered from a set of noised records. Next, it was found that all TEOAE recordings from our data set could be decomposed to a small number of primary components and the residual noise was comparable with the background noise contained in these recordings.

Study of Otoacoustic Emissions in Temporo-Mandibular Joint Dysfunction

Ossama A. Sobhy¹, Ahmed R. Koutb², Fathi Abdel-Baki¹, Tarek M. Ali², Iman Z. El-Raffa², Alaa H. Khater²

¹Otolaryngology Department, Faculty of Medicine, and

²Oral Surgery Department, Faculty of Dentistry, Alexandria University, Alexandria, Egypt

Costen's disease describes a variety of ear symptoms in temporo-mandibular joint (TMJ) dysfunction. Symptoms include ear fullness, otalgia and tinnitus. Many hypotheses had been proposed to explain the occurrence of ear manifestations in TMJ disease, but the latest is the one that suggests that abnormal projection of the trigeminal ganglion in TMJ disease to the cochlear blood supply, which is innervated by the trigeminal nerve, as the mechanism of occurrence of these symptoms.

Thirty patients with TMJ dysfunction were recruited from the oral surgery clinic, Faculty of Dentistry, Alexandria University. Pure tone audiometry, self-assessment tinnitus questionnaire, transient-evoked, as well as distortion product otoacoustic emissions (OAEs) were performed before and after conservative treatment of their TMJ dysfunction. Conservative therapy was in the form of counselling, physiotherapy, anti-inflammatory agents, muscle relaxants and occlusal splints.

Results showed normal pure tone audiometric results before and after therapy. Significant improvement in the scores of the tinnitus questionnaire was found. Although waveform reproducibility of the transient-evoked OAEs did not show statistically significant changes after therapy, the changes were clinically observable. On the other hand, distortion product OAEs showed significant increases in emission levels at most of the frequency bands. These results were paralleled to subjective improvement of tinnitus. The increase in emission levels were attributed to improved cochlear blood supply as a result of cessation of abnormal trigeminal nerve projection to the inner ear vasculature. The results lend support to the latest hypothesis of ear manifestations in TMJ dysfunction.

Correlation between Behavioural (Pure-Tone Audiogram) and Estimated Thresholds (Cochlea Scan)

Günter Reuter¹, Svenja Beinroth¹, Thomas Janssen², Thomas Lenarz¹

¹Department of Otolaryngology, Medical University of Hannover, Hannover, Germany

²Technical University Munich, ENT Department, Munich, Germany

Background. Most screening protocols are based upon pass/refer criteria using maximal primary tone levels of 65 dB HL or even more. As a consequence, cochlear hearing losses of up to 45 dB threshold elevation might be missed.

Methods. In the present study the objective hearing threshold was compared with Cochlea-Scan measurements using extrapolates DPOAE growth functions from a normal hearing control group, patients with hearing loss and ears with middle ear diseases.

Results. DPOAE I/O-Functions were recorded in 580 ears from normally hearing adults (46), patients with cochlear hearing loss (471) and with conductive hearing loss (63). When considering all test-frequencies (1.5, 2, 3, 4, 6 kHz) linear regression analysis of the data yielded a regression coefficient of $r = -0.73$. Average estimation error (behavioural minus estimated threshold) amounted to 10.1 dB. Regression line was close to the 45 degree line indicating an one-to-one relationship between behavioural and estimated thresholds. Correlation coefficient decreased with decreasing test-frequency from $r = 0.85$ at 6 kHz to $r = 0.62$ at 1.5 kHz. Lowest estimation error was 6.62 dB at 6 kHz, highest was 10.8 dB at 1.5 kHz.

Conclusions. There was a close relationship between behavioural and estimated thresholds. Accuracy of hearing threshold estimation is therefore suggested to be high enough for establishing the new method in audio logical diagnostics especially for newborns and children where behavioural testing do not reflect the real hearing threshold.

The Auditory P50 Component to Onsets and Offsets of Gaps in Noise

Hillel Pratt, Arnold Starr, Henry J. Michalewski, Naomi Bleich, Nomi Mittelman

Evoked Potentials Laboratory, Technion – Israel Institute of Technology, Haifa, Israel
Neurology Research Laboratory, University California Irvine, Irvine, California, USA

Objective. To compare the spatio-temporal distribution of cortical activity underlying the auditory Event-Related Potentials (ERP) component P50 in response to stimulus offset and onset, without confounds of spectral change.

Methods. Evoked potentials were recorded to onsets and offsets of gaps of half a second durations randomly distributed in continuous white noise, as well as to clicks. Latency and amplitude, as well as source current density estimates of component P50 were determined and compared among clicks, gap onset (noise offset) and gap offset (noise onset).

Results. A clear P50 was recorded in response to gap offsets (noise onsets) and clicks, but it was significantly smaller, or only detected as the corner of baseline as it deflected towards N1, in the potentials to gap onsets (noise offset). Latency of P50 to gap onsets (47 ms) was significantly earlier than to gap offsets (56 ms) or to clicks (53 ms). The amplitude of P50 to gap onset was significantly smaller than to gap offset or to clicks. Sources of P50 to gap onsets and offsets were significantly different, with gap onsets associated with left inferior temporal and occipital activation whereas gap offset and clicks, although different, both activated mostly bilateral superior parietal areas. Source current density was significantly higher to gap offset in the vicinity of the temporo-parietal junction.

Conclusions. P50 to stimulus onset (gap offset and clicks) is distinct from P50 to stimulus offset, with later and enhanced activity at different intracranial sources.

Significance. Stimulus onset and offset activate distinct cortical processes with different spatio-temporal distributions.

Generation Mechanisms of 40 Hz and 80 Hz ASSR Explained by Deconvolution Averaging

Özcan Özdamar^{1,2}, Jorge Bohórquez¹, Nuri Açıkgöz¹

¹*Department of Biomedical Engineering and*

²*Departments of Otolaryngology, Pediatrics and Neuroscience, University of Miami, Miami, Florida, USA*

In spite of their widespread use, the generation mechanisms of the 40 Hz and 80 Hz Auditory Steady State Responses (ASSR) are not well understood. 40 Hz responses are generally explained by superposition of the Middle Latency Responses (MLR) modeled with recordings typically obtained at low rates. Such models, however, do not explain all the characteristics of the 40 Hz response mostly due to adaptation effects. This study tests the validity of the superposition theory by using Auditory Brainstem Response (ABR) and MLR recordings at 40 and 80 Hz rates. Such fast rate recordings are acquired using deconvolution averaging with low jitter stimulus sequences (Özdamar and Bohórquez, JASA 2006). Low jitter 40 or 80 Hz stimuli generate quasi-ASSRs which resemble real- ASSRs generated by isochronic sequences. In this study real- and quasi-ASSRs are obtained from normal hearing subjects with 50 dB nHL click sequences at both rates using 204.8 ms sweep durations. Synthetic 40 Hz and 80 Hz ASSRs are generated using deconvolved ABR/MLRs recorded at appropriate rates. ABR/MLR recordings at 40 Hz show prominent V, Na, Pa, Nb, and Pb waves. Contrary to low rate recordings, Pb (or P1) component of the MLR present large amplitude at 40 Hz showing a possible resonance effect at this rate (Özdamar et al., Clin Neurophysiol 2007). Superposition of these three components (V, NaPa and NbPb) generates the typically large 40 Hz response. ABR/MLR deconvolved recordings at 80 Hz show mostly prominent V and N0/Na waves (sometimes called slow negativity SN10 component). The Pa and Pb components are diminished but still present at this high rate. Superposition of the biphasic V-Na complex (slow ABR) generates the typical small but robust 80 Hz response. The MLR components contribute little due to their low frequency content. Comparison of the synthetic and real 40 Hz and 80 Hz ASSRs in time and frequency domains show striking similarities, thus verifying the contributions of the ABR and MLR components as described above. The study shows that the amplitude and phase characteristics of 40 Hz and 80 Hz ASSRs can be reliably predicted with the superposition theory using the deconvolved ABR/MLR recordings obtained at corresponding rates.

Effects of Monotic and Dichotic Interference Tones on the 40-Hz Auditory Steady-State Response

Shaum P. Bhagat

School of Audiology and Speech-Language Pathology, The University of Memphis, Memphis, Tennessee, USA

Auditory steady-state responses (ASSRs) elicited with multiple carrier tones modulated at high rates (> 70 Hz) have been incorporated as a diagnostic test to evaluate auditory function in infants and young children. The benefit of utilizing multiple carriers is that several test frequencies can be evaluated at one time, increasing test efficiency while minimizing the time required to acquire ASSRs. Another time-saving approach involves testing both ears simultaneously with dichotic presentation of carrier tones. Multiple ASSRs acquired in infants exhibit frequency specificity and can be recorded with dichotic stimulation. In adults, the largest ASSRs are evoked by tones modulated near 40 Hz. Since many adults cannot participate in behavioral auditory tests, the development of an efficient objective test with adequate frequency specificity in adults is warranted. This investigation examined the frequency specificity and dichotic characteristics of 40-Hz ASSRs recorded with multiple carriers. ASSRs were acquired with presentation of probe and interfering tones in 31 normal-hearing adults. The effects of interfering tone frequency, modulation depth and modulation rate on monotic and dichotic ASSR amplitudes were evaluated. Significant decreases in monotic ASSR amplitudes occurred when the interfering tone was higher in frequency and within an octave of the probe tone. Monotic ASSR amplitude reductions were also observed for interfering tones modulated at lower depths than the probe tone. Probe and interfering tones modulated at different rates produced similar effects on monotic and dichotic ASSRs. The description of the effects of stimulus parameters on multiple 40-Hz ASSRs can benefit clinical applications of this technique.

This project was supported by a grant provided by The American Academy of Audiology Foundation.

ASSR Input/Output Functions: Does Response Analysis Method Affect Response Properties?

Robert Burkard¹, Kathleen Szalda McNeerney¹, Michael Sasha John²

¹State University of New York, Buffalo, New York, USA

²Rotman Research Institute, Toronto, Ontario, Canada

Nearfield ASSR I/O functions of chinchillas differ in several ways from human farfield responses. First, our nearfield ASSRs to two-tone or SAM stimuli often saturate or are notched. Second, the interference from multiple stimuli seen in nearfield studies is greater than is observed in the human data. Nearfield ASSRs are very rich harmonically – a finding not commonly noted in the adult human far-field responses. The present study compared response I/O functions measuring the RMS amplitude of the entire response, as well as at the first five harmonics of the modulation frequency. Eight young adult chinchillas served as the experimental subjects; recordings reported are from the inferior colliculus. Input/output functions (–10 to 80 dB pSPL; 10 dB steps) were obtained in response to two carrier frequencies (2000 Hz, 4000 Hz), modulated at two different frequencies (~90 and 70 Hz, respectively), for three different modulation techniques (tonebursts varied in repetition rate, two-tone stimuli varied in difference tone, and SAM stimuli varied in modulation rate). Stimuli were presented alone and in pairs for each technique. Responses were measured at the primary response modulation frequency (following cropping, windowing and FFT), as well as at the second through fifth harmonics. As previously reported, at higher stimulus levels the mean I/O functions for the primary Fourier component of the SAM and two-tone functions showed saturation or were notched, while the toneburst responses grew monotonically. There were substantial decrements in amplitude when the stimuli were paired, which began at moderate stimulus levels, and were most substantial at high stimulus levels. For RMS voltage, the average I/O functions for all stimuli were monotonic. For the two-stimulus condition, RMS voltage approximated that of the larger of the two single-stimulus conditions. When response amplitudes of the five harmonics were summed (based on assumption they were uncorrelated), the mean TB, 2 kHz TT, and SAM I/O functions were monotonic. The mean 4 kHz I/O functions for TT and SAM stimuli were notched at 70 dB SPL. For these data, response amplitudes decreased on the order of 1/3 when the second stimulus was added.

Keynote Lecture III

Magnetoencephalography of Auditory Cortex

Bernhard Ross

Rotman Research Institute, Baycrest Centre, University of Toronto, Toronto, Ontario, Canada

Modern whole head magnetoencephalography systems record brain activity from as many as 150 to 300 sensors simultaneously. Although underlying neural sources are the same for scalp recorded potential differences in EEG and extracranial recorded magnetic fields in MEG, the maps of activity projected onto the head show characteristic differences. The magnetic field distribution of auditory evoked responses consists of two dipolar pattern which are well separated for left and right hemisphere. In most cases evoked activity in auditory cortices can be modeled precisely with single equivalent current dipoles in left and right temporal lobes.

Besides source localization one important advantage of multichannel MEG recordings is that it allows extracting of evoked response waveforms with highest signal to noise ratio. The processing steps to exploit the information rich nature of MEG signals shall be demonstrated with data from a study about aging related changes in central processing of binaural information.

The stimuli for this study were designed to elicit multiple components of auditory evoked responses simultaneously as it was intended to gain as much information as possible out of a single experiment. Tones of four seconds duration were presented at 60 dB sensation level to both ears with stimulus onset asynchrony of 8.5 to 9.5 s. For the first two seconds the sounds were presented with equal phase to both ears (diotic stimulation). For the following two seconds the tones were of opposite phase at both ears (dichotic stimulation). The sounds were 40-Hz amplitude modulated and the shift of interaural phase relation occurred at an amplitude minimum in order to avoid perception of a discontinuity from monaural stimulus.

During signal preprocessing artifacts were identified based on their spatial distribution using principal component analysis or independent component analysis. Thus, in principal no data have to be rejected. Source analysis was based on single equivalent dipoles in left and right auditory cortex and resulted in time series of evoked activity.

P1-N1-P2 responses of similar magnetic field distribution and wave forms were evoked with the stimulus onset and the change of interaural phase difference. The group of young healthy subjects (mean age 25 years) showed onset and change responses of almost equal size at 500 Hz stimulus frequency. However the amplitude of the change response decreased with increasing frequency and was not detectable at 1500 Hz. The upper frequency limit for detecting changes in interaural phase differences was confirmed in behavioural tests using same stimuli and is consistent with earlier findings that interaural phase differences in continues sound are used for sound localization below 1500 Hz only.

The upper frequency limit for interaural phase detection decreased to 1100 Hz in the group of middle aged adults (mean 50 yrs.) and to about 900 Hz in older adults (mean 72 yrs.).

The results demonstrate a decline of binaural processing almost continuously over adult lifetime with onset noticeably earlier than aging related hearing loss. A possible underlying physiological mechanism is aging related decline in phase locked processing of bilateral inputs at early brainstem level, most likely the medial superior olivary nuclei. Thus, an effect of aging on auditory brainstem function is discussed even the corresponding responses were recorded from auditory cortices. Cortical evoked P1-N1-P2 responses itself were compared between the age groups. The onset response showed consistent latencies between groups rejecting the hypothesis that cortical responses slow down with aging. However, the P2 phase change response was significantly delayed indicating prolonged processing time for specific sound features at cortical level. The P2 latency effect was not visible in the middle aged group. Thus the observed cortical effect commences later in life than aging related changes at brainstem level.

