– Online – June 14th – July 9th

# IERASG 2021

XXVII International Evoked Response Audiometry Study Group Biennial Symposium

https://ierasg21.com

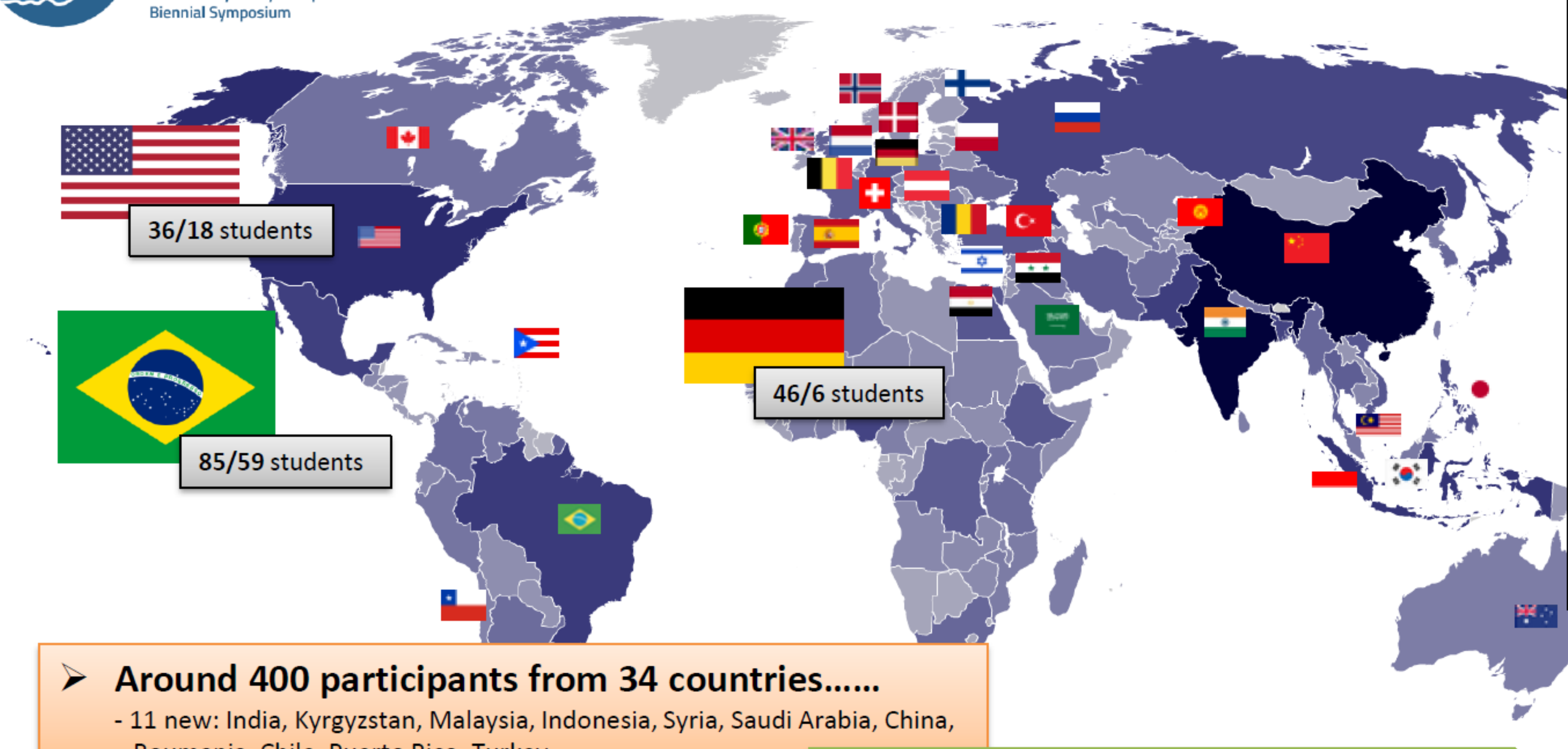
# PROGRAM & ABSTRACTS

- Online – June 14th – July 9th

# IERASG 2021

XXVII International Evoked Response Audiometry Study Group Biennial Symposium

## IERASG around the globe….




| participating countries | | |
|---|---|---|
| BRA | | Brazil |
| DEU | | Germany |
| USA | | USA |
| CAN | | Canada |
| EGY | | Egypt |
| AUS | | Australia |
| IND | | India |
| KOR | | South-Korea |
| BEL | | Belgium |
| NLD | | Netherlands |
| GBR | | Great Britain |
| DNK | | Denmark |
| POL | | Poland |
| AUT | | Austria |
| ESP | | Spain |
| KGZ | | Kyrgyzstan |
| MYS | | Malaysia |
| IDN | | Indonesia |
| SYR | | Syrian Arab Republic |
| CHE | | Switzerland |
| NZL | | New Zealand |
| RUS | | Russian Federation |
| SAU | | Saudi Arabia |
| CHN | | China |
| ISR | | Israel |
| ROU | | Roumania |
| CHI | | Chile |
| FIN | | Finland |
| Frau | | France |
| JPN | | Japan |
| NOR | | Norway |
| PRI | | Puerto Rico |
| POR | | Portugal |
| TUR | | Turkey |
| 34 | | 11 new countries |

➢ **Around 400 participants from 34 countries……**

- 11 new: India, Kyrgyzstan, Malaysia, Indonesia, Syria, Saudi Arabia, China, Roumania, Chile, Puerto Rico, Turkey….

➢ **More than 170 students ( = 45%) !!!**

**June 2021**

**Welcome to new and old friends of the International Evoked Response Audiometry Study Group (IERASG).** We are excited to have so many of you join us online for our 27th Biennial Symposium. It is heartening that, whilst the world continues to grapple with the challenges of a global pandemic that has caused much heartache across the world, we are still able to come together to celebrate and advance our work. We know that our science in the area of evoked responses and the application of our science to understanding and treating auditory disorders continues to be important. It is even more evident in these times of physical separation that our sense of hearing helps to connect people to each other and to their environment, and that our research is important and meaningful.

**IERASG began as an informal study group at the International Society of Audiology congress in London in 1968** established by **Professor Hallowell Davis** and his colleagues **("Hal's Club")**. Our biennial meetings were first held in 1970 in Freiburg, Germany; our IERASG connections between colleagues and friends **across the globe** have continued to grow with each biennial meeting since then. IERASG strives to be inclusive of all countries and of all people working at different levels in our field of evoked response audiometry. We are happy to have achieved this goal for our Virtual Symposium – we have 33 countries participating and many students and emerging researchers contributing oral papers and posters.

We have had many previous invited **Hallowell Davis lecturers** who have been influential and groundbreaking in their research, and this year's 2021 Hallowell Davis Lecture is no exception - this year we welcome Professor Bob Shannon who shares important insights from his foundational work in the area of cochlear implants. Professor Shannon's research over many decades has been key to the success of cochlear implants, an area of hearing research where electrophysiology plays a key role in optimising the use of this technology for people with severe-profound deafness.

We are delighted also to welcome contributions from four guest lecturers **(Professor Bidelman, Professor Rance, Dr. Rosengren, and Dr. Sandmann)** and to have captured important insights from past research in two special interviews with **Professor Ted Glattke** and **Professor Manny Don**. It is a delight to welcome back Manny Don in particular, former Council Member and IERASG Treasurer for many years before Professor Susan Small took over this role.

Please be sure to listen to all the papers and posters as well as our guest speakers – the future of our field lies with all of us, but especially with our students and emerging researchers. We hope that the conference contributes to their development and gives them opportunities to ask questions and connect with others who can support them to do excellent work. I look forward to seeing you online, and in person in two years' time at our next Symposium in 2023 in Cologne, Germany. You will learn more about 2023 in the Closing Ceremomy – a highlight of our Symposium as we get to hear from our Discussant **Professor Bob Burhard** who will present the Symposium Summary.

**Well done Symposium organisers and very special thanks to our Co-chairs, Professor Dr. Martin Walger and Associate Professor Mridula Sharma who have put together an outstanding programme for us!**

With warm wishes for an enjoyable and productive conference from me and my fellow IERASG Council Members!

**Suzanne C Purdy | CNZM, PhD | Chair, IERASG**

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# WELCOME ALL!

Welcome to our 27th **Biennial Symposium of the International Evoked Response Audiometry Study Group.**

The worldwide pandemic has forced us to change the way we will meet in 2021. We are very pleased that have been able to organize an innovative online meeting that will allow for lively exchange online plus excellent scientific presentations. We also look forward to the future when we will see you in person at our next meeting in 2023, which will be held in Cologne, Germany.

We have developed an exciting program that will occur over a period of four weeks beginning with our first workshop on 14th June. We expect many hundreds of scientists, clinicians and students from diverse backgrounds working in all areas of auditory evoked responses to participate. We surely will miss the spirit of our usual face to face meeting, including the exchange of recent knowledge and ideas, the networking and the social events of our biennial symposia, but we believe our Virtual 27th Symposium will bring us together in a unique way.

A big advantage of our online meeting this year is that we have never before had such a high number of students and participants from so many different countries around the world! All participants will enjoy the rare opportunity to hear and see cutting-edge audiology research and hearing from people who are leaders in our field. This is a rare opportunity during these difficult times.

A great program awaits us with two live events per week: we will start with two workshops, then we will officially launch the conference in week 2 with the Hallowell Davis Lecture, followed by excellent guest lectures on different topics, special interviews with outstanding scientists, a live manufacturer session and a virtual industrial exhibition. More than 100 contributions are presented live and we will have a lively exchange and networking, especially with our students, in live chats and discussions in virtual meeting rooms. Live sessions will be recorded and are available on our conference platform for all participants until the end of October 2021.

We are looking forward to an exciting 2021 conference with a fruitful exchange and friendly meetings in virtual space. **We all hope to welcome many of you again in person in Cologne, Germany in 2023!**

Kind regards and stay healthy,

**Co-Chairs, 27th IERASG Biennial Symposium**

Martin Walger
(Cologne)

Mridula Sharma
(Sydney)

**Chair, IERASG**

Suzanne Purdy
(Auckland)

Special thanks to:

**Scientific committee:** Steven Bell (GBR), Andy Beynon (NLD), Robert Burkard (USA), Barbara Cone (USA), Bob Cowan (AUS), Andrew Dimitrijevic (CAN), David McPherson (USA), Suzanne Purdy (NZL), Mridula Sharma (AUS) and Martin Walger (DEU)

**Organizing committee:** Dr. Heike Diekmann (Congress Communication Consulting, Cologne, DEU), ZwoNull Media (Edgar Nowatius, Leipzig, DEU), Lina Wiesel, Pauline Burkhardt and Tim Foerst (all from Cologne, DEU)

# CONTENT

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# PROGRAM OVERVIEW

| pre recorded online sessions | | | | |
|---|---|---|---|---|
| *all submissions available 24h/7d until October 30th 2021* | | | | |
| | | | *vote for the best student presentation!!!* | |
| Online Presentations | Industry | Poster Session | Student Short Presentations | Student Poster Presentations |
| Free online Papers: FP1 - FP13 | Industrial exhibition | Poster Session P1 - P10 | Student Short Presentations: SS1 - SS21 | Student Poster Presentations: SP1 - SP25 |

| Day 1 | Monday | 14th June | live from | Time (CEST) | Workshop 1 (part A) |
|---|---|---|---|---|---|
| | | WS-1A | | 16:00 | Electrically evoked Auditory Brainstem Responses (eABR) |
| | | | | | Andy Beynon (NLD) and Martin Walger (DEU) |
| | | WS-2A | live from | Time (CEST) | Workshop 2 (part A) |
| | | | | 22:00 | Advanced EEG analysis |
| | | | | | Andrew Dimitrijevic (CAN) |

| Day 2 | Friday | 18th June | live from | Time (CEST) | Workshop 1 (part B) |
|---|---|---|---|---|---|
| | | WS-1B | | 16:00 | Electrically evoked Cortical Responses (eCAEP) |
| | | | | | Andy Beynon (NLD) and Martin Walger (DEU) |
| | | WS-2B | live from | Time (CEST) | Workshop 2 (part B) |
| | | | | 22:00 | Advanced EEG analysis |
| | | | | | Andrew Dimitrijevic (CAN) |

| Day 3 | Monday | 21st June | live from | Time (CEST) | 28th Biennial IERASG Symposium 2021 |
|---|---|---|---|---|---|
| | | | | 21:00 | Opening Ceremony |
| | | | DEU, AUS, NZL | | Martin Walger (DEU), Mridula Sharma (AUS) and Suzanne Purdy (NZL) |
| | | HDL | | | Hallowell Davis Lecture |
| | | | | 21:15 | Robert Shannon (USA): Luck Favors the Prepared Mind |
| | | | NLD | | *Moderator: Andy Beynon (NLD) and Ignacio Calderón de Palma (NLD)* |
| | | RT | | 22:15 | Round Table: live presentations and discussion<br>Objective measures in Cochlear Implants and implantable hearing aids |
| | | | NLD | | *Moderator: Andy Beynon (NLD) and Ignacio Calderón de Palma (NLD)* |
| | | FP1 | | 23:30 | Free online Paper Session 1 - short presentations<br>Objective measures in Cochlear Implants and implantable hearing aids |
| | | | NLD | | *Moderator: Andy Beynon (NLD) and Ignacio Calderón de Palma (NLD)* |

## Program overview

| Day 4 | Friday | 25th June | live from | Time (CEST) | Guest Lecture 1 |
|---|---|---|---|---|---|
| | | GL1 | USA | 22:00 | **Gavin Bidelman (USA): Impact of auditory aging on speech processing** |
| | | | NZL | | *Moderator: Suzanne Purdy (NZL) and Abin Mathew (NZL)* |
| | | | | | ** with live-Chat and live discussion* |
| | | LP1 | | 22:45 | **Live Papers 1*:** objective assessment of speech discrimination |
| | | | NZL | | *Moderator: Suzanne Purdy (NZL) and Abin Mathew (NZL)* |
| | | | | | ** with live-Chat and live discussion* |
| | | FP2 | | 0:15 | **Free online Paper Session 2 - short presentations:** ABR, FFR, CAEP, speech perception and development |

| Day 5 | Monday | 28th June | live from | Time (CEST) | **Special Interview 1:** Lessons from the past, implications for the future |
|---|---|---|---|---|---|
| | | I-1 | USA | 21:00 | **Ted Glattke (Arizona, USA)** |
| | | | USA/AUS | | *Moderator: Barbara Cone (USA) and Joaquin Valderrama (Australia)* |
| | | MS | | 21:45 | **Manufacturer Session:** what´s new…live presentations |
| | | | DEU/POL | | Moderator: Martin Walger (DEU) and Wiktor Jedrejczak (POL) |
| | | | | 22:45 | **Meet the companies and sponsors, networking** virtual meeting room (Zoom) |
| | | | | 23:00 | **Live Papers 2*:** OAE, ABR and basic science |
| | | | GBR | | Moderator: Steven Bell (GBR) and Guy Lightfoot (GBR) |
| | | | | | **with live-Chat and live discussion* |

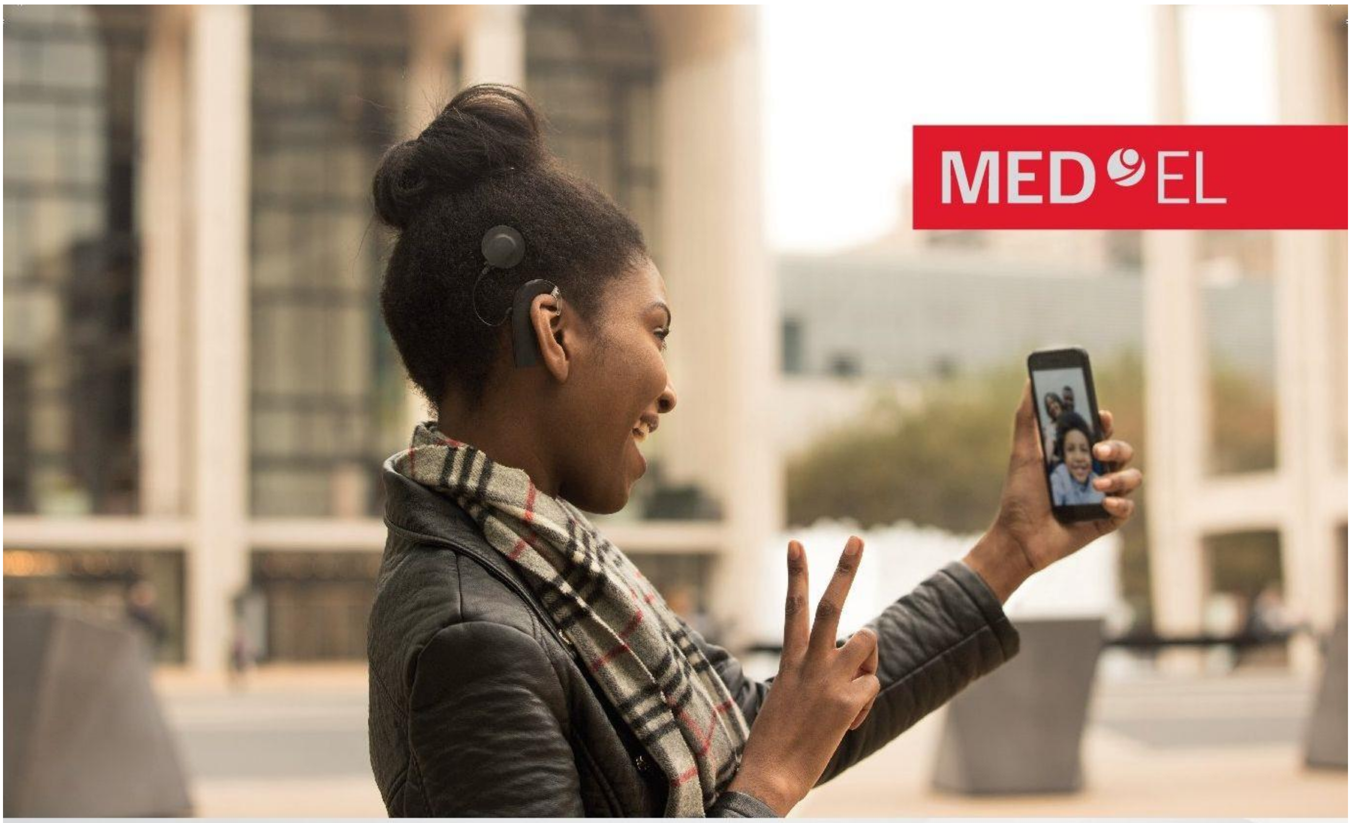
| Day 6 | Tuesday | 29th June | live from | Time (CEST) | Guest Lecture 2 |
|---|---|---|---|---|---|
| | | GL2 | AUS | 8:00 | **Gary Rance (AUS):** Auditory Neuropathy and Neurodegenerative Disease |
| | | | USA | | *Moderator: David McPherson (USA) and Garrett Gordon (USA)* |
| | | | | | **with live-Chat and live discussion* |
| | | LP2 | | 8:45 | **Live Papers 3*:** ANSD and neurodegenerative diseases |
| | | | USA | | *Moderator: David McPherson (USA) and Garrett Gordon (USA)* |
| | | | | | **with live-Chat and live discussion* |
| | | P | | 9:45 | **Poster Session:** Varia |
| | | | AUS | | *Moderators: Mridula Sharma (AUS) and Bob Cowan (AUS)* |
| | | | | | **with live-Chat and live discussion* |

| Day 7 | Friday | 2nd July | live from | Time (CEST) | Guest Lecture 3 |
|---|---|---|---|---|---|
| | | GL3 | AUS | 8:00 | **Sally Rosengren (AUS):** VEMPs as an electrophysiological measure of the vestibular system |
| | | | USA | | *Moderator: Bob Burkard (USA) and Kathleen McNerney (USA)* |
| | | | | | **with live-Chat and live discussion* |
| | | LP4 | | 8:45 | **Live Papers 4*:** Vestibular Evoked Myogenic Response (VEMP) |
| | | | USA | | *Moderator: Bob Burkard (USA) and Kathleen McNerney (USA)* |
| | | | | | **with live-Chat and live discussion* |
| | | SS1 | | 9:15 | **Student Live Session 1:** short presentations |
| | | | USA | | *Moderator: Steven Bell (GBR) and Guy Lightfoot (GBR)* |
| | | | | | **with live-Chat and live discussion* |
| | | SP-1 | | 10:30 | **Student Live Poster Session 1** |
| | | | USA | | *Moderator: Andrew Dimitrijevic (CAN) and David Purcell (CAN)* |
| | | | | | **with live-Chat and live discussion* |
| | | | | 11:30 | **Students networking and meet the experts** (Short Presentations 1 and Poster Session 1) |

| Day 8 | Monday | 5th July | live from | Time (CEST) | Guest Lecture 4 |
|---|---|---|---|---|---|
| | | GL4 | DEU | 16:00 | **Pascale Sandmann (DEU):** Event related potentials (ERP) and audiovisual interaction |
| | | | | | *Moderator: Andrew Dimitrijevic (CAN) and Joaquin Valderrama (AUS)* |
| | | | | | **with live-Chat and live discussion* |
| | | LP5 | | 16:45 | **Live Papers 5*:** CAEP, CI and audiovisual interaction |
| | | | CAN | | *Moderator: Andrew Dimitrijevic (CAN) and Joaquin Valderrama (AUS)* |
| | | | | | **with live-Chat and live discussion* |
| | | | | 17:45 | **Special Interview 2:** Lessons from the past, implications for the future |
| | | I-2 | USA | | **Manuel Don (San Francisco, USA)** |
| | | | | | *Moderator: Barbara Cone (USA) and Joaquin Valderrama (Australia)* |

| Day 9 | Friday | 9nd July | live from | Time (CEST) | Student Live Session 2*: short presentations (SS-12 to SS-21) |
|---|---|---|---|---|---|
| | | SS-2 | USA | 20:00 | *Moderator: Bob Burkhard (USA) and Monica Chapchap (BRA)* |
| | | | | | **with live-Chat and live discussion* |
| | | SP-2 | | 21:00 | **Student Poster Session 2:** short live presentations and live discussion (SP-13 to SP-23) |
| | | | AUS/USA | | *Moderators: Mridula Sharma (AUS), Cynthia Fowler (USA) and John Durrant (USA)* |
| | | | | 22:10 | **Students networking and meet the experts** (short presentations 2 and poster session 2) |

| | | | | | |
|---|---|---|---|---|---|
| | | | | 23:00 | |
| | | | USA | 23:00 | **Symposium Summary:** Bob Burkhard (USA) |
| | | | NZL | 23:20 | **Student Awards:** Suzanne Purdy (NZL) |
| | | | USA | 23:30 | **Presenting the new ERA Textbook**<br>"Basic Concepts of Clinical Electrophysiology in Audiology": John Durrant (USA) |
| | AUS | NZL | DEU | 23:40 | **Closing remarks:** Mridula Sharma (AUS), Suzanne Purdy (NZL) and Martin Walger (DEU) |
| | | | DEU | 23:50 | **IERASG 2023:** Invitation to Cologne, Germany: Martin Walger (GER) |





# SYMPOSIUM-HIGHLIGHTS

**Hallowell Davis Lecture: Luck favors the prepared mind**

Prof. Robert Shannon
Professor of Research Otolaryngology-Head & Neck Surgery
Otolaryngology
1520 San Pablo StreetHealth Sciences Campus
Los Angeles, USA
Email: rshannon@med.usc.edu

**Guest Lecture 1: Impact of auditory aging on speech processing**

Prof. Gavin Bidelman
The University of Memphis
Institute for Intelligent Systems
School of Comm. Sciences and Disorders
4055 North Park Loop, Memphis, TN 38152, USA
Email: gmbdlman@memphis.edu

**Guest Lecture 2: Auditory Neuropathy and Neurodegenerative Disease**

Prof. Gary Rance
Head of Department
Audiology & Speech Pathology
Medicine, Dentistry and Health Sciences
550 Swanston Street, CARLTON 3010
The University of Melbourne, Victoria 3010 Australia
Email: grance@unimelb.edu.au

**Guest Lecture 3: VEMPs as an electrophysiological measure of the vestibular system**

Dr. Sally Rosengren

Neurology Department, Royal Prince Alfred Hospital

Sydney, Australia

Central Clinical School, The University of Sydney

Sydney, Australia

Email: sallyrosengren@hotmail.com

**Guest Lecture 4: Event Related Potentials and audiovisual interaction**

Dr. Pascale Sandmann

Department of Oto-Rhino-Laryngology

Audiology and Pedaudiology

Cochlear Implant Center

University of Cologne

50924 Cologne, Germany

Email: pascale.sandmann@uk-koeln.de

## Special Interview 1: Lessons from the past, implications for the future

Prof. Ted Glattke

University of Arizona, USA

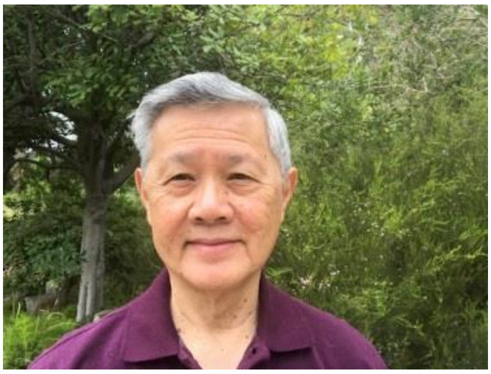
Head of the Department of Speech Pathology and Audiology

Editor ASHA Reports, Journal of Speech and Hearing Research

Journal of Communication Disorders

Retired in 2007

## Special Interview 2: Lessons from the past, implications for the future



Prof. “Manni” Don

Former Head, Electrophysiology Laboratory

5401 Willowick Drive

Division of Communication and Auditory Neuroscience

House Research Institute, 2100 West Third Street,

Los Angeles, California 90057

## Workshop 1: eABR and eCAEP

Dr. Andy Beynon
Donders Institute for Brain, Cognition and Behaviour
Centre for Neuroscience
Department of Otorhinolaryngology, Head and Neck Surgery
Radboud University Medical Centre,
Nijmegen, The Netherlands
Email: Andy.Beynon@radboudumc.nl

Prof. Martin Walger
Department of Oto-Rhino-Laryngology
Audiology and Pedaudiology
Cochlear Implant Center
University of Cologne
50924 Cologne, Germany
Email: martin.walger@uk-koeln.de

## Workshop 2: Advanced EEG analysis

Prof. Andrew Dimitrijevic, PhD
Research Director of the Cochlear Implant Program
Sunnybrook Health Science Centre
Department of Otolaryngology - Head and Neck Surgery
Faculty of Medicine, University of Toronto
2075 Bayview Ave., Room M1 102
Toronto, ON, M4N 3M5, Canada
CIbrainLAB.com
Email: andrew.dimitrijevic@sunnybrook.ca

# Luck Favors the Prepared Mind

Shannon R

Department of Otolaryngology, Keck Medicine of USC, Los Angeles, CA

The title is a famous quote from Louis Pasteur that reminds me of three projects that provide lessons for science. In this talk I will recount three discoveries that were somewhat accidental. I was either looking for something else and was "lucky" enough to see that what I'd found was far more important than my original goal, or I was skeptical that a project would work and was amazed by the level of success. In all three cases I was fortunate that I kept an open mind and could understand and appreciate the unexpected result.

**The Shannon Limit.** I was worried about delivering safe levels of electric stimulation to CI patients. Doug McCreery had performed many tests of electrical safety and had published a summary of his results spanning a wide range of parameters. I fit a simple line to his data to divide safe from unsafe outcomes, so I could use this equation to tell me if the parameters I selected were safe. Once I had that equation, I saw that it told a much more profound story about the causes of neural damage. That equation has been adopted by the FDA as the "Shannon Limit" for safety.

**The Noise Vocoder.** We were looking to make an acoustic simulation of a cochlear implant so families of CI patients could better understand the benefits and limitations. We used a band of noise to remove the spectral detail to simulate each electrode. The noise was modulated by the time envelope of speech from that spectral band – similar to the processing in a CI. When we played it, we were amazed that it was intelligible with only 4 bands! At first, we thought we had made a mistake and accidently mixed in some of the original signal, but after months of checking we realized we had not. The vocoder turned out to be not only a useful simulation, but also a powerful tool for understanding the CI and for studying the pattern recognition of speech by the brain.

**The Auditory Brainstem Implant.** In 1979 Bill House and Bill Hitselberger implanted electrodes near the cochlear nucleus of patients with NF2. These patients could not use a CI because their auditory nerve had been cut in removing a tumor. At first, I was opposed to such adventurism because I thought the CN was a poor stimulation location. So they hired me as the scientific director of the project. The outcomes were poor compared to a CI, but still beneficial to the patients. In the 2000s, Vittorio Colletti and other surgeons in Europe showed CI-like speech recognition by NF2 patients. I was skeptical and so had to go repeatedly to Italy to verify these amazing outcomes. It is still unclear exactly how ABI patients can achieve such excellent outcomes, but it certainly shows the power of the brain in adapting to wildly unnatural patterns of activation.

In summary, sometimes what you find is far better than what you were originally looking for. Stay alert to the possibilities and you may get "lucky" too.