The 40-Hz amplitude modulation of the stimulus evoked steady-state responses with almost amplitudes across the age groups. The change in interaural stimulus phase resulted in a reset of the steady-state response most clearly visible in the time course of the steady-state phase.

The interaural phase change was detectable in the steady-state response close to the reported thresholds. Using steady-state signals for change detection seems at least as effective than the long latency P1-N1-P2 transient response.

In summary, multiple component of MEG recorded auditory evoked responses were used to discuss aging related changes in central processing of binaural information.

Electrocochleography and Tinnitus

Hiroaki Nishida

Nishida ORL Clinic, Yokohama, Japan

In this paper, we describe the results of electrocochleography in patients having tinnitus and/or hearing impairment without vertigo, and discuss the pathology of these cases.

Subjects. Subjects were 68 ears of 60 patients presenting with tinnitus and/or hearing impairment without vertigo. Control groups were patients with Ménière disease and persons with normal audibility.

Methods. Electrocochleography by the extratympanic (ECochG) method was performed. As indices, we used respective potentials and the ratios of SP and AP (SP/AP ratios) at 90 dB nHL for AP and SP. For the SP/AP ratio, values > 0.4 were considered to be abnormally high. Statistical analyses performed were the Kruskal-Wallis test (Scheffe method).

Results. The incidences of cases with an SP/AP ratio > 0.4 in individuals having tinnitus and/or hearing impairment without vertigo (tinnitus/hearing impairment group), Ménière disease (Ménière group), and normal hearing group. This value was 73.5% (50 of 68 cases) in the tinnitus/hearing impairment group, 13.3% (six of 45) in the normal audibility group, and 63.6% (21 of 33) in the Ménière group, with the incidence in the tinnitus/hearing impairment group being significantly higher compared to the normal audibility group (X^2 test), and slightly higher than that in the Ménière group. The group with a breakdown consisted of 44 cases of cryptogenic sensorineural hearing impairment (64.7%), eight cases of tubal stenosis (11.7%), 11 cases of pruritus of external auditory meatus (16.1%) and five cases of low-tone acute sensorineural hearing impairment (7.3%). Also, in the tinnitus/hearing impairment group, 32 cases were cochlear hearing loss and six were retrocochlear hearing loss according to the SISI test.

Summary. In general, patients with Ménière disease/endolymphatic hydrops show a high SP/AP amplitude ratio. In this paper, electrocochleography identified a significantly higher SP/AP amplitude ratio among a group of patients with tinnitus/hearing impairment than was observed in the Ménière and normal audibility groups. This finding may suggest the involvement of endolymphatic hydrops in cochlea (tentative name: "edematous tinnitus") in the pathology of tinnitus, and may provide important information in the future for the treatment of edematous tinnitus.

ABR Evidence for a Dissociation between Symptoms and Underlying Pathological Changes in Meniere's Disease Patients

Manuel Don¹, Betty Kwong², Chiemi Tanaka³, Michael Waring¹

¹House Ear Institute, Los Angeles, California, USA

²Formerly with the House Ear Institute, Los Angeles, California, USA

³State University of New York, Buffalo, New York, USA

Previous work (Don et al., 2005) demonstrated that Meniere's disease (MD) patients who continued to have 3 or 4 of the hallmark symptoms (vertigo, fluctuating hearing loss, tinnitus, fullness) at the time of testing, could easily be distinguished from non-Meniere's normal-hearing (NMNH) subjects by the difference between the latency of the undermasked component in the 0.5 kHz high pass masked response and the latency of wave V in the response to clicks alone. For the MD cases, the latency of the undermasked component is nearly identical to that of wave V in the response to clicks alone whereas in the NMNH cases, it is prolonged. The distributions of the two test populations did not overlap, resulting in 100% sensitivity and 100% specificity for that study. Restricting the test population to those patients who continued to have 3 or 4 of the hallmark symptoms was an attempt to maximize the likelihood that the patients still had an "active" case of Meniere's disease or cochlear hydrops. We now present 16 patients diagnosed with Meniere's disease who had only two or fewer of the hallmark symptoms at the time of testing. Most of the subjects underwent medical treatment at some point between the time of diagnosis and the time of our testing. Results indicate that all but one of these 16 patients demonstrated undermasked components with latencies consistent with the previous results (Don et al., 2005) obtained from patients with active Meniere's disease or cochlear hydrops. This strongly suggests that although many patients diagnosed with Meniere's disease experience relief from two or more of their symptoms, the underlying pathology itself, or a change caused by the original pathology, still exists. A discussion of relationships to the extent of hearing loss, time from first diagnosis and specific remaining symptoms will be presented.

Reference:

Don M, Kwong B, Tanaka C. A diagnostic test for Meniere's disease and cochlear hydrops: Impaired high-pass noise masking of ABRs. *Otol Neurotol* 2005; 26: 711–22.

Preventing Noise and Drug Induced Hearing Loss with D-Methionine

Kathleen C. M. Campbell, Larry Hughes, Robert Meech

Southern Illinois University School of Medicine, Springfield, Illinois, USA

D-methionine, a component of fermented protein such as cheese or yogurt, markedly reduces cisplatin-, carboplatin-, aminoglycoside-, and noise induced hearing loss (NIHL). Permanent NIHL in response to a 6 hour 105 dB SPL narrow band of noise can also be markedly reduced, to levels similar to control animals, whether D-methionine administration starts either before or within hours after noise exposure. The maximum time delay has not yet been determined but is currently being investigated. D-methionine also protects against radiation induced oral mucositis. The FDA approved our IND for that application including the D-methionine safety data and oral drug formulation. A successful, phase 1b clinical trial for that application has been completed in India. Phase 2 clinical trials in India and the US should be completed within 12 months. Phase 2 clinical trials for cisplatin and aminoglycoside otoprotection are just starting in India. We now wish to design further research and clinical trials to prevent noise-induced hearing loss, aminoglycoside induced hearing loss, and cisplatin induced hearing loss. We are seeking more clinical trials populations in all areas. This presentation will focus on using D-methionine to provide prevention and rescue from noise-induced hearing loss.

Challenging the Jeffress Model of Azimuthal Sound Localization in Humans with Binaural Auditory Evoked Potentials

Helmut Riedel, Birger Kollmeier

Medizinische Physik, Fakultät V, Carl von Ossietzky Universität Oldenburg, Oldenburg, Germany

In the classical Jeffress model supported by bird studies, coincidence detectors connected by bilateral delay lines form a place code of interaural time difference (ITD). However, recent physiological studies in mammals (McAlpine and Grothe, 2003: Sound localization and delay lines – do mammals fit the model?) showed maximal firing rates of binaural neurons outside the physiological range and a dependence of the best ITD on their best frequency (BF) equivalent to a constant best interaural phase difference (IPD) of 45° . Both features are incompatible with the Jeffress model. In order to test the Jeffress model in humans, in the present study late responses to changes in IPD and ITD in bandpass noises were recorded. If the human binaural auditory system is arranged according to Jeffress, responses to IPD- and ITD-stimuli should not differ while responses to IPD-stimuli should be larger according to the recent findings in mammals. The bandpass noises had a center frequency of 500 Hz, three bandwidths (67, 200, 600 Hz) were tested. Four values of the interaural parameters were used: for the IPD they were -135° , -45° , 45° , and 135° . The ITD values were chosen to match the IPD-values for the center frequency of the noise band, i.e. -0.75 , -0.25 , 0.25 , and 0.75 ms. The 12 possible transitions of the 4 ITDs and IPDs were presented to the subjects in pseudo-random order at 70 dB SPL via insert earphones. Four hundred responses to each transition were averaged. For all bandwidths, IPD-transitions resulted in larger P2-N1 amplitudes than corresponding ITD-transitions. For the IPD-stimuli, the largest responses were evoked for 180° transitions. IPD-changes of 90° and -90° elicited smaller responses. For the ITD stimuli a similar response pattern was observed. The response was largest the ITD-changes of 1 ms corresponding to an IPD-change of 180° . Specifically, it was weaker for the largest ITD change of 1.5 ms. The results of the present study cannot be understood in terms of the Jeffress model, but are compatible with the recent physiological findings in mammals suggesting a population code of azimuthal sound localization rather than a place code.

Hearing Threshold Estimation with CochleaScan and ASSR Protocols

Stavros Hatzopoulos¹, Joseph Petruccelli², Silvano Prosser¹, Giada Buzzoni¹, Alessandro Martini¹

¹Department of Audiology, University of Ferrara, Ferrara, Italy

²Department of Mathematical Sciences, Worcester Polytechnic Institute, Worcester, Massachusetts, USA

The objective of the study was the evaluation of hearing threshold errors induced by the use of electrophysiological and acoustical methods in a population of normally hearing (30 subjects) and hearing-impaired adults (8 subjects with SNHL deficits).

Hearing threshold levels were assessed with Pure Tone Audiometry, Auditory Steady State Responses (AUDERA), and CochleaScan (Fischer-Zoth) DPOAE-protocols. Comparisons were conducted in three frequencies, namely at 1.5, 2.0, and 4.0 kHz in order to accelerate the total recording time requirements per subject.

For the Normal Hearing group both techniques underestimated the hearing level by 5 to 15 dB, with the ASSR values being the worst predictors. Linear regression models suggested a significant relationship between the PTA and the CochleaScan data in all tested frequencies, but the low R² values underlined the possible presence of other important factors. The relationship between the ASSR and the PTA values was found to be poor and the only significant relationship was observed at 4.0 kHz. For the Hearing Impaired group, the CochleaScan estimates were found to overestimate the hearing level at 4.0 kHz. Both techniques offered threshold estimates very close to the PTA values at 1.5 kHz. Linear Regression models suggested significant relationships between the PTA, CochleaScan and ASSR values. The CochleaScan presented a higher correlation index to the PTA but offered inconclusive estimates for hearing levels above 50 dB.

The data of the study support the hypothesis that the employed techniques can be part of ONE battery of tests. The CochleaScan protocols can be used in cases presenting up to moderate hearing deficits. The ASSR protocols can be used to assess higher grades of hearing impairment.

Second Stage of Universal Neonatal Screening with ABR – – Results and Problems

Majda Spindler

Department of Otorhinolaryngology and Cervicofacial Surgery, General Hospital Maribor, Maribor, Slovenia

In General Hospital of Maribor we started the universal neonatal screening before the year 2000. Our hospital covers a region of about 320,000 inhabitants and we have about 2000 newborn infants per year. In last three years 99.3 % of newborn babies were screened (at the neonatal department with otoacoustic emissions – OAE). If they don't pass, the second stage of screening is made at the ENT department with some examinations and ABR. From beginning of 2000 to the end of 2006 we tested 158 babies, those with unilateral (45) or bilateral negative OAE (86) and those with positive OAE (27) and risk factors and deafness in the family. From those 158 babies tested, 15 had conductive loss (palatoschisis, atresia of external ear channel, otitis). We found 11 deaf babies and 4 with a mild hearing loss. In a large group of 86 babies with bilateral negative OAE we found a normal value of ABR in 71 babies. The rest of them (15) had a mild to moderate hearing loss, but after a month the ABR was normal. We didn't find another significant difference between these two groups of babies. One year later all of them had normal OAE and normal ABR. In the group of infants with risk factors (except deafness) we didn't find any deaf baby. But from 11 deaf infants 5 of them have deafness in the family. We are doing universal neonatal screening for more than seven years. Now we have no problems with screening and early diagnostics, but with parents of deaf children. Some of them don't believe that the child is deaf until it is evident, and for this reason don't cooperate. Only 5 out of 11 decided on cochlear implantation. For the rest of them, the appropriate time is running out.

Posters

Electrically Evoked Middle Latency Response in the Cat: Effect of Stimulation Rate and Pulse Duration

Sung Wook Jeong, Woo Yong Bae, Soo Yong Ahn, Lee-Suk Kim

Department of Otolaryngology, Dong-A University Hospital, Busan, Korea

Electrically evoked middle latency response (EMLR) has several advantages over electrically evoked auditory brainstem response (EABR). The major component peaks of EMLR lie outside the region of stimulus artifacts and it reflects the activation of a more significant portion of the auditory pathway than EABR. It is known that several conditions alter the general morphology, amplitude, and latency of the waveforms of EMLR. The purpose of this study was to record and evaluate the effects of stimulation rate and pulse duration on detectability, latency and amplitude of EMLR in the cat. EMLR was recorded in response to nine experimental conditions – three conditions of pulse duration (150, 200, 250 μ s biphasic) at each of three conditions of stimulation rate (2, 6, and 10/s) – after electrical stimulation at the round window in 7 cats. PA was identified in all conditions. The latency of PA was shorter and the amplitude of PA was larger significantly for the stimulation rate of 10/s and the pulse duration of 250 μ s compared with other conditions. PB was obtained from 17 of the 63 waves. We found that the optimal stimulation condition for EMLR in our laboratory was the stimulation rate of 10/s and the pulse duration of 250 μ s. This data can provide a basis for the appropriate stimulation condition of EMLR in human.

Effect of Ear Muff Placement on the Click Stimulus Waveform and Implications for ABR Threshold

Siobhán Brennan, Paul Bacon, John Stevens

Department of Medical Physics, Royal Hallamshire Hospital, Sheffield, United Kingdom

Within the Newborn Hearing Screening Programme, disposable ear muffs are routinely used to deliver the click stimulus to a neonate's ear when performing automated auditory brainstem response tests. This study investigated whether changes in acoustic waveform with muff fit affects the psychoacoustic and electrophysiological thresholds. The acoustic properties of a muff for good seal and poor seal (acoustic leak) conditions were investigated using a coupler, probe microphone and sound level meter. Modified ear moulds were used to couple muffs to adult ears. Psychoacoustic and ABR thresholds were obtained from 15 normal hearing adults in both conditions. The results show that compared to a good seal condition, the poor seal condition: (1) made the click stimulus more oscillatory and of increased duration; (2) reduced psychoacoustic thresholds by an average of 4.6 dB (2 SD, -0.4 to +9.6 dB); (3) reduced the ABR thresholds by a similar magnitude. Results 2 and 3 were contrary to the expected result of a rise in psycho-acoustic and ABR threshold with loss of muff seal. It is concluded that good adherence of the muff to the skin (preventing acoustic leak) is necessary to ensure that the intended stimulus screening level is achieved.