*e-mail corresponding author: rshannon@med.usc.edu*

## Unraveling the impact of auditory aging on speech processing via concurrent brainstem and cortical evoked potentials

Bidelman G

School of Communication Sciences & Disorders, University of Memphis

Aging is associated with declines in auditory processing including speech comprehension. Perceptual deficits among the elderly could result from weaker neural activity within, or poorer signal transmission between various brain regions supporting speech. In a series of neuroimaging studies, we are probing these questions by recording neural activity simultaneously from the brainstem (BS) and primary auditory cortex (PAC) in human listeners via high-density EEG. This approach has enabled us to track how normal and pathological aging alter the neural processing and transmission of speech information at different levels of the neuraxis. Behaviorally, we find that older adults with and without hearing loss show slower, more variable speech perception than younger listeners, which coincides with reduced brainstem responses and increased, but delayed, cortical activity to speech. These deficits become overexaggerated in pathological aging due to mild cognitive impairment. We have also observed higher redundancy (i.e., lower interdependence) in speech encoding along the auditory pathway from BS to PAC in older ears, implying less neural flexibility in the aging system. Using functional connectivity assays, we have further shown that afferent (BS→PAC), but not efferent (PAC→BS), neural signaling not only weakens with hearing loss but fully mediates older listeners' speech comprehension difficulties, particularly in difficult noisy environments. Our findings underscore the importance of assessing connectivity (i.e., neural transmission) in understanding the brain basis of age-related hearing deficits and pave the way for new avenues of assessing the biological basis of real-world auditory skills across the lifespan.

**Bio**

Gavin M. Bidelman, PhD is Associate Professor with a joint appointment in the Institute for Intelligent Systems and School of Communication Sciences & Disorders at the University of Memphis where he directs the Auditory Cognitive Neuroscience Laboratory. He holds undergraduate degrees in music and engineering from the University of Michigan and a PhD in hearing science from Purdue University. Lab studies proceed on three main fronts: (1) understanding the neurocomputations involved in auditory perception and novel sound learning; (2) a neuroethological approach characterizing the upper bounds of brain plasticity via study of listeners with extraordinary auditory expertise (e.g., musicians, bilinguals); and translational work (3) examining changes in neurophysiological coding across the lifespan in both normal and clinical populations (hearing impaired, mild cognitive impairment). He has published ~100 scientific papers on the relation between human brain activity and audition. The work is currently supported by grants from the NIH and has been featured in the *New York Times*, *Huffington Post*, and *CBS News.* For further information, visit: www.memphis.edu/acnl/

# Auditory Neuropathy and Neurodegenerative Disease

Rance G [1] & Zanin J

[1] Department of Audiology & Speech Pathology, Centre for Auditory Neuroscience, The University of Melbourne, Australia

**Keywords:** Auditory neuropathy, neurodegenerative disease, diffusion weighted imaging

**Background:** "Auditory neuropathy" (AN) is a term used to describe disorders in which afferent neural transmission through the auditory nerve and brainstem is disrupted, but cochlear (outer) hair cell function is normal. There are a number of pathologic mechanisms (involving both pre- and post-synaptic sites) capable of producing the AN result pattern.

Auditory neuropathy is common in a number of generalized neurodegenerative conditions and the sensitivity of the auditory system to disruptions in the neural code means that hearing impairment (particularly affecting speech understanding) is often the first symptom to present in affected individuals.

**Methods and Results:** This presentation will include cross-sectional data exploring the correlation between overall disease progression and auditory function in diseases involving axonal neuropathy (such as Friedreich ataxia) and demyelinating processes (including Charcot-Marie-Tooth [Type 1] disease). We will also provide case studies showing within-patient changes in auditory function over-time. Furthermore, the presentation will summarize recent imaging findings (Diffusion Weighted Imaging [DWI]) in patients with auditory neural abnormalities affecting different regions in the auditory pathway. The correlation between anatomical features (such neural fibre density) and functional hearing ability in these individuals will be explored.

**Conclusions:** Measures exploiting the sensitivity of the auditory system to neural change may serve as clinical indicators of degenerative processes. As such, they may be used to track the natural history of disease progression and serve as biomarkers for therapeutic intervention.

The DWI studies summarized in this presentation suggest that the next generation of imaging technologies may have the capacity to predict functional hearing abilities in patients with auditory neural deficit.

**References:**

Zanin, J., Dhollander, T., Rance, G., Yu, L., Lan, L., Wang, H., ... & Wang, Q. (2020). Fiber-Specific Changes in White Matter Microstructure in Individuals With X-Linked Auditory Neuropathy. *Ear and hearing*, *41*(6), 1703-1714.

*e-mail corresponding author: grance@unimelb.edu.au*

# VEMPs as an electrophysiological measure of the vestibular system

Rosengren SM

Neurology Department, Royal Prince Alfred Hospital, Sydney, Australia, and Central Clinical School, The University of Sydney, Sydney, Australia.

**Keywords:** VEMP, otolith, saccule, utricle, vestibular evoked potential

This presentation will discuss the cVEMP and oVEMP as electrophysiological measures of the vestibular system. It will touch on the history and development of VEMPs, including the differentiation of VEMPs as vestibular rather than auditory reflexes and as muscle reflexes versus cortical potentials, as well as current applications. Discovery of the cVEMP in 1992 inspired a new wave of animal research investigating the sensitivity of the otolith organs to sound and vibration and the vestibular projections to the neck muscles. The addition of the oVEMP to the test battery provided not only a new test of utricular function but a new measure of the vestibulo-ocular reflex (VOR). VEMPs are useful clinically to test the otolith organs, but they can also provide interesting information about the ears and their connections to the eyes and postural muscles. For example, recent studies in humans have illuminated the extraordinary sensitivity of the otoliths to vibration and the exquisite precision of vestibular commands to the extraocular muscles to control eye movements during the VOR.

*e-mail corresponding author: sally@srosengren.org*

# ERP and audio-visual interaction

Sandmann P

Department of Otorhinolaryngology, Head and Neck Surgery, Audiology and Pediatric Audiology, Cochlear Implant Center, University of Cologne, Germany

Hearing loss and cochlear implantation induce functional changes in the auditory cortex (e.g. Sandmann et al., 2015). However, cortical alterations in these individuals are not restricted to the auditory system but can also extend to the visual system. For instance, previous studies have used event-related potentials (ERPs) to show that patients with cochlear implants (CI) recruit the auditory cortex to process not only auditory but also visual stimuli (e.g. Sandmann et al., 2012). Interestingly, the CI users with increased *visual* activation of the *auditory* cortex revealed reduced *auditory* speech recognition ability. This suggests that in CI users the recruitment of the auditory cortex during visual tasks – also referred to as cross-modal plasticity – is maladaptive with respect to the rehabilitation success and contributes to the variability of the CI outcome.

In my talk, I am going to present an overview of ERP studies which show that cross-modal plasticity and the perception of a degraded CI signal can affect the interaction between the auditory and the visual modality. Indeed, behavioural results indicate that CI patients have improved ability to integrate visual and auditory input when compared with normal-hearing listeners, at least in conditions with audio-visual speech (e.g. words) and environmental stimuli (e.g. dog barking). This is consistent with ERP results of CI users which show enhanced visual modulation of auditory-cortex activation when compared with normal-hearing listeners (e.g. Schierholz et al., 2017). Further, the results of current ERP studies point to distinct strategies in CI users and normal-hearing listeners during the perception of naturalistic audio-visual stimuli. This talk presents not only the behavioural and ERP results of current cross-sectional and prospective longitudinal studies which have used different tasks and different types of audio-visual stimuli. It also discusses the clinical relevance of these interesting results.

**References:**

Sandmann, P., Plotz, K., Hauthal, N., de Vos, M., Schönfeld, R., & Debener, S. (2015). Rapid bilateral improvement in auditory cortex activity in postlingually deafened adults following cochlear implantation. *Clinical Neurophysiology*, *126*(3), 594-607.

Sandmann, P., Dillier, N., Eichele, T., Meyer, M., Kegel, A., Pascual-Marqui, R. D., Marcar, V. L., Jäncke, L., & Debener, S. (2012). Visual activation of auditory cortex reflects maladaptive plasticity in cochlear implant users. *Brain,* 135, 555 - 568.

Schierholz, I., Finke, M., Kral, A., Büchner, A., Rach, S., Lenarz, T., Dengler, R., & Sandmann, P. (2017). Auditory and audio–visual processing in patients with cochlear, auditory brainstem, and auditory midbrain implants: An EEG study. *Human Brain Mapping*, *38*(4), 2206-2225.

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# DETAILED PROGRAM

## WEEK 1: PRE-SYMPOSIUM WORKSHOPS – JUNE 14TH AND 18TH

### DAY 1

| 14th June | live from | time at (CEST) | Workshop 1 (part A) | |
|---|---|---|---|---|
| WS-1A | | 16:00 | **Electrically evoked Auditory Brainstem Responses (eABR)** | |
| NLD | DEU | | Andy Beynon (NLD) and Martin Walger (GER) | |
| | | 16:00 | Andy Beynon (NLD) and Martin Walger (DEU) | Welcome and Introduction |
| WS-1A-1 | | 16:10 | Martin Walger (DEU) | Physiological basics, indication and clinical application of eABR |
| WS-1A-2 | DEU | 16:40 | Oliver Dziemba et al (DEU) | Bipolar electrical stimulus for "Click-equivalent" stimulation in measurements of electrically evoked auditory potentials |
| WS-1A-3 | DEU | 16:50 | Thomas Steffens (DEU) | Assessing maturation effects of the auditory brainstem with eABR |
| WS-1A-4 | | 17:00 | Martin Walger (DEU) | practical demonstration of eABR recording; evaluation of eABR parameters and clinical cases |
| | | 17:30 | All participants | Live Chat; questions and answers, clinical cases and general discussion |
| | | 18:00 | *End of Part A* | |

| WS-2A | live from | time at (CEST) | Workshop 2 (part A) | |
|---|---|---|---|---|
| | | 22:00 | **Advanced EEG analysis** | |
| | CAN | | Andrew Dimitrijevic (CAN) | |
| WS-2A-1 | | *22:00* | *Andrew Dimitrijevic (CAN)* | Welcome and Introduction |
| WS-2A-2 | | *22:05* | | *EEG data simulation and analysis: time-frequency decompositions (EEGLAB, FieldTrip, Brainstorm)* |
| | | *23:00* | | *questions and answers* |
| | | *0:00* | *End of Part A* | |

### DAY 2

| 18th June | live from | time at (CEST) | Workshop 1 (part B) | |
|---|---|---|---|---|
| WS-1B | | 16:00 | **Electrically evoked Cortical Responses (eCAEP)** | |
| NLD | DEU | | Andy Beynon (NLD) and Martin Walger (DEU) | |
| | | 16:00 | *Martin Walger (DEU) and Andy Beynon (NLD)* | Welcome and Introduction |
| WS-1B-1 | | 16:10 | *Andy Beynon (NLD)* | Short introduction on corticals |
| WS-1B-2 | | 16:30 | | Obtaining eSVP/eACC/eP300 in CI patients: practical setup and patient demos |
| | | 17:30 | | Pitfalls, Tips & trics & Discussion |
| | | 18:00 | *End of Part B* | |

| WS-2B | live from | time at (CEST) | Workshop 2 (part B) | |
|---|---|---|---|---|
| | | 22:00 | **Advanced EEG analysis** | |
| | CAN | | Andrew Dimitrijevic (CAN) | |
| WS-2B-1 | | *22:00* | *Andrew Dimitrijevic (CAN)* | Welcome and Introduction |
| WS-2B-2 | | *22:05* | | *Temporal Response Functions and Brainstorm source analysis* |
| | | *23:00* | | *questions and answers* |
| | | *0:00* | *End of Part A* | |

Week 2: Hallowell Davis Lecture - Guest Lecture 1 - Round Table - free Papers and Poster - June 21st and 25th

# WEEK 2: JUNE 21ST AND 25TH

## DAY 3

| 21st June | live from | time at (CEST) | 28th Biennial IERASG Symposium | |
|---|---|---|---|---|
| Opening | DEU/AUS/NZL | 21:00 | Opening Ceremony | |
| DEU | AUS | NZL | Martin Walger (DEU), Mridula Sharma (AUS) and Suzanne Purdy (NZL) | |
| HDL | | 21:15 | Hallowell Davis Lecture | |
| | USA | | Robert Shannon (USA): Luck Favors the Prepared Mind | |
| | NLD | | Moderator: Andy Beynon (NLD) and Ignacio Calderón de Palma (NLD) | |

| RT | live from | 22:15 | Round Table*: Objective measures in CI and implantable hearing aids | |
|---|---|---|---|---|
| | NLD | | Moderator: Andy Beynon (NLD) and Ignacio Calderón de Palma (NLD) | |
| RT-1 | DEU | 22:15 | Lenarz T, Salcher R, Bardt M, Buechner A | Intra-operative Monitoring Using Electrocochleography and Fluoroscopy for Hearing Preservation with the SlimJ Electrode |
| RT-2 | AUS | 22:30 | Lai WK, Chu P, Sanli H, Kong J, da Cruz M and Birman C | Objective methods to detect electrode array irregularities within the cochlea: A comparison |
| RT-3 | DEU | 22:45 | Rahne T, Müller A, Dziemba O, Oberhoffner T and Fröhlich L | Recording auditory evoked potentials for intraoperative optimization of floating mass transducer coupling efficiency of a middle ear floating mass transducer |
| RT-4 | DEU | 23:00 | Wagner L, Kranick M, Plontke S K , Rahne T | Optimizing stimulation parameters to record electrically evoked cortical auditory potentials in cochlear implant users |
| RT-5 | IDN | 23:15 | Putranto FM, Bashiruddin J, Zizlavsky S, Mangunatmadja I, Pandelaki J, Bardosono S and Hasansulama W | The role of Multimodal Imaging of Subcortical Auditory Tract in Predicting Implanted Electrical Evoked Auditory Brainstem Respons (Imp-eABR) |
| | | 23:20 | Live Round Table discussion | |
| | | | * live presentations with live-Chat and live discussion | |

| FP1 | live from | 23:40 | Short presentations (2min) and live discussion of free papers 1: Objective measures in CI and implantable hearing aids | |
|---|---|---|---|---|
| | pre-recorded online presentations | | Free online Paper Session 1 | watch all FP1 presentations in full length: https://ierasg21.com |
| | NLD | | Moderator: Andy Beynon (NLD) and Ignacio Calderón de Palma (NLD) | |
| FP-1 | AUS | 23:45 | Melman R and Plant K | Mitigation of stimulation artifacts |
| FP-2 | DEU | 23:50 | Haumann S, Timm M, Büchner A, Lenarz T and Salcher R | Cochlear monitoring during and after CI-Insertion using intracochlearly recorded Electrocochleography |
| FP-3 | RUS | 23:55 | Lalayants MR, Bakhshinyan VV and Tavartkiladze GA | Electrically-Evoked ABR Through Cochlear Implant in Children with Auditory Neuropathy Spectrum Disorder |
| FP-4 | RUS | 0:00 | Lalayants MR, Bakhshinyan VV and Tavartkiladze GA | Electrocochleography Obtained through Cochlear Implant in Children with Auditory Neuropathy Spectrum Disorder |

## DAY 4

| 25th June | live from | time at (CEST) | Guest Lecture 1* | |
|---|---|---|---|---|
| GL1 | USA | 22:00 | Gavin Bidelman (Memphis, USA): Impact of auditory aging on speech processing | |
| | NZL | | Moderator: Suzanne Purdy (NZL) and Abin Mathew (NZL) | |
| | | | *with live-Chat and live discussion | |
| LP1 | | 22:45 | Live papers 1*: objective assessment of speech discrimination | |
| | NZL | | Moderator: Suzanne Purdy (NZL) and Abin Mathew (NZL) | |
| LP-1 | EGY | 22:45 | ElKholy, W, Galal, E, Aly, B. | Acoustic Change Complex Elicited using Speech-In-Noise Stimuli in Normal Hearers and Children with Selective Auditory Attention Deficit |
| LP-2 | ESP | 23:00 | Arenillas-Alcón S, Costa-Faidella J, Ribas-Prats T, Gómez-Roig MD and Escera C | Frequency-following responses (FFR) reveal functional differences in encoding voice pitch and formant structure at birth |
| LP-3 | USA | 23:15 | Jacobs EJ, McPherson DL, Nissen SL, Petersen DB, Cardon G | Spatial resolution of quantitative electroencephalography during phonemic discrimination tasks: an abbreviated meta-analysis |
| LP-4 | USA | 23:30 | Antony R, Martin B, Shafer V and Behrens S | Encoding and perception of voicing and aspiration in native and non-native listeners in quiet and in background noise |
| LP-5 | AUS | 23:45 | Zhang VW, Ching TYC, Van Dun B, Bardy F, Ibrahim R, Wong C, Rance G, Chisari D, Sharma M and Dillon H | The relationship between the acoustic change complex and behavioural response of speech discrimination in infants and young children |
| LP-6 | NZL | 0:00 | Wise K, Purdy SC and Maslin MRD | Objective assessment of auditory discrimination using the optimised mismatch response (MMR) |
| | | | * with live-Chat and live discussion | |

| FP2 | live at | 0:15 | **Short presentations** (2min) **and live discussion of Free Papers 2:** ABR, FFR, CAEP, speech perception and development | |
|---|---|---|---|---|
| | pre-recorded online presentations | | **Free online Paper Session 2** (FP-6 to FP-14) | watch all FP2 presentations in full length: https://ierasg21.com |
| | AUS/NZL | | Moderators: Mridula Sharma (AUS) and Suzanne Purdy (NZL) | |
| FP-6 | ESP | 0:20 | Martinez M, Valderrama JT, Alvarez I, Vargas JL and De la Torre A | The transient response to interaural time differences |
| FP-7 | EGY | 0:25 | Shalaby A, Elkabarity R, Shafik N and Abdelfattah M | Effect of Regularity of Hearing Aid Use on Acoustic Change Complex |
| FP-8 | CAN | 0:30 | Duda V, Paul B, Scully C, Bigras C, Jemel B and Hébert S | Eliciting an N1 response using stimuli frequency- and intensity-matched to Tinnitus |
| FP-9 | USA | 0:35 | Bhatt I and Washnik N | Suprathreshold auditory measures for detecting early-stage noise-induced hearing loss in young adults |
| FP-10 | USA | 0:40 | Washnik N, Bhatt I and Sergeev A | Suprathresholds auditory electrophysiological and perceptual measures in young musicians with high noise exposure background |
| FP-11 | IND | 0:45 | Kumar P, Kumar Singh N and Sinha S | SUB-CORTICAL AND CORTICAL RESPONSES IN CHILDREN WITH CENTRAL AUDITORY PROCESSING DISORDERS |
| FP-12 | IND | 0:50 | Kumar P | AIDED SPEECH EVOKED CORTICAL POTENTIAL IN CHILDREN FITTED WITH HEARING AIDS |
| FP-13 | MYS | 0:55 | Dzulkarnain AAA, Kamal Azizi A, Sulaiman, NH | Auditory Brainstem Response using psychological task in Huffaz and non Huffaz |

## WEEK 3: JUNE 28TH, 29TH AND 2ND JULY

### DAY 5

| 28th June | live from | time at (CEST) | **Special Interview 1:** Lessons from the past, implications for the future | |
|---|---|---|---|---|
| **I-1** | USA | **21:00** | **Ted Glattke** (Arizona, USA) | |
| | USA | | Interviewers: Barbara Cone (USA) and Joaquin Valderrama (Australia) | |
| | | | | |
| **MS** | live from | **21:45** | **Manufacturer Session 1*:** what´s new…live presentations | |
| | DEU | | Moderator: Martin Walger (DEU) and Wiktor Jedrejczak (POL) | |
| MS-1 | BEL | 21:45 | **Cochlear:** Remo Arts (BEL) | The potential of TIM and ECochG research tools |
| MS-2 | DEU | 22:00 | **MedEl:** Philipp Spitzer<br>Team Leader, Objective Measures Development Strategies | Why is AutoART using tiny amplitude steps for ECAP recordings? |
| MS-3 | RUS | 22:15 | **Neurosoft:** Michael Soganov (RUS) | ABR Updates in Neurosoft Products – Neuro-Audio, Audio-SMART & Neuro-IOM |
| MS-4 | DNK | 22:30 | **Interacoustics:** James Harte (DNK) | Translating insights from hearing science to product innovation |
| MS-5 | USA | 22:35 | **Intelligent Hearing Systems:** Raquel A. Lauture (USA) | Recording FFRs using the SmartEP Advanced Auditory Research Module |
| MS-6 | CAN | 22:40 | **simHERA:** Tony Herdman (CAN) | simHERA: introducing an innovative way to train audiologists |
| | | **22:45** | **Meet the companies and sponsors, networking** | virtual meeting room (Zoom) |
| | | | *** Note:** the live manufacturer session will be recorded and is available until 30th of October | |

| LP2 | live from | 23:00 | **Live Papers 2*:** OAE, ABR and basic science | |
|---|---|---|---|---|
| | | | Moderator: Steven Bell (GBR) and Guy Lightfoot (GBR) | |
| LP-7 | USA | 23:00 | Bhatt I, Washnik N, Chuzie O | Evaluating cochlear tuning and medial olivocochlear reflex strength in young musicians and non-musicians |
| LP-8-short | POL | 23:15 | Jedrzejczak WW, Ganc M, Pilka E, Kochanek K and Skarzynski H | Ultra-high frequency distortion product otoacoustic emissions in subjects with tinnitus and with hearing loss |
| LP-9 | GBR | 23:20 | McKearney RM, Simpson DM, Chesnaye MA and Bell SL | Detecting the ABR using Machine Learning |
| LP-10 | GBR | 23:35 | Chesnaye MA, Bell SL, Harte JM and Simpson DM | Controlling test specificity for auditory evoked response detection using a frequency domain bootstrap |
| LP-11 | ESP | 23:50 | Martinez M, Alvarez I, Valderrama JT, Vargas JL and De la Torre A | Recording auditory brainstem responses with randomized stimulation level |
| LP-12 | ESP | 0:05 | Ribas-Prats T, Arenillas-Alcón S, Lip-Sosa DL, Costa-Faidella J, Mazarico E, Gómez-Roig D and Escera C | Altered neural encoding of speech sounds at birth is associated with fetal growth restriction |
| LP-13 | USA | 0:20 | Mulsow J, Finneran J, Houser D, Strahan M and Burkard R | Derived-Band Auditory Brainstem Responses in Bottlenose Dolphins and California Sea Lions |
| LP-14 | KOR | 0:35 | Ahn JH | Interpreting auditory brainstem evoked responses and distortion product otoacoustic emissions in diabetic patients with normal hearing |
| | | | ***with live-Chat and live discussion** | |

## Day 6

| 29th June | live from | time at (CEST) | Guest Lecture 2* | |
|---|---|---|---|---|
| **GL2** | AUS | **8:00** | **Gary Rance (Melbourne, Australia): Auditory Neuropathy and Neurodegenerative Disease** | |
| | USA | | Moderator: David McPherson (USA) and Garrett Gordon (USA) | |
| | | | *** with live-Chat and live discussion** | |
| **LP3** | | **8:45** | **Live Papers 3*:** ANSD and neurodegenerative diseases | |
| | USA | | Moderator: David McPherson (USA) and Garrett Gordon (USA) | |
| LP-15 | CAN | 8:45 | Herdman A, Smith K and Parfett A | Can the cochlear microphonic be useful in identifying infants with auditory neuropathy spectrum disorder (ANSD) during paediatric evoked response audiometry? |
| LP-16 | MYS | 9:00 | Dzulkarnain AAA, Shahrudin FA, Jamal FN, Rahmat S, Basri NA, Sidek SN, Yusof HM and Khalid M | Auditory Brainstem Response using psychological task in Autism Spectrum Disorder (ASD) children |
| LP-17 | ESP | 9:15 | Ribas-Prats T, Arenillas-Alcón S, Pérez Cruz M, Costa-Faidella J, Gómez-Roig MD and Escera C | Perinatal central nervous system dysfunction in large-for-gestational-age newborns disclosed with frequency-following responses to complex sounds |
| LP-18 | BRA | 9:30 | Bicas RCS, Alcântara YB, de Andrade KCL, Costa KVT, Menezes PL, Frizzo ACF | CENTRAL HEARING FUNCTION OF CHILDREN WITH MICROCEPHALY BY ZIKA VIRUS |
| | | | ***with live-Chat and live discussion** | |

| | live at | 9:45 | **Short presentations** (2min) **and live discussion of Posters:** Varia | |
|---|---|---|---|---|
| **P** | **uploaded online Posters** | | **Poster Session:** Varia | |
| | AUS | | Moderators: Mridula Sharma (AUS) and Bob Cowan (AUS) | |
| P-1 | USA | 9:45 | Cardon G and Sharma A | Cortical Neurophysiologic Correlates of Auditory Threshold in Adults and Children with Normal Hearing and Auditory Neuropathy |
| P-2 | USA | 9:50 | Easwar V, Beh K, McGrath E, Galloy M, Scollie S and Purcell D | Variability in the estimated amplitude of vowel-evoked envelope following responses caused by assumed brain processing delays |
| P-3 | BRA | 9:55 | Evangelista CK, Lemos FA, Santos AB, Arenillas-Alcón SA, Ribas-Prats TR, Escera C and Balen SA | Characterization of subcortical auditory neural responses in babies with congenital syphilis |
| P-4 | KOR | 10:00 | Koo M, Jeon J, Moon H, Suh MW, Lee JH, Oh SH and Park MK | Effects of Noise and Serial Position on Free Recall of Spoken Words and Pupil Dilation during Encoding in Normal-Hearing Adults |
| P-5 | DEU | 10:05 | Layer N, Weglage A, Müller V, Walger M, Lang-Roth R, Meister H and Sandmann P | Electrophysiological correlates of audiovisual speech perception in CI patients |
| P-6 | BRA | 10:10 | Ormundo DS, Leweis DR | How close can we estimate hearing in infants with NB CE-Chirp® LS stimulus? |
| P-7 | BRA | 10:15 | Ormundo DS, Leweis DR | Assessment of neuronal synchrony in hearing infants with CE-Chirp® LS stimulus |
| P-8 | USA | 10:20 | Abdrabbou M and Tucker D | The Effect of Silence and the Emergence of Tinnitus Perception on Auditory Brainstem Response and Auditory Middle Latency Response |
| P-9 | DEU | 10:25 | Weglage A, Layer N, Müller V, Walger M, Lang-Roth R and Sandmann P | Visual face processing in postlingually deafened patients before and after cochlear implantation |
| P-10 | DNK | 10:30 | Jørgensen KF and Michel F | Cochlear® Trans Impedance Matrix measurements – detection of tip fold-over in clinical settings |

## Day 7

| 2nd July | live from | time at (CEST) | Guest Lecture 3* | |
|---|---|---|---|---|
| **GL3** | AUS | **8:00** | **Sally Rosengren (Sydney, Australia): VEMPs as an electrophysiological measure of the vestibular system** | |
| | USA | | Moderator: Bob Burkard (USA) and Kathleen McNerney (USA) | |
| | | | ***with live-Chat and live discussion** | |
| **LP4** | | **8:45** | **Live Papers 4*:** Vestibular evoked myogenic response (VEMP) | |
| | USA | | Moderator: Bob Burkard (USA) and Kathleen McNerney (USA) | |
| LP-19 | DEU | 8:45 | Fröhlich L, Manthey A, Rahne T, Plontke S, Neuser L | Vestibular evoked myogenic potentials to electrical stimulation by cochlear implants – Prevalence and influence of stimulation parameters |
| LP-20 | POL | 9:00 | Sosna-Duranowska M, Tacikowska G, Gos E, Krupa A, Skarzynski PH and Skarzynski H | Vestibular function after cochlear implantation in partial deafness |
| | | | ***with live-Chat and live discussion** | |

| SS1 | live from | 9:15 | Student live session 1*: short presentations (SS-1 to SS-11) | |
|---|---|---|---|---|
| | GBR | | Moderator: Steven Bell (GBR) and Guy Lightfoot (GBR) | |
| SS-1 | NLD | 9:15 | Jwair S, Ramekers D, Thomeer H and Versnel H | The electrocochleography in normal-hearing guinea pigs during cochlear implantation |
| SS-2 | CHE | 9:20 | Sijgers L, Dalbert A, Tabibi S, Dillier N, Röösli C, Huber A and Pfiffner F | Simultaneous intra- and extracochlear electrocochleography for intraoperative monitoring during cochlear implantation |
| SS-3 | BEL | 9:25 | Keshishzadeh S, Garrett M and Verhulst S | Individualized auditory models based on the auditory evoked potential recordings |
| SS-4 | BEL | 9:30 | de Poortere N, Keppler H, Dhooge I and Verhulst S | Test-retest reliability of potential biomarkers for cochlear synaptopathy |
| SS-5 | AUS | 9:35 | Faundez JP, Van Yper L, Undurraga J and McAlpine D | The effects of stimuli and analysis parameters on two objectives measures of ITD processing in normal hearing adults. |
| SS-6 | EGY | 9:40 | Moharam M, Ehrmann-Mueller D, Hagen R and Shehata-Dieler W | Intraoperative monitoring of cochlear nerve function during acoustic neuroma surgery via transtemporal approach: Warning signs as predictors of postoperative hearing loss |
| SS-7 | NLD | 9:45 | Calderon De Palma JI, Mylanus EAM, Wanrooij M and Beynon AJ | Polarity effects on facilitation of the auditory nerve and behavioural responses in cochlear implant recipients using biphasic pulses |
| SS-8 | DEU | 9:50 | Herrmann DP, Rak K, Kurz A, Hagen R and Cebulla M | Intraoperative monitoring of the implantation success in cochlear implants using eABR |
| SS-9 | NLD | 9:55 | Stultiens JJA, Boutabla A, Cavuscens S, Ranieri M, Kingma H, Guinand N, Van de Berg R and Pérez Fornos A | Characterization of intraoperative electrically evoked compound action potentials of the vestibular nerve in translabyrinthine and intralabyrinthine configurations |
| SS-10 | IND | 10:00 | Darshan D, Ananya B and Kumari Apeksha | High-Frequency Audiometry and Vestibular Evoked Myogenic Potential - Critique in Women with Polycystic Ovary Syndrome |
| SS-11 | CHE/NLD | 10:05 | Boutabla A, Cavuscens S, Ranieri M, Mégevand P, Rochas V, van de Berg R, Guinand N and Pérez Fornos A | Cortical activation evoked by electrical stimulation of the vestibular nerve in humans |
| | | | *with live-Chat and live discussion | |
| | | | Student awards! Vote for the best student short presentation!!! | https:ierasg21.com |

| | live at | 10:30 | Student Poster Session 1: short live presentations (2min) and live discussion (SP-1 to SP-12) | |
|---|---|---|---|---|
| SP1 | uploaded online Posters | | Moderator: Andrew Dimitrijevic (CAN) and David Purcell (CAN) | |
| | | | ABR and ASSR | |
| SP-1 | DNK | 10:30 | Kristensen SGB and Elberling C | A new method for calculating the auditory brainstem response grand average |
| SP-2 | DEU | 10:35 | Kordus M, Wendt S and Langer J | Auditory Steady-State Responses and Auditory Brain Responses - hearing threshold estimation by sensorineural and mixed hearing loss |
| SP-3 | BRA | 10:40 | Forneck LLM, Pinto JD, Ferreira L and Biaggio EPV | Auditory Brainstem Response with iChirp in the Infant's audiological diagnosis: Reference Parameters |
| SP-4 | IND | 10:45 | Dzulkarnain AAA, Chahed N | Use of Level Specific CE-Chirp Auditory Brainstem Response in Infants with and without Hearing Impairment |
| SP-5 | BRA | 10:50 | Pinto JD, Motta LLM, Ferreira L and Biaggio EPV | Auditory Brainstem Response with iChirp in the Infant's audiological diagnosis |
| SP-6 | MYS | 10:55 | Shahrudin FA, Dzulkarnain AAA, Jamal FN, Rahmat S, Ramli M, Basri NA, Jusoh M, Sidek SN, Yusof HM and Khalid M | Evaluation of sound-working memory therapy intervention in Autism Spectrum Disorder (ASD) children using Auditory Brainstem Response (ABR) sensory gating |
| | | | VEMP and other myogenic responses | |
| SP-7 | IND | 11:00 | Gladys N, Adline PD, Aju A and Akhilesh PM | Effect of Gender on Cervical Vestibular Evoked Myogenic Potential |
| SP-8 | BRA | 11:05 | Thomazi ABOT, Scheuer M, Pimentel BN and Santos Filha VAV | Comparison between Vestibular Evoked Myogenic Potential and Handedness |
| SP-9 | AUS | 11:10 | Abrahamse R, Xu Rattanasone N, Demuth K and Benders T | Using eye-tracking to measure word processing in 3-5-year-olds with hearing loss |
| | | | OAE and efferent system (MOCS) | |
| SP-10 | MYS | 11:15 | Amirullah N, Rahmat S and Dzulkarnain AAA | The effects of attention on the MOCS as measured by TEOAE suppression |
| SP-11 | MYS | 11:20 | Amirullah NA, Rahmat S and Dzulkarnain AAA | The effects of nature sounds and Quranic recitation on the MOCS as measured by TEOAE suppression |
| SP-12 | MYS | 11:25 | Jamal FN, Dzulkarnain AAA, Shahrudin FA, Rahmat S, Basri NA, Sidek SN, Yusof HM and Khalid M | Suppression Distortion Product Otoacoustic Emission (Suppression DPOAE) using Various Contralateral Suppressors among Autism Spectrum Disorder Children |
| | | | Student awards! Vote for the best Student Poster!!! | https:ierasg21.com |
| | live at | 11:30 | Students networking and meet the experts (short presentations 1 and poster session 1) | |

## WEEK 4: JULY 5TH AND 9TH JULY

## DAY 8

| 5th July | live from | time at (CEST) | Guest Lecture 4* | |
|---|---|---|---|---|
| GL4 | DEU | 16:00 | Pascale Sandmann (DEU): Event Related Potentials (ERP) and audiovisual interaction | |
| | | | Moderator: Andrew Dimitrijevic (CAN) and Joaquin Valderrama (AUS) | |
| | | | *with live-Chat and live discussion | |
| | DEU/CAN | 16:45 | Live Papers 5*: CAEP, CI and audiovisual interaction | |
| | | | Moderator: Andrew Dimitrijevic (CAN) and Joaquin Valderrama (AUS) | |
| LP-21 | USA | 16:45 | Grose J, Kane S and Buss E | Electrophysiological and psychophysical measures of dynamic interaural phase differences |
| LP-22 | DNK | 17:00 | Morris DJ, Brännström KJ, Agirrezabal M, Sabourin C and Aaby Gade P | The Lateralized Readiness Potential as a measure to resolve functional hearing loss |
| LP-23 | KOR | 17:15 | Han JH, Lee J and Lee HJ | Ear-specific hemispheric asymmetry in unilateral deafness revealed by auditory cortical activity |
| LP-24 | IND | 17:30 | Basavanahalli Jagadeesh A, Maruthy S, Kumar P and Ajith U | Pre-stimulus baseline differences in Active and Passive listening |
| | | | *with live-Chat and live discussion | |

| | | | | |
|---|---|---|---|---|
| I-2 | USA | 17:45 | **Special Interview 2:** Lessons from the past, implications for the future | |
| | | | **Manuel Don** (San Francisco, USA) | |
| | | | Interviewers: Barbara Cone (USA) and Joaquin Valderrama (Australia) | |

## DAY 9

| 9nd July | live from | time at (CEST) | **Student live session 2*: short presentations** (SS-12 to SS-21) | |
|---|---|---|---|---|
| **SS2** | USA | **20:00** | Moderator: Bob Burkhard (USA) and Monica Chapchap (BRA) | |
| SS-12 | IND | 20:00 | Bhat M, Hariprakash P and Krishna Y | Revisiting Dichotic Listening Paradigm using Event Related Potential - A Neuropsychophysiological study |
| SS-13 | NLD | 20:05 | Vestjens JP and Beynon AJ | Determining frequency and spectral ripple discrimination thresholds using the auditory change complex: a comparison with psychophysical discrimination |
| SS-14 | BEL | 20:10 | Kestens K, Van Yper L, Degeest S and Keppler H | The P300 auditory evoked potential: an objective measurement of listening effort? |
| SS-15 | BRA | 20:15 | Luiz A, Toledo W and Frizzo A | A PROPOSAL OF PHONOLOGICAL AUDITORY ELECTROPHYSIOLOGICAL HEARING ASSESSMENT |
| SS-16 | BRA | 20:20 | Maximiano MVA, Kamita MK, Dias Piovezana AL, Ferreira Neves Lobo I, Stivanin Rodriguez L and Gentile Matas C | Study of Long Latency Auditory Evoked Potentials in children with reading and writing disorders: Speech and Tone Burst stimulus |
| SS-17 | BEL | 20:25 | Gillis M, Decruy L, Vanthornhout J and Francart T | Hearing loss is associated with delayed neural responses to continuous speech |
| SS-18 | GBR | 20:30 | Deoisres S, Lu Y, Simpson DM and Bell SL | The effects of extended silent pauses between words in continuous speech stimulus on cortical responses |
| SS-19 | USA | 20:35 | Momtaz S, Moncrieff DW, Bidelman GM | Dichotic listening deficits in amblyaudia are characterized by aberrant neural oscillations in auditory cortex |
| SS-20 | RUS | 20:40 | Tufatulin GS | The spectral shape of stimuli, using for aided free field ASSR: real ear measurements |
| SS-21 | DEU | 20:45 | Ladek AS, Rahne T, Plontke SK, Wagner L | Measuring electrically evoked Mismatch Negativity in cochlear implant users |
| | | | ***with live-Chat and live discussion** | |
| | | | **Student awards! Vote for the best Student Short Presentation!!!** | **https:ierasg21.com** |

| SP2 | live at | 21:00 | **Student Poster Session 2: short live presentations** (2min) **and live discussion** (SP-13 to SP-23) | |
|---|---|---|---|---|
| | **uploaded online Posters** | | Moderators: Mridula Sharma (AUS), Cynthia Fowler (USA) and John Durrant (USA) | |
| | | | **CAEP:** development, training, music, speech discrimination | |
| SP-13 | BRA | 21:00 | Alcântara YB, Toledo WWF, Machado MS, de Lima, KR, Carli FVBO and Frizzo ACF | Benefits of the hearing aid associated with musical auditory training in elderly with presbycusis |
| SP-14 | BRA | 21:05 | Machado MS, Lima KR, Luiz ALF, Toledo WWF, Góes VB, Frizzo ACF | Açaí's Effect on Long Latency Auditory Evoked Potential |
| SP-15 | USA | 21:10 | McFarlane K and Cone B | Spatial Release from Masking Represented in Cortical Auditory Evoked Potentials |
| SP-16 | DNK | 21:15 | Deshpande P, Brandt C, Debener S and Neher T | A digit-based behavioral and electrophysiological test battery for assessing different speech processing abilities |
| SP-17 | BRA | 21:20 | Toledo W, Alcântara Y, Machado M, Lima K, Luiz A, Goes V and Frizzo A | Assessment of auditory function in elderly presbycusis patients with and without mild cognitive impairment |
| SP-18 | USA | 21:25 | Ukaegbe O and Tucker D | Auditory Evoked Potentials and P300 in Young Female Adults who Perceive Temporary Tinnitus after a Brief Period of Silence |
| SP-19 | IND | 21:30 | Vasudevan H, Prakash Palaniswamy H and Rajashekhar B | Behavioural and Electrophysiological measures of attention in continuous subjective tinnitus |
| SP-20 | BRA | 21:35 | Lima KR, Machado MS, Luiz ALF, Toledo WWF, Góes VB, Frizzo ACF | Auditory evoked potentials: a comparative analysis of the registration of the mediated sum with the sum of the weighted average |
| SP-21 | BRA | 21:40 | Temp DA, Machado RQ, Piber DV, Mattiazzi AL, Folgearini JS, Patatt FSA and Biaggio EPV | Minimum levels of cortical and behavioral auditory responses in children and adolescents with hearing loss |
| SP-22 | BEL | 21:45 | Van Canneyt J, Wouters J and Francart T | Cortical compensation for hearing loss, but not age, in neural tracking of the fundamental frequency of the voice |
| SP-23 | CAN | 21:50 | Prince P, Paul BT, Chen J, Le T, Lin V Dimitrijevic A | Neural correlates of visual stimulus encoding and verbal working memory differ between cochlear implant users and normal hearing controls |
| SP-24 | IND | 21:55 | Vivek R and Vanaja CS | Cortical evoked potentials in children using cochlear implants: early and late-implanted. |
| SP-25 | CAN | 22:00 | Xiu B and Dimitrijevic A | Electrophysiological correlates of subjecve cognive demand in cochlear implant users during listening in noise |
| | | | **Student awards! Vote for the best Student Posters!!!** | **https:ierasg21.com** |
| | live at | 22:10 | **Students networking and meet the experts** (short presentations 2 and poster session 2) | |

| live at | 23:00 | **Summary, Student Awards and Closing Ceremony** |
|---|---|---|
| USA | 23:00 | **Symposium Summary:** Bob Burkhard (USA) |
| NZL | 23:20 | **Student Awards:** Suzanne Purdy (NZL) |
| USA | 23:30 | **Presenting the new ERA Textbook** "Basic Concepts of Clinical Electrophysiology in Audiology": John Durrant (USA) |
| DEU | 23:40 | **Closing remarks:** Mridula Sharma (AUS), Suzanne Purdy (NZL) and Martin Walger (DEU) |
| DEU | 23:50 | **IERASG 2023**: Invitation to Cologne, Germany: Martin Walger (DEU) |
| | 0:00 | **End of the IERASG Symposium*** |
| | | * all recorded live contributions, uploaded online presentations and posters will be available to registered participants until the end of October 2021 |

## Workshop 1, Part A: eABR

**Andy Beynon and Martin Walger**

The workshop will focus on the physiological basics and practical clinical hands-on training to perform electrically-evoked responses on the brainstem level. The prerequisites to setup your CI is the electrical stimulator (typically, the manufacturer's CI interface hard/software) on the one hand and your clinical EP system to record the EABRs on the other hand.

Our guest speaker Oliver Dziemba (Germany) will present the basis of Click-equivalent bipolar electrical stimulation of the Cochlea and Thomas Steffens (Germany) will focus on eABR as an important tool for evaluation of maturational processes after cochlear implantation.

Besides the technical specifications regarding the stimulation and recording parameters settings to evoke short latency brainstem potentials (hardware requirements), also non-technical factors and quality assessments are presented and discussed.

The hands-on training will mainly focus on avoiding external noise factors, the role of different stimulus lengths, stimulation rates, filter settings, and the fact how to deal with electrical artefacts caused by the CI, i.e. all important factors to take into account when obtaining adequate responses for further analysis. Practical 'tips and tricks' will be given to facilitate successful clinical assessment of electrically-evoked brainstem potentials in CI patients.

After this workshop, the participant:

- is able to setup, perform and interprete two-channel auditory brainstem responses
- knows advantages, limitations and pitfalls of brainstem EPs
- is able to recognize external interferences that might happen during intraop EP recordings in the OR and is able to solve these practical problems

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# Bipolar electrical stimulus for „click-equivalent“ stimulation in measurements of electrically evoked auditory potentials

Dziemba OC[1], Hocke T[2], Brzoska T[1], Müller A[3]

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[2] Cochlear Deutschland GmbH & Co. KG Hannover, Germany
[3] ORL Department Friedrichshain Clinic, Vivantes Hearing Center Berlin, Germany

**Keywords:** cochlear implant; diagnostic; electrical evoked auditory response

**Background:** The aim of this study was to determine the optimum electrical stimulation mode for the measurement of electrically evoked potentials. To quantify the broadband excitation electrically evoked compound action potentials were recorded in cochlear implant recipients. The full width half maximum (FWHM) was determined for spread of excitation along the electrode array.

**Methods:** The study sample consisted of 20 adult cochlear implant users without any comorbidity. For the ECAP recordings, the clinical software Custom Sound EP 4.x (Cochlear®Ltd.) was used in Advanced NRT mode. The number of averages was 50. The applied current level was chosen at the patient’s loudest acceptable presentation level. The stimulation-active electrode was electrode 11 and the stimulation indifferent electrode was electrode 18 (BP+6). All intracochlear electrodes but electrode 11 and 18 were used sequentially for ECAP recording. The record indifferent electrode was set to the extracochlear electrode MP 1.

**Results:** The applied alternating, intracochlear stimulation mode leads to neural excitation along approximately 80% of the length of the electrode array. The median of the full width at half maximum values covered the range of 18 electrodes on the implant array.

**Conclusion:** The use of a bipolar stimulation mode BP+6 facilitates an electrical excitation covering a median length of about 80% of the length of the electrode array in terms of the FWHM concept. Recent studies provide evidence for the use of electrode 11 as the stimulating, active electrode. For this broadband stimulation the standard clinical software can be used.

## References:

Dziemba OC, Hocke T, Müller A, Kaftan H (2018): Excitation characteristic of a bipolar stimulus for broadband stimulation in measurements of electrically evoked auditory potentials. Z Med Phys 2018; 28: 73–77. doi:10.1016/j.zemedi.2017.09.008

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## Assessing maturation effects of the auditory brainstem with EABR

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EABR has some key advantages with regard to the assessment of brainstem maturation in comparison to ECAP measurements. Especially when EABR measurements are performed intraoperatively during CI surgery, this is often the first and earliest possibility to obtain information about brainstem maturation in deaf or profoundly deaf children with much better quality than in awake children. Considering anatomical and electrophysiological models of the generation of ABR potentials, as that of Ponton, Moore and Eggermont, EABR can gain additionally information about the processes underlying brainstem maturation than by simply measuring interpeak latency I - V alone.

The two different maturation processes, myelination of nerve fibres and synaptic optimisation, and their particular influence on inter-peak latencies are outlined and used to interpret some examples of individual EABR measurements.

The differentiated information on the maturation status of individual patients shown here can only be obtained with the EABR measurement and not with ECAP measurements.

Auditory Brain Stem Response Generation by Parallel Pathways: Differential of Axonal Conduction Time and Synaptic Transmission. Ponton, C. W.; Moore, J. K.; Eggermont, J. J. Ear & Hearing 17(5), 1996, pp 402-410

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## Workshop 1, Part B: Electrically evoked cortical responses (eCAEP)

**Andy Beynon and Martin Walger**

*Different practical setups to obtain electrically-evoked auditory cortical potentials*

The aim of this instructional workshop is to give the clinician/clinical researcher basic knowledge how to obtain auditory cortical responses in patients with a cochlear implant. The workshop consists of hands-on demos how to setup your EP device, accompanied by practical background information, tips & tricks, and how to deal with pitfalls that may ruin your data, most of the time caused by (usually trivial) hard/software mistakes.

The workshop will also demonstrate different configurations to record exogenous and endogenous components of auditory detection, discrimination and cognitive processing using straight-forward single/dual-channel setups, thus relatively easy executable in everyday clinical settings.

After this workshop, the participant:

- knows the differences between acoustically- and electrically-evoked potential recordings
- is familiar with the main electrical stimulation parameters and its influence on EP response morphology
- is aware of prerequisite hardware to successfully obtain eAEP recordings
- is able to setup hard/software configurations for electrophysiological cochlear implant assessment

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# Workshop 2: Advanced EEG analysis

**Andrew Dimitrijevic**

Welcome to the IERASG workshop! The workshop will be spread across two days. Videos will be posted online. These are meant to give you a "head start" and make sure that things are working.

**Day 1** will cover simulating EEG/ERP data and analyses. This includes looking at "ERP" peaks and performing time-frequency analyses. A real data set will be provided. Participants will learn how to perform analysis in EEGLAB, FieldTrip, and Brainstorm.

**Day 2** will cover source analysis and an introduction to temporal response functions (a method to look at brain responses to continuous speech).

Unlisted videos can be found here:

https://www.youtube.com/playlist?list=PLxnkLO0KmNyr7RRRaBMtudgWF3z5f1SQe

Participants are encouraged to run these analysis routines on their own dataset. There will be time for Q&A.

All analysis will be in freely available Matlab programs (EGLAB, FieldTrip, and Brainstorm)

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## Intra-operative Monitoring Using Electrocochleography and Fluoroscopy for Hearing Preservation with the SlimJ Electrode

Lenarz T, Salcher R, Bardt M, Buechner A

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**Introduction:** The development of advanced electrode array designs and surgical techniques has allowed hearing preserving cochlear implantation for candidates with significant residual hearing. The SlimJ electrode array (Advanced Bionics LLC, California) was developed to provide: atraumatic insertion, easy handling and preservation of hearing. With electro-cochleography (ECochG) it is possible to monitor the electrode array's insertion in real time, adapting insertion speed, depth and angle to minimize insertion trauma. This study used ECochG to record cochlear microphonics (CM) and fluoroscopy to examine location to provide feedback to the surgeon.

**Methods:** A straight electrode array, having a full insertion depth of 23 mm, was inserted up to the point when CM amplitude decreased by 6 dB during insertion. Fluoroscopy was used to visualize the electrode's trajectory. A slow insertion speed was used, aiming for an approximately two-minute (0.2 mm per second) insertion. If the CM amplitude dropped, insertion was paused, the array slightly withdrawn and rotated to seek a deeper insertion. Where the CM amplitude could no longer be maintained, a partial insertion was made, the array being carefully stabilized using a specifically drilled slot in the bone of the facial recess. Participants were grouped by the CM amplitude that remained at the end of the surgery, expressed as a percentage of the maximum CM recorded during electrode array insertion: group 1 over 80%, group 2 20% to 80% and group 3 less than 20%. All participants underwent post-operative hearing threshold and speech perception measures for at least 4 months post-surgery.

**Results:** The SlimJ array was successfully inserted in all cases through the round window. For the 47 participants who had substantial pre-operative residual hearing, preservation could be studied. Mean angular insertion depth was 369 degrees (SD 46 degrees) with a range from 283 to 511 degrees. Between pre-operative and one month post-surgery, 34 (72%) had a low-frequency hearing threshold change of less than 30 dB and 19 (40%) had less than a 15 dB shift. Four months post-surgery, data for 26 participants showed 18 (69%) had a shift of less than 15dB. Changes in CM amplitude observed during electrode array insertion were in line with surgical feedback, with fluoroscopy providing useful additional control.

**Conclusion:** Having an implant system that provides the surgeon with real-time control over cochlear health appears to contribute to hearing preservation. An atraumatic electrode array design, coupled with real-time feedback allowed hearing preservation in over half of the participants.

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## Objective methods to detect electrode array irregularities within the cochlea: A comparison

Lai WK [1], Chu P, Sanli H, Kong J, da Cruz M, Birman C

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**Keywords:** EABR, intra-operative monitoring, Stimulus Artefact Profile, Trans-Impedance Matrix.

**Background:** . Insertion of the electrode array into the cochlea can be compromised by irregularities such as tip-foldovers or kinks, which will in turn have consequences for the use of the device. These can occur even with the most experienced surgeons. Hence, an objective method of detecting such irregularities is highly desirable, allowing surgeons to correct them as they occur. The gold standard for detecting such irregularities is imaging (e.g. X-ray or CT). At NextSense CIS, our routine intra-operative EABR monitoring includes recording the stimulus artefacts arising from CG or BP stimulation. The stimulus artefact profiles (SAPs) provide empirical information on the geometry of the electrode array within the cochlea.

Recently, the Trans-Impedance Matrix (TIM) has been added to the telemetry features of Cochlear's family of Nucleus cochlear implants. TIM involves measuring the electric field arising from stimulation on a given intracochlear electrodes at all 22 intracochlear sites, resulting in a 22 x 22 measurement matrix. It is possible to then deduce the relative electrode array geometry based on the electric field measurements.

**Methods:** In conjunction with routine intra-operative EABR monitoring, TIM measurements were also carried out in over 100 CI surgeries. In cases where irregularities are flagged by the SAPs and/or TIM, post-operative imaging was requested so that the results can be compared.

**Results:** Results from all three monitoring methods were compared against each other. In general, SAPs provide very good detection of array geometry irregularities, as confirmed by imaging data. In addition the foldovers and kinks, SAPs are also able to detect insertions deeper than 360 degrees. TIM measurements are able to detect gross irregularities such as foldovers, but not kinks or insertion depth. There is also a degree of interpretation required when the local impedances are unexpectedly high. The details of the comparisons will be discussed.

**Conclusion:** Compared to reference imaging data, the SAPs are the most reliable in informing on the electrode array geometry. Although TIM can also detect gross irregularities such as foldovers, interpretations are more difficult in borderline instances because of strong influences by local impedance variations. In its present form, TIM is nevertheless a useful screening tool for flagging the need for image confirmation, and where necessary, for the surgeon to revise the electrode array insertion or positioning. Where possible, SAP is currently our preferred objective monitoring method for detecting electrode array irregularities.

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## Recording auditory evoked potentials for intraoperative optimization of floating mass transducer coupling efficiency of a middle ear floating mass transducer

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**Keywords:** ABR, Active middle ear implant, Coupling quality, Floating mass transducer, Objective measures, Intraoperative

**Background:** Evaluating the effectiveness of intraoperative auditory brainstem responses (ABRs) to stimulation by the Vibrant Soundbridge (VSB) active middle ear implant for quantifying the implant’s floating mass transducer (FMT) coupling quality is of utmost interest. Postoperatively, various coupling efficiency is observed. Reduced coupling limits achievable dynamic range and thus speech perception.

**Methods:** In a diagnostic multicentric study, patients (> 18 years) who received a VSB with different coupling modalities were included. Pre- and postoperative bone conduction thresholds, intraoperative VSB-evoked ABR thresholds (VSB-ABR) using a modified audio processor programmed to preoperative bone conduction thresholds, postoperative vibrogram thresholds, and postoperative VSB-ABR thresholds were measured. Coupling quality was calculated from the difference between the pure tone average at 1000, 2000, and 4000 Hz (3PTA) vibrogram and postoperative 3PTA bone conduction thresholds.

**Results:** Twenty-three patients (13 males, 10 females, mean age 56.6 (± 12.5) years) were included in the study. Intraoperative VSB-ABR response thresholds could be obtained in all except one patient where the threshold was > 30 dB nHL. Postoperatively, an insufficient coupling of 36.7 dB was confirmed in this patient. In a Bland–Altman analysis of the intraoperative VSB-ABRs and coupling quality, the limits of agreement exceeded ± 10 dB, i.e., the maximum allowed difference considered as not clinically important but the variation was within the general precision of auditory brainstem responses to predict behavioral thresholds. Five outliers were identified. In two patients, the postoperative VSB-ABR thresholds were in agreement with the coupling quality, indicating a change of coupling before the postoperative testing.

**Conclusion:** The response thresholds recorded in this set-up have the potential to predict the VSB coupling quality and optimize postoperative audiological results. Latency functions may assist to predict maximum achievable dynamic range.

### Reference:

Fröhlich L, Rahne T, Plontke SK, Oberhoffner T, Dahl R, Mlynski R, Dziemba O, Aristeidou A, Gadyuchko M, Koscielny S, Hoth S, Kropp MH, Mir-Salim P, Müller A (2020): Intraoperative quantification of floating mass transducer coupling quality in active middle ear implants: a multicenter study. European Archives of Oto-Rhino-Laryngology. 2020 Sep 3. doi: 10.1007/s00405-020-06313-z.

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## Optimizing stimulation parameters to record electrically evoked cortical auditory potentials in cochlear implant users

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**Keywords:** eCERA,

**Background:**. Electrically cortical auditory evoked potentials (eCAEPs) are used in clinical routine to evaluate hearing function in patients with cochlear implants. There are different studies with eABR but some systematic examination of the effect of burst duration, stimulated electrode position, and stimulation level on the P1–N1–P2 complex elicited via the direct stimulation of selected electrode contacts on a cochlear implant (CI) electrode array are missing.

**Methods:** It is a prospective observational study of 20 adult cochlear implant users with a MED-EL CI system. eCAEPs were recorded simultaneously with the Eclipse (Interacoustics) and the Neuropack S1 MEB-9400 (Nihon Kohden) recording systems. Tone bursts with durations of 50, 100, and 150 ms were used for stimulation at the maximum comfortable loudness level (MCL) and MCL minus 50% dynamic range (DR) at selected apical, medial, and basal intracochlear electrodes.

**Results:** Individual P1–N1 and N1–P2 amplitudes were significantly higher at the MCL level of stimulation than at the MCL minus 50% DR. Burst length and stimulated electrode position did not affect the eCAEP responses. Residual noise was lower in the Neuropack S1 MEB-9400 system.

**Conclusion:** This study shows the feasibility of eCAEP recording using the MAESTRO software. The eCAEP morphology was independent of the burst duration and the stimulated electrode position. This allows a large flexibility in using direct cochlear stimulation to elicit eCAEPs.

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## The role of Multimodal Imaging of Subcortical Auditory Tract in Predicting Implanted Electrical Evoked Auditory Brainstem Respons (Imp-eABR)

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[2] Otorhinolaryngology Department; [3] Pediatric Department; [4] Radiology Department

[5] Clinical Nutrition Department Faculty of Medicine University Indonesia – Cipto Mangunkusumo Hospital Jakarta

[6] Otorhinolaryngology Department Faculty of Medicine Padjadjaran University/Hasan Sadikin General Hospital, Bandung, Indonesia

**Keywords**: eABR, Diffusion Tensor Imaging, Cochlear Implant, Lateral Lemniscus

**Background**: Poor multi electrode post implant Electrically Evoked Auditory Responses (Imp-eABR) score has been showed corelated to post implanted language development. This parameter is important to communicate post implant prognosis but has limited role in candidacy process. Conventional magnetic resonance imaging (MRI) is one of objective preimplant modality, but its role is limited to cochlea and cochlear nerve morphology status. Diffusion tensor imaging (DTI) is a new imaging technique to determine quality of nerve tract and its role in auditory research has been found related to subjective performance. The aim of this study is to investigate the role of MRI and DTI of sub cortical auditory tract in predicting Imp-eABR score.