Technical Aspects of Stimulus Presentation through the Hearing Aid for ASSR Recording

Stanislav Bronyakin, Oleg Belov, George Tavartkiladze

National Research Centre for Audiology and Hearing Rehabilitation, Moscow, Russia

Recently objective methods are widely used for hearing threshold determination as well as for the evaluation of the results of hearing aid fitting and speech processor programming in CI users. The main goal of our study was to evaluate the usefulness of ASSR registration for the objective verification of the gain parameters in patients with hearing aids. The ASSR registration was performed in patients wearing HA based on the Gennum platform with the use of AUDERA device. The automatic algorithm implementing the phase coherence technique for the response detection was applied at frequencies of 500, 1000, 2000, and 4000 Hz. The amplitude-modulated stimulus was presented (i) to the HA microphone located in the sound-proof room and (ii) through the audio input of the HA. For the second condition the appropriate calibration was performed. Stimulation level was precisely adjusted to produce equal HA output level for both conditions. The second approach was developed due to multiple problems existing with free-field quality. In both stimulus presentation conditions the amplitude characteristics as well as modulated tone spectrum were analysed at each frequency at the input and the output of HA. The results obtained suggest that the described approach could be used for objective measures of HA amplification parameters in patients with hearing loss.

Fast Infant Audiogram Determination Using an Intensity-Ramping ASSR Technique

Rafael E. Delgado^{1,2}, Nuri Açıkgoz², Linda Hood³, Özcan Özdamar², Jorge Bohórquez²

¹*Intelligent Hearing Systems, Miami, Florida, USA*

²*University of Miami, Department of Biomedical Engineering, Coral Gables, Florida, USA*

³*Vanderbilt University, Department of Hearing and Speech Sciences, Nashville, Tennessee, USA*

A study demonstrating the acquisition of Auditory Steady State Responses (ASSR) from infants and children elicited using a linear Intensity-Ramping function is presented. In the typical ASSR testing technique, the stimulus intensity is maintained constant until a response is detected. Testing at individual intensities is repeated until the ASSR threshold is determined. With the present ASSR Intensity-Ramping technique, the stimulus intensity is changed during the one second stimulus presentation cycle. The stimulus may be composed of a single frequency, multiple frequencies or transients such as clicks or chirps presented to one or both ears simultaneously using unique modulation or repetition frequencies for each component and ear. When using a binaural multi-frequency stimulus with the ramping technique, the resulting data not only contains frequency response information but also frequency-specific threshold information in a single recording for both ears. EEG data corresponding to the stimulus presentation cycles are averaged until a pre-specified residual noise level is achieved. Analysis of the recordings is conducted to determine the response onset for each frequency or stimulus component using a time-domain envelope detection filter. The effects on thresholds and frequency specificity of different filter durations are examined. Because the stimulus time-intensity functions are known, thresholds can be estimated from the response onset time position. In the present study, data were collected binaurally combining 500 and 2000 Hz frequencies in one recording and 1000 and 4000 Hz frequencies in a second recording in order to obtain a dual-ear four frequency ASSR audiogram. Validation results from simulations and adult data are also presented. Preliminary results from adults indicate a strong agreement with behavioral thresholds. The ASSR Intensity-Ramping technique is expected to significantly decrease testing time over currently available ASSR testing methods.

This research is supported by an NIH NIDCD grant to Intelligent Hearing Systems.

Meta-Analysis of Variables that Affect Accuracy of Threshold Estimation via Measurement of the Auditory Ateady-State Response

Abreena I. Tlumak, Elaine Rubinstein, John D. Durrant

University of Pittsburgh, Pittsburgh, Pennsylvania, USA

Reported are the results of meta-analyses of data derived collectively from a sample of 56 published research studies on electric response audiometry (ERA) using the auditory steady-state responses (ASSRs). Selected characteristics for analyses were type of population (with or without hearing loss), modulation parameters, number of sweeps acquired during response analysis, electrode montage, and 80- vs. 40-Hz modulation rate. Several specific methodological issues and hypotheses thus were posited to rigorously test common conclusions drawn from the ASSR literature on the accuracy of ASSR-ERA. Results both substantiate and disprove these inferences, helping to identify those methodological issues which appear to, or not, significantly affect the accuracy of estimating threshold using ASSR measurement. In addition to these findings, another practical outcome of this study was the development of various summary tables of the data analyzed from the literature sampled, which will be made available to conference attendees.

The Measurement of Gap Detection in Adults with Normal Hearing Using Cortical Auditory Evoked Potentials (CAEPs)

Kirsty Gardner-Berry^{1,2}, Suzanne Carolyn Purdy^{1,3}, Harvey Dillon¹, Simon Carlisle²

¹National Acoustic Laboratories, Sydney, New South Wales, Australia

²The University of Sydney, School of Physiology (Faculty of Medicine), Sydney, New South Wales, Australia

³The University of Auckland, Speech Science (Department of Psychology), Auckland, New Zealand

Conditions such as auditory neuropathy/desynchrony and auditory processing disorders are known to cause problems with gap detection and speech discrimination ability. Traditional methods for testing gap detection ability require a behavioral response. However, this may not always be possible when evaluating young babies or those with multiple disabilities. In this study a series of adults with normal hearing were evaluated to see if cortical auditory evoked potentials (CAEPs) could be used to measure gap detection. Gap detection was also measured behaviorally. The vowel /ah/ was used with a 2000 ms duration. Gaps of different sizes ranging from 5 to 155 ms were placed in the center of the speech sound and the stimuli were presented to separate ears through an insert earphone. The stimulus elicited onset and offset responses in addition to a gap detection response. Characteristics of these responses will be described.

Late Evoked Potential Tracking of Time Compressed Speech

Herbert Jay Gould, Sarah Hay, Monique Pousson

School of Audiology and Speech-Language Pathology, The University of Memphis, Memphis, Tennessee, USA

Time compressed speech is created by removing small sections of an ongoing speech signal and abutting the remaining portions. This technique has been used in over 100 published studies evaluating basic speech processing in normal and disordered individuals since the late 1940s. The current work uses a 72 channel electrode array to generate both surface topographic maps and tomographic source analysis of neural activity that occurs with progressively greater speech compression levels. The Northwestern Auditory Test #6 word lists A–D were compressed at levels of 0%, 50%, 70%, 80% and 90 % using a computer based compression system. The files were then formatted to be compatible with the Neuroscan stimulus system. A trigger for post hoc averaging was established at the beginning of each carrier phrase in the list. Ten subjects with normal hearing and no reported history of neurologic disorders served as subjects for this study. A Neuroscan electrode cap with 72 channels was applied and the subject was seated in a sound attenuating electrically shielded room. The stimuli were presented in a counterbalanced manner across subjects. As only 4 lists were available the list used in the 0% condition was also used in the 90% compression condition. EEG was filtered 0.1 to 30 Hz and continuously collected. Epochs of –200 to 2000 ms were created post hoc using EEGSYS from Source Signal Imaging and averaged for each compression level. Laplacian transforms were created to display a reference free recording. The results show a posterior lateral activity that tracks the offset of the target word. The duration of the activity appears related to the compression level difficulty in extracting information from the speech signal. The changes in neural activity that occur progressing from a easily intelligible to an unintelligible signal may be explained in terms of a 'what-where' theory of auditory processing.

Time-Frequency Analysis of Auditory Steady State Responses

W. Wiktor Jedrzejczak^{1,2}, Krzysztof Kochanek¹, Lech Sliwa¹, Adam Pilka¹, Katarzyna J. Blinowska²

¹*Institute of Physiology and Pathology of Hearing, Warsaw, Poland*

²*Department of Biomedical Physics, Institute of Experimental Physics, Warsaw University, Warsaw, Poland*

Auditory steady state responses (ASSRs) are effectively detected and analyzed in frequency domain by Fourier analysis. However, the responses are hidden in EEG activity and there are fluctuations of their amplitude between trials. Therefore it seems interesting whether time properties of those responses can be extracted from EEG. In the present study time evolution of ASSRs was investigated by means of time-frequency (t-f) methods. For this purpose two methods were chosen: the “basic” t-f method i.e. windowed Fourier transform, and high resolution algorithm of adaptive approximations. As a first step simulated signals were analyzed. The influence of noise and number of sinusoidal components was studied. Finally, time-frequency properties of real recorded signals were investigated. The cases of single and multiple stimulation were analyzed.

Evaluation of Hearing Protector Attenuation by Auditory Brainstem Responses

Krzysztof Kochanek¹, Jan Žera², Adam Piłka¹, Rafał Młynski², Henryk Skarżyński¹

¹*Institute of Physiology and Pathology of Hearing, and*

²*Central Institute of Labour Protection – National Research Institute, Warsaw, Poland*

Attenuation provided by hearing protection devices (HPDs: earmuffs and earplugs) is commonly assessed by the so-called real ear at threshold method (REAT). However, the REAT method does not represent the release in physiological load of noise on hearing system when hearing protector is used especially at high noise levels. In this work, the decrease of noise-imposed load due to the application of hearing protector was assessed using the Auditory Brainstem Responses (ABRs) evoked by 4000 Hz tone pips. Effectiveness of protector attenuation was assessed by two methods. In first method, one compared intensity series of wave V determined from the ABRs registered without and with noise protectors to stimuli presented in free acoustic field. The measure of protector attenuation was determined by comparing stimulus levels at which the same latency was obtained in both conditions. In method two, one examined the influence of wide-band noise of different levels on responses to 50 dB nHL stimuli presented to the ear through an acoustic waveguide. The ABRs were registered with and without ear protectors. The effectiveness of protector was found by determining noise level difference for which the same change of wave V latency was observed in both situations. The investigation showed that the ABR method makes it possible to effectively assess the hearing protector attenuation.

Auditory Steady-State Responses in Hearing Impaired Children

Doris R. Lewis, Daniela Bortoloti Calil

Pontifícia Universidade Católica de São Paulo, São Paulo, Brazil

Newborn hearing screening (NHS) is becoming every day a powerful tool to detect hearing impairment in infants. It is of great importance that hearing evaluation after hearing screening can provide reliable information about hearing status. Some children are unable to respond for auditory stimulus correctly and for this reason objective tests must be applied. The Auditory Steady-State Response (ASSR) is an objective technique, which can help to predict the hearing status in very young children in several frequencies and in both ears. The method consists in using tones amplitude and/or frequency modulated (AM/FM) using a modulated tone in a rate of approximately 80 Hz. Previous studies demonstrated that the responses for the ASSR can be recorded within 10 to 20 dB of behavioral thresholds.

Objective. The purpose of this study was to demonstrate the results of the audiological evaluation among hearing impaired children and correlate the results with the Auditory Steady-State Response.

Design. Behavioral tests, immitance measures, otoacoustic emissions, click Auditory Brainstem Response and Auditory Steady-State Response were applied in a group of eight children aged 3–35 months, hearing impaired with moderate to profound hearing loss. The tests were performed at the Childrens Hearing Care Center (CeAC/DERDIC/PUCSP) in São Paulo, Brazil. The center belongs to the Catholic University of São Paulo (PUCSP) and assists children from birth to three years old.

Results. Four girls and four boys with sensorineural hearing loss were evaluated. The ASSR took around 42 minutes to be performed in the children in both ears. All children had type A tympanometry, and no otoacoustic emissions. Five children had no responses registered in ABR. Two children had responses at 50 dB nHL for both ears at the click ABR, and one child showed an ABR with 50 dB nHL on left ear and 80 dB nHL on right ear. For the ASSR it was possible to register the responses for all eight children, showing a correlation in all results for four children. Another four children showed responses for the ASSR when there were no responses for ABR or behavioral tests.

Effect of the Post-Auricular Muscle Response on ASSR Detection

Marcin Masalski^{1,2}, Stefan Giżewski¹, Maria Zalesska-Kręcicka²

¹*Wroclaw University of Technology, and*

²*Medical University of Wroclaw, Wroclaw, Poland*

Post-auricular muscle response (PAMR) can be observed during ASSR examination as an increase in response amplitude when recording electrode is placed on mastoid and referenced to the vertex or high forehead. PAMR is believed to be unstable response however latest studies shows that PAMR can be enhanced by lateral rotation of the eyes. The aim of this study was to investigate the presence of concomitant PAMR during ASSR to multiple simultaneous stimuli. Examinations were carried out on 10 normal hearing subjects in the age 20–50 years using custom set-up system with real time response detection. ASSRs were evoked by multiple simultaneous stimuli at carrier frequencies 500 Hz, 1 kHz, 2 kHz, 4 kHz presented at modulation frequencies in the 80–100 Hz range. The PAMR was considered to be present when EEG signal amplitude at modulation frequency was above 95% confidence interval of the ASSR amplitude. Results of the examinations revealed large intra subject variability of PAMR detection. Further analysis was carried out with a respect to stimulus intensity and carrier frequency of the stimulus. Benefit of PAMR in hearing threshold estimation by mean of ASSR is limited due to increase of EEG amplitude causes by PAMR enhancing procedure.

Assessment of Deconvolved Transtympanal Electrocochleography Obtained at High Stimulus Rates in Patients with Meniere's Disease and Acoustic Tumor

Krzysztof Morawski¹, Jorge Bohorquez², Katarzyna Pierchala¹, Fred Telischi^{2,3},
Ozcan Ozdamar^{2,3}, Kazimierz Niemczyk¹

¹Department of Otolaryngology, Medical University of Warsaw, Warsaw, Poland

²Department of Biomedical Engineering, and

³Department of Otolaryngology, Ear Institute, University of Miami, Miami, Florida, USA

Problem Addressed. To investigate a new strategy of deconvolution of auditory evoked responses recorded at high stimulation rates in patients with Meniere's disease (MD) and with acoustic tumors (AT).

Methods and Measures. Patients with MD (n = 15), with AT (n = 10), and 6 healthy subjects were tested using a new strategy of evaluation of the auditory system using "Continuous Loop Averaging Deconvolution" (CLAD) technique (Delgado & Ozdamar, JASA 2004; Ozdamar & Bohorquez, JASA 2006). In all subjects transtympanal electrocochleography (TT-ECoChG) was tested. Ears were stimulated by clicks presented at average rates ranging from 58/s to 780/s in CLAD strategy. Recorded data produced high quality traces in which action potential (AP) and summing potential (SP) were easily identified. SP/AP ratio and AP amplitude and latency were computed for each stimulation rate. The "critical point" (CP) was defined as the stimulus rate in which the slope of the AP amplitude adaptation curve was reduced significantly.

Results. In all cases, when stimulus rate increased AP was systematically reduced with stable or slightly reduced SP. Three AP rate adaptation patterns were observed: "pattern A" for which SP/AP at stimulus rate of 300/s and CP value equal to 625/s; "pattern B" (SP/AP 200/s; CP 234/s), "pattern C" (SP/AP 100/s, CP 136/s). In healthy subjects "pattern A" was observed, in AT patients mostly "pattern C", in MD subjects all patterns were present. Relations between MD or AT stages and mentioned patterns were discussed.

Conclusions. These very high stimulation rates provides a valuable tool for stress testing of the auditory system that could be used to define degree of damage of peripheral auditory system.

Clinical Significance of Study. CLAD strategy may support traditional audiological test battery in diagnosis of various auditory pathologies.

Support: KBN – Poland, Grant No 4 P05C 056 17.

What Can /ba/-/pa/ Tell Us about Temporal Processing?