**Methods**: In our clinical study, the role of cochlear nerve area from 1,5 T MRI and DTI parameters of lateral lemniscus and colliculus inferior in predicting Imp-eABR score was investigated. Multi electrodes Imp-eABR has been performed to 29 post implanted ears with normal cochlea morphology at 5 electrodes – 2 apical electrodes, 2 medial electrodes and 1 basal electrode at 30 nC, using lateral type cochlear implant design. Responses were scored using modified Gibson Imp-eABR scoring method, with maximal score is 10 and good response is set when score is more or equal to 8. DTI parameters - fractional anisotrophy (FA), mean diffusivity (MD), axial diffusivity (AD) and radial diffusivity (RD), of lemniscus lateral and colliculus inferior was measured using voxel wise analysis with DSI Studio software. These DTI parameters, cochlear nerve size and implant age were corelated to Imp-eABR scores.

**Results**: The mean of Imp-eABR score was 6,3 $\pm$ 2,63, 12 ears have score more or equal to 8 and 17 ears have score less than 8. Only implant age, cochlear nerve size, and lemniscus lateral DTI parameters has correlation to either Imp-eABR total scores and or Imp-eABR scores less than 8. Area Under Curve analysis showed that ipsilateral and contralateral RD of lemniscus lateral has the biggest value to predict Imp-eABR score more than or equal to 8, with cut off value 0,45. Multivariate analysis showed that size of cochlear nerve, and RD of ipsi and contralateral lemniscus lateral has significant role in predicting Imp-eABR score with $r^2$ 72,3%.

**Conclusion**: The data showed cochlear nerve size and RD of lateral lemniscus has significant role in predicting Imp-eABR score. Further studies need to be performed to analysed how this model could predict post implant auditory and speech performance.

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## Mitigation of stimulation artifacts

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[1] Cochlear Limited, Australia

**Keywords:** ECAP, Forward masking, stimulation artifact.

**Background:** Electrically-evoked compound action potentials (ECAP) acquired from spiral ganglion cells are often contaminated by electrical stimulation artifacts due to the short latency of the neural response. The most common techniques for reducing the stimulation artifact are the forward masking paradigm [1] and alternation of stimulus polarity, the former of which introduces additional noise sources and may reduce response magnitude while the latter significantly impacts the morphology of the response and in some cases does not eliminate the artifact. In this study we developed a novel method to model and remove stimulation artifact without the need of forward masking of alternating polarity stimulation.

The stimulation artifact has constant phase and may be modelled as a power sum of unit step functions raised to a fractional value, $\alpha$, where $0 \leq \alpha \leq 1$. As cochlear implant electrodes are highly polarizable, they behave more like a capacitor than a pure resistor and as such it is expected that $\alpha$ will be close to 1. This observation may be leveraged to provide an estimate of initial conditions which enables this non-linear model to reliably converge.

**Methods:** The Fricke-Warburg model was used as the basis for developing a mathematical model of the electrode-electrolyte interface, with a train of step functions defined such that they matched the timing of the biphasic pulse innovation. 48 699 unique Forward masked ECAP traces were acquired for a range of current levels on 435 electrode contacts. The model was fit to the stimulation artifact derived from the difference between the “masker-probe” and “masker only” sub-traces using a robust numerical least squares method with the alpha component constrained via a trust region reflection technique [2], with initial conditions derived from electrode properties. The statistical properties of the residuals after subtracting the model from the fitted data were analysed to estimate efficacy of the fit.

The fitting process was repeated using “probe only” measurements with the ECAP trace derived as the residuals after subtracting the model. The correlation coefficient of the derived ECAP response was compared to the forward masked response to determine the efficacy of response fit and quantify potential morphological impacts.

**Results:** The fitted stimulation artifact residuals were distributed according to a student t distribution, with mean of zero and standard deviation of 5.75µV. Pearson’s correlation coefficients of the forward-masked response and response derived from the residuals’ probe-model measurements improved with increased response amplitude with an average correlation > 0.9 for response magnitudes exceeding 100µV.

**Conclusion:** A constant phase model of the stimulation artifact provides a good representation of the stimulation artifact and may be used to eliminate the stimulation artifact of an ECAP response without the need for forward masking or alternating polarity stimulation. This allows for the acquisition of ECAP responses with fewer measurements, without sacrificing waveform morphology or introducing additional independent noise sources.

### References:

[1] Miller CA, Abbas PJ, Brown CJ. An improved method of reducing stimulus artifact in the electrically evoked whole-nerve potential. Ear and Hearing. 2000 Aug;21(4):280-290. DOI: 10.1097/00003446-200008000-00003
[2] M. Branch, T. Coleman, and Y. li, “A Subspace, Interior, and Conjugate Gradient Method for Large-Scale Bound-Constrained Minimization Problems,” *SIAM Journal on Scientific Computing*, vol. 21, Dec. 1999, doi: 10.1137/S1064827595289108.

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## Cochlear monitoring during and after CI-Insertion using intracochlearly recorded Electrocochleography

Haumann S, Timm M, Büchner A, Lenarz T, Salcher R.

ENT clinic, Hannover Medical School; Chair: Prof. Prof. h.c. Dr. Th. Lenarz; Cluster of Excellence Hearing4All

**Keywords:** Electrocochleography, cochlear geometry, cochlear implant, hearing preservation

**Background:** To preserve residual hearing during CI insertion it is desirable to use intraoperative monitoring of the cochlea. A promising approach is the recording of cochlear microphonics using Electrocochleography (ECochG).

**Methods:** During the insertion of hearing preservation CI electrodes the potentials were recorded using the CI electrode at contact 1. After insertion the recording was done at different electrode contacts. The stimulation was done acoustically using 500 Hz tone bursts. For recording the clinical CI software (Maestro, Medel) was used. After 6 months the recording at different contacts was repeated. The location of the electrode in the cochlea during insertion was estimated using preoperative radio imaging (CT scan) and mathematical modelling, the postoperative location was measured using postoperative radio imaging (cone beam CT scan). Up to now 6 patients were included.

**Results:** In most of the cases the signal amplitude rose during the insertion. In patients with good residual hearing the largest amplitudes were recorded at electrode contacts which lay closest to the generators of the stimulation frequency.

**Conclusion:** The intracochlear ECochG during and after CI insertion is very good possible and seems to yield consistent results to the location of the electrode in the cochlea.

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## Electrically-Evoked ABR Through Cochlear Implant in Children with Auditory Neuropathy Spectrum Disorder

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**Keywords:** auditory neuropathy, eABR, cochlear implantation

**Objective:** The aim of this preliminary study was to estimate applicability of electrically evoked auditory brainstem response (eABR) for the estimation of neural integrity in children with auditory neuropathy spectrum disorder (ANSD) and compare eABR data with other objective measurements and hearing performance.

**Material and methods:** 3 children with ANSD confirmed by ABR, cochlear microphonic (CM) and otoacoustic emission (OAE) testing with profound hearing loss according to the age-appropriate behavioral tests were enrolled in the study. ANSD has congenial/early onset, without any hearing loss risk factors and comorbid issues. OAE was present in non-implanted ear and even in the implanted ear in Patient#1. Patient#1, 12 y.o. boy, 10 years after cochlear implantation (CI) with CI24RE(CA) Cochlear Implant, achieved hearing and speech development appropriate to his age. Patient#2, 5 y.o. and Patient#3, 5 y.o., both were implanted 2 years ago with CI512 but showed very different outcomes after CI. Patient #2 has notable hearing perception development, patient#3 – poor outcomes after 2 years CI usage. The eCAP testing, free field audiometry, age- and development-appropriate speech recognition tests were performed in these patients. eABR was recorded via Eclipse EP25 Interacoustics with eABR External Trigger protocol during the physiological sleep. Electrical bipolar stimulation was achieved with Custom Sound EP software. At least 3 electrodes were tested in each patient. eABR thresholds in CU were tested with stimulus pulse width (PW) of 25 and 37us for patients #1 and #2, and at PW level up to 100us for patient#3.

**Results:** In patient #1 and #2 the registered eCAPs were within the normal range. In patient #3 eCAPs were not stable from session to session, recordable at 14 electrodes as maximum. Free-field audiometry thresholds were within the expected range in all implanted patients. Maximum word recognition score for patient #1 was 100% at the 65 dB HL presentation level. Closed-set speech recognition test demonstrated hearing perception development in Patient #2 after 2 years of CI usage, thought open-set test was not yet applicable for the child. In Patient #3 speech recognition was absent. eABR wave eV with the latency about 4ms was registered in Patients #1 and #2 at all tested electrodes. eABR thresholds were corresponded to C-levels of the last patient MAP. Testing of Patient #3 with different stimulus parameters (increasing PW from 25 to 100 us, decreasing stimulation rate from 26 to11 stimuli per sec, changing mode of stimulation) did not reveal the wave eV.

**Preliminary conclusions:** eABR measurements in 3 children with ANSD demonstrated restoration of neuronal conduction and synchronous firing in auditory pathway up to brainstem after cochlear implantation in 2 patients, which was not achieved in Patient#3. eABR results were matched with hearing performance and eCAP measurements in these 3 patients. Patients #1 and #2 most probably have auditory synaptopathy while Patient #3 has auditory neuropathy. We might expect the same results of rehabilitation for Patients #1 and #2. eABR registration combined with other objective tests firstly performed only after CI might be useful tool for hearing rehabilitation outcomes forecast in patients with ANSD after CI. Thereby, experience in eABR application for clinical practice should be expanded.

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## Electrocochleography Obtained through Cochlear Implant in Children with Auditory Neuropathy Spectrum Disorder

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**Keywords:** auditory neuropathy, electrocochleography, cochlear implantation

**Objective:** Electrocochleography (ECoG) is a useful tool to specify site of lesion in patients with auditory neuropathy spectrum disorder (ANSD) to distinguish auditory synaptopathy and auditory neuropathy. Standard ECoG testing in children requires patient's sedation/general anesthesia for accurate placement of active electrode ideally at promontorium. Intra- and postoperative ECoG registration using intracochlear electrodes appears to be feasible instrument to asses inner ear electrophysiological features in cochlear implant recipients with ANSD of different etiology without sedation, which is convenient in case of children.

**Material and methods:** 12 children with ANSD with profound hearing loss according age-appropriate behavioral tests were enrolled in the investigation. ANSD etiology were: otoferline gene mutation in 3 cases; cochlear nerve deficiency in 2 cases; prematurity with other perinatal risk factors - 2 cases; etiology was unknown in 5 children. 7 children were implanted with CI512 or CI24RE(CA) Cochlear Implants, 5 children - with Advanced Bionics HiRes 90K Advantage CI. Electrocochleography, acoustic stimulation and recording were performed using Active Insertion Monitoring systems for Advanced Bionics users and Cochlear Research Platform - for Cochlear users. ECoG was performed at least in two modes for each patient: 1. Frequency sweep mode - ECoG via most apical intracochlear electrode (by default but variable) for different frequencies from 125 Hz to 4000 Hz (depending on the system); 2. Electrode sweep mode - ECoG via every second intracochlear electrode for stimulation with 500 Hz tone burs (by default but variable). All patient were tested postoperatively and only 3 patients implanted in 2020 were also tested intraoperatively. Cochlear microphonic and auditory nerve neurofonic were estimated.

**Results:** Cochlear microphonics were recordable in all patients with ANSD for most tested frequencies. Cochlear microphonic thresholds were registered at some unexpected low levels - 35 dB HL at 125 Hz and 65 dB HL at 2000Hz in some cases. ECoG parameters were different in patients with ANSD of different etiology. ECoG thresholds were not comparable with behavioral thresholds. Due to preserved cochlear structures in patients with ANSD, ECoG performed for different frequencies allows to specify the electrode location in the cochlea.

**Preliminary conclusions:** ECoG obtained through cochlear implant appear to be an easy performing informative tool to estimate preserved cochlear structures in patients with ANSD of different etiology after cochlear implantation. ECoG findings do not correlate with audiometric tests in patients with ANSD, therefore intraoperative ECoG should not be used for estimating residual hearing level in patients with ANSD.

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# Acoustic Change Complex Elicited using Speech-In-Noise Stimuli in Normal Hearers and Children with Selective Auditory Attention Deficit

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**Keywords:** Cortical auditory evoked potentials; acoustic change complex; selective auditory attention; speech in noise; Arabic word in noise test

**Background:** Acoustic Change Complex (ACC) is a cortical auditory evoked potential that reflects the neural detection and discrimination of sound obtained in response to stimulus changes. Selective auditory attention (SAA) refers to the ability to acknowledge some stimuli while ignoring others that occur at the same time. This research was designed to assess SAA ability in normal hearing children and children with SAA deficit using ACC potential as compared to behavioral tests.

**Methods:** ACC was recorded in 30 normal hearing children and their results were compared to 15 children with SAA deficit. Stimuli used were 500 msec. vowel /o/ in pink noise at different SNRs (+8, +4, 0, -4 and -8). ACC response parameters were compared to Words In Noise test-Arabic version (WIN-A) test scores.

**Results:** ACC response (ACC P1 and ACC N2) was successfully recorded in all normal hearing children. In contrast, two children with SAA (13%) showed identifiable ACC response at +8 SNR only. In normal hearers, as SNR decreased, there was significant decrease in ACC percent identification, increase in latency and decrease in amplitude.

**Conclusions:** ACC was detected in all normal hearing children, with a cutoff normalcy of zero SNR, which is recommended to be used in evaluating young children who cannot be behaviorally assessed. With few exceptions, children with SAA deficit failed to show ACC response using the present protocol. Accordingly, more research is needed to assess children suspected to have SAA deficit using longer stimuli or higher SNRs.

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# Frequency-following responses (FFR) reveal functional differences in encoding voice pitch and formant structure at birth

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**Keywords:** newborns, FFR, encoding, speech sounds

**Background:** Neural encoding of voice pitch and formant structure play a crucial role in speech acquisition. However, the extent to what newborns are capable of extracting this information from speech sounds remains unclear. Considering that an early detection of language impairments could guide appropriate interventions, knowing the expected speech perceptual skills in newborns becomes a matter of clinical relevance. Thus, our aim was to characterize the functional maturity of voice pitch and formant structure encoding mechanisms at birth with non-invasive electrophysiological recordings of the frequency-following response (FFR).

**Methods:** Using the adult population as a reference, we recorded the FFR elicited by 4000 presentations (in alternating polarities) of a new speech sound: a two-vowel, rising-pitch-ending stimulus (/oa/) that is optimally designed to allow the simultaneous assessment of voice pitch and formant structure encoding in a relatively short period of time. A sample of 34 healthy term newborns, without obstetric pathologies or risk factors related to hearing impairments, and 18 young adults, with no self-reported history of neurological, psychiatric or hearing impairment, were recruited from Sant Joan de Déu Hospital (Barcelona, Spain) and University of Barcelona (Spain), respectively. FFRs elicited to both stimulus polarities were averaged ($FFR_{ENV}$) to isolate the encoding of $F_0$, which was analysed separately for /a/ steady (90-160 ms) and /a/ rising (160-250 ms) pitch sections (spectral signal-to-noise ratio [SNR] and pitch measures extracted from the autocorrelation). Subtraction of the FFR elicited to both polarities ($FFR_{TFS}$) emphasized the encoding of the harmonic structure. The corresponding spectral peaks (SNR) of the formants during the /o/ (10-80 ms) and /a/ (90-160 ms) vowel sections were analysed separately.

**Results:** $FFR_{ENV}$ analyses revealed no group differences in $F_0$ spectral SNR and pitch strength values during the /a/ steady and the /a/ rising sections. Likewise, both groups showed lower $F_0$ values during the rising section than the steady section. In contrast, $FFR_{TFS}$ analyses yielded significant group differences in formant structure encoding. Adults exhibited larger SNRs than newborns both at lower and higher formant frequencies, and showed larger SNRs to the first formant frequency of the presented vowel: at 452 Hz (/o/´s $F_1$) during the /o/ section, and at 678 Hz (/a/´s $F_1$) during the /a/ section. Likewise, newborns exhibited a significantly larger SNR to the /o/'s $F_1$ during the /o/ section as well, but presented a barely measurable signal at 678 Hz.

**Conclusion:** Our work provides the first evidence that newborns, in addition to their known ability to accurately encode changes in voice pitch, are also able to encode the formant structure of vocalic sounds at spectral components below ca. 500 Hz. This frequency limit matches the low-pass filter characteristics of the womb as reported in the literature. Therefore, while voice pitch encoding appears adult-like at birth, formant structure representation is maturing in a frequency-dependent manner. Furthermore, we demonstrate the feasibility to assess both components of the speech signal within clinical evaluation times (30 min) in a hospital setting, and suggest the possibility to use this new stimulus as a tool to perform a longitudinal assessment of speech encoding in babies from their first hours of life throughout their first years.

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## Spatial resolution of quantitative electroencephalography during phonemic discrimination tasks: an abbreviated meta-analysis

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**Keywords**: spatial resolution, electroencephalography, functional magnetic resonance imaging, phoneme discrimination task

**Background:** Phonological processing is an essential linguistic skill in language acquisition, processing, and communication is a complex neurological activity. Several studies, some using quantitative electroencephalography (qEEG) and others using functional magnetic resonance imaging (fMRI), have been conducted to investigate these neural substrates of phonological processing. Traditionally, it has been shown that qEEG's strength is in capturing temporal resolution, and fMRI's strength is in capturing spatial resolution. However, the spatial resolution of qEEG has greatly improved and some studies have suggested qEEG has reached near levels of specificity comparable to fMRI. The present comprehensive review evaluates the ability of consistency in qEEG studies to identify localization of phonological processing.

**Methods**: A total of 802 studies were screened, resulting in the identification of 154 articles that would provide information on spatial specificity of qEEG when measuring phonemic discrimination. Articles were selected based on six inclusion criteria developed to ensure that the studies would be similar enough to be comparable and include enough statistical information to be analyzed. Eighteen studies, representing 19 experiments, were identified that met the criteria for the meta-analysis. The study's event rate was defined as the number of times an anatomical area was coded as a source reference, divided by the number of participants in the study.

**Results**: Due to the relatively small sample size, a fixed-effect model was used; this limited our observations to the current reviewed studies. Cochran's *Q* and a chi-squared test showed there was a high level of heterogeneity and little consistency between studies. Results show that each of these experiments had relatively low event rates, culminating into a summary event rate of 0.240.

**Conclusion**: The results of this meta-analysis indicated that the qEEG studies included in this study are not as accurate or consistent in source localization as fMRI studies. Because a fixed-effect model was used, the results of this study cannot be generalized to all qEEG studies. However, it does suggest that studies may have been assuming source localization that might be incorrect. Overall, the study made it clear that there is not enough information available to effectively compare qEEG spatial resolution to that of fMRI. However, research like the 2011 study by Brodbeck et al., which found that high-resolution qEEG paired with an individual's MRI, could identify areas of epileptic activity with greater accuracy than MRI alone. This would suggest that the technology is available to further refine the localization (spatial resolution) of qEEG.

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## Encoding and perception of voicing and aspiration in native and non-native listeners in quiet and in background noise

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**Keywords:** cortical auditory evoked potentials, T-complex, non-native speech perception, voicing, aspiration, Hindi, American English, Tamil, speech perception in noise

**Background:** The neurophysiologic processing of voiced consonants has been well studied, but there has been little research on neurophysiologic processing of aspiration in speech sounds. The aim was to determine whether individuals from language groups for whom aspiration and/or voicing are phonologically contrastive differ in the perception and neurophysiologic processing of these speech features relative to those who do not use these features contrastively. Native listeners from three language groups were used: Hindi listeners who have both of these features, American English listeners who have only voicing in their phonetic inventory, and Tamil listeners who have neither. Perception and processing were evaluated in quiet and in background noise because group differences between native and non-native listeners were hypothesized to be larger in the presence of background noise. This is the first study to test the Automatic Speech Perception (ASP) model in noise using auditory evoked potentials (AEPs).

**Methods:** Sixteen participants between 20-45 years of age with normal hearing were included in each language group. Natural digitized speech sounds were used. Hindi /ba/, /pa/, and /pha/ and American English /ba/, and /pa/ were presented at 70 dB SPL using insert earphones in quiet, and in background noise. The speech was presented in a noise-filled envelope of four talker babble at signal-to-noise ratio of 0. Behavioural testing included two identification tests and a speech discrimination task. Auditory evoked potentials were recorded from 32 channels using a Neuroscan system.

**Results:** The native listeners had significantly higher percent categorization scores on the identification tasks both in quiet and in noise, whereas the non-native listeners had lower scores. Language group differences were more evident in noise. Further, the percent categorization scores were lower for aspirated speech sounds (Hindi /pha/, English /pa/), relative to the unaspirated speech sounds (Hindi /ba/, Hindi /pa/, English /ba/) in noise. The Tamil and English participants also identified the Hindi /pha/ as /a/ in noise. Interestingly, this confusion error was not noted in Hindi participants. Significant group differences were present for the AEPs at midline-central and lateral-temporal electrode sites. AEP latencies were significantly longer for aspirated speech sounds and shorter for Hindi /ba/ and English /ba/. Amplitudes for all waveform peaks examined were attenuated in noise relative to in quiet, except for P1. The Ta and Tb amplitudes were larger at the left electrode site in native American English participants for the American English stimuli. Further, interaction between group*stimulus*condition*laterality was present with larger Ta peak amplitudes to Hindi /pha/ in quiet on the left hemisphere than right only in Hindi listeners.

**Conclusion:** A perceptual advantage was observed in native listeners while processing speech in noise in the behavioural tasks. Higher percent categorization scores in native listeners and fewer confusion errors in noise indicate that the Automatic Speech Perception (ASP) model holds, even in noise, because native listeners showed evidence of automatic processing of the speech cues. AEP findings supported acoustic-phonetic processing of both voicing and aspiration in quiet and in noise at both midline-central and lateral-temporal electrode sites. Lastly, greater Na amplitudes over the right hemisphere indicated recruitment of additional brain regions for processing speech in noise. The most important finding is that our brains encode the speech sounds even if they are not present in our native language and cannot be used for further processing; additional processing of these encoded sounds takes place only in native listeners. The results contribute toward a better understanding of cross-linguistic speech processing in noise and could be useful when examining non-native speech perception in clinical population including those with deficits in auditory processing.

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## The relationship between the acoustic change complex and behavioural response of speech discrimination in infants and young children

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**Keywords:** cortical auditory-evoked potentials (CAEPs), acoustic change complex (ACC), Visual Reinforcement Infant Speech Discrimination (VRISD), infants, children, speech discrimination

**Background and Aim:** Previous studies have shown that the acoustic change complex (ACC) responses, an objective measure of auditory evoked potential that reflects discrimination capacity, can be reliably elicited in awake infants with or without hearing loss[1,2,3]. The aim of this study was to further investigate the relationship between the ACCs and behavioural measurements of auditory speech discrimination in 12 month-old infants and 3-year-old children with normal hearing and those with hearing loss.

**Methodology:** Participants were 90 infants (mean age of 10.5±1.8 months) and 73 young children (mean age of 3.4 ± 0.1 years). In the infants group, 49 had hearing loss wearing bilateral hearing aids (BHAs), and 41 had normal hearing. In the 3-year-old children's group, 37 had hearing loss wearing BHAs and 36 had normal hearing. Children's speech discrimination performance was recorded by ACCs and behavioural performance. In the behavioural task, infants and young children were trained and tested using visual reinforcement paradigm and play operant procedure, respectively. The ACC was recorded for three contrastive pairs: a vowel contrast (Formant 2 differences: [u] vs [i]), spectral-ripple noise (SRN; a high-frequency noise amplitude modulated in the frequency domain with or without a 90°phase-shift), and a voicing contrast (presence or absence of voicing in sibilants [s] vs [z]); presented in the free field at 20 sones (65 ~ 70 dB SPL). The clinical HEARLab system was used for stimuli presentation and data acquisition, and the electrophysiological data were offline processed by a custom-designed MATLAB script. The behavioral testing was performed and scored using the Intelligent Hearing System VRISD software module. The speech contrasts ([u] vs [i] and [s] vs [z]) were used for both groups, and the SRN stimulus was also included in the 3-year-old behavioral task.

**Results:** Out of the total 90 infants, 14% of them (n=13) could not be conditioned in the VRISD assessment. There were 93% and 74% of the infants with ACC results that showed discrimination for the [UI] and [SZ] contrasts, respectively. Less than 40% of the infants showed discriminated results in behavioural task for both contrasts. Among the infants who had discriminated ACC, about half of them didn't show discriminated behavioural results for each stimulus contrast. In 3-year-old group, 6 children (8%) could not be conditioned in the behavioural assessment. There were 100%, 48%, and 75% of the children with discriminated results in ACC for the [UI], SRN and [SZ] contrasts, respectively. The discrimination rates in the behavioural task were 92%, 67% and 82% for the three contrasts. Among the infants who had discriminated ACC, 92%, 60% and 82% of them also had discriminated behavioural results for the [UI], SRN and [SZ] contrasts, respectively.

**Conclusions:** The ACC is preferable to the behavioral assessment in the first year of life. The behavioral results showed higher discrimination rates at 3 years old than at younger age. The reasons for non-discrimination in ACC and behavioral measures will be discussed.

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# Objective assessment of auditory discrimination using the optimised mismatch response (MMR)

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**Keywords:** CAEPs, hearing aid validation, infant hearing loss, MMN, optimised MMN, MMR.

**Background:** Cortical auditory-evoked potentials (CAEPs) can provide objective validation of infant hearing aid fittings. Presence of CAEPs with amplified sound indicates audibility but there is limited evidence for CAEPs being linked to sound discrimination in infants. The mismatch response (MMR) is a CAEP generated when repetitive acoustic signals are presented serially and interspersed with deviant/rarely-occurring ones. MMR reflects the auditory system's ability to discriminate rare sounds from the standard[1]. The 'optimised' MMR (oMMR) measures discrimination using multiple deviant stimuli presented in an interleaved fashion instead of serially; saving time and potentially making the oMMR clinically relevant[2]. There is a dearth of data showing response characteristics and reliability of detection of oMMRs to speech stimuli relevant for validation of hearing aid fittings. Therefore the present study aimed to address this shortfall.

**Methods:** Adults (10 F, 7 M) were tested. Standards (70% probability) were interposed with 3 deviants (10% probability). Stimuli types were natural (NS)[3] and synthetic (SS)[4] speech tokens (/m/, /g/, /t/, /s/) spanning a range of frequencies, and complex tones (CT)[5] centred at 0.5, 1, 2, and 4 kHz.

**Results:** Residual noise for all stimuli types was low ($M$ = 0.92 to 1.05 µV, $SD$ = 0.59 to 0.65). RM-ANOVAs revealed N1 CAEP waveform amplitudes for SS /s/ were significantly lower compared to other stimuli types (CT; NS), ($F$ (8) = 7.047, $p$ < .001). Hotelling's $T^2$ revealed response detection rates for CT stimuli for standard (ST), deviant (DEV) and difference (DIF) waveforms were superior to NS and SS stimuli: ST & DEV= 95% reliability (95% confidence threshold a response was detected; p = 0.05), DIF = 88% reliability. Response detection rates ranged from 90% to 78% and 84% to 76%, for NS and SS stimuli respectively.

**Conclusions:** Clinical feasibility of oMMR to CT stimuli was well supported by adult data. SS stimuli yielded poorer N1 and P2 CAEP amplitudes. CT stimuli provided superior response detection rates for MMR difference waveforms, compared to NS & SS. oMMR may have potential as a part of a suite of infant objective assessments, alongside ABR and CAEPs. Future investigation involves oMMR with infants, towards a method of clinical validation of sound discriminability with amplification.

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## The transient response to interaural time differences

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**Keywords:** binaural hearing, interaural time differences, auditory evoked potentials, sound lateralization

**Background:** Binaural hearing allows many benefits in everyday listening environments such as the segregation of different sound sources, which is the key to understand speech in noise environments. Undurraga et al. (2016) [J Assoc Res Otolaryngol 2016; 17:591-607] presented a novel methodology that delivered a steady-state auditory evoked potential sensitive to binaural hearing. The present work escalates on the aforementioned methodology, and uses deconvolution to obtain the transient response associated with binaural-hearing neural processes.

**Methods:** In this work we generate a stereo stimulation signal that recreates a sound source that changes its location between two different points in space. The locations were separated from each other +/-90º (+/- 45º with respect to the midline). The sound source alternated its location randomly with a uniform probability distribution in the interval [1-2] seconds. The sound source consisted of a 520-Hz burst of windowed tones with a uniform Stimulus Onset Asynchrony of [5-20] ms (equivalent to a mean stimulation rate of 40 Hz). The spacing between source locations of ± 90.0 ° corresponds to an ITD of +/- 480 µs. This ITD was generated by advancing the carrier phase at one ear to 240µs and the carrier phase at other ear to -240µs. The envelope was diotic for both ears. To appreciate the effect produced by the change in ITD, the evoked response to a signal with ITD= 0µs was also recorded as a control measure (the sound source does not change position, located in midline). For both stimulation signals (ITD = +/- 480µs and ITD = 0µs), 5 recordings of 5 minutes duration each were recorded for each subject, with a stimulation intensity of 50 dB hearing level. The subject pool consisted of 6 normal-hearing listeners (3 females, [25-48] years).

**Results:** Through the deconvolution procedure previously developed by this research team, it has been possible to obtain both the evoked response associated with the windowed tones, and the evoked response associated with the change in location of the sound source. The windowed tones elicited a clear and reproducible MLR response. The change in location generated a novel evoked potential with a negative peak at approximately 100 ms and a positive peak at 150/200 ms in all six subjects.

**Conclusion:** In this preliminary study we have been able to obtain a reproducible auditory evoked potential associated with a binaural stimulus thanks to the stimulus design and the flexibility of the deconvolution methodologies. This finding represents an objective measure of neural activity associated with binaural hearing and could be used in assessing auditory processing disorders related with binaurality.

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## Effect of Regularity of Hearing Aid Use on Acoustic Change Complex

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**Keywords:** Acoustic Complex Change, Hearing Aids, Signal to Noise Ratio, Cortical Auditory Evoked Potentials, temporal resolution, selective auditory ability

**Background:** Cortical auditory evoked potentials (CAEPs) are non-invasive measures used to quantify central auditory system function in humans. More specifically, CAEP has a unique role in measuring central auditory processing following amplification with hearing aids. The recently introduced Acoustic Change Complex (ACC) is thought to reflect neural discrimination through detection of changes at the level of auditory cortex. These potentials can be used to objectively measure auditory abilities such as temporal resolution and selective auditory abilities, among others. The question posed in this research was whether regularity of hearing aid use had an effect on ACC or not in pediatric hearing aid users.

**Methods:** A case-control study was done to compare between regular and irregular hearing aid users. Ten pairs of hearing-impaired children with moderate or moderately severe hearing loss fitted with binaural hearing aids were included. Subject pairs were matched as regards age, degree of hearing loss and duration of H.As use. ACC potential was recorded in both unaided and aided conditions using 500 msec. 1000 Hz gap-in-tone stimuli varying in gap duration to reach the threshold, and using 500 msec. vowel /o/ in pink noise at +8 and 0 SNRs. Both stimuli were selected as a measure of temporal resolution and selective auditory attention. ACC percent identification, latency, amplitude, waveform morphology and gap detection threshold were recorded in sound-field condition.

**Results:** Regular HA users showed lower ACC gap detection thresholds in both aided and unaided conditions. ACC percent identification using vowel /o/ in noise was higher in favorable SNRs (+8 versus 0) and in aided condition compared to the unaided one in both study subgroups. However, percent identification was comparable in both subgroups at +8 SNR and significantly different at 0 SNR. The majority of the hearing-impaired children showed increased amplitudes, decreased latencies, and better waveform morphology in the aided condition.

**Conclusion:** It can be concluded that hearing-impaired subjects are able to process speech and tonal stimuli with greater accuracy at the level of the auditory cortex, and in a more effective manner when these children use their hearing aids regularly. ACC can be used as an objective measure for temporal resolution and auditory figure ground using gap-in-tone and vowel-in-noise at 0 SNR. Thus, it can be included in the follow-up protocol and serial evaluation in pediatric hearing aid users.

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## Eliciting an N1 response using stimuli frequency- and intensity-matched to Tinnitus

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**Keywords:** Tinnitus, N1, high frequencies

**Background and Aim:** The mechanism of tinnitus is still unknown. Previous studies have used EEGs to determine the physiological changes that occur in patients that report tinnitus. However, none of these studies have used stimuli matched to the frequency and intensity of the perceived tinnitus.

**Methods:** Participants with reported non-pulsatile, subjective tinnitus (n=15) were individually matched based on audiogram, sex and age to non-tinnitus controls (n=15). Tinnitus participants underwent a MatLab tinnitus matching procedure which allowed the matching of the pitch and loudness of the tinnitus to a narrowband stimulus presented via ER2a transducers. Three stimuli were presented where the stimulus was (1) at a frequency that matched the perception of the tinnitus, (2) was 1/3rd of an octave above or (3) 1/3rd an octave below the tinnitus pitch. These stimuli were presented for 5 seconds with inserted gaps and an EEG was used to record the response of the auditory cortex. All stimuli were presented at a tinnitus-matched intensity level between 5 to 47 dB above threshold.

**Results:** An N1 response peaked at about 120 ms following the onset of the stimulus. It was maximum over the fronto-central sites and declined in amplitude at the lateral sites. It inverted in amplitude at the mastoids. Confidence interval testing was conducted at Fz and Cz where the amplitude was maximal. It showed a significant N1 for the tinnitus group at and below the frequency of the tinnitus, however it was not significant at any of the frequency conditions for the control group. Frontal and central data of the individual data was entered into a 2-way ANOVA with repeated measures on group (tinnitus vs. controls), and frequency (below, at, above tinnitus). Although the N1 was larger in the tinnitus group at and below tinnitus frequency, the between and within-subjects effects failed to reach significance.

**Conclusions:** These results show that the larger N1 found in the tinnitus group may be associated with reorganization of the auditory cortex. Tinnitus may thus be related to a cortical overrepresentation of frequency regions distal to the dominant frequency of the tinnitus.

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# Suprathreshold auditory measures for detecting early-stage noise-induced hearing loss in young adults

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**Keywords:** TEOAE, CEOAE, cochlear tuning, medial olivocochlear reflex

**Background:** Recent animal studies revealed that the synaptic junctions between inner hair cells (IHCs) and auditory neurons (ANs) could be permanently damaged well before there is a significant loss of cochlear hair cells (e.g., Kujawa & Liberman, 2009). The auditory nerve fibers with a low spontaneous-firing rate neuron exhibit unusual susceptibility to cochlear synaptopathy compared to high spontaneous-firing rate neurons (Furman et al., 2013). The preferential loss of low spontaneous rate firing neurons can compromise auditory processing in difficult listening situations. However, it remains unclear to what extent different suprathreshold auditory measures can be used to identify early-stage NIHL in young adults. The present study evaluates suprathreshold auditory measures between young adults with high and low NEB (Kohrman et al., 2020).

**Methods:** An initial sample of 100 English-speaking healthy adults (18-35 years; Females=70) was obtained from five university classes. We identified 15 participants with the lowest NEB scores (10 females) and 15 participants with the highest NEB scores (10 females). The participants with no history of reoccurring middle ear infection and those reporting no chronic health conditions were selected in both groups. The study included conventional audiometry, extended high-frequency audiometry, middle-ear muscle reflex (MEMR) thresholds, distortion-product otoacoustic emissions (DPOAE), QuickSIN, and suprathreshold auditory brainstem responses (ABR) measures.

**Results:** We found that (1) individuals with high NEB revealed significantly reduced QuickSIN performance than those with low NEB (MD = 0.95, $t(28)=4.5$, $p<0.001$), (2) NEB revealed a significant positive relationship with QuickSIN ($r(30) = 0.37$, $p = 0.039$) (3) ABR wave I amplitude was significantly lower in individuals with high NEB compared to those with low NEB (MD= -0.105, $t(26)= -2.7$, $p=0.012$), (4) MEMR and DPOAE measures showed a modest association with NEB, and (5) audiometric thresholds across the frequency range did not show statistically significant association with NEB.

**Conclusion:** Our preliminary results suggest that young adults with high NEB might exhibit impaired peripheral neural coding deficits leading to reduced SIN performance despite clinically normal hearing thresholds. Suprathreshold SIN performance and suprathreshold ABR wave I amplitude are sensitive measures for detecting early-stage NIHL in young adults.

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# Suprathresholds auditory electrophysiological and perceptual measures in young musicians with high noise exposure background

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**Keywords:** ABR, noise exposure background, speech in noise

**Background**: Recent animal studies revealed that one of the most susceptible structures in the inner ear are synapses between inner hair cells and cochlear nerve terminals that degenerate first in the noise-exposed ears. This neural degeneration due to noise exposure does not affect the hearing sensitivity but likely degrades understanding speech/signals in a challenging listening environment (Furman et al., 2013). The extent to which high noise exposure background (NEB) affects the central auditory structures and their functions remain unknown. Considering the fact that a large portion of student musicians is exposed to high noise levels (Washnik et al., 2015), there is a critical need to measure the changes in peripheral and central auditory system and associated perceptual deficits in student musicians with a history of high noise exposure. The aims of the proposed study were to determine: (a) the effects of noise exposure on the peripheral and central auditory nervous system (CANS) functioning, and (b) the effect of noise exposure history on speech recognition in noise in student musicians with high NEB.

**Methods**: To examine for the signs of cochlear nerve damage and its effect on speech in noise abilities we recruited 19 student musicians with self-reported high NEB and 20 non-musician students with self-reported low NEB. A test battery was administered that consist of two sets of procedures: (a) electrophysiological tests including auditory brainstem responses (ABRs) at three different stimulus rates (11.3Hz, 51.3 Hz, and 81.3 Hz), P300, and distortion product otoacoustic emissions, and (b) behavioral tests including conventional and extended high-frequency audiometry, Consonant-Vowel Nucleus-Consonant (*CNC*) word test and *AzBio* sentence test for assessing speech in noise abilities.

**Results**: The results showed that the higher NEB is significantly associated with reduced ABR wave I amplitude obtained at a rate 11.3/sec. The findings of speech in noise tests showed significantly reduced performance in CNC word recognition tests by female musicians than female non-musicians. A similar pattern was observed in the CNC test among male musicians versus non-musicians. However, the difference was not statistically significant. No effect of NEB was found on the amplitude of P300 and high rate ABR wave I. No significant difference was found in DPOAEs and hearing thresholds between the two groups.

**Conclusion**: The data of this study indicates that noise exposure might reduce coding precision at the peripheral auditory system resulting into suprathreshold speech perception difficulties in student musicians, particularly in the female population.

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## Sub-cortical and cortical responses in children with central auditory processing disorders

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**Key Words:** Central Auditory processing disorder, auditory brainstem response, auditory late latency response

**Background:** Central auditory processing involves several domains such as sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition, including temporal integration, temporal discrimination, temporal ordering, and temporal masking; auditory performance in competing acoustic signals and auditory performance with degraded acoustic signal. Disruption of central auditory processing may lead to deficit in perception of speech, environmental sound or music in the absence of peripheral hearing loss. The present study aimed to evaluate the sub-cortical and cortical processing in children with central auditory processing disorders (CAPD).

**Method:** To identify children with CAPD, 869 school going children with normal hearing were screened using screening checklist for auditory processing (SCAP) and audiological screening test for auditory processing (STAP) from 3 different schools. Those children who were referred based on the SCAP and STAP, further diagnostic CAPD tests was administered for the confirmation of the auditory processing deficit. There were 30 children with CAPD considered for clinical group and 30 typically developing children served as reference group. Speech evoked ABR (Sp-ABR) and speech evoked ALLR (sp-ALLR) were recorded from both the groups and compared using 40 ms /da/ speech stimuli.

**Results:** Based on Shiparo-Wilk test of normality, both parametric and non-parametric tests were done depending upon the distribution of the data. For Sp-ABR, MANOVA showed a significant difference between groups for Wave V [$F(1,118)=265.70$, $p<0.05$], wave A [$F(1,118)=127.85$, $p<0.05$] and wave V/A slope [$F(1,118)=13.41$, $p<0.05$]. Mann-Whitney U test revealed a significant difference in amplitude of second harmonics [$Z = -3.44$, $p<0.05$], third harmonics [$Z = -1.86$, $p<0.05$] and fourth harmonics [$Z=-2.59$, $p<0.05$] between two groups except fundamental frequency [$Z=0.67$, $p>0.05$]. For Sp-ALLR, one way ANOVA was done which revealed no significant main effect between two groups for absolute latencies of Wave P1 [$F(1,115)=1.26$, $p>0.05$], wave N1 [$F(1,109)=3.65$, $p>0.05$], wave P2 [$F(1,118)=5.78$, $p>0.05$] and wave N2 [$F(1,118)=0.57$, $p>0.05$]. Similarly, Mann-Whitney U test showed no significant difference in peak-to-peak amplitude of wave P1-N1 [$Z =-0.04$, $p>0.05$], wave N1-P2 [$Z =-1.62$, $p>0.05$] and wave P2-N2 [$Z =-2.64$, $p>0.05$] between both the groups.

**Conclusion:** The above finding indicated probably children with CAPD have difficulty in processing of rapidly changing stimulus which can be correlated with delay in onset latencies of speech evoked ABR. Children with CAPD also find difficulty in processing different harmonics whereas they have similar processing of pitch. The differentiations between two phonemes are independent of pitch and they are dependent on transient portion of the stimulus. Whereas cortical potential probably not sensitive enough to identify deficit at cortical level in children with CAPD possibly because of larger variation in latency and amplitude measures and often show blunt responses in comparison to sub-cortical responses.

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## Aided Speech evoked cortical potential in children fitted with hearing aid

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**Key Words:** Cortical auditory evoked potential, Hearing aids, Speech stimulus

**Background:** Behavioral assessment of hearing aid benefit in children and young infants with hearing impairment is always difficult and questionable and hence Audiologist are dependent on more accurate measures like cortical auditory evoked potentials (CAEPs) using speech stimuli for fitting hearing aids as well as estimating the benefits with hearing aids. Hence, the aim of the present study was to assess the aided CAEPs in children fitted with hearing aids and compared with typically developing children. Further, the effect of three speech stimuli (/m/, /t/ & /g/) as well as of different intensities (75dBSPL, 65dBSPL & 55dBSPL) on the latency and amplitude of CAEPs were also estimated.

**Method:** The study included 44 children with normal hearing (mean age: 3.90±0.90 years) and 50 children using hearing aids (mean age: 3.16±1.06 years) in the age range of 6 months to 5 years. All the participants in the clinical group had bilateral severe-to-profound sensorineural hearing impairment using their own bilateral digital hearing aids. Prior to enrolment for CAEPs, both clinical and control group children underwent behavioural threshold estimation, immittance evaluation, transient evoked oto-acoustic emission and click evoked auditory brainstem response. The CAEPs were recorded using HEARLab (version 1.0) evoked potential system with the aided cortical assessment module default settings. Both the groups were recorded CAEPs at each speech stimuli (/m/, /g/ & /t/) at each intensities (75 dB, 65 dB & 55 dB). Statistical analyses were carried out on collected data using the SPSS (Version 21). Shiparo-Wilk test showed non-normal distribution of data and hence non-parametric tests (For between group comparisons: Mann-Whitney U test, Kruskal Wallis test and for within group comparison: Friedman test) were done.

**Results:** The aided CAEPs in the clinical group had biphasic responses i.e. positive peaks (P1) and negative peaks (N2). Mann Whitney U test showed prolonged (poorer) latencies and reduced amplitude of the P1 and N2 in hearing aid users in comparison to typically developing children. Further, Kruskal Wallis test showed the effect of intensity on amplitude measures showed statistically significant differences ($p<0.05$ level) however latencies did not show any significance differences ($p>0.05$). In addition, the amplitudes of the peaks P1 and N2 decreased (lower) as the intensity was decreased from 75 dBSPL to 55dBSPL. The effect of speech stimuli on the latency and amplitude measures revealed no significant differences in performance across the speech stimuli in both the groups ($p>0.05$).

**Conclusion:** The present study highlights the significance of CAEPs in estimating hearing aid benefit in younger children with hearing impairment. In addition, it also showed that different speech stimuli can be detected at cortex level in hearing aid users though there was no difference in terms of latencies across speech stimuli.

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## Auditory Brainstem Response using psychological task in Huffaz and non Huffaz

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**Keywords:** ABR, sensory gating, Huffaz, cognitive interference

**Background:** Auditory brainstem response (ABR) can be influenced by cognitive task due to the sensory inhibition process known as auditory sensory gating. Investigation of ABR with cognitive tasks among individual with strong memory abilities such as Huffaz (someone who memorized the whole chapters of Islamic scripture of Holy Al-Quran) is lacking in the literature. Therefore, the aim of this study is to investigate sensory gating abilities using ABR with a psychological task in Huffaz and Non-Hufaz population.

**Methods:** A total of 11 Huffaz and 12 Non-Huffaz with normal earing and normal ear function participated in this study. The ABR was acquired from the participants using a tone burst stimulus (2-1-2 cycles) at 3000 Hz with a stimulus repetition rate of 39.9 Hz. The ABR was conducted under two recording conditions of (i) without cognitive interference and (ii) with cognitive interference. The cognitive interference was elicited using a Stroop task procedure. The ABR wave V amplitudes and latencies were compared between test conditions and groups at 95% of confidence intervals.

**Results:** The findings showed no changes in the ABR wave V amplitudes and latencies between the test conditions in both groups with a lack of statistical differences.

**Conclusion:** There was no difference in the auditory sensory gating abilities between Huffaz and Non-Huffaz as shown by the ABR sensory gating outcomes. The absence of statistical differences between both groups in sensory gating abilities could be because Quranic memorization is only affecting the long-term memory compared to the short-term working memory abilities.

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# Evaluating cochlear tuning and medial olivocochlear reflex strength in young musicians and non-musicians

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**Keywords:** TEOAE, CEOAE, cochlear tuning, medial olivocochlear reflex

**Background:** Musical training has been associated with better speech-in-noise performance compared to non-musicians. The musician advantage has been studied using behavioral and electrophysiologic measures (Başkent & Gaudrain, 2016). However, the relationship between musicianship and cochlear tuning has not been adequately examined. This study investigates the relationship between musicianship and cochlear tuning using click-evoked otoacoustic emissions (CEOAEs).

**Methods:** We recruited a sample of 28 young adults aged 18-30 years with clinically normal hearing thresholds (≤15 dB HL) from 250-8000 Hz. The sample contains 14 musician students with 5 years of professional musical training and 14 non-musicians without professional musical training. We recorded CEOAE using SmartTrOAE connected with the ER-10D probe. The non-linear clicks were used at 80 dB pSPL at the rate of 19.3 Hz, and the CEOAE waveform was recorded from 2 to 20 ms with a sampling period of 25 µs. A total of 1024 sweeps were averaged, and the averaged CEOAE signal was used to perform a time-frequency analysis. The time-frequency analysis was performed using S-transform described by Mishra and Biswal (2016). The cochlear group delay was calculated to estimate cochlear tuning. The influence of medial olivocochlear reflex (MOCR) on cochlear tuning was evaluated with two sets of CEOAEs elicited in a linear mode with 75 µs clicks presented at 60 dB pSPL in the contralateral acoustic stimulation (CAS)-off condition and CAS-on condition. CAS was a white noise (125-8000 Hz) was presented through the SmartTrOAE software connected with ER-3A insert earphones. The cochlear group delay in CAS-off and CAS-on conditions were calculated using the S-transform described earlier.

**Results:** Our initial analysis showed that all participants exhibit significantly shorter group delays for higher frequencies than lower frequencies. The independent sample t-test revealed no significant difference between cochlear tuning estimates and MOCR strength between musicians and non-musicians. We will run a mixed model regression analysis to further evaluate the cochlear tunning estimates between the study groups. We will evaluate CEOAE responses in the time domain to quantify the influence of MOCR on CEOAE signals and compare them between the study groups. The results will be presented at the conference.

**Conclusion:** Our preliminary results suggest that cochlear tunning is sharper for lower frequencies compared to higher frequencies, which is consistent with earlier findings. Our primary analysis could not obtain a statistically significant association between cochlear tuning estimates and musicianship. Our preliminary results suggest that the musician advantage might be mediated by the retrocochlear structures responsible for sound coding, auditory processing, and cognitive control.

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## Ultra-high frequency distortion product otoacoustic emissions in subjects with tinnitus and with hearing loss

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**Keywords:** tinnitus, otoacoustic emissions, DPOAE, pure tone audiometry

**Background:** Several studies showed that distortion product otoacoustic emissions (DPOAEs) may be an early marker of hearing loss and also tinnitus. The purpose of this study was to investigate if DPOAEs measured up to as high frequencies as 16 kHz may provide even more information.

**Methods:** Pure tone audiometry (PTA) and DPOAEs were measured in 55 tinnitus patients and in control group of 63 subjects without tinnitus. Both measures were acquired up to 16 kHz.

**Results:** The data was divided into 3 datasets according to audiometric result: better than 25 dB HL in all tested frequencies from 0.125 kHz up to 16 kHz, better than 25 dB up to 8 kHz, and hearing impaired. The comparison of tinnitus subjects with control group matched according to PTA did not yield any significant differences in DPOAEs. However in both groups hearing loss caused decrease of DPOAEs, specifically in range of 2-6 kHz.

**Conclusion:** The present study shows that when matching tinnitus subjects with control group with similar PTA results there seem to be no difference in DPOAEs, i.e. the decrease in DPOAEs seems to be related only to hearing loss and there is no additional influence of tinnitus on DPOAEs.

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## Detecting the ABR using Machine Learning

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**Keywords:** ABR, Machine Learning, Signal Detection

**Background:** The ABR has an important role in the objective hearing assessment of newborns and individuals for whom behavioural assessment techniques are unreliable. Interpretation of the ABR relies predominantly upon the visual inspection of waveforms by clinicians and may be supported by the use of statistical detection methods. ABR interpretation is known to vary considerably, even amongst experts (Vidler & Parker, 2004). Machine learning algorithms have been used to excellent effect in multiple clinical detection challenges. This study aims to train a machine learning algorithm to detect the ABR and compare its performance to that of well-established statistical ABR detection methods.

**Methods:** Simulated data derived from subject recorded ABRs and no-stimulus EEG data were split into a training set and a test set. Simulation was used to allow the ground truth of the data to be known (‘ABR present’ or ‘response absent’) as well as to boost the amount of data available for the machine learning algorithm to learn from. Four machine learning approaches were evaluated using nested k-fold cross-validation applied to the training set. The best machine learning algorithm was selected for evaluation on the test set and its performance was compared to that of existing detection methods: Fsp, Fmp, Hotelling’s $T^2$ test, and q-sample uniform scores test.

**Results:** The best machine learning algorithm was a stacked ensemble. On the unseen test set data, the stacked ensemble algorithm achieved a significantly greater detection rate across ensemble sizes compared to all of the standard statistical detection methods evaluated. On average, 8% more ABR ensembles were correctly detected compared to the next-best detection methods (Hotelling’s $T^2$ test and the modified q-sample uniform scores test). The stacked ensemble achieved a consistently high level of specificity ($\geq$ 99%) across the range of ensemble sizes analysed. This attribute is important for clinical applications in order to minimise the chances of an ABR being incorrectly detected where none is present (the false positive rate).

**Conclusion:** Using simulated data, the stacked ensemble machine learning algorithm was found to perform better than standard statistical detection methods. The results are promising, and this algorithm may have potential in assisting clinicians in interpreting ABR data as well as in ABR screening devices. Further work is required to assess the machine learning algorithm’s performance on a large body of subject recorded data from individuals with varying degrees of hearing loss.

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## Controlling test specificity for auditory evoked response detection using a frequency domain bootstrap

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**Keywords:** Auditory Brainstem Response detection, statistical assumptions, independence violations, bootstrap.

**Background:** Statistical detection methods are frequently used to automate auditory evoked response (AER) detection and assist clinicians with AER measurement procedures. These methods, however, are built around various statistical assumptions (stationarity, Gaussianity, and independence) that can be violated for AER data, potentially resulting in increased error rates. The aim for this work is to provide an in-depth assessment of test specificity for auditory brainstem response detection, and to explore a novel frequency domain bootstrap (FDB) approach for improving test specificity in serially correlated (i.e. correlation between successive samples) non-stationary AER data. Potential shortcomings for the FDB are also considered and addressed through some modifications.

**Methods:** The FDB proceeds by generating many “surrogate recordings”, all with similar serial correlation as the original recording being analysed, which is in contrast with some other bootstrap approaches. Analysing the surrogate recordings with the detection method then gives a distribution of test values, which is assumed to approximate the null distribution for "no AEP present". The FDB furthermore assumes that the background activity is stationary with a smooth power spectral density (PSD) function, which is assessed by drawing comparisons with various FDB modifications. The modifications aim to account for non-stationarities and circumvent sharp peaks in the PSD (due to e.g. power-line noise) through interpolation. The detection method adopted for the analysis was the Hotelling’s T2 test, which was evaluated using either F-distributions, the FDB, or the modified FDB. Data for the assessment consisted of simulated colored noise, an auditory brainstem response threshold series from 12 adults with normal-hearing, and a large amount of no-stimulus data from 17 adults with normal hearing.

**Results:** When using conventional F-distributions without bootstrap, FPRs deviated significantly from the nominal alpha-levels depending on filter settings and stimulus rates used, which can be attributed to a violation of the independence assumption between epochs. The latter was overcome by using the FDB, which showed an improved control over the FPR. The FDB modification for non-stationary data had little impact relative to the original FDB in subject-recorded data, but showed an advantage in simulations, whereas the FDB modification for sharp peaks in the PSD showed an improved control over the FPRs in both simulations and subject-recorded data. All methods showed similar test sensitivities.

**Conclusion:** When compared to theoretical F-distributions, the FDB can be used to obtain improved control over test specificity in serially correlated, non-stationary AER data. Results suggest that the impact of non-stationarities on the FDB is small in good quality data with appropriate automatic artefact rejection, although sharp peaks in the PSD of the background activity (due to e.g. power-line noise) can have a detrimental impact, which can be circumvented by the proposed modifications.

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## Recording auditory brainstem responses with randomized stimulation level

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**Keywords:** ABR, randomized stimulation level

**Background:** Auditory evoked potential (AEP) recording in a conventional way consists in averaging auditory responses, corresponding to a burst of stimuli all of them with the same stimulation level and with a constant inter-stimulus interval (ISI). The protocol may start in descending sequential order, (i.e. starting with the highest stimulation level -typically 80 dB hearing level (HL)- and ending with the lowest one -typically 20 dB HL-), or in ascending sequential order. This work presents a novel modality of ABR recording based on randomized stimulation level (RSL). This means that stimuli with different intensity levels will be presented with a randomized pattern and averaged separatelly according to their respective intensity. In this work we compare the proposed RSL technique with the conventional one regarding: i) the morphology of the obtained evoked response ; ii) the degree of comfort of the subject while performing the test; and iii) how difficult is the identification of the evoked response for the audiologist in the proposed procedure compared with the conventional one, since in the conventional procedure the responses are obtained sequentially, while in the proposed one all the responses are simultaneously observed with improving quality as more responses are averaged.

**Methods:** Six subjects with no self-reported history of auditory dysfunction (3 females, aged from 25 to 29 years) participated in this study. AEPs were elicited using both the conventional and the RSL procedures. In both cases, 100 µs rarefaction clicks presented ipsilaterally following an ISI with a uniform distribution in the range [38-48] ms were used. In the conventional acquisition four stimulation levels were used (i.e. 80-60-40-20 dB HL), being 16 minutes the total recording time. In RSL, the four different simulation levels were mixed up to form a unique stimulation signal in which each stimulus presents a randomized intensity. The recording time was also 16 minutes.

A survey evaluating the degree of comfort of the subject under study compared the conventional procedure (in both ascending and descending sequential order) with the randomized procedure: http://sl.ugr.es/subjective_evaluation_sound_stimulus.

In addition, a different survey compared both techniques from the audiologist point of view: http://sl.ugr.es/comparing_ABR_recording_techniques.

**Results:** Results showed auditory brainstem responses to be very similar between the two techniques. In the 10-30 ms (early MLR portion) there were important differences in some subjects. The most notable was one subject in which it was appreciated what could be a post-auricular muscle response, associated with a high stimulation level only for conventional stimulation.

The survey evaluating the degree of comfort of the subject under study (n>100) showed that RSL is preferred to the conventional stimulation procedure.

The survey assessing audiologists' satisfaction showed that the evoked response can be identified with RSL earlier than with the conventional procedure.

**Conclusion:** Our results indicate that RSL provides evoked responses similar to the conventional method using the entire recording time. However, RSL has advantages in clinical practice. On the one hand, the subject feels more comfortable while the test is being carried out. On the other hand, with RSL the audiologist is able to quickly appreciate whether there is an evoked response in the auditory pathway of the patient, and therefore the proposed RSL technique seems to be a promising procedure for saving time in ABR explorations.

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# Altered neural encoding of speech sounds at birth is associated with fetal growth restriction

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**Keywords:** auditory processing, FFR, large-for-gestational-age, speech encoding.

**Background:** Infants born after fetal growth restriction (FGR) --an obstetric condition defined as the failure to achieve the genetic growth potential-- are prone to neurodevelopmental delays, with language being one of the major affected areas. Yet, while verbal comprehension and expressive language impairments have been observed in FGR infants, children and even adults, specific related impairments at birth, such as in the ability to encode the sounds of speech, necessary for language acquisition, remain to be disclosed. Here, we used the frequency-following response (FFR), a brain potential correlate of the neural phase locking to complex auditory stimuli, to explore the encoding of speech sounds in FGR neonates.