Patricia J. Muir, Carrie J. Scarff, Rachel M. Martin, Angela D. Reynolds, Jos J. Eggermont

University of Calgary, Calgary, Alberta, Canada

It has been theorized that a fundamental deficit in the perception of rapid acoustic events contributes to specific language impairment (SLI) and auditory processing disorders (APD) in children (Tallal et al., 1996). This theory remains controversial (Studdert-Kennedy, 2002). Delays in the maturation of the auditory pathway are also implicated in APD and associated language deficits (Chermak & Musiek, 1997). The maturational state of the cortex limits neural conduction times and synchrony, which has significant implications for temporal processing (Eggermont & Ponton, 2003) especially in the millisecond range. Thirty-two channel long latency auditory evoked potential (AEP) recordings were obtained in response to /ba/-/pa/ continuum stimuli (VOT = 10–70 ms) presented to the right ear in neurologically normal children (aged 9–16 years) and an age-matched cohort of children with language learning disabilities who also completed a battery of behavioural auditory, language, reading and temporal measures. The auditory processing battery is the weakest link in demonstrating group behavioural differences, being outperformed by the reading, language, and specialized temporal measures. The electrophysiological response to the /ba/-/pa/ continuum does not mature fully until the late teen years. Significant maturational changes occur between younger (9–12 years) and older (13–17 yrs) age groups at all VOTs. Responses to fine temporal changes are evident even in less mature waveforms and, in spite of strong behavioural evidence of temporal processing difficulties, are measurable for most of the experimental children and are present at most electrodes. Experimental children show delays in maturation of the AEP particularly beyond N1 at longer VOTs. Controlling for age, weak to moderate correlations were observed between several composite behavioural temporal measures and the P2 and N2 amplitudes with the strongest correlations occurring at the longer VOTs. Latency only showed one weak correlation (VOT70 N1) that may not be meaningful. The electrophysiology findings do not support the existence of an auditory cortical based temporal processing disorder in our experimental group. Other factors such as auditory working memory, attention, and language may better account for the behavioural differences.

Effect of Repetition Rate on Both Acoustic and Electrically Evoked Auditory Potentials of Guinea Pigs

Pavel Prado-Gutiérrez, Armando Alvaré-Jaramillo,
 Francisco A. Gonzalez-Marrero, Francisco Martín-Gonzales

Cuban Neuroscience Center, Havana, Cuba

Auditory processing of temporal structure of stimulus is very important for normal hearing people and also for cochlear implant users. Due to the marked repetitive characteristic of acoustic and electrical stimulation, repetition rate becomes a temporal parameter of major interest in the study of both kind of stimulus. We investigated the effect of repetition rate on both acoustically and electrically evoked auditory potentials of guinea pigs. Auditory Brain Stem Responses (ABR) were recorded in 6 animals. It was measured the amplitude of wave I, II and III of the responses to clicks with a repetition rate of 5, 10, 25, 50, and 100 Hz. The effect of this parameter was analyzed at 20, 30, and 40 dB above ABR threshold using stimulus durations of 0.06, 0.1, and 1 ms. The higher the repetition rate the lower the ABR amplitude. Drop of the response depended on both stimulus intensity and duration of pulse -there was a larger decrease when pulse width and intensity were increased. For electrical stimulation, guinea pigs were deafened by co-administration of kanamycin and frusemide. Animals were acutely implanted with a 4-electrode array. It was measured the amplitude of wave III of electrically evoked Auditory Brain Stem Responses (EABR) to biphasic current pulses with a repetition rate of 5, 10, 25, 50, 100, and 200 Hz. Like acoustically evoked responses, the higher the repetition rate the lower the EABR amplitude. We also analyzed the effect of increasing intensity (from 300 to 1000 μ A), pulse width (from 66 to 127 μ s/phase) and inter-phase gap (from 10 to 50 μ s) on the decrease of the response. Preliminary results suggest that the effect of repetition rate on the amplitude of the evoked potential is strengthened with the increase of these parameters. These results open the gate to study the possible relation between the effect of repetition rate on the auditory response and the degeneration of the auditory pathway of deaf individuals with different duration of deafness.

Reference Electrode Position for Single Ear Cortical Auditory Evoked Potential (CAEP) Recording. Does It Really Matter?

Mridula Sharma^{1,2}, Suzanne C. Purdy^{1,2}, Kevin J Munro³

¹University of Auckland, Auckland, New Zealand

²Macquarie University, Sydney, New South Wales, Australia

³University of Manchester, Manchester, United Kingdom

The effects of reference electrode position on CAEPs were studied in ten young adults with normal hearing. CAEPs were recorded in response to a 75-dB SPL 1000 Hz toneburst (20-20-20 ms) presented at 1125 ms ISI via an insert earphone. There were three reference electrode positions, right ear, left ear and the nape of the neck. The non-inverting electrode was placed at the midline (vertex, Cz), and left (C3) and right (C4) hemispheres and sound was presented separately to the left and right ears, in counterbalanced order. Repeated measures ANOVA, with test ear and reference electrode as within-subject factors, showed some significant interactions between reference electrode position and stimulation ear for CAEP latencies but not amplitudes. The effect of reference electrode was further investigated with only the ear reference electrode positions included in the analysis, to determine whether CAEPs differ when recorded with the reference electrode on the side ipsilateral versus contralateral to the stimulus ear. This analysis showed a significant difference for N1 latency at Cz, C3 and C4; latencies were slightly earlier for recordings made with a contralateral reference electrode, for both right and left ear stimulation. Historically researchers and clinicians have used a variety of reference electrode positions when recording CAEPs, including a single earlobe/mastoid, linked earlobes, nape of neck, etc. Few studies have compared CAEPs recorded with different reference electrode in the same participants. These findings indicate that reference electrode has a statistically significant, but small, effect on CAEP latencies.

Auditory Event-Related Potentials and Perceptual Judgments of Speech

Kate M. Autin¹, Edward J. Golob^{1,2}

¹*Tulane University, New Orleans, Louisiana, USA*

²*University California Irvine, Irvine, California, USA*

When two different speech stimuli are presented dichotically the right ear stimulus is identified more often ("right ear advantage"). The right ear advantage is thought to indicate left hemisphere specializations for speech, however theorists disagree on the neural mechanisms. Some propose that right ear stimuli receive enhanced processing while others suggest that left ear stimuli receive diminished processing ("left ear disadvantage"). These two hypotheses were tested in the present study by measuring auditory event-related potentials (ERPs; 64 channels, DC-100 Hz) in dichotic listening, with separate ERPs for right vs. left ear percepts. A control task was used as a baseline to define enhanced vs. diminished processing in dichotic listening. Subjects ($n = 18$) heard dichotic consonant-vowel pairs (/da/, /ga/, /ka/, /ta/) in both tasks, followed 1.5 s later by a visual query. Subjects indicated the consonant-vowel that was heard best (dichotic listening) or made a perceptual judgment of the query (control). Auditory ERP's (P50, N100, P200) were averaged as a function of ear percept (dichotic listening: left or right ear) and task (control, dichotic listening). Behavioral results showed a right ear advantage in 17/18 subjects ($p < 0.0001$). Auditory ERPs varied with perceptual judgments, with the control task and right ear percepts having comparable P50 amplitudes (~50 ms latency), both of which were significantly larger than left ear percepts ($p < 0.01$). Comparisons between dichotic listening and control tasks showed larger P200 amplitudes in the control task ($p < 0.01$). Auditory ERP results suggest that early cortical processing contributes to perceptual judgments of ambiguous speech, with a left ear disadvantage rather than a right ear advantage. P200 differences between tasks may reflect attention to stimulus features required for perceptual judgments of speech.

Visual Cues Can Modulate the Automatic Organization of Auditory Streams

Torsten Rahne, Hellmut von Specht, Martin Böckmann

Experimental Audiology and Medical Physics, Otto-von-Guericke University, Magdeburg, Germany

The task of assigning concurrent sounds to different auditory objects is known to be dependent on different temporal and spectral cues. When tones of high and low pitch are played in fast alternation, they can be either perceived as a single, integrated melody, or as two parallel, segregated lines. The predominant percept depends on the parameters presentation rate and pitch separation which includes an extended 'ambiguous' range where both percepts are possible. We conducted an electrophysiologic (EEG) and a biomagnetic (MEG) experiment to clarify if the unattended sound organization can be modulated by the synchronous presentation of visual cues. Both experiments use an oddball paradigm to probe the predominant type of sound organization. In each condition, two sets of tones of different pitches were interleaved. One of these sets contained tones in random order, the other one rising triples of sounds that were occasionally reversed. The stimulation rate and the frequency separation between the sets were selected such that both types of organization – integration and segregation – would be possible. Visual stimuli were presented in synchronization with either the within-set frequency pattern or an across-set installed intensity pattern, promoting either an integrated or segregated perceptual organization, respectively. In one experiment, we recorded event-related brain potentials in absence of any task required from the subjects. A mismatch negativity (MMN) component was expected to occur when the sounds were segregated, thus indexing whether the subjects detected integrated or segregated organization of the sounds. We repeated the experiment with MEG to get more detailed information about the involved neural generators. Indeed, the results of both experiments reveal a clear difference between the conditions. Whereas the synchronization of the visual stimuli with the within-stream auditory pattern evoked a MMN response consistent with a segregated organization of the sound streams. On the other hand, synchronization with the across-stream auditory pattern did not yield any mismatch-type response, in accordance with an integrated organization. Alongside with psychoacoustic measurements supporting this view, the electrophysiological and biomagnetic results obviously indicate that the automatic sound organization may be affected by the simultaneous presentation of visual stimuli.

Effects of Discrimination Training on the MMN Elicited by Pitch Modulation Direction Changes

Martin Boeckmann

Otto-von-Guericke University of Magdeburg, ENT Clinic, Magdeburg, Germany

The mismatch negativity (MMN) component of the event-related potentials is generally considered to reflect the precision of the representation of sound features in auditory sensory memory. Several studies have demonstrated plasticity by means of an increased MMN with extensive discrimination trainings, such as learning complex tone sequences. Occasional reversions of the modulation direction in a series of continuous pitch glides elicit also a MMN, demonstrating that this feature is also stored in auditory sensory memory. The aim of our study is to determine whether a short-term discrimination training for detection of modulation direction demonstrates plasticity in the MMN. Ten subjects received a training of pitch glide discrimination. In three different levels of difficulty, they were presented with a total of 900 stimuli of rising and falling pitches. In a Go/NoGo paradigm, they had to react to one of the change directions by pressing a button. This training session lasted for about 100 minutes. ERP measurements were conducted directly before and after the training and 24 hours after the training. Here, pitch glides with five different edge frequencies and a frequency change of 50% of the lower edge frequency were presented at an SOA of 500 ms. Occasional deviant stimuli were falling in frequency instead of rising. If the discrimination of falling from rising frequency sounds were improved by the training, we expected to find an increased amplitude of MMN at least after 24 hours. A control experiment using tones of constant frequency deviants should clarify if a general increase in MMN occurred due to an improved representation of pitch. As reported before, the results show clearly that changes in the direction of modulation elicit a clear MMN. However, although the subjects passed the training rather successfully, the MMN changes only slightly from before the training to directly or 24 h after the training. This could indicate that the effect of plasticity occurs more slowly as compared to similar experiments on other kinds of deviants. As expected, the control experiment on constant frequency tones shows that the training has no effect on frequency representation.

Application of Phase Spectral Analysis for Cortical Auditory Evoked Potential Detection in Adults

Kiyoko Kobayashi, Maiko Mishina, Shinya Kobayashi

Higashinagano National Hospital Organization, Japan

The *purpose* of this study is to investigate whether the N1–P2 complexes of cortical auditory evoked potentials (CAEPs) can be detected by phase spectral analysis, and whether this method is practically useful for the hearing screening test of CAEPs as compared with usual averaged recordings.

Materials and Methods. The averaged waveforms of CAEPs to clicks with the intensity levels of 60 or 70 dB nHL were recorded in waking adults with normal hearing as volunteers. In some subjects these responses were recorded with gradually decreasing levels from 60 to 0 dB nHL by 10 dB steps. Furthermore, no stimulus recordings were added. These averaged waveform configurations were indicated for visual analysis. The same CAEPs were analyzed by phase spectral analysis of group averages in which the component synchrony measure (CSM) for ten group averages was calculated from phase variance for the Fourier component followed by Fridman's technique (Fridman et al., 1984). Then, these averaged waveform configurations and CSMs were compared.

Results. In cases of averaged waveform configuration, the latencies to 60 dB nHL clicks were 94.0~105.5 ms (N1, $n = 5$) and 165~174 ms (P2, $n = 5$), but as the stimulus intensities decreased, the latency variance became great. The wave form configurations were also unstable in interaural and intraaural subjects for identifying the responses, especially at under 40 dB nHL. Whereas, the high CSMs were observed (0.63~0.9) at the frequency spectrums of 4~10 Hz constantly until at rather lower intensity by phase spectral analysis. The detection of the response also seemed to be easier than that of visual analysis.

Conclusions. The phase spectral analysis by Fridman's technique can detect the N1–P2 complexes of CAEPs. Those frequency spectrums were observed on 4~10 Hz in awake adults. Concerning the threshold detection and the application for the automatic hearing screening, further research seemed to be needed.

Comparison of ECAP Amplitude Growth Function between the Children with Auditory Neuropathy and Those with Non-Neuropathic Sensorineural Hearing Loss. Preliminary Report

Lee-Suk Kim, Sung Wook Jeong, Soo Yong Ahn, Jae Ryong Kim

Department of Otolaryngology, Dong-A University Hospital, Busan, Korea

Cochlear implantation (CI) has been reported to be very successful for rehabilitation of patients with auditory neuropathy (AN), and is recommended as a viable option for AN patients. Because the diseased auditory nerve has been considered not suitable for CI, the question of how the AN patients who have pathology of auditory nerve could receive benefit from CI can be raised. For this question, it need to be reminded that the most patients with non-neuropathic sensorineural hearing loss, who are optimal candidates for CI have varying degrees of degeneration of spiral ganglion cells. Spiral ganglion cell survival has been shown to be estimated by electrophysiologic measures using electrical stimulation. Especially the slopes of growth functions of electrically evoked compound action potential (ECAP) of the auditory nerve were reported to predict the number of surviving spiral ganglion cells reliably. We compared the slopes of ECAP amplitude growth functions of implanted AN children with those of implanted children with non-neuropathic sensorineural hearing loss in order to assess the status of auditory nerve of AN children. The slope of the ECAP amplitude growth function of implanted children with AN does not differ significantly from that of implanted children with sensorineural hearing loss. The result of this study suggests that the neural status of both groups be comparable, and that such AN children be therefore suitable candidates for implantation. Continued research in the field of electrophysiology and pathology to reveal the exact nature of the lesions in patients with AN is needed to establish the role of CI in management of patients with AN.