**Methods:** In the present study, the FFR elicited to a standardized speech token –the syllable /da/— was recorded in four blocks of 1000 artifact-free responses after each neonate passed the universal hearing screening and the corroboration of the auditory pathway integrity was completed with the recording of two blocks of 2000 ABRs to a click stimulus (100 µs square; 60 dB SPL). Exclusion criteria were multiple gestations, preterm delivery, chromosomal or major structural abnormalities or risk factors associated with hearing impairment. Although the initial sample was 101 neonates, five cases were discharged because the FFR signal could not be identified. Thus, the outcome available was from 96 neonates, 45 AGA and 51 FGR. To explore the encoding of the complex sound encoding, the fast Fourier transform was applied to the FFR and the analysis was centered on the fundamental frequency of the stimulus. The spectral amplitude at this frequency peak and its signal-to-noise ratio (SNR) were quantified.

**Results:** The SNR was strongly attenuated in the FGR group compared to the AGA group ($P$ = .008), while no differences between groups were observed for spectral amplitudes. These findings suggest that FGR population presents a deficit in the neural pitch tracking of speech sounds at birth.

**Conclusions:** This study provides the first evidence of functional deficits in the encoding of complex sound features in FGR neonates born at term. Through recordings of the FFR elicited to the syllable /da/, we disclose here that being born at term with FGR is associated with impaired fundamental frequency encoding of speech sounds, as quantified through the SNR estimate. Our results pave the way for future research on the potential clinical use of the FFR in this population who has been associated with neurodevelopmental delays, being language one of the major affected areas. If confirmed, a disrupted FFR recorded at birth may help deriving FGR neonates at risk of literacy impairments for postnatal follow-ups.

**References:**

Ribas-Prats T, Arenillas-Alcón S, Lip-Sosa DL et al. Deficient neural encoding of speech sounds in term neonates born after fetal growth restriction. *Dev Sci.* 2020. Submitted.

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## Derived-Band Auditory Brainstem Responses in Bottlenose Dolphins and California Sea Lions

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**Keywords**: marine mammals, auditory brainstem responses, high-pass subtractive masking, traveling-wave velocity

**Introduction**: We have over the last several years investigated auditory brainstem responses (ABRs) in the bottlenose dolphin, and compared stimulus dependencies of ABR peak latencies and amplitudes to published ABR results in terrestrial mammals. This body of work typically assessed dolphins who were underwater, and because of their poor hearing in the human audio-frequency range, were largely limited to frequencies above 10 kHz. In the present study, we assessed the ABR using the high-pass masking approach in both bottlenose dolphins and in California sea lions (the sea lions have a hearing range that is more similar to humans) in an effort to extend the investigation of marine-mammal traveling-wave velocities into the human audio-frequency range.

**Methods**: Three bottlenose dolphins and three California sea lions were experimental subjects. Stimuli were "pink" equalized noisebursts and (uncorrelated) pink high-pass masking noise (bandwidth: 0.5-32 kHz sea lion; 1-152 kHz dolphin). Noisebursts were presented at a fixed level, and the broadband masking noise was presented at a level that just masked the ABR to the noiseburst. The noise was digitally high-pass filtered with cutoff frequencies ranging from 0.5-32 kHz (for sea lions) and 1 (or 4)-152 kHz (for dolphins). Stimuli were presented by earphone for sea lions and in an underwater direct field for dolphins. Octave-wide derived-band ABRs were produced by subtracting the ABR from one high-pass masked ABR from a response to a high-pass masker cutoff one octave higher in frequency. ABR peak latencies and amplitudes were assessed across high-pass/derived-band frequency.

**Results**: High-pass/derived-band ABRs were observed down to at least several kHz in sea lions, but were not present below ~8-11 kHz in dolphins. Although all previously-reported ABR peaks were commonly observed for unmasked ABRs, often several peaks (including the first ABR wave, presumably coming from the 8$^{th}$ nerve) were not seen, especially for the lower high-pass/derived-band frequencies. For ABR peak P4-N5 in both marine mammals, high-pass and derived-band peak latency increased, and peak amplitude decreased, with decreasing high-pass/derived-band frequency.

**Conclusions**: Place-specific ABRs were obtained in both sea lions and dolphins with responses observed at lower frequencies in the sea lions. The short-term goal of this work is to create an 'optimal' chirp for bottlenose dolphins and California sea lions based on empirical ABR data. The long-term goal is to determine the cochlear traveling-wave velocity in select marine mammals. As empirically-determined cochlear place by best frequency maps are not available for either bottlenose dolphins or California sea lions, traveling wave velocity estimates (in, e.g., mm/ms) are not calculable at the present time. Where is Donald Greenwood when you need him?

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## Interpreting auditory brainstem evoked responses and distortion product otoacoustic emissions in diabetic patients with normal hearing

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**Keywords:** Diabetes mellitus Hearing, ABR, DPOAE, Tinnitus, Pure tone audiometry

**Objective:** Hearing impairment is a reported late complication of diabetes mellitus (DM). Pre- vious studies have suggested that microangiopathic complications may cause cochlear nerve function deterioration. We evaluated the auditory brainstem evoked responses (ABRs) and distor- tion product otoacoustic emission (DPOAE) results according to the presence of DM in subjects with normal hearing.

**Methods:** A cross-sectional comparative study was conducted from January 2016 to January 2018. Auditory function tests including ABR and DPOAE were performed for outpatients com- plaining of unilateral tinnitus. All of analyses were conducted in ears without tinnitus on con- tralateral side of tinnitus ears. We included subjects showing hearing thresholds within 25 dB at 0.5, 1k, 2k, and 4k on pure tone audiometry. 45 ears in patients with type 2 diabetes mellitus and 85 ears in non-diabetic patients were finally enrolled in our study.

**Results:** Diabetic subjects showed significantly more prolonged absolute peak latencies (I, III, V) and inter-peak latencies (I–V, III–V) than non-diabetic subjects. However, there was no significant difference in the inter-peak latency (I–III) between these two groups. Diabetic subjects also showed significantly lower amplitudes at f2 frequencies of 1001, 1200, 1587, 4004, 5042, and 6348 Hz than non-diabetic subjects. Additionally, the prevalence of a DPOAE response, defined as 3 dB above the noise floor, was significantly lower in diabetic subjects than that in non-diabetic subjects.

**Conclusion:** Diabetic patients with normal hearing can still have abnormal ABR and DPOAE results due to diabetic neuroangiopathy. ABR and DPOAE assessments can help in detecting subclinical auditory dysfunction, which precedes the manifestation of hearing impairment in diabetic patients.

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# Can the cochlear microphonic be useful in identifying infants with auditory neuropathy spectrum disorder (ANSD) during paediatric evoked response audiometry?

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**Keywords:** auditory neuropathy spectrum disorder, paediatric ABR, cochlear microphonic

**Background:** Auditory neuropathy spectrum disorder (ANSD) can be challenging to identify in infants during newborn hearing assessments when the classical indicators are not found, such as present otoacoustic emissions (OAEs) revealing functioning outer hair cells and absent/abnormal auditory brainstem responses indicating atypical neural synchrony. One issue is that OAEs may be absent in up to 25% of ANSD cases due to middle ear or other pathologies. This might lead to incorrectly inferring that an infant's elevated hearing thresholds are due to outer hair cell pathologies, despite underlying neural desynchrony due to ANSD. The cochlear microphonic (CM), recorded using click-evoked auditory brainstem responses (ABR), may serve as adjunct indicator of neural desynchrony in paediatric populations of < 6 months of age, specifically with respect to the CM amplitudes and durations. We aimed to test if the CM could be used for such a purpose.

**Methods:** We performed retrospective analyses on click-ABR recordings from 16 infants with ANSD (24 ears; mean 3.5 months, corrected) and compare these results to published results from typical-hearing infants (Hunter et al., 2018). In our study, cases with ANSD were identified by experienced clinicians based on the presence of OAEs (OAE+) and absent/abnormal ABR, or by CM presence with abnormal/absent ABR and supporting follow-up evidence from behavioral results for infants with absent OAEs (OAE-). To highlight the CM waves, ABRs to condesation clicks were subtracted from ABRs to rarefaction clicks. The CM amplitudes, CM durations, and CM/V ratio values were measured for infants with ANSD in our study and compared to published results for infants with typical-hearing (Hunter et al. 2018).

**Results:** Mean CM durations were significantly longer in ANSD ears (4.197 ± 1.154ms) than typical-hearing, well-baby (0.73 ± 0.3ms) and NICU (0.82 ± 0.51ms) infants. CM amplitudes were significantly larger in ANSD (0.322 ± 0.173μV) than well baby (0.24 ± 0.09μV), but not NICU (0.26 ± 0.13μV) infants. OAE+ and OAE- ANSD ears did not differ significantly in CM duration or amplitude but did differ significantly in mean CM/V ratios (6.602 ± 2.987, 2.040 ± 1.112, respectively). CM/V ratios correctly identified ANSD in 16 of 19 ANSD ears when wave Vs were observable.

**Conclusions:** Significant group differences in CM duration indicate that this measure might be useful for identifying infants with ANSD during paediatric evoked response audiometry. The CM amplitude measure was less discriminative between infants with ANSD and typical hearing. In addition, the CM/V ratios missed categorized 3 of the 19 ANSD infants with absent OAEs for which the measure would be most applicable. Results should be viewed with caution given the retrospective nature of the analyses and limited sample size.

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## Auditory Brainstem Response using psychological task in Autism Spectrum Disorder (ASD) children

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**Keywords:** ABR, sensory gating, autism, cognitive interference

**Background:** Auditory brainstem response (ABR) can be influenced by cognitive task due to the sensory inhibition process known as auditory sensory gating. The ABR wave V amplitude has been reported to decrease with cognitive tasks compared to the standard ABR. Any abnormality in the ABR cognitive task may suggest a possibility of auditory sensory gating deficit. However, in the literature, ABR with cognitive tasks have only been conducted among the normal hearing population. Therefore, this study aims to investigate ABR using a psychological task in normally developing children and children with autism spectrum disorder (ASD).

**Methods:** A total of 20 normally developing children and ASD children with normal hearing and middle ear function are expected to participate in this study. The ABR will be elicited using tone burst and narrow band LS CE Chirp stimuli at 1000 Hz (2-0-2 envelopes) using ipsilateral recording under condition 1 (without cognitive interference) and condition 2 (with cognitive interference). The cognitive interference will be elicited using a Stroop task procedure. The ABR wave V amplitude, latencies, total of correct response (cognitive task) and test reaction time will be measured and evaluated at 95% confidence intervals.

**Results:** Two-way Repeated measure ANOVA will be used to analyze the ABR results within group (between test conditions) and between groups (normal versus ASD children). The results were hypothesized to show no changes in the ABR wave V amplitude from condition 1 (without cognitive interference) to condition 2 (with cognitive interference) in the ASD group.

**Conclusion:** This study will provide a better understanding of the influence of cognitive interference in the ABR from the ASD population. A presence of abnormality in this study may suggest a possibility of auditory sensory gating deficit, especially in ASD children.

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## Perinatal central nervous system dysfunction in large-for-gestational-age newborns disclosed with frequency-following responses to complex sounds

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**Keywords:** auditory processing, FFR, large-for-gestational-age, speech encoding.

**Background**: Being born small-for-gestational-age has been associated with several adverse outcomes at birth and long-term consequences. The opposite tail of the birth weight continuum, however, has received less attention. Being born large-for-gestational-age has been associated with metabolic and cardiovascular diseases, yet no prior studies explored perinatal affection of the central nervous system. The frequency-following response (FFR) is an auditory electrophysiological signal that accurately reflects the neural encoding of complex sounds and that can be recorded non-invasively. The present study aims at characterizing the functional reliability of the central nervous system in encoding speech sounds of large-for-gestational-age newborns as disclosed by the FFR elicited by a consonant-vowel syllable.

**Study design**: A sample of 25 large-for-gestational-age mother-newborn pairs were recruited from the maternity unit of Sant Joan de Déu Hospital, Barcelona. They were paired by age and sex with 25 born adequate-for-gestational-age newborns selected from a previous cohort study. The neonatal electrophysiological recordings were carried out while newborns were naturally sleeping in their cradle. Before recording the FFR to the consonant-vowel /da/, the status of the auditory pathway was assessed by examining auditory brainstem responses to click stimuli. The primary clinical outcomes explored were the spectral amplitude and the normalized spectral amplitude of the FFR, both magnitudes reflecting the encoding strength of the fundamental frequency of the eliciting stimulus. Maternal and neonatal clinical data were also reviewed.

**Results**: Typical auditory brainstem responses to click stimuli were detected in all newborns so that auditory pathway integrity was confirmed. Large-for-gestational-age newborns displayed smaller FFR spectral amplitudes compared to the adequate-for-gestational-age group in the consonant transition ($P$ = .002) and in the vowel ($P$ = .004) regions of the consonant-vowel stimulus. Similar results were obtained with normalized spectral amplitudes (consonant transition region: $P$ = .01; vowel region: $P$ = .003).

**Conclusions**: Results revealed specific central nervous system dysfunctionalities in large-for-gestational-age newborns born at term. Recording the neonatal FFR, specific deficits in the encoding of speech sounds were found. This study discloses for the first time perinatal central-nervous-system consequences of being born large-for-gestational-age and suggests the need of follow-up studies to determine the extent of these dysfunctionalities.

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Ribas-Prats, T., Arenillas-Alcón, S., Pérez Cruz, M. et al. Perinatal central nervous system dysfunction in large-for-gestational-age neonates revealed with frequency-following responses to speech. *BJOG*. 2021. Submitted.

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## Central hearing function of children with microcephaly by Zika virus

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**Keywords:** Auditory Cortex. Zika Virus. Microcephaly. Auditory evoked potentials.

Zika virus became an epidemic in Brazil from early 2015, with the first cases of suspected microcephaly caused by Zika virus confirmed in the states of Rio Grande do Norte and Pernambuco. Since then, research has highlighted the need for further investigations to better understand the physiology, symptoms and prognoses in order to better follow up children with congenital Zika virus syndrome. Changes in central functions are expected in most patients with microcephaly and significantly impar neuropsychomotor development, vision and hearing. So far, studies show controversial results and this investigation was an opportunity to learn about the influence of this neurological condition on the electrophysiological parameters and also made possible to compare the findings of the Early Language Milestone Scale with the results of the electrophysiological exams. This is a descriptive cross-sectional study developed in the Audiology Sector of the Center for Studies in Education and Health, the Faculty of Philosophy and Sciences, at Paulista State University, Marília Campus, São Paulo, and the State University of Health Sciences of Alagoas, Audiology Laboratory of the Specialized Center for Rehabilitation The study included 20 children of both genders, composed by the research group, with microcephaly due to congenital Zika virus syndrome and by the control group, comparison group. In this research cortical auditory evoked potential exams were performed and the language development scale, aiming to apply electrophysiological and behavioral measures to assess hearing and language. Longer values were observed in the latency of the N1-P2 components and greater amplitude of the N1 component of the auditory cortical potential in the research group. The scale also showed significant impairment in the linguistic development of the children in the research group. The Smart tools EP software, the new objetive analisys tools was used for neural response analysis showed abnormalities in neurotransmission of frequency spectral characteristics in the auditory pathway in children with Zika microcephaly in frequency domain analysis. The software calculations showed much higher slope and total área waves values in this population, also suggesting failure in the automated perception control of acoustic changes related to the activity of the N1 component. Electrophysiological and behavioral measurements showed a pattern of atypical development of the auditory and linguistic system in children with suspected microcephaly by Zika virus.

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# Cortical Neurophysiologic Correlates of Auditory Threshold in Adults and Children with Normal Hearing and Auditory Neuropathy

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**Keywords:** Auditory Neuropathy Spectrum Disorder (ANSD), cortical auditory evoked potentials, auditory threshold

**Background:** Auditory threshold estimation using the auditory brainstem response or auditory steady state response is limited in some populations (e.g., individuals with auditory neuropathy spectrum disorder [ANSD] or those who have difficulty remaining still during testing and/or cannot tolerate general anesthetic). However, cortical auditory evoked potentials (CAEPs) can be recorded in many such patients and have been employed previously in threshold approximation (Chang et al., 2012; Cone & Whitaker, 2013; He et al., 2013; Punch et al., 2016; Visram et al., 2015). Thus, we studied CAEP estimates of auditory thresholds in participants with normal hearing, sensorineural hearing loss, and ANSD.

**Methods:** We recorded CAEPs at varying intensity levels to speech stimuli (i.e., /ba/) and tones (i.e., 1 kHz) to estimate auditory thresholds in normal-hearing adults (n = 10) and children (n = 10) and cases of children with sensorineural hearing loss (SNHL) and ANSD.

**Results:** Results showed a pattern of CAEP amplitude decrease and latency increase as stimulus intensities declined until waveform components disappeared near auditory threshold levels. Overall, CAEP thresholds were within 10 dB HL of behavioral thresholds for both stimuli. Additionally, in cases of children with SNHL and ANSD, CAEPs were both successfully recorded and reasonably approximated behavioral auditory thresholds.

**Conclusion:** The above findings suggest that CAEPs may be clinically useful in estimating auditory threshold in populations for whom such a method does not currently exist. Physiologic threshold estimation in difficult-to-test clinical populations, especially those with ANSD, could lead to earlier intervention and improved outcomes.

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# Variability in the estimated amplitude of vowel-evoked envelope following responses caused by assumed brain processing delays

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**Keywords:** envelope following responses, Fourier analyzer, vowel

**Background:** We investigated the effect of brain processing delay on the estimated amplitude of vowel-evoked envelope following responses (EFRs). EFRs are useful in assessing the neural processing of voicing-related envelopes in vowels at the fundamental frequency of voice ($f_0$). When elicited by naturally spoken vowels, EFR characteristics at $f_0$ are estimated using a Fourier analyzer (FA)—a method that uses the known $f_0$ over time to account for variations during production. The accuracy of the FA in estimating EFR characteristics is, however, dependent on the temporal alignment between the $f_0$ time course and the recorded electroencephalogram (EEG). Given the predominant subcortical generators of vowel-evoked EFRs, a commonly-used constant brain delay correction for aligning EEG with the $f_0$ time course is 10 ms. Since EFRs at $f_0$ could entail additional generators with different delays, and individual variability in processing delays could occur, here, we compared EFR amplitude at a wide range of plausible brain processing delays to infer analysis-related variability in estimated EFR amplitude.

**Methods:** In 21 young normal hearing adults, EFRs were elicited by the three vowels (duration=384 ms; average $f_0$=97 Hz) in a male-spoken token "susashi" presented monaurally at 65 dB SPL using a shielded ER2 insert earphone. Each vowel was modified to elicit two individual EFRs, one from the first formant (F1) and one from the second and higher formants (F2+). $f_0$ was steady in all vowels (maximum range=1.5 Hz). EEG was recorded between the vertex and nape. F1 and F2+-elicited EFRs were estimated using an FA with brain delays ranging from 5 to 25 ms in 0.5 ms increments. In addition, the FA was applied to EEG with and without bandpass filtering between 65 and 130 Hz—a frequency region that encompasses the talker $f_0$. The outcome measure of interest was the range (maximum-minimum) in EFR amplitude across all brain processing delays, calculated per participant.

**Results:** When EEG was not bandpass filtered and all stimuli were considered together, the overall average range was 24.3 nV (SD=14.2). When individual stimuli were considered, the largest average range was as high as 33.6 nV for /a/ F2+ and as small as 18.1 nV for /i/ F2+. When EEG was bandpass filtered between 65 and 130 Hz, the overall average ranges were much smaller (5.8 nV; SD=4.0). The largest and smallest average ranges were found for /i/ F2+ (7.7 nV) and /u/ F1 (4.6 nV), respectively.

**Conclusion:** The assumed brain processing delay had little effect on EFR amplitude estimates when bandpass filtering was applied to retain the frequencies at and around $f_0$. Bandpass filtering presumably reduces interference from neural activity at other frequencies leaking into the frequency region of interest. Averaging EFR amplitude over the analysis window, frequency resolution and steady $f_0$ may have contributed to the relatively low sensitivity of EFR characteristics to the brain processing delay used in analysis.

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## Characterization of subcortical auditory neural responses in babies with congenital syphilis

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**Keywords:** Congenital Syphilis, Hearing, Auditory Evoked Potentials

**Background:** Syphilis is a bacterial disease caused by sexual contact transmission of the bacterium Treponema Pallidum. When a pregnant woman is inadequately treated, the transmission of syphilis to the baby may occur. Currently, the literature lacks studies demonstrating the effects of syphilis on the subcortical auditory pathway. The frequency-following response (FFR) is a non-invasive electrophysiological measure that provides information about the auditory processing quality of sounds in the auditory pathway and speech acoustic configuration, from brainstem to cortex. The objective of this study was hence to characterize the FFR of babies exposed to syphilis.

**Methods:** The present results belong to an ongoing study in which a sample of 72 babies was tested at a mean age of 36.14 ± 16.49 days of life. Babies were classified into three groups: GExp with 6 babies whose mothers had prenatal syphilis treatment; GCS with 33 babies whose mothers received perinatal syphilis treatment; and Gcontrol with 33 babies whose mothers were free of syphilis, serving as control. The FFR was obtained with a consonant-vowel /da/ stimulus lasting 170 ms, delivered at the intensity of 80dBnHL in the right ear. A total of 4000 artifact-free recordings were obtained. Data were analyzed following the procedures used in Ribas-Prats et al (2019; Hear Res, 371, 28) to obtain a comprehensive picture of the FFR in time and spectral domains, including cross-correlation between stimulus and response, pitch error and pitch strength, signal-to-noise ratio, neural lag, fundamental frequency spectral amplitude, its harmonics on a fixed time window and points below noise floor.

**Results:** The Kruskal-Wallis Test was applied, and a significant result was observed for the cross-correlation between stimulus-response ($p = 0.013$), pre-stimulus RMS ($p = 0.006$), and pitch strength ($p = 0.033$). Thus, we applied the Mann-Whitney U test by pairing the groups. When we paired the GCS x GControl group, we found a significant difference in some parameters: cross-correlation ($p = 0.005$), pitch strength ($p = 0.010$), pre-stimulus RMS ($p = 0.002$) in the time domain. Also, in these groups, we observed significant differences in some parameters of the frequency domain: spectral amplitude of the harmonics in the vowel region ($p = 0.031$) and in the harmonics of the entire response ($p = 0.032$).

**Conclusion:** The data brings contributions about the auditory pathway after exposure to syphilis in babies, proving that when treated in prenatal, it does not influence the processing of sounds and their temporal and spectral characteristics, which are important for language acquisition. However, we had seen that when babies were treated after birth, syphilis may influence these responses and may cause an alteration in the auditory pathway.

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## Effects of Noise and Serial Position on Free Recall of Spoken Words and Pupil Dilation during Encoding in Normal-Hearing Adults

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**Keywords:** working memory, listening effort, hearing in noise, free recall, pupillometry, cognitive demand, memory, reading span, baseline, serial position

**Background:** A question about cognitive benefits from amplification strategies of hearing aids beyond improved clarity and audibility has been raised. This preliminary study assessed the effects of noise and stimulus presentation order on recall of spoken words and recorded pupil sizes, known to be sensitive to cognitive task demands, while normal-hearing listeners were trying to encode a series of words for a subsequent recall task.

**Methods:** In three listening conditions (stationary noise in Experiment 1; quiet versus four-talker babble in Experiment 2), participants were assigned to remember as many words as possible to recall them in any order after each list of seven sentences. In the two noise conditions, lists of sentences fixed at 65 dB SPL were presented at an easily audible level via a loudspeaker. Reading span (RS) scores were used as a grouping variable, based on a median split.

**Results:** The primacy effect was present apart from the noise interference, and the high-RS group significantly outperformed the low-RS group at free recall measured in the quiet and four-talker babble noise conditions. RS scores were positively correlated with free-recall scores. In both quiet and four-talker babble noise conditions, sentence baselines after correction to the initial stimulus baseline increased significantly with increasing memory load. Larger sentence baselines but smaller peak pupil dilations seemed to be associated with noise interruption.

**Conclusion:** The analysis method of pupil dilation used in this study is likely to provide a more thorough understanding of how listeners respond to a later recall task in comparison with previously used methods. Further studies are needed to confirm the applicability of our method in people with impaired hearing using multiple repetitions to estimate the allocation of relevant cognitive re-sources.

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## Electrophysiological correlates of audiovisual speech perception in CI patients

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**Keywords:** Audiovisual benefit, multisensory integration, audiovisual interaction, CI, syllables

**Background:** Spoken language communication is audiovisual, as both auditory and visual information contribute to speech comprehension. Especially in acoustically difficult situations, watching lip movements can facilitate understanding. Given that a cochlear implant (CI) provides only limited acoustic information, it is likely that CI patients tend to rely more on lip movements than normal-hearing (NH) individuals. Indeed, behavioural results show higher benefits for CI patients when combining auditory and visual speech information compared to NH individuals (Rouger et al., 2007). However, the electrophysiological correlates of this multisensory enhancement in CI users are not yet well understood.

**Methods:** In this EEG study, we investigate audiovisual interactions during syllable processing in postlingual CI patients and NH individuals (both N=18). The participants are presented with auditory, visual, and audiovisual syllables. In the auditory condition, the participants only hear the syllables, while in the visual-only and audiovisual conditions they see a computer-based animation of the syllables (articulation model MASSY; Fagel & Clemens, 2004). The participants' task is to press a corresponding button as fast as possible as soon as the syllable is recognized. An additional lipreading test is used to assess lipreading skills. To examine the electrophysiological correlates of syllable perception, we analyse event-related potentials (ERPs) evoked by the syllables in all conditions (audiovisual, auditory-only, visual-only).

**Results:** On the behavioural level, both groups show similar response patterns for syllable discrimination. Specifically, both groups have shorter response times for audiovisual syllables compared to auditory-only or visual-only syllables, suggesting audiovisual integration in both groups. But CI users demonstrate significantly higher scores in the lipreading test. On the ERP level, an audiovisual interaction is confirmed, as indicated by a visual modulation of the auditory ERP response in both groups. However, this ERP modulation around P2 latency is more pronounced over fronto-central scalp regions in CI users, while it is enlarged over parieto-occipital scalp regions in NH listeners.

**Conclusion:** Behavioural and EEG results reveal that both groups show audiovisual integration of speech stimuli such as syllables. This finding is supported by previous studies (e.g. Schierholz et al., 2015) using non-linguistic audiovisual stimuli. With increasing difficulty of the stimuli (words or sentences) there might be a greater audiovisual benefit for CI users. The ERP differences between groups suggest a compensatory strategy of the CI patients to overcome the degraded auditory CI input. A planned source analysis will reveal differences between CI patients and NH listeners with respect to cortical areas involved in processing of audiovisual stimuli.

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## How close can we estimate hearing in infants with *NB CE-Chirp® LS* stimulus?

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**Keywords:** ABR threshold, Infants, Stimulus

**Background:** Infants up to six months corrected age do not respond consistently to behavioral audiometric measures. Therefore, electrophysiological measures, by air and bone conduction, are required to estimate infants' hearing. Currently, ABR tests using frequency specific with *toneburst* stimuli is the gold standard recommendation in international guidelines regarding Pediatric Audiology. However, new frequency specific transient stimuli as *NB CE-Chirp® LS* were developed to increase wave V amplitude and improve tracings morphology. Better visual identification of wave V can lead to best estimation of infants' audiogram, and to improve hearing aid gain fitting when necessary. But how does *NB CE-Chirp® LS* behaves in infants' audiologic assessment? Goal: to describe ABR thresholds with *NB CE-Chirp® LS* stimulus in hearing infants, describing absolute latencies and amplitudes.

**Methods:** ABR test was performed with Interacoustics Eclipse EP25, in the Pediatric Audiology Center at PUC-SP, after approval from the ethics committee. *NB CE-Chirp® LS* was delivered to infants' ear with insert earphone ER-3A, and alternating polarity. Repetition rate varied among the four frequencies as it follows: 37.1/s for 500 Hz; 39.1/s for 1000 Hz; 45.1/s for 2000 Hz e 49.1/s for 4000 Hz. Response acquisition was performed with non-inverting electrode at high forehead, the ground at side forehead and inverting electrodes at right and left mastoid. Filter setting was high pass of 30 Hz and low pass of 1500 Hz. The beginning ABR threshold determination was in 30 dB nHL to 500 Hz and 20 dB nHL to 1000, 2000 and 4000 Hz. With visual identification of wave V in these levels, intensity was decreased 10 dB steps until acquisition of a genuinely absent response. Then, the stimulus was increased in 5 dB steps until the acquisition of a genuinely present response. Absent responses were classified as a flat waveform, with Fmp lower than 2.25 and residual noise lower than 25 nV. Present responses were classified with two repetitions with the presence of wave V recorded after 5 ms, with Fmp above 2.25 and residual noise lower than 25 nV. An independent judge was called to interpret wave forms and mark latency and amplitudes in the waveforms collected.

**Results:** Eighteen hearing infants were evaluated. Their mean gestational age was 39,6 weeks and age at assessment was 54,6 days of life. All infants had present Transient Evoked Otoacoustic Emissions and neural synchrony in ABR with click stimulus at 70 dB nHL. The mean ABR threshold was 23,8 dB nHL (±4,2) for 500 Hz; 14,4 dB nHL (±5,7) for 1000 Hz; 6,0 dB nHL (±5,0) for 2000 Hz and 7,0 dB nHL (±5,9) for 4000 Hz. The mean absolute latency for ABR thresholds was 8,86 ms (±1,12) for 500 Hz; 9,21 ms (±0,95) for 1000 Hz; 9,44 ms (±0,78) for 2000 Hz and 9,64 ms (±0,52) for 4000 Hz. The mean amplitude of ABR threshold was 0,123 nV (±0,035) for 500 Hz; 0,127 nV (±0,039) for 1000 Hz; 0,141 nV (±0,052) for 2000 Hz and 0,105 nV (±0,028) for 4000 Hz.

**Conclusion:** ABR thresholds were recorded with low intensities at all tested frequencies, improving the estimation of infants' audiogram. Wave V was recorded with higher amplitude and better morphology with clear visual identification. Latencies were similar for all frequencies, improving the visual identification of responses at low intensity levels and increasing the response confidence. These characteristics can facilitate behavioral threshold estimation, even for examiners with little experience in the art of ABR peak-picking wave V.

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## Assessment of neuronal synchrony in hearing infants with *CE-Chirp® LS* stimulus

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**Keywords:** Neuronal Synchrony, Infants, Stimulus, Auditory Brainstem Response

**Background:** It is known that previously *CE-Chirp®* stimulus presented limitations when used to evoke neuronal synchrony responses at high intensities, due to upward spread of excitation. Therefore, the *Level Specific* (LS) approach was developed to ensure a better neuronal synchronization among different intensity levels. This new *CE-Chirp® LS* stimulus was designed with small changes in durations for each 5 dB intensity variation. Thus, lower and higher intensities present a long and a short duration respectively, ensuring good neuronal synchrony in adults' ABRs in the same way as clicks, with the advantage of evoking a higher wave V amplitude. However, what about infants that are within maturational process? Thus, it was our goal to compare absolute latencies, interpeak intervals and wave V amplitude between *CE-Chirp® LS* and click stimuli in normal hearing infants at 70 dB nHL.

**Methods:** ABR test was performed with Interacoustics Eclipse EP25, in the Pediatric Audiology Center at PUC-SP, after approval from the ethics committee. Both stimuli were delivered with insert earphone ER-3A, in the same audiology session, with alternating polarity, repetition rate of 45.1/s, at 70 dB nHL. Response acquisition was performed with non-inverting electrode at high forehead, the ground at side forehead and inverting electrodes at right and left mastoids. High pass filter was 30 Hz and low pass at 1500 Hz. Two waveforms were recorded with the presence of waves I, III and V, Fmp above 3.31 and residual noise lower than 40 nV. At least 1500 sweeps were recorded in each averaging. Wave V amplitude was measured from its positive peak through SN10 negative peak.

**Results:** Eighteen hearing infants were evaluated. Their mean gestational age was 39,6 weeks and age at assessment was 54,6 days of life. All infants had present Transient Evoked Otoacoustic Emissions and neural synchrony in ABR with click stimulus at 70 dB nHL. There was not statistically significant difference between ears and genders for each stimulus. Absolute latency Wave I was 1,53 ms (±0,12) for click and 1,77 ms (±0,16) for *CE-Chirp® LS* – (p<0,001); Wave III was 4,39 ms (±0,20) for click and 4,47 (±0,25) for *CE-Chirp® LS* – (p=0,087); Wave V was 6,60 ms (±0,30) for click and 6,59 ms (±0,34) for *CE-Chirp® LS* – (p=0,210). Interpeak Interval I-III was 2,86 ms (±0,18) for click and 2,69 (±0,23) for *CE-Chirp® LS* – ((p<0,001); Interpeak Interval III-V was 2,21 ms (±0,15) for click and 2,13 ms (±0,14) for *CE-Chirp® LS* – (p=0,728); Interpeak Interval I-V was 5,07 ms (±0,28) for click and 4,82 ms (±0,31) for *CE-Chirp® LS* – (p<0,001). Wave V amplitude was 0,401 nV (±0,099) for click and 0,532 nV (±0,162) for *CE-Chirp® LS* – (p=0,001).

**Conclusion:** It was possible to record neuronal synchrony in all normal hearing infants using *CE-Chirp® LS* stimulus at 70 dB nHL. ABR waveforms with *CE-Chirp® LS* showed good morphology and a higher wave V amplitude when compared to clicks. Good morphology, high amplitudes and time saving can be considered advantages of the *CE-Chirp® LS* when assessing hearing in infants.

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## The Effect of Silence and the Emergence of Tinnitus Perception on Auditory Brainstem Response and Auditory Middle Latency Response

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**Keywords:** ABR, AMLR, Tinnitus, Silence

**Background:** Silence has been reported to play a significant role in the emergence of tinnitus perceptions in healthy normal hearing adults with no prior tinnitus complaints (Del Bo et al., 2008; Heller & Bergman, 1953; Knobel & Sanchez, 2008; Denise A. Tucker et al., 2005). These perceptions are typically temporary and disappear as soon as some environmental sounds are present to mask the tinnitus perception. AER recording could potentially be a useful tool to monitor any changes in CANS activity associated with tinnitus perception during silence. The purpose of this study is to investigate the differences in the central pathway activities between subject who perceived tinnitus and those who did not perceive tinnitus during silence using Auditory Brainstem Response (ABR) and Auditory Middle Latency Response (AMLR).

**Methods:** This study examined temporary tinnitus perceptions during a brief period of silence in 60 normal hearing adult female participants aged 18- 40 years. AMLR and ABR recordings were obtained ipsilaterally from right ear stimulation before and after ten minutes of silence exposure. Repeated measures ANOVA used to examine the effect of tinnitus perception on ABR wave V and AMLR Na/Pa latency and amplitude before and after silence exposure. Qualtrics silence survey used to document tinnitus sounds perceived by the subjects during silence and general health questionnaire to document normal health and the absence of chronic tinnitus or hearing problems.

**Results:** All participants in the study had normal hearing threshold better than 20 dB HL for the tested octave frequencies between 250 and 8000 Hz and type A tympanogram. Responses to the survey were analyzed to determine the percentage of those who perceived tinnitus among the study participants. In total 55% of the participants perceived tinnitus during silence with majority of the subjects who perceived tinnitus-like sounds reported that those perceptions occurred within the first five minutes of the silence exposure. Results of the current study revealed a statistically significant difference in AMLR Na/Pa amplitude between subjects who perceived tinnitus and those who did not perceive tinnitus during silence (P= 0.006) with subjects who perceived tinnitus had larger AMLR Na/Pa amplitudes. No statistically significant effect of tinnitus perception on ABR wave V latency ($F = 0.15$, $\rho = 0.7$), amplitude ($F = 0.32$, $\rho = 0.58$). No statistically significant group difference as a result of tinnitus perception on ipsilateral AMLR Na latency ($F_{1,58}$= 0.005, $\rho$ = 0.95), Pa latency ($F_{1,58}$ =0.74, $\rho$ = 0.39).

**Conclusion:** Results of this study found that tinnitus-perceiving subjects possessed higher neurological brain activities as measured by larger Ipsilateral AMLR Na/Pa amplitude compared to non-tinnitus perceiving subjects in both pre-silence and post-silence recordings. These findings indicate that the silence exposure facilitate tinnitus perception in these subjects. Further research is needed to document if this difference holds true for higher auditory evoked response measure, such as the Auditory Late Latency Response (ALLR) and the P300 response.

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# Visual face processing in postlingually deafened patients before and after cochlear implantation

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**Keywords:** cochlear implant, longitudinal study, visual face processing

**Background** Sensorineural hearing loss and implantation of a cochlear implant (CI) can cause changes not only in the auditory but also in the visual system.

Prior studies have reported that congenitally deaf patients show shorter response times and enhanced amplitudes of event-related potentials (ERPs) to visual stimuli when compared to normal-hearing (NH) listeners (Bottari et al., 2011; Hauthal 2014). Results in CI users have been less consistent, showing either reduced or enhanced amplitudes of visual ERPs in CI users compared to NH listeners (Stropahl et al., 2015; Sandmann et al., 2012). This ongoing prospective longitudinal study aims to better understand the temporal dynamics of cortical auditory and visual changes induced by cochlear implantation, and to assess the behavioural consequences of these cortical changes, in particular in auditory, visual and audio-visual speech conditions.

**Methods:** Postlingually deafened patients are examined by means of EEG before and on two occasions after cochlear implantation (approximately five weeks and six months after the first fitting of the CI). A group of matched NH controls is tested in three separate EEG sessions as well. The participants perform a visual speech reading task (word identification; paradigm 1) and a face categorization task with static faces (categorization of male and female faces; paradigm 2). Here we present the behavioural results and the ERPs in response to the different types of visual stimuli for the first and the third EEG session.

**Results:** Preliminary results show comparable performance and similar reaction times in CI users (so far N=6) and in NH listeners (so far N=7) for both EEG paradigms and for the two time points. By contrast, the electrophysiological data reveal group differences for the early cortical processing stages (sensory processing), at least on the descriptive level. In response to face onset (paradigm 1), the patients prior to cochlear implantation show a smaller P1, but an enlarged P2 ERP when compared to the NH listeners. These group differences appear to be reduced over the first six months of CI experience. With regard to higher-order cognitive processing stages (paradigm 2), the P3 ERP to static (target) faces is comparable between both groups.

**Conclusion:** In the speech reading and face categorization tasks, the behavioural results of hearing impaired patients and CI users are comparable to NH controls. However, during speech reading, patients prior to implantation show different allocation of neuronal resources at early cortical processing stages (P1, P2) when compared to NH listeners. At the higher cognitive processing (P3) the results are comparable between these groups, indicating a similar level of neuronal effort to complete the visual task. Six months later, differences in cortical visual processing are reduced between the implanted patients and the NH listeners, pointing to cortical visual reorganisation over the first months of CI experience. The effects of these cortical changes need to be discussed, in particular with regards to (behavioural) speech recognition ability as well as the cortical auditory and audio-visual speech processing.

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# Cochlear® Trans Impedance Matrix measurements – detection of tip fold-over in clinical settings

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**Keywords:** Cochlear Implant, Trans Impedance Matrix

**Background:** Cochlear® Trans Impedance Matrix (TIM) measurement is a research tool in Custom Sound EP 6.0. TIM measurement is an objective tool using the back-telemetry capability of the implant. The impedance is measured between all electrode contacts creating a 22 x 22 heatmap visualizing the impedance relationship across the electrode array – hence trans impedance. From the heatmap it is possible, to a certain degree, to assess the positioning of the electrode array in the cochlea, for instance the presence of a tip fold-over. Other uses such as longitudinal monitoring of the electrode are being investigated. The measurement is performed within 90 seconds, inaudible and causes no discomfort to the CI user.

**Objective:** Study whether TIM can be used as a clinical diagnostic tool with emphasis on detection of tip fold-over, both intra-operatively and for already implanted recipients (post implantation).

**Methods:** TIM measurements have been routinely performed intra-operatively since December 2020 (n = 32 ears, CI6XX series only). Post implantation TIM was measured during yearly follow-up of experienced users when there was sufficient time or poorer than expected hearing outcome (n = 41 ears, CI24RE(CA), CI5XX and CI6XX series).

Collected TIM data was categorized by visual inspection of the TIM heatmap. The proposed categories were: 1) normal TIM 2) mirrored impedance spread 3) high probability tip fold-over 4) single dot, low probability tip fold-over and 5) inconclusive/noisy.

**Results:** *Intra surgery*: out of the 32 ears 31 were categorized as normal. One ear implanted with CI632 was categorized as tip fold-over (high probability). Intra surgery CT-scan confirmed tip fold-over. The CI632 electrode was immediately explanted followed by re-implantation with CI612 electrode. TIM subsequently normal.

*Post implantation*: out of 41 ears 29 were categorized as normal, five ears with mirrored impedance spread (5 x CI532), one ear as high probability tip fold-over (CI632), three ears with single dot low probability tip fold-over all with normal CI outcome (CI532, CI24RE(CA) and CI622) and three ears as inconclusive all with normal CI outcome (3 x CI24RE(CA).

The single high probability tip fold-over was subsequently confirmed by CT-scan.

**Conclusion:** Based on the collected data both intra- and post implantation TIM measurement proves to be a promising diagnostic tool for detection of tip fold-over. More research is needed in order to investigate whether 1) correlation between TIM and CI outcome 2) relationship between TIM and electrode type and 3) relationship between TIM and neural responses.

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# Vestibular evoked myogenic potentials to electrical stimulation by cochlear implants – Prevalence and influence of stimulation parameters

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**Keywords:** vestibular evoked myogenic potential, cochlear implant, co-stimulation

**Background:** One of the major challenges for treatment of patients with cochlear implants (CIs) is the precise electrical stimulation of cochlear spiral ganglion cells. Current spread can lead to co-stimulation of other neural structures such as the facial nerve but also vestibular structures. It has been shown that cervical and ocular vestibular evoked myogenic potentials (cVEMPs, oVEMPs), which are clinically recorded to sound or vibration to asses otolith function, can also be elicited electrically by a CI (e-VEMPs) [1], [2]. The objective of this study was to investigate the prevalence of e-VEMPs in CI patients with respect to stimulation mode and electrical stimulus parameters.

**Methods:** In an ongoing study in Germany, e-cVEMPs and e-oVEMPs are recorded in CI users who are treated with a perimodiolar cochlear implant electrode array (Cochlear Ltd, Sydney, Australia). The e-VEMP responses are recorded to four 57 µs biphasic pulses at 1000 Hz in monopolar stimulation mode at electrodes 3 and 20 (E3, E20) as well as in bipolar transmodiolar stimulation mode (E3-14) at the maximum tolerable current level (MCL). If an e-VEMP can be detected, further recordings are performed for different numbers of pulses and stimulation frequencies (two pulses at 1000 Hz, two pulses at 500 Hz and one single pulse).

**Results:** The first results show that e-VEMPs were present in 37% of the included patients. 32% showed e-cVEMP responses, and e-oVEMPs could be recorded in 26%. The e-VEMP prevalence was higher for monopolar stimulation at E3 (32%) compared to bipolar stimulation (16%) and monopolar stimulation at E20 (5%). The variation of stimulation frequency and the number of pulses did not show a significant influence on the occurrence of e-VEMPs. Individual e-VEMP thresholds in some patients were as low as the electrical hearing levels (T-levels).

**Conclusion:** The results indicate that electrical co-stimulation of vestibular structures occurs in approximately 37% of CI patients at current levels used during daily electrical stimulation within clinical maps. Other influencing parameters as well as the question whether this co-stimulation is useful to some patients or an undesirable effect which should be avoided have to be addressed by further investigations.

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## Vestibular function after cochlear implantation in partial deafness

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**Keywords:** Partial deafness, vestibular preservation, round window approach

**Introduction:** Since the indications for cochlear implantation have broadened and include patients with low-frequency residual hearing, single-sided deafness, or an already implanted ear (meaning bilateral cochlear implantation), more emphasis needs to be on vestibular protection. The aim of the study was the assessment of vestibular preservation after cochlear implantation when hearing preservation techniques were adopted.

**Materials and methods:** 107 patients operated on in the otorhinolaryngosurgery department were enrolled in the study: 59 females and 48 males, aged 10.4–80.2 years (M = 44.4; SD = 18.4) with hearing loss lasting from 1.4 to 56 years (M = 22.7; SD = 13.5). The patients underwent cVEMP, oVEMP, a caloric test, and vHIT assessment preoperatively, and, postoperatively, cVEMP and oVEMP at 1–3 months and a caloric test and vHIT at 4–6 months.

**Results:** After cochlear implantation, we reported postoperative loss of cVEMP in 19.2% of the patients, oVEMP in 17.4%, reduction of caloric response in 11.6%, and postoperative destruction of the lateral, anterior, and posterior semicircular canal as measured with vHIT in 7.1%, 3.9%, and 4% respectively.

**Conclusions:** Hearing preservation techniques in cochlear implantation are connected with vestibular protection, but the risk of vestibular damage in never totally eliminated. The vestibular preservation is associated with hearing preservation and the relation is statistically significant. Since the risk of vestibular damage is appreciable, preoperative otoneurological diagnostics need to be conducted in the following situations: qualification for a second implant, after otosurgery (especially if the opposite ear is to be implanted), having a history of vestibular complaints, and when there are no strict audiological or anatomical indications on which side to operate.

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## The electrocochleography in normal-hearing guinea pigs during cochlear implantation.

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**Keywords:** Electrocochleography, cochlear implant, acute effects, insertion trauma, cochleostomy

**Background:** Electrocochleography (ECochG) refers to the recording of the electrical activity of hair cells and the auditory nerve in response to acoustic stimuli. ECochG is increasingly used in cochlear implant (CI) surgery, in order to monitor the traumatic effect of insertion of the electrode array. However, the obtained results are often poorly understood. Here we aim to elucidate ECochG affected by acute trauma by performing cochlear implantation in normal-hearing guinea pigs while performing ECochG at multiple time points during the procedure.

**Methods:** Thirteen normal-hearing guinea pigs were anesthetized, tracheostomized, and artificially ventilated with 1-2% isoflurane in O2 and N2O (1:2) throughout the experiment. Acute cochlear implantation consisted of (1) retro-auricular bullostomy to expose the cochlear round window and basal turn, (2) hand-drilling of 0.5- or 0.6-mm cochleostomy in the basal turn approximately 0.5 mm from the round window, (3) insertion of a short (~4 mm) four-contact animal electrode array (Advanced Bionics). Before and after each of these steps, ECochG was performed using a golden-ball electrode in the round-window niche; after insertion array electrodes were additionally used. Acoustical stimulation (clicks and 0.25-32 kHz tones) and data acquisition was controlled using a TDT RZ6 and custom-made software. The ECochG signal was analyzed among others in terms of amplitude and threshold of cochlear microphonics (CM) and the compound action potential (CAP). The midmodiolar sections of the implanted cochlea of each animal were histologically analyzed.

**Results:** For seven animals the cochleostomy severely affected the CAP and CM, while for the other 6 animals the CAP and CM were hardly affected. Histological analysis showed that the basilar membrane was severely affected in the first group, and unaffected in the second group. The CAP threshold shifts varied from 10 to 60 dB at high frequencies for the first group, and from 0 to 20 dB for the second group. After electrode insertion the responses for animals in both groups declined further: ~10 dB CAP threshold shift for the first group and ~35 dB for 3/6 animals of the second group. The other three animals of the second group maintained the same thresholds as before insertion. After removal of the electrode array the responses decreased slightly for all animals of both groups, showing final threshold shifts of 10 to 70 dB. Threshold shifts were observed not only for high frequencies for which an effect is expected (considering the basal location of cochleostomy and electrode array), but also, albeit to a smaller extent, for the lower frequencies (1 kHz and below).

**Conclusion:** ECochG is affected by both cochleostomy and subsequent insertion of an electrode array. The extent of deterioration of ECochG was associated with the severity of trauma by cochleostomy or electrode insertion. In addition, even though the cochleostomy is drilled in the basal turn and the electrode array does not reach beyond the basal turn, ECochG responses to the lower frequencies can be significantly affected as well. This implies that both cochleostomy and subsequent array insertion can affect the low-frequency residual hearing of CI recipients, even with relatively short arrays located basally in the cochlea.

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## Simultaneous intra- and extracochlear electrocochleography for intraoperative monitoring during cochlear implantation

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**Keywords:** ECochG, electrocochleography, hearing preservation, CI surgery

**Background:** The desire to preserve residual hearing following cochlear implantation has recently led to the use of ECochG as an intra-operative monitoring tool. Although various studies investigated the relationship between intra-operative ECochG measurements and surgical outcomes in recent years, the limited interpretability of ECochG response changes leads to conflicting study results. Specifically, the movement of the recording electrode with respect to the different signal generators in intracochlear recordings makes the interpretation of signal changes with respect to cochlear trauma difficult.

**Methods:** In this study, we compared ECochG signals recorded simultaneously from intracochlear locations and from a fixed extracochlear location. We measured ECochG responses to 500 Hz tone bursts with alternating starting phases during cochlear implant insertions in six human cochlear implant recipients.

**Results:** Our results show that an amplitude decrease with associated near 180-degree phase shift and harmonic distortions in the intracochlear difference curve during the first half of insertion was not accompanied by a decrease in the extracochlear difference curve's amplitude (n = 1), while late amplitude decreases in intracochlear difference curves (near full insertion, n = 2) did correspond to extracochlear amplitude decreases.

**Conclusion:** These findings suggest that comparison of ECochG signals recorded simultaneously from intracochlear locations and from a fixed extracochlear location can potentially allow a differentiation between traumatic and atraumatic signal changes in intracochlear recordings

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## Individualized auditory models based on the auditory evoked potential recordings

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**Keywords:** envelope following response, cochlear synaptopathy, individualized auditory models, sensorineural hearing-loss

**Background:** According to animal studies, auditory evoked potentials (AEPs) are one of the candidate non-invasive diagnostic tools of cochlear synaptopathy (CS), since the AEP-based derived metrics relate directly to the number of histologically-verified synapse counts in animal models. Scalp-recorded AEP markers of CS are sensitive to both outer-hair-cell (OHC) and auditory nerve (AN) aspects of sensorineural hearing loss (SNHL), and hence the impaired functionality of these cochlear/neural elements affects AEP-derived metrics differently, and yields mixed success in deriving individualized SNHL profiles from recorded AEP markers.

**Methods:** To improve the quality of AEP-based SNHL profiles, auditory models which incorporate different sources of SNHL, can be used in combination with experimentally recorded AEPs to form a powerful tool to develop personalized SNHL profiles. Here, we show how simulated and recorded AEPs (i.e. auditory brainstem response, ABR; and envelope following response, EFR) of normal-hearing (NH) and hearing-impaired (HI) subjects can be used to personalize auditory processing models. To this end, we first determined the cochlear-gain-loss parameters associated with OHC damage, based on individual distortion product otoacoustic emission (DPOAE) thresholds, after which AEPs were simulated for different degrees of AN-damage by reducing the population of different AN fiber types in a CF-dependent manner to introduce CS to the model. Using a forward-backward classification technique, we determined which ABR/EFR marker is best suited to develop these individualized models and adopted that marker to predict the AN-damage profile of the study participants.

**Results:** Our results showed that the EFR strength to a rectangularly amplitude modulated (RAM) pure-tone stimulus yields the best prediction of individual CS profiles in terms of backward-classification accuracy (83.81±2.66%). In this context, young NH listeners were predicted to have either normal or mild degrees of CS, whereas higher degrees of CS were predicted for the older NH an HI subjects. To validate the proposed method, we applied the trained forward classifier to recorded RAM-EFRs of a new cohort of young NH listeners. The classifier predicted that these listeners mostly had mild forms of CS, which supports that our method is generalizable to other recording setups.

**Conclusion:** The RAM-EFR metric together with the DPOAE threshold, offers a frequency-dependent CS profiling tool to build personalized auditory models. These models can be used in future development of individualized hearing-aid algorithms that wish to compensate for the CS aspect of SNHL as well.

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## Test-retest reliability of potential biomarkers for cochlear synaptopathy

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**Keywords:** Cochlear synaptopathy, suprathreshold auditory evoked potentials, test-retest reliability

**Background:** Suprathreshold auditory evoked potentials are promising biomarkers to diagnose cochlear synaptopathy (CS) [1]; however, studies on test-retest reliability are scarce. This study aims to investigate the test-retest reliability of these biomarkers, in order to create and implement an optimized clinical protocol for the detection of CS.

**Methods:** Fifteen normal hearing young adults (18 and 25 years) who weren't exposed to any noise, contributed in three sessions with approximately two to three days in between every session. Subjects completed a recruiting questionnaire, which was used to exclude subjects from the cohort with known hearing pathologies, history of ear surgery or tinnitus. Auditory status was evaluated by the use of tympanometry, PTA, DPOAE-measurements, speech-tests and AEP-measurements. Auditory brainstem responses were elicited with suprathreshold sounds, both clicks and tonebursts and were presented at 70, 80 and 90 dBpeSPL with a slow rate of 11 Hz and with center frequencies 500 Hz, 1 kHz and 4 kHz respectively. Envelope following responses were evoked using a 4 kHz sinusoidal amplitude modulated tone (SAM) and two rectangular amplitude modulation (RAM) waveforms (4 kHz and 6 kHz). The test-retest reliability was assessed by a three-layered approach which consisted of repeated measures ANOVA, interclass correlation coefficients (ICC) and standard error of measurement (SEM).

**Results:** Repeated measures ANOVA-analyses show no systematically significant differences in variables between the three different test sessions. High ICC's were found for PTA- and speech-test-results, with the exception of 6, 8 and 20 kHz and the broadband speech-in-quiet-condition respectively. EFR-strenghts and Click-ABR-latencies show overall high ICC-values while varying results are found for click- and TB-amplitudes, and TB peak-V-latencies. These results and additional analyses will be discussed on the IERASG21-congress.

**Discussion:** By demonstrating a high degree of test-retest reliability, the suprathreshold auditory evoked potentials seem to be reliable biomarkers to diagnose cochlear synaptopathy in future clinical and research settings. During autumn of 2021, this data analysis will be used to conduct an experimental study, whereby subjects will be exposed on a musical event and different groups will be formed depending on lifetime noise exposure history, noise exposure on the musical event, or the use of hearing protection devices.

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## The effects of stimuli and analysis parameters on two objectives measures of ITD processing in normal hearing adults

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**Background.** Binaural hearing and, in particular, interaural timing differences (ITDs) are crucial for sound source localisation, sound segregation, and speech perception in noise. Despite its importance, there is currently no clinical tool to objectively assess ITD processing. While recent studies have shown that electroencephalography (EEG) measures – such as the 'acoustic change complex' (ACC, Ross et al., 2007) and the 'interaural phase modulation-following response' (IPMFR; Haywood, et al., 2015; Undurraga et al., 2016) - can be used to assess ITD processing in a laboratory setting, the question remains whether they can be used in the clinic. This study is the first step towards the development of a clinical tool to objectively assess ITD processing. To this end, we assess the effects of stimulus and analysis parameters. More specifically, we examined the effect of intensity, interaural level differences (ILDs), and interaural phase modulations; as well as referencing and noise reduction techniques.

**Methods.** Twenty normal-hearing adults participated in our study. The stimulus comprised of a 500 Hz carrier tone, 100% amplitude modulated at a rate of 40.4 Hz. IPDs were conveyed in the temporal fine structure and periodically switched from +90° (right-leading) to –90° (left-leading), and from 0° (diotic) to 180° (out-of-phase). Changes in IPD were presented at a rate of either 0.6 Hz or 6.7 Hz to elicit ACC or IPM-FR, respectively. Stimuli were presented at intensity levels of 65, 70, and 75 dB(A), and with ILDs of 0, 5, and 10 dB(A). The EEG data was analysed in two ways: one that resembles a laboratory set-up (i.e. multichannel recording referenced to Cz, using spatial filtering techniques), and one that resembles a clinical setup (i.e. two-channel recording referenced to Fpz without spatial filtering).

**Results.** ACC and IPM-FR could be obtained in all participants. ACC amplitudes did not change as a function of intensity for any of the IPM conditions (ANOVA; +/-90°, $p = 0.056$; 0°/180°, $p= 0.087$), however, smaller responses were observed when introducing ILDs, however, there are no statistically significant differences across conditions (ANOVA; +/-90°, $p = 0.2$; 0°/180°, $p= 0.55$). Unlike the ACC amplitudes, IPM-FR amplitudes did change with intensity: larger amplitude were found for 70 and 75 compared to 65 dB(A) in both IPM conditions (ANOVA; +/-90°, $p < 0.05$; 0°/180°, $p < 0.05$). Introducing +/-10 dB ILDs resulted in smaller IPM-FRs only in the 0°/180° condition (ANOVA; $p < 0.05$). Both ACC and IPM-FR amplitudes were affected by the EEG data analysis strategies with smaller responses obtained when referenced to Fpz. While noise reduction techniques did not change the response amplitude, using noise reduction did result in better signalto- noise ratios.

**Conclusions.** ACC and IPM-FR represent objective neural measures of ITD processing. Amplitudes of IPM-FRs and ACCs are affected by interaural asymmetries of 10 dB(A) depending on the IPM, and are reduced when referenced to Fpz. Both techniques are promising to clinically assess ITD processing, but stimuli and analysis parameters should be carefully considered.

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# Intraoperative monitoring of cochlear nerve function during acoustic neuroma surgery via transtemporal approach: Warning signs as predictors of postoperative hearing loss

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**Keywords**: BAEP, acoustic neuroma, intraoperative monitoring

**Background**: The aim of this work is to define critical warning brainstem auditory evoked potential (BAEP) signs as a marker for the postoperative hearing outcome.

**Methods**: 162 patients who underwent resection of acoustic neuroma via a transtemporal approach with intraoperative monitoring (IOM) at the Department of Otorhinolaryngology, Plastic, Esthetic and Reconstructive Head and Neck Surgery, from January 2011 to December 2017. BAEP was performed in all patients, while intraoperative direct recording of the cochlear nerve function was done in 131 patients. The main outcome measures were postoperative hearing thresholds (Pure tone audiometry), postoperative speech discrimination and postoperative classification of the hearing level.