Normative ASSR, ABR and High-Frequency Tympanometry Data for Two-Month Old Infants

Emma Reichman¹, Karen Boyle¹, Michael Bradnam^{1,2}, Ruth Hamilton^{1,2},
Jim Harrigan¹, Juan Mora¹, Vivien Thorpe¹

¹Royal Hospital for Sick Children, and

²Glasgow University, Glasgow, United Kingdom

Purpose. The purpose of this study was to record normative ABR, ASSR and high frequency tympanometry data for infants at around two months of age. This is the average age at which infants present to the Audiology Department at The Royal Hospital for Sick Children, Glasgow for assessment following referral from newborn hearing screening.

Methods. Healthy term-born infants who passed the newborn hearing screen (aABR) were recruited. One ear was tested from each infant to ensure independence of data points. A threshold was found for up to eight different test types (ABR click air and bone conduction, tone pip 1 kHz and 4 kHz, ASSR at 500 Hz, 1 kHz, 2 kHz and 4 kHz) using the GSI Audera system. High frequency tympanometry at 1000 Hz was also performed. 'Comfort Cups', which are normally used for aABR screening, were used to overcome the problems associated with using traditional transducer types on infants including variable ear canal size with inserts and masking difficulties with headphones.

Results. Thirty-two infants have been tested at a median age of 7.1 weeks (range 3.1– 0.7 weeks). Threshold ranges (ABR): click air conduction 30 to 50 dB nHL; click bone conduction 0 to 30 dB nHL; 1 kHz tone pip 40 to 70 dB nHL; 4 kHz tone pip 10 to 60 dB nHL. Threshold ranges (ASSR): 500 Hz, 50 to 80 dB nHL; 1 kHz, 40 to 80 dB nHL; 2 kHz, 30 to 70 dB nHL; 4 kHz, 30 to 80 dB nHL. These values will require correction factors for the output of the 'Comfort Cup'. Value ranges for high frequency tympanometry (1000 Hz): Ear Canal Volume 0.29 to 1.19 ml; Compliance 0.7 to 2.89 mmho; Middle Ear Pressure –133 to 76 daPa.

Discussion. Collection of local normative data is the optimal method to improve the accuracy of the diagnosis of hearing impairment. These data will therefore increase the robustness of diagnoses based on ABR, ASSR and tympanometry.

Reduction of Bone-Conduction Artefact when Recording ASSR

Ruth Brooke, Siobhán Brennan, John Stevens

Department of Medical Physics, Royal Hallamshire Hospital, Sheffield, United Kingdom

Stimulus artefact has been observed when recording bone conduction ASSRs (Small & Stapells, 2004; Brennan et. al., submitted). The aim of the investigation was to study ASSR bone conduction artefact and methods of reducing it. ASSR recordings were carried out using the MASTER system (John & Picton, 2000) and a simulation of a patient. Stimuli were tones with carrier frequencies 500, 1000, 2000. and 4000 Hz, amplitude modulated at 83, 87, 91 and 95 Hz, respectively. The effects of screening and grounding the cable and transducer and altering lead/cable layout, analogue-to-digital conversion rate and stimulus intensity were investigated. Current flowing through the cable and transducer produced artefact at the stimulus modulation rates for 1000, 2000, and 4000 Hz carrier frequencies when using sampling rates of 1000 and 2000 Hz. The artefact was not measurable above the noise floor for sampling rates of 1250 and 1600 Hz. Altering lead/cable layout and transducer orientation significantly affected artefact amplitude. Screening the bone conductor with mu-metal and grounding the cable and transducer screen also significantly reduced artefact to a level not measurable above background noise. A mu-metal screen had a significantly greater effect than one made of aluminium or copper.

References:

- Small SA, Stapells DR. Normal brief-tone bone-conduction behavioural thresholds using the B-71 transducer: Three occlusion conditions. *J Am Acad Aud* 2003; 14 (10): 556–62.
- Brennan SK, Stevens JC, Brown BH. Effect of varying the stimulus mixed modulation phase setting on auditory steady state responses. Submitted for publication.
- John MS, Picton TW. MASTER: a Windows program for recording multiple auditory steady-state responses. *Comput Meth Prog Biomed* 2000; 61: 125–50.

Otoacoustic Emissions, Ear Fullness and Tinnitus in the Recovery Course of Sudden Hearing Loss

Ieda Maria Ishida, Makoto Sugiura, Masaaki Teranishi, Naomi Katayama, Tsutomu Nakashima

Nagoya University, Graduate School of Medicine, Department of Otorhinolaryngology, Nagoya, Japan

Otoacoustic emissions (OAEs) provide objective and sensitive testing of cochlear outer hair cell function and have been reported to have a direct relationship to hearing threshold sensitivity. Symptoms such as tinnitus and ear fullness are controversial factors in sudden hearing loss (SHL). In the current study, follow-up data on ear fullness, tinnitus and OAEs from 8 SHL patients with good hearing improvement (Group A) and 8 SHL patients with poor hearing improvement (Group B) were analyzed to elucidate how ear fullness, tinnitus and OAEs change in the recovery course of pure-tone behavioural thresholds (BEH) in SHL. Follow-up continued until no change in BEH for > 1-week.

Results. All patients had ear fullness and tinnitus at SHL onset. However, these symptoms improved only in Group A, showing relationships between BEH recovery and improvement of ear fullness ($p < 0.05$) and tinnitus ($p < 0.01$). No patients (Group A or B) had OAEs at their first examination. No patient from Group B showed OAEs at least 3 months follow-up. In Group A, OAEs appeared simultaneously with BEH improvement in 63% of the patients and later than BEH improvement in 37%. Improvement in OAEs never occurred before BEH improvement. Group A tended to have BEH improvements primarily in the low to mid frequencies, with high frequencies showing less recovery. When hearing recovery was not full, OAEs did not reappear for these frequencies. Patients with fast BEH recovery also had almost simultaneous OAE appearance and fast improvement of ear fullness and tinnitus, whereas patients with delayed BEH improvement had gradual OAE appearance and improvement of ear fullness and tinnitus. Patients with poor hearing improvement tended to have absent OAEs, and persistent ear fullness and tinnitus. In summary: neither ear fullness, tinnitus, nor OAEs were predictor factors of hearing recovery, as changes in these symptoms were not seen before BEH improvement. Instead, OAEs may indicate that the cochlea has not yet recovered completely, despite of the BEH improvement, implying that OAEs are a sensitive and direct way of reflecting cochlear function.

DPOAE Fine Structure and Contralateral DPOAE Suppression in Human Ears Exposed to Noise in a Discotheque

Thomas Janssen, Jörg Müller

ENT-Department, Technical University Munich, Munich, Germany

Distortion product otoacoustic emissions (DPOAEs) are capable to quantitatively assess outer hair cell (OHC) integrity. Reflex strength of the efferent hearing system (ERS), which is thought to reduce OHC motility during noise over-exposure, can be determined by evaluating DPOAE-level during contralateral acoustic stimulation (CAS). The purpose of our study was to find out to what extent noise induced temporary hearing threshold shift (TTS) is reflected in the fine structure of DPOAEs and whether ERS can be used to predict cochlear vulnerability. Fifteen normally hearing volunteers were exposed to noise in a discotheque for 3 h. Average noise-level was 102 dB (A). High-resolution behavioural thresholds and DPOAE-grams ($\Delta f = 48$ Hz) were measured between 3.5 and 4.5 kHz before and after noise exposure. Primary-tone level L_2 was set to 40, 30, and 20 dB SPL ($f_2/f_1 = 1.2$, $L_1 = 0.4L_2 + 39$). DPOAE-hearing threshold was estimated using extrapolated DPOAE I/O-functions. For CAS, broad-band noise of 60 dB SPL was used. Changes in absolute DPOAE-level, estimated DPOAE-hearing threshold, and behavioural threshold exhibited a high inter-individual variability. TTS ranged from -10 to 30 dB. Mean TTS across subjects and frequency was 14.2 dB, mean change in DPOAE-level was 12.9 dB ($L_2 = 30$ dB SPL). There was a weak correlation between TTS and change in DPOAE-level. However, TTS and estimated DPOAE-hearing threshold were more closely related. Roughness of the fine structures of both measures decreased with increasing TTS. On average across subjects, ERS amounted to 10.3 dB. There was a weak correlation between ERS and change in DPOAE-level but there was no correlation between ERS and TTS. Also, no correlation between absolute DPOAE-level and TTS could be observed. Variability of susceptibility to noise-induced hearing loss known from psychoacoustic tests was reflected in our DPOAEs. Since most of the subjects exhibited a congruent relationship between subjective and objective measures, DPOAEs are suggested to be a suited means for assessing OHC integrity during TTS. However, due to the fact that there was neither a correlation between absolute DPOAE-level and TTS nor a correlation between ERS and TTS, DPOAEs seem not to allow any prediction of cochlear vulnerability.

Contralateral Suppression of Click Evoked Otoacoustic Emission in Patients with Cerebello-Pontine Angle Tumor and Multiple Sclerosis

Grazyna Lisowska¹, Grzegorz Namyslowski¹, Agata Hajduk¹, Stanislaw Kwiek²,
Jerzy Luszawki², Piotr Bazowski²

¹Otolaryngology Department, Medical University of Silesia, Zabrze, Poland

²Neurosurgery Department, Medical University of Silesia, Katowice, Poland

The amplitude of click evoked otoacoustic emissions can be suppressed (reduced) with contralateral acoustic stimulation (CAS). This is thought to be due to the inhibitory control that the medial efferent auditory nerve exerts on outer hair cell function. One commonly used test of medial olivocochlear (MOC) function in humans involves measuring the degree of suppression of ipsilateral otoacoustic emissions by CAS. This effect is called contralateral suppression (CS). The objective of this study was to investigate the effect of cerebello-pontine angle (CPA) tumor and multiple sclerosis (MS) on the MOC function by examining alterations in CEOAE amplitude that result from contralateral broadband noise (BBN) stimulation. Contralateral suppression of CEOAEs using BBN at 50 dB SL was measured in 16 ($n = 32$ ears) patients with unilateral CPA tumor, 14 ($n = 28$ ears) patients with MS and 26 ($n = 52$ ears) controls, matched for age and gender. All subjects had average hearing threshold level across the octave frequencies 1 to 6 kHz less than 25 dB HL and normal middle-ear function. The principle findings were that control ears demonstrated significantly more suppression (CS: -2.07 ± 1.14 dB) than the ears of patients with CPA (CS: -0.56 ± 0.8 dB) and than the ears of patients with MS (CS: -0.63 ± 1.1 dB). There was, however, no significant difference in suppression between the tumor (CS: -0.56 ± 0.8 dB) and non-tumor ears (CS: -0.55 ± 0.8 dB). Moreover, for 1.4 dB cut-off levels of contralateral suppression the sensitivity of the efferent test was 90% and specificity was 70%. To conclude, the results of this study show significantly less CEOAE amplitude suppression resulting from contralateral BBN in both tumor and non-tumor ears and in patients with MS compared with a control group.

Hearing Improvement after Acoustic Neuroma Surgery

Grazyna Lisowska¹, Grzegorz Namyslowski¹, Agata Hajduk¹, Stanislaw Kwiek², Jerzy Luszawski²,
Piotr Bazowski², Wojcich Scierski¹, Jan Pilch¹

¹Otolaryngology Department, Medical University of Silesia, Zabrze, Poland

²Neurosurgery Department, Medical University of Silesia, Katowice, Poland

Hearing improvement after acoustic neuroma surgery is an uncommon occurrence. In this study, we present changes obtained in the pure tone audiogram (PTA), speech discrimination score (SDS), auditory brain-stem responses (ABRs), and distortion-product otoacoustic emissions (DPOAEs) of a vestibular schwannoma patient whose hearing improved after cerebello-pontine angle (CPA) surgery.

A 57-year-old woman with a 6-month history of partially reversible sudden hearing loss and tinnitus in the right ear was diagnosed and treated because of the acoustic neuroma. Audiological findings revealed middle retrocochlear hearing impairment and in magnetic resonance imaging CPA tumor was diagnosed. Patient underwent total tumor excision via retrosigmoid approach, with preservation of the facial and cochlear nerves. During the tumor removal, the ABRs and DPOAEs were recorded to monitor brainstem and cochlear function. Postoperatively, a vestibular schwannoma (Antoni type A, WHO grade I) was diagnosed. The subjective and objective audiological tests, performed in this patient one month after acoustic neuroma surgery, demonstrated hearing improvement.

In conclusion, patients with good otoacoustic emissions and with monitoring of the cochlear function during the tumor removal, seem to have a better chance for hearing preservation, or even hearing improvement after CPA surgery.

Influence of Ageing and Gender on Contralateral Suppression of Click Evoked and Distortion Product Otoacoustic Emissions

Grazyna Lisowska, Grzegorz Namyslowski

Otolaryngology Department, Medical University of Silesia, Zabrze, Poland

It is known that the cochlear or neural activity recorded in the ipsilateral ear can be modulated by stimulation of the contralateral ear. This effect, which is called contralateral suppression, is presumed to be mediated by the olivocochlear efferent system, mainly the medial olivocochlear (MOC) bundle. One commonly used test of MOC function in humans involves measuring the degree of suppression of an ipsilateral otoacoustic emissions by a contralateral acoustic stimulation (CAS). The objective of this study was to measure age-related changes of MOC system and to evaluate the influence of gender on contralateral suppression effect. To evaluate the function of MOC system click evoked otoacoustic emissions (CEOAEs) and distortion-product otoacoustic emissions (DPOAEs) were recorded in 146 ($n = 292$ ears) right-handed subjects with and without continuous contralateral broadband noise (BBN) stimulation. BBN was presented at 50 dB SL and otoacoustic emissions were recorded in response to nonlinear clicks and two different primary tones ($L1 = 65$, $L2 = 55$ dB SPL; $f2/f1 = 1.22$) from 1 to 5 kHz. Subjects were divided into three age groups: young adult (19.8 ± 4.6 years, $n = 140$ ears), middle-aged (31.2 ± 4.3 years, $n = 100$ ears) and old (48.2 ± 5.9 years, $n = 52$ ears). All subjects had normal hearing and middle-ear function based upon standard audiometric criteria. The principle findings were that CEOAE and DPOAE levels were smaller in the old group compared to the young and middle-aged groups and that contralateral suppression declined with age and was greater in males than in females. In addition, contralateral suppression in the 1- to 2-kHz range was greater than in the range above 2 kHz for all ages. Moreover, in the old group more enhancements of CEOAE and DPOAE amplitudes during CAS were observed, but especially at the higher frequencies. In conclusion, influence of age and gender on the function of MOC system was found.

Changes in DPOAE Fine Structure and Hearing Threshold due to Occupational Noise Exposure of One Day

Jörg Müller, Thomas Janssen

ENT-Department, Technical University Munich, Munich, Germany

Noise-induced hearing impairment is the second most frequent occupational illness. Thus, it is very important for occupational medicine to find methods for early detection of hearing loss and also for predicting individual cochlear vulnerability. Distortion product otoacoustic emissions (DPOAEs) are known to be an appropriate measure to examine small changes in outer hair cell (OHC) function. The purpose of our study was to investigate if DPOAEs are capable to detect OHC dysfunction after a short period of noise exposure. Pure-tone audiograms and high-resolution DPOAE grams (between $f_2 = 3.5$ and 4.5 kHz, $\Delta f_2 = 48$ Hz, $L_2 = 30$ and 20 dB SL) were recorded in 52 factory workers and in 10 office workers before and after one workday (7.5 h). Only data from 31 factory workers (noise group) and 9 office workers (control group) were analyzed due to strong criteria for measurement reliability. In order to investigate individual reflex strength of the efferent hearing system, which was found to be correlated to noise-induced hearing impairment in guinea-pigs (Maison & Liberman, 2000), contralateral DPOAE suppression was measured in dips of the DPOAE fine structure (Müller et al., 2006). It could be observed that in the noise group both hearing threshold and DPOAE level around 4 kHz slightly decreased after one workday by 1.6 dB and 1.1 dB, respectively. Whereas, in the control group, both measures increased by 2.8 and 0.6 dB. Significant difference ($p < 0.1$) between groups was found for pure-tone hearing thresholds and DPOAEs. Correlation between change in hearing threshold and change in DPOAE level was lower in the noise group ($\sigma = 0.08$) compared to the control group ($\sigma = 0.49$). Efferent reflex strength and change in hearing threshold did not correlate ($\sigma = 0.04$). Thus, efferent reflex strength does not seem to be a predictor for assessing cochlear vulnerability. Both DPOAEs and audiograms showed on average reduced hearing capability for the factory workers after just one workday. DPOAEs are an objective measure and its measuring time is far shorter than that needed to obtain behavioural thresholds. Therefore, we suggest that DPOAEs are an alternative method to detect marginal changes in OHC function in occupational medicine.

A Novel Approach for Automated Hearing Threshold Estimation

Alessia Paglialonga^{1,2}, Thomas Janssen³, Gerhard Hoferer⁴, Andre Lodwig⁴, Peter Zoth⁴

¹CNR Institute of Biomedical Engineering, Milan, Italy

²Bioengineering Department, Politecnico di Milano, Milan, Italy

³ENT-Department, Technische Universität München, München, Germany

⁴R&D Dept. of Fischer-Zoth Diagnosesysteme GmbH, Germering, Germany

A novel approach for pure tone threshold estimation from extrapolated distortion product otoacoustic emissions (DPOAE) I/O-functions was recently developed (Boege & Janssen, 2002; Gorga et al., 2003). Using an optimized primary tone level setting that accounts for the nonlinear interaction of the two primaries at the DPOAE generation site at f_2 , the sound pressure of the DPOAE is an almost linear function of the primary tone level L_2 and therefore an estimate of the pure-tone threshold at that frequency (f_2) can be derived, thus providing frequency-specific and quantitative information about the hearing loss. Clinical trials were set up for the validation of a hand held device (the Cochlea-Scan, by Fischer-Zoth Diagnosesysteme GmbH) that incorporates this algorithm and enables automated measurement of the hearing threshold. Pure-tone threshold estimation was performed, in several clinical sites, at test-frequencies of 1.5, 2, 3, 4, and 6 kHz on about 900 ears from normal hearing and cochlear hearing loss patients and the relationship between the behavioral (pure-tone audiogram) threshold and the estimated hearing threshold (DPOAE-audiogram) was evaluated. Data from the different laboratories were collected and statistical analysis was performed to quantify the correlation between the subjective and the objective measures. Aim of this paper is to describe the details of the clinical trials and of the processing of the data. Some relevant results will be also shown.

Study of Parameters to Optimize 2f₂-f₁ DPOAE Output

Jennifer H. Horn^{1,2}, Sheila Pratt^{1,2}, John D. Durrant¹

¹University of Pittsburgh, Pittsburgh, Pennsylvania, USA

²Geriatric Research Education & Clinical Center, VA Pittsburgh Healthcare System, Pittsburgh, Pennsylvania, USA

Previous research suggests clinical applications of 2f₂-f₁ DPOAEs to be limited by its low amplitude versus noise floor. Past research established optimal parameters for the more robust 2f₁-f₂, e.g. L₁-L₂ = 10 dB; f₂/f₁ = 1.22; L₁ = 65 dB SPL. These parameters reflect the basilar-membrane distance (f₂/f₁) and level differences (L₁-L₂) of primaries peculiar to this distortion product generated by cochlear nonlinearities. Consequently, the same parameters do not optimize 2f₂-f₁. This study was conducted to determine best test parameters for eliciting 2f₂-f₁ DPOAEs. Understanding how 2f₂-f₁ is elicited in the normal-hearing ear could be important for understanding normal and impaired hearing mechanisms alike. Twenty young adults with normal hearing and normal middle ear function were examined. Forty 2f₂-f₁ DPOAE input-output (I/O) functions were collected from each participant. Combinations included five frequency ratios (f₂/f₁ = 1.04 to 1.12, in 0.02 steps), three level differences (for 2000 Hz; L₁-L₂ = 0, 5, -5 dB) or five level differences (for 4000 Hz; L₁-L₂ = 0, 5, 10, 15, -5 dB), and seven intensity levels (L₂ = 40-70 dB SPL in 5-dB steps). Parameters were chosen to expand on information known from previous studies. These particular frequencies were chosen because of the high-frequency nature of 2f₂-f₁. DPOAE response presence and amplitudes were measured. Three-way ANOVAs (frequency ratio x level difference x intensity level) were applied to DPOAE amplitudes for each signal frequency. Three main effects, frequency ratio x level difference and level difference x intensity interactions, and three-way interaction were statistically significant (p < 0.05) for both signal frequencies. In general, mean amplitudes were greater and DPOAEs were more often present at 2000 Hz for all parameter combinations. Mean DPOAE amplitudes were greater with smaller frequency ratios. Essentially equal level differences (L₁-L₂ = 0,5) created I/Os of greatest amplitude. In conclusion, no single parameter combination resulted in clear maxima for 2f₂-f₁, which is consistent with results from past studies. Therefore, this finding is not the result of too few parameters tested. Overall, results suggest that to maximize 2f₂-f₁, a low frequency ratio, essentially equal levels of primaries, and moderate intensity levels are needed. Such parameters may permit clinically-useful measurements.

Morphology Changes in Electrocochleography Recorded during Reversible Ischemic Episodes. An Animal Model

Krzysztof Morawski¹, Fred Telischi^{2,3}, Jorge Bohorquez³, Kazimierz Niemczyk¹, Ozcan Ozdamar^{2,3}

¹Department of Otolaryngology, Medical University in Warsaw, Poland

²University of Miami Ear Institute, Department of Otolaryngology, and

³University of Miami, Department of Biomedical Engineering, Miami, Florida, USA

The authors of this study investigated effect of local, reversible ischemia on auditory function. Changes observed in morphology of electrocochleography (ECoChG) recordings were analyzed.

Material and Methods. Fifteen young rabbits were used for this study. Three reversible ischemic episodes within the cochlea were induced by directly compressing the internal auditory artery (IAA). CBF was measured using a laser-Doppler (LD) probe positioned at the round window niche. ECoChG was recorded directly from the promontory. The following stimulation was applied: 4-, 8-, and 12-kHz tone-bursts and click of 70 dB SPL intensities. In all monitored ears, compound action potentials (CAP) and cochlear microphonics (CM) were investigated. Additionally, some details of CAP morphology (peak P1, summation potential (SP), and width of CAP) were investigated for better understanding auditory status following reversible ischemia.

Results. Analyzed on-line CM and CAP data were displayed as CAP-N1-Amplitude and CAP-N1-Latency every 3–6 seconds. In all investigated ears, followed ischemia/reperfusion episode CM and CAP-Amplitude at all test frequencies were reduced, while CAP-Latency increased. Also value of amplitude of peak P1 and SP were reduced. The above changes in morphology of ECoChG were described with details depending on frequencies and number of successive ischemic episodes. All results are discussed in aspect of intraoperative monitoring of auditory status during acoustic tumor surgery.

Conclusions. ECoChG recorded from the RW appeared to effectively mirror even minimal changes in auditory function during cochlear reversible ischemia in real time domain. A comprehensive analysis of ECoChG morphology changes provides fast and effective information about peripheral auditory status. This model of auditory function monitoring and on-line analysis may be used during acoustic tumor surgery.

Distortion Product Otoacoustic Emissions in Sensorineural Hearing Loss

Mona Mourad, Dina Ryad, Gada Malky

Alexandria Faculty of Medicine, Alexandria, Egypt

DPOAEs are one type of evoked emissions that has a potential role in evaluating hearing at different spectral regions. The aim of this study was to investigate whether DPOAEs reflect the pure tone audiometric threshold configuration of sensorineural hearing loss. One hundred ears were selected for the study; 42 ears were selected controls and 58 ears represent SNHL with different audiometric configurations. Ears with SNHL were subdivided into four subgroups: (1) high frequency HL; (2) notch noise induced HL; (3) flat HL; (4) low frequency HL. DPOAEs were measured using ILO otodynamic analyser version-5. Measurement included DP-gram where DP amplitude was measured as a function of frequency 1-6 kHz in $\frac{1}{2}$ -octave intervals, DPOAE I/O function for 1, 2, 4, 6 kHz and for increases in primary tone levels (35–80 dB SPL in 5 step intervals).

Results. (1) normal ears exhibited a characteristic DPgram contour, with two peaks at 1.5 and 6 kHz centred by dip at 3 kHz; (2) DP-grams were statistically different between normal ears and ears with SNHL; (3) DP-grams of SNHL subgroups followed the frequency patterns of all different audiometric configurations; (4) there was negative correlation between DPOAE amplitudes and hearing thresholds that was strongest at 1.5 kHz and above; (5) poor low frequency performance. Scatter diagrams of DPOAE detection thresholds as a function of audiometric hearing thresholds are presented.

Discussion and Conclusions. DPOAE potential use and limitations in clinical evaluations to delineate objectively normally responding cochlear regions from impaired ones.

ASSR Measures of Binaural Processing: Effect of Dichotic Modulation Rate Separation on Brainstem (80 Hz) and Early Cortical (40 Hz) Auditory Steady-State Responses

Elais M. Ponton, Jennifer L. Hatton, David R. Stapells

School of Audiology & Speech Sciences, The University of British Columbia, Vancouver, BC, Canada

The ASSR to stimuli amplitude modulated (AM) using modulation rates near 80 Hz is reliably recorded in sleeping infants; responses to 40-Hz AM stimuli are best recorded in awake adults. A unique feature of the ASSR is that responses may be separately evaluated in response to multiple stimuli presented simultaneously – to one ear or to both ears – provided each stimulus has its own signature modulation rate. Previous ASSR interaction research has suggested cortical (40-Hz) ASSRs show larger interactions with dichotic stimuli compared to brainstem (80-Hz) ASSRs (Armstrong & Stapells, IERASG 2007; John et al., 1998) – one would thus expect greater effects of small rate separations on 40-Hz ASSRs. The present study investigated the effect of between-ears (dichotic) AM rate separation for brainstem and cortical ASSRs, with the aim of gaining insight into the “tuning” of binaural modulation rate interactions at brainstem and cortical levels. Two groups, each with 10 normal adults, participated. In the binaural conditions, the test ear received the 1000-Hz stimulus modulated at 85 Hz (the 80-Hz group) or 40 Hz (the 40-Hz group); the non-test ear received a 1000-Hz carrier frequency stimulus amplitude modulated at a rate that was 0, 0.25, 0.5, 1, 2, or 3 Hz above or below the test-ear modulation rate. A monaural 85- or 40-Hz stimulus in the test ear served as a baseline measure. All stimuli were presented at 60 dB SPL. Results indicate (i) no change in test-ear ASSR amplitude for any binaural rate separation, except 0 Hz (i.e. diotic stimuli), where the responses were significantly larger (165% of monaural amplitude, $p < 0.0001$) than all other conditions, and (ii) surprisingly, no difference was seen between 85-Hz and 40-Hz ASSRs in the effects of dichotic rate separation. These results suggest little or no interactions exist between dichotic modulation rates at brainstem and early cortical levels of processing, with no effects of binaural rate separations as small as 0.25 Hz. The practical implication is that modulation rates for dichotic stimuli may be very close with no loss of response amplitude.

Work supported by NSERC-Canada.

Efficiency of Single Versus Multiple Stimuli for 40 Hz Auditory Steady-State Responses

Charles M. Fontaine, David R. Stapells

University of British Columbia School of Audiology and Speech Sciences, Vancouver, Canada

Previous research has questioned the use of the multiple-stimulus auditory steady-state response (ASSR) technique when recording responses to stimuli modulated at rates near 40 Hz, as these responses show large interactions (amplitude decreases) when multiple stimuli are presented simultaneously [e.g. John et al., *Audiology*, 1998]. The present study investigated whether these interactions make the multiple-stimulus ASSR technique less efficient than single stimuli for recording the 40-Hz ASSR. ASSRs were elicited in 12 normal-hearing, awake adults to 500-, 1000-, 2000-, and 4000-Hz carrier frequencies amplitude-modulated in the 40-Hz range in three conditions: individually [monotic-single(MS) – one carrier], simultaneously in one ear [monotic-multiple(MM) – total four carriers], and simultaneously in both ears [dichotic-multiple(DM) – total eight carriers], at intensities of 30, 55, and 80 dB HL.

Results. In general, response amplitudes (collapsed across frequency and intensity) decreased with increasing number of simultaneous stimuli, and were 270, 155, and 107 nV for MS, MM and DM conditions, respectively. At 30 dB HL, however, amplitudes showed little or no decrease (and changes were not significant). Relative efficiency (relative test efficiency of multiple versus single conditions; efficiencies greater than 1 indicate multiple-stimulus condition is more efficient than single-stimulus condition) increased from single- to multiple-stimulus conditions, but there was no significant difference between MM and DM conditions. Mean relative efficiencies were 1.00, 1.38, and 1.39 for MS, MM and DM conditions, respectively. In contrast to 30 and 55 dB HL, at 80 dB HL there was no significant increase (nor decrease) in relative efficiency with multiple stimuli. These results suggest that 40-Hz ASSRs to low and moderate intensities are most efficiently assessed using monotic-multiple stimuli, but that there may be little advantage to simultaneously stimulating both ears. High intensities might be more efficiently assessed using single stimuli.

Work supported by NSERC-Canada & CIHR.

Multiple-Stimulus Interactions in the Brainstem (80 Hz) and Cortical (14 & 40 Hz) Auditory Steady-State Responses

Maxine Armstrong, David R. Stapells

University of British Columbia School of Audiology & Speech Sciences, Vancouver, Canada

This study evaluated the effects of three different modulation rates and three different rate separations on interactions in the auditory steady-state responses (ASSRs) to multiple simultaneous stimuli. Responses from 12 normal-hearing subjects were examined using three amplitude-modulation rates (14, 40 and 80 Hz) and four conditions: 1-tone (1000 Hz), 2-tone monotic (1000 and 2000 Hz), 2-tone dichotic, and 4-tone monotic (500, 1000, 2000, and 4000 Hz). Individual stimuli were calibrated at 80 dB SPL. Within the multiple-tone conditions, separation between the amplitude-modulation rates was varied from 2 to 6 Hz. The single 1000-Hz tone condition served as the baseline and interactions between responses to multiple tones were measured as a function of the change in response amplitude from this baseline. Results indicate separation (2–6 Hz) between modulation rates had no effect on the interactions between responses. Both modulation rate and condition had significant effects on ASSR interactions. In general, interactions became greater as the number of stimuli increased from 1 to 4 tones. However, each modulation rate had a different pattern of interactions. The response amplitudes for all modulation rates were significantly decreased in the 4-tone condition. The 2-tone dichotic condition amplitudes were also decreased from the baseline for the 40-Hz ASSRs, but not for the 14- and 80-Hz ASSR amplitudes. Furthermore, the 40-Hz and 80-Hz ASSR amplitudes in the 2-tone monotic condition were decreased from the baseline whereas the 14-Hz ASSR amplitudes showed no change in this condition. Interaction patterns thus differed between brainstem and cortical processes, and between 14-vs 40-Hz cortical processes (indicating differing cortical generators). Results from relative efficiency calculations indicate that, at 80 dB SPL, ASSRs to multiple tones are not significantly more efficient than ASSRs to single tones for any modulation rate range. Brainstem and cortical ASSR interaction patterns may be useful in the future for the assessment of processing at different levels of the auditory pathways.

Work supported by CIHR, NSERC-Canada and BCMSF.

Masking

Guy Lightfoot, Adrian Cairns

Royal Liverpool University Hospital, Liverpool, United Kingdom

We could find no peer-reviewed study that evaluated the intensity of wide-band noise required to mask the ABR. We conducted such a study using 20 volunteer adults, half using TDH-39 earphones and half using ER-3A inserts. The level of masking required to just mask clicks and tone pips was determined two ways: behaviourally and electrophysiologically. From these data we were able to formulate an appropriate masking formula to prevent cross-hearing.

Electroaudiometry and Electric Evoked Auditory Brain-Stem Responses in Cochlear Implants Candidates Can be Compared

Saba Battelino¹, Dušan Butinar², Anton Gros¹

¹Department of Otorhinolaryngology and Cervicofacial Surgery, and
Institute of Clinical Neurophysiology, Division of Neurology, University Medical Centre Ljubljana, Ljubljana, Slovenia

Background. Reliable preoperative assessment of the integrity and functioning of the central auditory pathway is advisable in all cochlear implants candidates. Different subjective and objective techniques, non-invasive and invasive, can be used. The postoperative hearing with use of cochlear implant is a final confirm of function of the auditory pathway.

Patients and Methods. Electroaudiometry is a subjective, non-invasive investigation where the stimulating electrode is laying in the external ear canal. The voltage of electric current needed to produce an auditory sensation in patient is measured. It was performed in 86 deaf patients (172 ears). To perform electric evoked auditory brain-stem responses, a »golf club« stimulating electrode is placed as close as possible to the round window, after myringotomy was made. Electric evoked auditory brain-stem responses were measured between vertex and opposite lobe in general anaesthesia. It was also performed in 52 deaf patients, after electroaudiometry. Results of both examinations were statistically compared with logistic regression, as well with the results of hearing after cochlear implantation.

Results. Using electroaudiometry, the positive response was obtained in 154 ears. Using electric evoked auditory brain-stem responses, the positive response was obtained in 67 ears. Successful unilateral cochlear implantation was made in 62 patients (ears). Using logistic regression, the electroaudiometry and electric evoked auditory brain-stem responses were compared. B (regressive coefficient) was 1.256 and Wald = 4.246, statistically significant ($p = 0.039$). Compared results of electroaudiometry and cochlear implantation results, B = 2.21 and Wald = 74.83, also statistically significant ($p = 0.000$). Electrically evoked auditory brain-stem responses results were compared with cochlear implants results B = 0.621 and Wald = 9.013 also statistically significant ($p = 0.003$).

Conclusion. Results of so different techniques as electroaudiometry and electric evoked auditory brain-stem responses can be compared ($p = 0.039$). Electroaudiometry confirming functional auditory pathway can be compared with successful cochlear implant use ($p = 0.00$). Positive results obtained with electric evoked auditory brain-stem responses can also be predictive for successful cochlear implant use ($p = 0.003$).

Research on Bone-Conducted Auditory Steady-State Responses in Adults with Normal Hearing

Lingyan Mo, Fan Zhang, Demin Han

Center of Otorhinolaryngology Head and Neck Surgery, Tongren Hospital, Beijing, China

Objective. To investigate the amplitude and the threshold difference to bone-conducted auditory steady-state responses (BC ASSR) between single and multiple stimulus conditions.

Methods. Two groups of subjects with air conduction pure tone thresholds from 0.25–8 kHz better than 20 dB HL were involved in this study. There were 30 subjects (11 males) aged 19–38 in experiment 1, and 12 subjects (5 males) aged 21–23 in experiment 2. Brief tones of 0.5, 1, 2, 4 kHz (with rise- and fall-time of 4 ms for 0.5 kHz and 2 ms for 1, 2, and 4 kHz), repeated at the rate of 77, 87, 93, 101 Hz, respectively, were presented using a B-71 bone oscillator. The single stimulus condition was one brief tone presented at a time whereas the multiple stimulus condition was the above four stimuli presented at the same time. The constituent stimuli in multiple stimulus condition were adjusted to be the same intensity as those in single stimulus condition. In Experiment 1, behavioral bone-conduction thresholds to single ASSR stimuli were measured at 0.5, 1, 2, 4 kHz; the BC ASSR phases and amplitudes at 50 dB nHL to single and multiple stimulus condition were also measured at each frequency in Experiment 2. The data were processed by 2-way (condition X frequency) repeated measures analysis of variance (ANOVA). The criterion of statistical significance was $p < 0.01$ for all comparisons. Neman-Keuls post-hoc comparisons were performed only for significant main effects.

Results. 1) The mean and standard deviation values of bone-conduction behavioral thresholds to ASSR stimuli at 0.5, 1, 2, 4 kHz were 62.6 ± 4.8 , 47.1 ± 4.8 , 46.8 ± 6.2 , 32.4 ± 5.1 dB re: 1 uN (ppe), respectively. There was significant frequency effect ($F = 182.083$; $\mu 3,87$; $p = 0.000$), post-hoc tests indicated the highest thresholds were at 0.5 kHz. 2) The mean behavioural bone-conduction thresholds at each frequency were taken as the normal hearing levels for the signal used in the present study. ANOVA showed significant difference in amplitude between single and multiple stimulus condition ($F = 18.329$ $\mu 1,11$; $p = 0.001$) at 50 dB nHL. There was also significant difference ($F = 11.608$; $\mu 3,33$; $p = 0.000$) among frequencies, post hoc comparison indicated that the amplitudes in single stimulus condition were significantly larger than those in multiple stimulus condition at 0.5 and 1 kHz. 3) ANOVA showed no significant difference between two conditions ($F = 4.755$; $\mu 1, 11$; $p = 0.052$). The mean and standard deviation of BC ASSR thresholds at 0.5, 1, 2, 4 kHz was 97.4 ± 7.0 , 70.0 ± 10.6 , 62.0 ± 8.3 , 56.1 ± 6.8 dB re: 1 uN (ppe) respectively. However, there was significant difference among frequencies ($F = 70.508$; $\mu 3,33$; $p = 0.000$). Post hoc tests indicated the highest threshold was at 0.5 kHz.

Conclusion. For BC ASSR: 1) at presentation level of 50 dB nHL, the amplitudes in single stimulus condition were significantly larger than those in multiple stimulus condition; 2) There was no significant threshold difference between single and multiple stimulus condition.

Diagnostic Gain of a 75 dB HL as an Adjunct to a 70 dB SL BAEP

Zoran Rodi, Janez Zidar, Dušan Butinar

Institute of Clinical Neurophysiology, Division of Neurology, University Medical Centre Ljubljana, Ljubljana, Slovenia

Introduction. Routine BAEPs using a 70 db SL biphasic auditory stimulus (click) are widely performed in testing the function of auditory pathways.

Aim. A 75 dB HL stimulation was added to the routine protocol in order to increase sensitivity.

Methods. Forty consecutive patients referred to our BAEP lab for functional testing of auditory pathway were enrolled into the study. Standard stimulation and recording setup was used as described elsewhere. Subjective threshold for the click was measured first, followed by the recording of BAEP to the 75 db HL, and to the 70 dB SL stimulation. Cursors were set at peaks from N1 to N5, and interpeak intervals N1–N3, N1–N5, and N3–N5 were calculated. Normative values for peak latencies were only available for a 70 dB SL BAEPs. Non-parametric t-test was used to evaluate the differences between two groups.

Results. In a 70 dB SL BAEP one of peaks N1, N3 or N5 was missing in 4 (10%) patients. Latencies of peaks N1, N3 or N5 were prolonged in 10 (25%) patients. One of interpeak intervals N1–N3, N3–N5 or N1–N5 was prolonged in 6 (15%) patients. Altogether a 70 dB SL BAEP was abnormal in 12 (30%) patients. In 75 db HL BAEP one of peaks N1, N3 or N5 was missing in 19 (48%) patients. With 70 dB SL and 75 dB HL combined, BAEP was abnormal in 22 (55%) patients. There was no statistically significant difference in interpeak intervals between 70 dB SL and 75 dB HL stimulation.

Conclusion. Adding the 75 dB HL stimulation to 70 dB SL seems to increase the sensitivity of BAEP study from approximately 1/3 to 1/2.

Does the 40-Hz ASSR Show the Binaural Masking Level Difference?

Ieda M. Ishida, David R. Stapells

School of Audiology & Speech Sciences, The University of British Columbia, Vancouver, British Columbia, Canada

The binaural masking level difference (BMLD) is a phenomenon that demonstrates how we benefit from using both ears instead of one when detecting signals in noise. Thresholds in noise improve when either the signal or noise has an interaural phase or level difference. Although the BMLD is believed to represent brainstem mechanisms, neither transient nor steady-state (80 Hz) brainstem responses reflect the BMLD. The transient middle-latency early cortical response also does not show the BMLD. In contrast, later transient (N1–P2) and steady-state (< 20 Hz) cortical responses do show the BMLD (Fowler & Mikami, 1995; Kevanishvili & Lagidze, 1987; Wong & Stapells, 2004). It is not known whether the 40-Hz cortical auditory steady-state response (ASSR) shows the BMLD, although limited data (2 subjects tested, actual BMLDs not determined) from Galambos & Makeig (1992) suggest it does not.

The *purpose* of the present study was to determine whether the 40-Hz ASSR reflects the BMLD.

Methods. Stimuli were 500-Hz tones, sinusoidally amplitude-modulated at 40 Hz, and presented at 60 dB SPL in 500-Hz masking noise. Stimuli/maskers were presented either diotically (SoNo) or in dichotic conditions (SpiNo: stimulus inverted; SoNpi: noise inverted), with the order of the three conditions randomized. Behavioural and ASSR masking thresholds were determined and BMLDs calculated.

Results. Preliminary data from six adults with normal hearing showed clear behavioural BMLDs (SoNo–SpiNo: mean = 8.3 dB; SoNo–SoNpi: mean = 6.3 dB). However, the 40-Hz ASSR BMLDs were absent (SoNo–SpiNo: mean = –1.7 dB; SoNo–SoNpi: mean = –1.0 dB). Consistent with no 40-Hz BMLD, no change in amplitude occurred with phase inversion (mean SoNo = 100 nV; SpiNo = 93 nV; SoNpi = 119 nV).

Conclusions. In agreement with Galambos & Makeig (1992), these results indicate that the 40-Hz ASSR does not reflect the behavioural BMLD. The auditory cortical processing reflected by the 40-Hz ASSR must be different from that of the < 20-Hz ASSR, given that the slower ASSR does show the BMLD (Wong & Stapells, 2004). This pattern of results suggests that the 80- and 40-Hz ASSRs reflect neuronal populations that are different from those producing the behavioural BMLD.

Work supported by NSERC and CIHR.

The Time Course and Reliability of P50 in Normal Adults

Cynthia G. Fowler

University of Wisconsin-Madison, Madison, Wisconsin, USA

P50 is an evoked potential that provides a measure of sensory gating, or the preattentive ability of the brain to suppress an irrelevant signal. This response is typically recorded from paired clicks presented 500 ms apart, with 8–10 s between click pairs. The auditory evoked potential generated approximately 50 ms after each click is measured, and generally expressed as the amplitude ratio of the two responses. In normal people, the second click is presumably irrelevant; hence, the response is reduced relative to the response to the first click (Boutros & Belger, 1999). In people with certain functional brain deficits, a failure of suppression is indicated by a large response to the second stimulus. The present study evaluated the time course and reliability of the P50 responses in normal adults. Clicks within the pair were separated by 100 to 600 ms, and the interval between pairs of clicks was a constant 10 s. The P50 was recorded from electrodes at Pz and Cz, both linked to the earlobes, with a ground at the nasion. Physiological activity was recorded over 128 ms after each click, and responses to the two clicks were stored in two buffers. Preliminary data indicate that the amount of suppression of the response to the second click varied by pair separation, and was greatest at 300 ms. The amplitude ratio was a stable measure of click suppression both within a session and across sessions spaced at one week.

Low Frequency Envelope-Following Responses to Sentences

Steven J. Aiken, Terence W. Picton

Rotman Research Institute, Baycrest Centre for Geriatric Care, University of Toronto, Toronto, Ontario, Canada

The low-frequency (2–20 Hz) temporal amplitude envelope of speech comprises energy changes corresponding to phonemic and syllabic transitions, and is important for intelligibility (Drullman et al., 2004). Responses to the speech envelope could be useful for validating the neural encoding of intelligible speech, particularly during hearing aid fittings – since hearing aid gain and compression characteristics for sentential stimuli should more closely resemble real world performance than for isolated brief syllables. Cortical responses to 6 different sentences were recorded and these responses were cross-correlated with the low frequency log-envelopes of the sentences. The significance and latency of the maximum correlation for each sentence was used to determine the presence and latency of the brain's response. Responses were also cross-correlated with a simple model based on a series of overlapping transient responses to stimulus change (the derivative of the log-envelope). In order to improve the signal to noise ratio over ongoing EEG recordings, we averaged the responses over multiple presentations, and derived source waveforms from multi-channel scalp recordings. Source localization indicated a pair of bilateral symmetrical vertical and horizontal dipoles in the posterior auditory cortices. Correlations between the log-envelope and the vertical dipole source waveforms were significant for all sentences and for all but one of the participants (mean $r = 0.35$), at an average delay of 175 (left)–180 ms (right). Correlations between the transient response model (P1 at 68 ms, N1 at 124 ms and P2 at 208 ms) and the vertical dipole source waveforms were detected for all subjects and all participants (mean $r = 0.30$), at an average delay of 6 (right)–10 ms (left). These results show that the human auditory cortex either directly follows the speech envelope or consistently reacts to changes in this envelope. The delay between the envelope and the response is approximately 180 ms.

Authors Index

- Aas-Hansen, Øyvind 39
 Abdel-Baki, Fathi 98
 Açıkgöz, Nuri 101, 117
 Ahn, Soo Yong 114, 133
 Aiken, Steven J. 155
 Alaerts, Jane 54, 85
 Ali, Tarek M. 98
 Alvaré-Jaramillo, Armando 127
 Armstead, Nicky 69, 72
 Armstrong, Maxine 148
 Arslan, Edoardo 74
 Autin, Kate M. 129

 Bacon, Paul 66, 115
 Bae, Woo Yong 114
 Bai, John-Yuhan 57
 Bate, Karen M. 76
 Battelino, Saba 150
 Bazowski, Piotr 138, 139
 Beinroth, Svenja 99
 Bell, Steven L. 87, 94
 Belov, Oleg 97, 116
 Bermejo, Sandra 51
 Bhagat, Shaum P. 102
 Billings, Curtis J. 59
 Bleich, Naomi 100
 Blinowska, Katarzyna J. 121
 Böckmann, Martin 130, 131
 Bohórquez, Jorge 45, 101, 117, 125, 144
 Bojano, Alberico 55
 Booth, Laura 69, 72
 Boyle, Karen 134
 Bradnam, Michael 134
 Brandreth, Marian 66
 Brennan, Siobhán 50, 115, 135
 Brockhaus-Dumke, Anke 42
 Bronyakin, Stanislav 116
 Brooke, Ruth 135
 Burkard, Robert 103
 Butinar, Dušan 44, 68, 73, 150, 152
 Buzzoni, Giada 110

 Cacace, Anthony T. 33, 34
 Cairns, Adrian 149
 Calil, Daniela B. 123
 Campbell, Kathleen C. M. 108
 Carlisle, Simon 119
 Carter, Lyndal 62
 Cebulla, Mario 82, 83
 Celmins, Dzintra 33, 34
 Charro, Lidia 51
 Christodoulou, Kyproula 73

 Cone-Wesson, Barbara 71
 Cotecchia, Tiziana 55

 D'haenens, Wendy 47
 Damsgård, Børge 39
 Delgado, Rafael E. 117
 Della Volpe, Antonio 55
 Dhooge, Ingeborg 47
 Digeser, Frank 35
 Dillier, Norbert 43
 Dillon, Harvey 60, 62, 119
 Dimitrijevic, Andrew 57, 58
 Don, Manuel 82, 84, 107
 Doyle, Pat 93
 Durrant, John D. 78, 93, 118, 143

 Eggermont, Jos J. 126
 Elberling, Claus 82, 83, 84
 El-Raffa, Iman Z. 98
 Evans, Matthew G. 46

 Fancy, Sarah 69, 72
 Faucher, Karine 39
 Fontaine, Charles M. 147
 Fowler, Cynthia G. 154
 Friesen, Lendra M. 61
 Fuerstenberg, Dirk 42
 Fuhr, Torgrim 39

 Gardner-Berry, Kirsty 119
 Garinis, Angela 71
 Gaya, Jose 51
 Geczy, Branka 44, 68
 Gibson, William P. R. 76
 Giżewski, Stefan 124
 Golding, Maryanne 60, 62
 Golob, Edward J. 30, 129
 Gonzalez-Marrero, Francisco A. 127
 Gould, Herbert Jay 120
 Grandori, Ferdinando 94

 Hajduk, Agata 138, 139
 Hamilton, Ruth 134
 Han, Demin 151
 Harrigan, Jim 134
 Hatton, Jennifer L. 65, 146
 Hatzopoulos, Stavros 110
 Hay, Sarah 120
 Hernández, Maria C. 51
 Herrera, Didiesle 67
 Hessel, Horst 35
 Hoferer, Gerhard 142
 Hood, Linda 117

- Hoppe, Ulrich 35
Horn, Jennifer H. 143
Hughes, Larry 108
Hugstmyr, Ann Iren 49
Igelmund, Peter 42
Irimajiri, Rie 30
Ishida, Ieda M. 136, 153
Izzo, Raffaele 55
Janssen, Thomas 96, 99, 137, 141, 142
Jedrzejczak, W. Wiktor 121
Jelicic, Ljiljana 70
Jeong, Sung Wook 114, 133
John, Michael Sasha 53, 90, 103
Johnson, Krista L. 81
Katayama, Naomi 136
Katsch, Richard 60
Kelly, Andrea S. 56
Keogh, Lindsey 78
Khater, Alaa H. 98
Kim, Jae Ryong 133
Kim, Lee-Suk 114, 133
Kistler, Doris J. 92
Kobayashi, Kiyoko 132
Kobayashi, Shinya 132
Kochanek, Krzysztof 52, 95, 121, 122
Kollmeier, Birger 109
Koutb, Ahmed R. 98
Koutsou, Pantelitsa 73
Kraus, Nina 77, 81
Kurtz, Isaac 88, 89
Kwiek, Stanislaw 138, 139
Kwong, Betty 107
Lage, Agustin 67
Laukli, Einar 39, 49, 63
Lenarz, Thomas 99
Lewis, Doris R. 123
Lightfoot, Guy 149
Lisowska, Grazyna 138, 139, 140
Ljubic, Aleksandar 70
Lodwig, Andre 142
Lolli, Brenda 58
Lusawski, Jerzy 138, 139
Lutman, Mark E. 94
Luts, Heleen 54, 85
Lv, Jing 87
Malky, Gada 145
Maloff, Erin 84
Manders, Alastair J. 87
Mansi, Nicola 55
Marler, Jeffrey A. 92
Martin, Rachel M. 126
Martín-Gonzales, Francisco 127
Martini, Alessandro 110
Masalski, Marcin 86, 124
McFarland, Dennis J. 33, 34
McMahon, Catherine M. 76
McNeil, Malcolm 93
McNerney, Kathleen Szalda 103
Meech, Robert 108
Meister, Hartmut 42
Mens, Lucas 48
Mervis, Carolyn B. 92
Michalewski, Henry 57, 58
Michalewski, Henry J. 30, 74, 100
Mijares, Eleina 67
Mishina, Maiko 132
Mittelman, Nomi 100
Młyński, Rafał 122
Mo, Lingyan 151
Moonen, Marc 91
Mora, Juan 134
Morawski, Krzysztof 45, 125, 144
Morgan, Catherine 80
Mourad, Mona 145
Muir, Patricia J. 126
Müller, Jörg 137, 141
Munro, Kevin J. 41, 56, 80, 128
Nakashima, Tsutomu 136
Namyslowski, Grzegorz 138, 139, 140
Niemczyk, Kazimierz 45, 125, 144
Nishida, Hiroaki 106
Ortman, Amanda 93
Oswald, Johann A. 96
Ozdamar, Özcan 101, 117, 125, 144,
Paglialonga, Alessia 94, 142
Pantev, Christo 32
Parazzini, Marta 94
Parker, David J. 41
Pastore, Vincenzo 55
Pérez-Abalo, Maria Cecilia 51, 67
Petrucelli, Joseph 110
Phelps, Randall 78
Phillips, Andy 69, 72
Picton, Terence 32, 40, 53, 90, 155
Pierchala, Katarzyna 125
Pilch, Jan 139
Piłka, Adam 52, 95, 121, 122

- Piotrowska, Anna 52
 Pisareva, Nataliya Y. 41
 Ponce de León, Maribel 51
 Ponton, Curtis W. 36, 37
 Ponton, Elais M. 36, 37, 146
 Pousson, Monique 120
 Prado-Gutiérrez, Pavel 127
 Pratt, Hillel 57, 100
 Pratt, Sheila 93, 143
 Prosser, Silvano 110
 Purcell, David 32
 Purdy, Suzanne C. 41, 56, 60, 80, 119, 128

 Rahne, Torsten 130
 Ravazzani, Paolo 94
 Reichman, Emma 134
 Reuter, Günter 99
 Reynolds, Angela D. 126
 Ribaric-Jankes, Ksenija 70
 Riedel, Helmut 109
 Rioja, Lilian 51
 Rodi, Zoran 152
 Rodríguez, Ernesto 51
 Ross, Bernhard 32, 40, 104
 Roxberg, Jill 93
 Rubinstein, Elaine 118
 Rutzler, Katie 69, 72
 Ryad, Diaa 145

 Sabo, Diane 78
 Sahakian, Ani 69
 Sanli, Halit 76
 Santarelli, Rosamaria 74
 Savio, Guillermo 67
 Scarff, Carrie J. 126
 Scierski, Wojcich 139
 Seymour, John 60, 62
 Sharma, Mridula 56, 80, 128
 Shehata-Dieler, Wafaa 83
 Sibella, Federica 94
 Simpson, David M. 87
 Sininger, Yvonne S. 31
 Skarżyński, Henryk 52, 95, 122
 Small, Susan A. 79
 Smurzynski, Jacek 95
 Snik, Ad 48
 Sobhy, Ossama A. 98
 Sokolov, Yuri 88, 89
 Souza, Pamela E. 59
 Sovilj, Mirjana 70

 Spindler, Majda 111
 Stapells, David R. 64, 65, 79, 146, 147, 148, 153
 Starr, Arnold 30, 57, 58, 73, 74, 100
 Steinman, Aaron H. 88, 89
 Stenklev, Niels Christian 39
 Stevens, John 50, 66, 115, 135
 Stürzebecher, Ekkehard 82, 83
 Sugiura, Makoto 136
 Swaya, Katie 56
 Śliwa, Lech 52, 121

 Tanaka, Chiemi 107
 Tavartkiladze, George 97, 116
 Telischi, Fred 45, 125, 144
 Teranishi, Masaaki 136
 Thornton, Roger 38
 Thorpe, Vivien 134
 Thuroczy, Gyorgy 94
 Tlumak, Abreena I. 118
 Tognola, Gabriella 94
 Tremblay, Kelly 40, 59, 61

 Urban, Zsolt 92

 van der Reijden, Christoph 48
 Van Dun, Bram 85, 91
 Van Maanen, Anna 64
 Varrichio, Sarah 71
 Vatovec, Jagoda 44, 68, 73
 Vinck, Bart 47
 von Specht, Hellmut 130
 von Wedel, Hasso 42

 Walger, Martin 42
 Waring, Michael 107
 Wightman, Frederic L. 92
 Wohlberedt, Torsten 35
 Wong, Aileen 71
 Wouters, Jan 54, 85, 91

 Xu, Zheng-min 75

 Zalesska-Kręcicka, Maria 124
 Zecker, Steven G. 81
 Zeng, Fan-Gang 57
 Zhang, Fan 151
 Zidar, Janez 73, 152
 Zimmerman, Earl 33, 34
 Zoth, Peter 142
 Žera, Jan 122



MICARDIS
TELHISARTAN



MICARDISPLUS
TELHISARTAN - HIDROKLOROTIAZID



Asasantin[®] retard
ER - dypiridamole+ASA

Mirapexin[®]
pramipeksol



Movalis[®]
meloxicam

SPIRIVA[®]
tiotropium

Berodual[®]N
ipratropium + fenoterol

Value through Innovation



**Boehringer
Ingelheim**

Oglas 5/07

Boehringer Ingelheim Pharma, Podružnica Ljubljana, Goce Delčeva 1, 1000 Ljubljana, Slovenija



**A bright new world of sounds
tailored to you ...**



- enjoy a more discreet hearing aid - without compromise
- understand everything around you
- enjoy sounds you haven't heard in years

widex  **Inteo[™]**



WIDEX
high definition hearing

SLUŠNI APARATI - WIDEX d.o.o., Ljubljana, Resljeva cesta 32
phone.: 01/234 57 00, fax: 01/234 57 10, e-mail: widex@widex.si, web site: www.widex.si

- robust efficacy and an excellent safety profile in the treatment of vertigo and in Ménière's disease
- reduces the intensity, frequency and duration of vertigo episodes
- has been used in over 130 million people worldwide with over 30 years of clinical experience

Solvay Pharmaceuticals GmbH, Podružnica Ljubljana
Dunajska 22, 1511 Ljubljana, tel: 01/ 430 21 22, fax: 01/ 430 21 24
www.solvay.com



a Passion for Progress®

We care for your health

*We believe our first responsibility is to the doctors,
nurses and patients, to mothers and fathers and
all others who use our products and services.*



JANSSEN-CILAG
Division of *Johnson & Johnson* S.E.

Serotonergic dual action

Cipralex[®]
- simply superior



Fast • Effective • Excellent tolerability

Lundbeck



Cipralex[®]
escitalopram

Abbreviated prescribing information:

Presentation: "Cipralex" tablets containing 10 mg escitalopram (as oxalate). **Indications:** Major depression. Panic disorder with or without agoraphobia. Social anxiety disorder. **Dosage:** Usual dose 10mg once daily. Maximum dose 20 mg/day. In the elderly (>65 years), in panic disorder patients, and in patients with reduced hepatic function, an initial dose of 5 mg is recommended. Caution is advised in patients with severely reduced renal function. Not recommended in children and adolescent (<18 years). When stopping treatment with escitalopram, the dose should gradually be reduced over a period of one or two weeks. **Contraindications:** Hypersensitivity to escitalopram. Concomitant

treatment with non-selective MAOIs. **Pregnancy and lactation:** Careful consideration prior to use in pregnant women. Lactating women should not be treated. **Precautions:** The special warnings and precautions that apply to the SSRI class. **Drug interactions:** Reversible, selective MAOIs. Selegiline (irreversible MAO-B inhibitor). Medicinal products lowering the seizure threshold. St. John's Wort. Enzyme inhibitors (e.g. omeprazole and cimetidine) may require reduction of escitalopram dose. Drugs metabolised by enzymes CYP 2D6 or 2C19. **Adverse events:** Most frequent during first and second weeks. Comprise SSRI class adverse events, e.g. nausea, diarrhoea, and constipation. **Overdosage:** Dose of 190 mg escitalopram has been taken without

any serious symptoms.

Consult full prescribing information before prescribing. Producer: H.Lundbeck A/S, Copenhagen, Denmark. Date of preparation of information: March 2004.

Owner of trading permission in Slovenia: Lundbeck Pharma d.o.o., Titova c. 8, 2000 Maribor

www.cipralex.com

COMMERCIAL EXHIBITION

Exhibitors:

- 1 Pfizer SARL Luxembourg, Branch Office Ljubljana
- 2 Intelligent Hearing Systems
- 3 Compumedics Neuroscan
- 4 GN Otometrics A/S
- 5 Lundbeck Pharma d. o. o.
- 6 I.C. Neuronix, S.L.
- 7 Pliva Ljubljana d. o. o.
- 8 GlaxoSmithKline d. o. o.
- 9 Interacoustic

ENTRANCE TO THE CONFERENCE HALL