**Results**: The most significant risk factor is permanent loss of wave V as it increases the risk of postoperative hearing loss by 18 times; followed by three-steps increment of the stimulus intensity as it increases the risk by 5.75 times; and finally, the response thresholds obtained during intraoperative direct recording of cochlear nerve function. Each unite increment of the threshold increases the risk of postoperative hearing loss by 6.7%.

**Conclusions**: We believe that the intraoperative BAEP critical signs during IOM detected in this study can be used as a helpful tool to predict postoperative hearing loss in the patients with acoustic neuroma.

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# Polarity effects on facilitation of the auditory nerve and behavioural responses in cochlear implant recipients using biphasic pulses

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**Keywords:** Cochlear Implants, facilitation, polarity, compound action potential.

**Background:** Temporal interactions between pulses delivered by a cochlear implant and polarity sensitivity are measures that can provide insights into dynamics of the auditory nerve and neural health. Facilitation of the auditory nerve has been studied in humans, using a variety of pulse shapes and relative polarities between stimuli, using, in general, either electrophysiologic or behavioural approaches. Furthermore, biphasic pulses have been previously used to study the influence of polarity, by presenting paired pulses with opposite polarity separated by intervals, forming quadraphasic (QP) pulses. Here, we present a study on the influence of polarity on temporal interactions between equal amplitude/opposite polarity pulses, using combined electrophysiology and behavioural evaluations.

**Methods:** In 5 adult CI patients, behavioural thresholds and reaction times were measured using paired pulse arrangements with two polarity conditions (pairs with cathodic/anodic centred phase) and four inter-pulse intervals (range 59-350 µs). Pulse trains, with 1 s duration, were presented to a single electrode using the method of constant stimuli. Simultaneously, electrically-evoked compound action potentials (eCAPs) were recorded using the masked response extraction paradigm. A separate session was included for eCAP recordings to include inter-pulse intervals of 13 µs and 10000 µs. An exponential function was fitted to data in order to extract strength of facilitation and recovery characteristics of the eCAP.

**Results:** Overall, a decrease in threshold and an increase in eCAP amplitudes was observed with decreasing inter-pulse interval. The facilitation effect generally appeared at or below 150 µs inter-pulse interval and followed an exponential trend, consistent with previous observations. The strength of this effect was polarity dependent. Stimuli with anodic-centred phase produced larger amplitudes for the eCAP at the shortest masker probe intervals when compared with cathodic-centred pulses. These results were in-line with behavioural thresholds.

**Conclusion:** The present work extends on previous research that provided insights into facilitation of the auditory nerve in human subjects, when using biphasic stimulation. Both electrophysiologic and behavioural responses provided further evidence on the influence of peripheral temporal interactions between biphasic pulses that are related to neural health. This might be a resource to explain poor CI performance and facilitate new or better coding strategies that minimize outcome variability.

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## Intraoperative monitoring of the implantation success in cochlear implants using eABR

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**Keywords:** cochlear implant, eABR

**Background:** Various intraoperative methods have been developed to verify the technical functionality of the cochlear implant (CI) during surgery. Furthermore, the response of the auditory nerve to electrical stimulation can be recorded to confirm neural activation. However, none of these methods provides insights about the higher neuronal processing, i.e. hearing by means of the electrical pulses emitted by the CI. In addition, a final assessment of the electrode position is only possible postoperatively by means of imaging procedures and at the cost of additional radiation exposure for the patient. Thus, an incorrect electrode position can only be corrected in a second procedure. The purpose of the proposed study is to intraoperatively monitor the implantation success by recording electrically evoked brainstem responses (eABR). With such a tool, misplacements of the electrode array could be detected early, allowing immediate repositioning.

**Methods:** In a planned study, intraoperative eABR recordings will be conducted with 33 patients. A test setup consisting of a CI interface (MAXbox/MAESTRO, MEDEL GmbH, Innsbruck, Austria) for stimulation and a biosignal amplifier (Eclipse, Interacoustics, Middelfart, Denmark) for recording eABRs was assembled. The eABRs will be recorded with surface electrodes placed on the mastoids and the forehead of the patients. Stimuli of different levels will be emitted from an apical and basal electrode contact location on the array. Parameters such as the amplitude and latency of the recorded waves will be used to analyze the eABR in each patient.

**Results:** Results of a preliminary measurement with a conscious CI user showed the suitability of the test setup for the planned study. Brainstem responses evoked by pulses from an apical stimulation electrode showed a distinct morphology, and higher amplitude and shorter latency of wave eV compared to stimulation from a basal electrode.

**Conclusion:** Prior to the start of the study, the experimental setup was validated and the parameters for stimulation and recording of the eABRs were successfully determined. In agreement with previous studies (Firszt et al., 2002), the preliminary results of the eABR recordings showed a different morphology, amplitude, and latency depending on the location of the stimulating electrode contact.

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## Characterization of intraoperative electrically evoked compound action potentials of the vestibular nerve in translabyrinthine and intralabyrinthine configurations

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**Keywords:** compound action potentials, vestibular nerve, veCAP, vestibular implant

**Background:** Bilateral vestibulopathy can have a serious impact on quality of life. The vestibular implant was designed to aid these patients by providing motion information through electrical stimulation of the ampullary nerves. However, correct electrode placement is still a challenge and adequate measures for electrode positioning are lacking. Electrically evoked compound action potentials of the vestibular nerve (veCAPs) provide an objective electrophysiological measurement of the nerve response to electrical stimulation. The objective is to characterize the veCAPs in translabyrinthine and intralabyrinthine configurations and investigate the potential usefulness of this tool in vestibular implantation.

**Methods:** Adult patients undergoing destructive labyrinth surgery (e.g. for vestibular schwannoma) were selected. A custom manufactured vestibular implantation electrode was used with two electrode leads, each with three electrode contacts at the tip (MED-EL, Innsbruck, Austria). During the surgery, the branches were placed in the superior and lateral semicircular canal, respectively. All 12 intralabyrinthine and 18 translabyrinthine stimulation-recording configurations were tested and responses were characterized using latency and amplitude growth. Registration: ABR NL 54761.068.15; https://www.trialregister.nl/trial/6839 (ongoing)

**Results:** veCAP responses could be recorded in several, but not in all patients. Translabyrinthine configuration provided more successful veCAP recordings. The amplitude of vECAPs responses increased monotonically with increasing current amplitudes, even though notable differences are observed across stimulation-recording pairs, both within and between semicircular canals. Mean latencies for the first negative peak of both configurations showed comparable results to cochlear ECAPs recorded in humans (360-366 µs).

**Conclusion:** Recording of veCAPs is possible, both in translabyrinthine and intralabyrinthine configurations, although the former seems more fruitful. These objective measures might possibly aid the determining of the optimum electrode location during surgery, although its reliability should be investigated in future trials. Additionally, veCAP measurements might be integrated in the post-operative battery to monitor device function and to improve fitting procedures.

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# High-Frequency Audiometry and Vestibular Evoked Myogenic Potential - Critique in Women with Polycystic Ovary Syndrome

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**Introduction:** Polycystic ovary syndrome (PCOS) is the most commonly seen clinical condition in women during their reproductive age and is often associated with hyperandrogenism and chronic anovulation. Biochemical and hormonal changes can result in vascular occlusion or vascular stenosis, which restrict the supply of oxygen and nutrients to the inner ear and can result in sensorineural hearing loss mainly at the high-frequency region in females with PCOS (Kucur et al., 2013). Due to the close anatomical and physiological relationship between the hearing and vestibular apparatus of the inner ear, there is a probability of impaired vestibular functioning along with the cochlear functioning in individuals with PCOS. Hence, the present study aims to investigate the high-frequency audiometry and vestibular functioning in women with PCOS.

**Methods:** Ten women diagnosed with PCOS and 10 healthy women without PCOS in the age range of 18-40 years served as the participants. Participants with the complaint of tinnitus, middle ear disease, and family history of hearing loss were excluded from the study. A detailed case history including information about the auditory and the vestibular symptoms were obtained following High-frequency audiometry, Cervical VEMP (cVEMP) and ocular VEMP (oVEMP).

**Results:** The latency, amplitude, and peak-to-peak amplitude (Pk-Pk amplitude) for all the peaks of cVEMP and oVEMP were tabulated. Shapiro-Wilks test of normality showed data to be normality distributed ($p > 0.05$) and thus parametric tests were done. Paired-Samples T-test, in comparison between the ears showed no significant difference of the cVEMP and oVEMP values ($p > 0.05$), thus the right ear and left ear data were combined making a total of 20 ears of women with PCOS and 20 ears without PCOS. One-Way ANOVA showed a statistically significant difference for all the parameters across the groups. The ANOVA statistics for cVEMP P13 latency ($F (1, 38) = 127.71$, $p < 0.05$), N23 latency ($F (1, 38) = 158.52$, $p < 0.05$) and P13-N23 Pk-Pk amplitude ($F (1, 38) = 41.22$, $p < 0.05$). The ANOVA statistic for oVEMP N10 latency ($F (1, 38) = 128.53$, $p < 0.05$), P15 latency ($F (1, 38) = 42.48$, $p < 0.05$) and N10=P15 Pk-Pk amplitude ($F (1, 38) = 116.15$, $p < 0.05$). High-frequency audiometry showed a statistically significant difference in thresholds for frequencies 10 kHz to 20 kHz between women with and without PCOS.

**Conclusion:** The findings of the study suggest a significant effect of hormonal disturbances on the auditory and vestibular system in women with PCOS. Hence, aural care should be taken for early identification and early intervention in women with PCOS.

**Reference:**

Cuneyt Kucur and Suna Kabil Kucur (2013): Extended High Frequency Audiometry in Polycystic Ovary Syndrome. *The Scientific World Journal.*

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# Cortical activation evoked by electrical stimulation of the vestibular nerve in humans

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**Introduction:** Investigating spatial and temporal patterns of cortical responses resulting from vestibular percepts is crucial in order to understand the mechanisms underlying the integration of sensory information in the multidimensional system of balance. The vestibular implant is an unprecedented setting for such an investigation, allowing direct stimulation of the vestibular pathways without the influence of other sensory modalities (e.g., vision, proprioception).

**Methods:** This study was conducted in three patients with bilateral vestibulopathy who received a prototype implant with 1-3 vestibular electrodes (MED-EL, Innsbruck, Austria). The cortical responses evoked by the electrical stimulation delivered by one of the vestibular electrodes (biphasic current pulses of variable intensity, 200µs/phase, 400 pulses per second) were recorded using a 256-channel electroencephalography system (Clinical GES 400, Electrical Geodesics Inc, Oregon, USA).

**Results:** Our preliminary results show cortical activation synchronous with electrical stimulation of the vestibular system. These responses are characterized by cortical vestibular potentials with latencies ranging from 25ms to 150ms. Further analyses are currently underway to determine the topographic distribution of evoked responses, as well as the 3D localization of cortical regions responding to stimulation using inverse solution mathematical models.

**Conclusion:** These results will contribute to our fundamental knowledge on the cortical integration of vestibular stimuli. This will not only contribute to the development of the vestibular implant, but also to improve our understanding of certain syndromes which remain poorly understood, such as “mal de débarquement” syndromes or uncompensated unilateral deficits.

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## A new method for calculating the auditory brainstem response grand average

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**Keywords:** ABR, grand average, waveform, wave I, wave V

**Background:** When recording evoked potentials from a homogeneous group of subjects under the same conditions, the calculation of grand averages or grand mean waveforms has been a common choice of analysis and presentation. However, currently no consensus exists of the procedure of calculating the grand average that respects multiple waveform morphology features. Previously we have suggested a grand average method for auditory brainstem response (ABR), which temporally align the wave V of all underlying waveforms to the mean wave V latency of the group before calculating the grand average. This procedure results in a well-represented wave V morphology, but due to inter-subject variability in the wave I-V interval, the negative consequence of this procedure is a smearing of the wave I morphology. To compensate for the shortcoming of this grand average procedure’s ability to correctly represent both wave I and wave V, we hereby suggest a new principle for the underlying temporal transformation.

**Methods:** The principle of the new grand average temporal transformation method is for each individual underlying ABR (1) to compress – or expand – the time-axis such that the wave I-V latency interval becomes identical to the group mean interval, and (2) to time shift the entire compressed ABR such that the latency of wave V (or wave I) becomes identical to the group mean latency. Click-evoked ABRs were recorded using the Interacoustics Eclipse EP25 ABR system in 20 normal-hearing adults (N=20 ears) with a median age of 25 years. Grand average waveforms were calculated using either no temporal transformation of the underlying ABRs (GAnorm), temporal alignment of wave I (GAI), temporal alignment of wave V (GAV) or the new temporal transformation method (GAI-V).

**Results:** Higher amplitudes of the individual waves in the grand average indicate that the grand average better represents the group mean amplitude of the individual ABR waves. The GAI results in a higher wave I amplitude than GAnorm. GAV results in a higher wave V amplitude than GAnorm. GAI-V gives both higher wave I and wave V amplitudes than GAnorm. Besides this, GAnorm and GAI demonstrates larger standard deviations across the group in the wave V peak-trough latency region, which results in a visually less step peak-to-trough slope than both GAV and GAI-V. By adjusting for the naturally occurring inter-subject variability in absolute wave V latency, both GAV and GAI-V are able to visually capture the steepness of the wave V peak-to-trough slope.

**Conclusion:** The present study suggests applying a temporal transformation of the underlying ABRs to reduce grand average waveform smearing caused by inter-subject variability. This results in a grand average waveform that are able to account for multiple waveform morphology features in the same grand average waveform. The grand average methods compared here, highlights the importance of stating which underlying calculation approach were used when presenting data in a grand average format.

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## Auditory Steady-State Responses and Auditory Brain Responses - hearing threshold estimation by sensorineural and mixed hearing loss

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**Keywords:** Auditory Brain Response (ABR), Auditory Steady-State Response (ASSR), hearing threshold, sensorineural and mixed hearing loss

**Background:** Determining hearing thresholds plays an important role in audiological diagnostics especially in non-cooperative patients. ABR is usually useful in estimating hearing thresholds in the range from 1 kHz to 4 kHz, in moderate to severe hearing loss (typically non-steep sloping hearing loss). ASSR can estimate hearing threshold in the same frequency range as ABR, and has the ability to differentiate hearing losses from severe to profound. The objective of the study was to evaluate the clinical value of multiple ASSR and ABR technique in threshold estimation by subjects with sensorineural (SNHL) and mixed (MHL) hearing loss.

**Methods:** Total of seventeen adult subjects (6 male, 11 female, age range 17-83 years) with different degree of sensorineural and mixed hearing loss participated in the study (3 out of 11 subjects were tested as normal hearing control group). ASSR and ABR thresholds were evaluated on the same day, pure tone audiometry (PTA) was performed at the same day or one day prior to ABR and ASSR measurements. All subjects were tested in the sound-attenuated booth at the AMEOS Clinic Halberstadt. Commercial software module (Interacoustics A/S, Assens, Denmark, OtoAccess v. 1.0) on an Interacoustics Eclipse EP25 platform was used. Air-conducted stimuli were presented through supra-aural TDH 39 earphones. For the ASSR and ABR measurements, active electrodes were placed at the right and left vertex, and the ipsilateral mastoids, whereas the ground electrode was located at the low forehead. Electrodes impedance was kept as ≤ 3 kΩ. Click stimulus with the repetition rate 21/s (ABR measurements) and NB-Chirps (center frequencies 0.5, 1, 2 and 4 kHz) with repetitions rates around 90/s and 110/s for the right and left ear respectively (ASSR measurements) were presented, artifact rejection criterium was set at ± 40 μV. Multiple NB-Chirps (4 to the right and 4 to the left) were presented simultaneously to both ears (ASSR measurements). For ABR measurement click Stimulus was presented to one ear and the contralateral ear was masked with white noise.

**Results:** 22 ears of 17 subjects were examined. The following results were compared: ASSR to PTA; click-ABR to PTA; and click-ABRs to ASSR. For SNHL (10 ears) the average multiple ASSR thresholds (± SD) at 0.5, 1, 2 and 4 kHz were equal 34.5 ± 22.8; 46 ± 24.25; 54 ± 20.9; 63 ± 24.8 dB HL respectively, for the same frequency configuration PTAs were equal 44.5 ± 18.6; 50 ± 19.4; 59.5 ± 22.9, 70.5 ± 21.14 dB HL; finally click-ABR thresholds equals 60 ± 25.8 dB HL. For MHL (7 ears) the average multiple ASSR thresholds for 0.5, 1, 2 and 4 kHz were equal 55 ± 24.2; 57 ± 22.7; 62 ± 23; 50 ± 43.8 dB HL respectively, for the same frequency configuration PTA thresholds equals 88.5 ± 24.4; 82 ± 22.7; 83 ± 22.1; 81 ± 38.8 dB HL respectively and click-ABR thresholds was equal 65 ± 10.4 dB HL. For normal hearing control group (5 ears) the average multiple ASSR thresholds for 0.5, 1, 2 and 4 kHz were equal 24 ± 10.8; 22 ± 7.5; 21 ± 4.1; 26 ± 6.5 dB HL respectively, for the same frequency configuration PTA were equal 22 ± 4.8; 20 ± 3.5; 21 ± 4.5; 26 ± 4.5 dB HL; finally click-ABR thresholds equals 21 ± 5.4 dB HL. For sensorineural hearing loss the average difference score (± SD) between ASSR and ABR thresholds for given frequencies were within 5 – 10 dB HL range of audiometric threshold, and 6 – 14 dB HL for difference score between ABR and ASSR. For mixed hearing loss the difference score between ASSR and PTA thresholds ranged from 20 to 33 dB HL, 16 dB HL for difference score between ABR and PTA, and 5 – 15 dB HL difference score between ASSR and ABR.

**Conclusion:** Multiple ASSR is a valuable technique for the determination of degree and configuration of hearing loss, however the degree of hearing loss considerably affects the ASSR threshold accuracy. In general, estimated ASSR-based audiograms correspond well with the behavioral thresholds for the SNHL, which is consistent with data presented in the literature [1, 2], more variability for MHL was observed. The ABR thresholds proved to be useful to estimate moderate MHL, however, a discrepancy between the ABR and ASSR thresholds in case of sensorineural steep-slope audiograms was seen.

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# Auditory Brainstem Response with iChirp in the Infant's audiological diagnosis: Reference Parameters

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**Keywords:** ABR, newborn, electrophysiology

**Background:** ABR is the gold-standard procedure to diagnose hearing-related deficits in the first months of life. Thus, the constant effort to improve the techniques have led to modifications in certain parameters such as the stimuli used in order to evoke better and more accurate responses. Stimuli such as the iChirp were created as an alternative to compensate for the stimulation delay of the higher frequencies compared to the lower frequencies, as they stimulate the cochlea simultaneously as a whole, unlike the stimuli typically used in ABR, Click and Tone Burst. The family of chirps have been considerably studied in the infant population, for presenting better wave morphologies and in less time than the standard stimuli, although few studies have attempted to set out reference parameters to enable its clinical use. Thus, the aim of this study was to suggest reference values for the evaluation in neonates.

**Methods:** Using two types of iChirp stimuli, broadband and narrowband, we evoked ABR responses in 62 neonates (29 females and 33 males). Both were presented in three different intensities, 60dBnHL, 40dBnHL e 20dBnHL. With iChirp-narrowband, the wave V was researched in the frequencies of 500Hz, 1KHz, 2KHz and 4KHz. The following recording parameters were used to evoke the responses in the Smart Ep equipment from Intelligent Hearing Systems: rare polarity, 2048 sweeps, rate of 27.7 stimuli per second, low pass filter of 100 to 3kHz and gain of 100k, with a recording analysis of 12ms for iChirp-broadband and 24ms for iChirp-narrowband. Considering the age of the sample and, in order to don't compromise the accuracy of the data, the neonates were randomly divided into three groups: 30 of them were submitted to the ABR with the stimuli of iChirp-broadband, 16 with iChirp-narrowband in the frequencies of 500Hz and 2KHz and the others 16 in the frequencies of 1KHz and 4KHz. The variables of latency and amplitude were extracted to sum the reference values for this population.

**Results:** The mean and standard deviation of the latency and amplitude values for the iChirp-broadband were extracted for the three levels of intensity: 60dBnHL (10.00±0.43; 0.22±0.07), 40dBnHL (11.09±0.35; 0.22±0.08) and 20dBnHL (12.07±0.39; 0.15±0.05) respectively. Similarly, the reference values, i.e. mean and standard deviation, for latency and amplitude with iChirp-narrowband were withdrawn from the waveforms elicited with the four frequencies at the three intensities researched: 500Hz at 60dBnHL (8.02±0.67; 0.17±0.05), 40dBnHL (9.58±1.12; 0.13±0.04), 20dBnHL (11.06±1.27; 0.08±0.03); 1KHz at 60dBnHL (8.04±0.87; 0.21±0.07), 40dBnHL (9.41±0.89; 0.16±0.07), 20dBnHL (10.92±1.21; 0.14±0.15); 2KHz at 60dBnHL (7.98±0.47; 0.18±0.05), 40dBnHL (9.13±0.53; 0.14±0.05), 20dBnHL (10.46±0.74; 0.70±0.04); 4KHz at 60dBnHL (7.73±0.41; 0.15±0.05), 40dBnHL (9.06±0.72; 0.12±0.05), 20dBnHL (10.6±1.11; 0.11±0.15).

**Conclusion:** Reference values were elaborated in different frequencies ranges, both broadband and narrowband, and in three different intensities for the use of the iChirp stimuli in the ABR assessment of neonates.

**Reference:**

Bargen GA (2015): Chirp-Evoked Auditory Brainstem Response in Children: A Review. American Journal of Audiology. 2015;24:573–583. doi: 10.1044/2015_AJA-15-0016.

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## Use of Level Specific CE-Chirp Auditory Brainstem Response in Infants with and without Hearing Impairment

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**Keywords:** LS CE-Chirp, ABR, Infants

**Background:** Universal Newborn Hearing Screening (UNHS) is part of the early hearing detection and intervention (EHDI) initiative that aims for early diagnosis, intervention, and follow-up, of hearing-impaired babies. One of the tools used for UNHS is the Auditory Brainstem Response (ABR). ABR can be elicited by many stimuli including LS CE Chirp, and previous studies reported that this most recent innovated stimulus has a lot of advantages; for instance, it provides most neural synchrony thus, produces larger amplitudes of waves I, III and V. To date, the knowledge on test-time efficiency of the ABR to LS CE-Chirp is limited and only reported from the adult population. This study aims to investigate the test-efficiency of the ABR elicited from LS CE Chirp stimulus in infants with or without hearing impairment.

**Method:** A total of 70 infants ( 35 normal hearing, 35 hearing- impaired) age between 1 and 3 months old will participate in this study. The selected infants must have normal outer and middle ear function. ABR will be acquired using two stimuli (LS CE-Chirp and click) at 70, 30 dBnHL and continue until the auditory thresholds of the patients. The ABR will be acquired using three stimulus repetition rates ( 88.1, 66.1, and 33.3 cps), and the signal averaging will be stopped based on the following; (i) F test at multiple points equal to 3.1(ii) visual detection (iii) fixed signal average at 2500 sweeps. The ABR test time, amplitude, absolute latency, interpeak latencies ( IPL), and threshold estimation level will be recorded and statistically evaluated.

**Results:** Two-Way Repeated measure ANOVA will be used to analyze ABR results (test time, amplitude, absolute latencies, interpeak latencies ( IPL), and auditory thresholds) elicited from LS CE-Chirp and click stimuli. The results will be compared between ABR to LS CE-Chirp and click stimulus within and between groups (normal hearing and hearing-impaired population). It is hypothesized that the ABR to LS CE Chirp will has shorter test time, larger amplitudes of waves I, III and V, longer absolute latencies of waves I, III and V, longer IPL of waves I-III, III-V and I- V than ABR to click stimulus among all combinations. This study also hypothesized that the ABR threshold levels from LS CE- Chirp is lowered than ABR to click stimulus.

**Conclusion:** This study's outcome can be used as a guideline or protocol for ABR test in pediatric, to serve a better health service to our next generation by maintaining the efficiency of aural rehabilitation in the way of early diagnosis and intervention.

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## Auditory Brainstem Response with iChirp in the Infant's audiological diagnosis

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**Keywords:** ABR, newborn, electrophysiology

**Background:** ABR was proven to be evoked by a set of different stimuli, other than the traditional Click for auditory synchrony assessment, or Tone Burst (TB) for frequency-specific testing. Many efforts have been made to further refine audiological assessment of newborns, hence, the premise behind the creation of stimuli such as the iChirp sums on the possibility to evoke more robust responses which could aid in a more accurate audiological testing and therefore diagnosis. Thus, the aim of this study was to investigate the use of the iChirp stimulus in audiological diagnosis compared to stimuli typically used in ABR in newborns.

**Methods:** We evoked ABR responses in 62 neonates (29 females and 33 males) using a combination of stimuli through insert earphones that were later compared, Click X iChirp-broadband (iChirp-BD) and TB X iChirp-narrowband (iChirp-NB). All stimuli were presented in three levels of intensity (60dBnHL, 40dBnHL and 20dBnHL) with the same recording parameters in the Smart Ep equipment from Intelligent Hearing Systems, as follows: rare polarity, 2048 sweeps, rate of 27.7 stimuli per second, low pass filter of 100 to 3kHz and gain of 100k, with a recording analysis of 12ms for Click and iChirp-BD and 24ms for TB and iChirp-NB. The latter stimuli were used to research the V wave in four frequencies, 500Hz, 1KHz, 2KHz and 4KHz. An additional analysis of the Residual Noise (RN) was performed to compare the TB and iChirp-NB. To avoid tiredness and fatigue, which could compromise the confidence and repeatability of the waveforms, the newborns were randomly divided, so 30 of them were submitted to ABR using Click and iChirp-BD stimuli, 16 with TB and iChirp-NB stimuli in the frequencies of 500Hz and 2KHz and another 16 newborns in the frequencies of 1KHz and 4KHz. The data was statistically analyzed through the Student's T test.

**Results:** Higher latency and amplitude values were observed for the iChirp-BD when compared to Click (p=<0,001* for all intensities; p=0,008* for 60dBnHL; p=<0,001* for 40dBnHL and 20dBnHL), respectively. Similarly, statistically higher latency values were also evidenced for iChirp-NB in contrast to TB for the frequencies of 500Hz and 2KHz in all intensities (p=0,002* for 60dBnHL, p=0,001* for 40dBnHL, p=0,005* for 20dBnHL; p=<0,001* for all intensities), respectively. Higher amplitudes were found in the iChirp-NB evoked waveforms when compared to TB in all frequencies, although it seemed to differ according to the intensities applied. Statistically significant difference was obtained in this analysis for the frequencies of 500 and 1KHz in all intensities (p=<0,001* for 60dBnHL and 40dBnHL, p=0,010* for 20dBnHL; p=<0,001* for 60dBnHL and 40dBnHL, p=0,019* for 20dBnHL), respectively. The frequency of 4KHz seemed to significantly differ only for the intensity of 60dBnHL (p=<0,001*) and 40dBnHL (p=<0,001*) but not for 20dBnHL, while a single statistical difference was evidenced for the frequency of 2KHz in the intensity of 60dBnHL (p=<0,001*). Higher RN values were observed when the iChirp-NB and TB were compared, with statistically significant differences for the three intensities in the frequencies of 500Hz, 1KHz and 4Kz.

**Conclusion:** In general, the iChirp-BD and iChirp-NB stimuli showed higher latency values and greater amplitudes when compared to Click and TB stimuli. Better RN values were observed when contrasting the iChirp-NB with the TB. The iChirp stimulus appears to be promising in the infant's audiological diagnosis, once its use promoted greater amplitudes and better wave morphology, which facilitates the visualization of the responses and provides greater efficiency in the investigation of hearing thresholds.

**Reference:**

Bargen GA (2015): Chirp-Evoked Auditory Brainstem Response in Children: A Review. American Journal of Audiology. 2015;24:573–583. doi: 10.1044/2015_AJA-15-0016.

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# Evaluation of sound-working memory therapy intervention in Autism Spectrum Disorder (ASD) children using Auditory Brainstem Response (ABR) sensory gating

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**Keywords:** ABR, sensory gating, autism, sound therapy

**Background:** Sound therapy is an intervention to provide extensive treatment for Autism Spectrum Disorder (ASD) children. However, there is a lack of scientific evidence on the validity of this method that has been performed in the previous studies including (i) the use of parental-report questionnaires for pre and post-intervention and (ii) an absence of objective test such as auditory-evoked potential (AEP) to evaluate the effectiveness of sound-therapy to regulate emotion in ASD children. This study aims to investigate the effectiveness of sound therapy in regulating the emotion of ASD children using Auditory Brainstem Response (ABR) Sensory Gating through Stroop Task and parental-reported questionnaires (Emotion Regulation Checklist (ERC) and Malay Sensory Gating Survey (SGS)).

**Methods:** A total of 40 ASD children will be recruited and divided into 5 groups in which 2 groups will be assigned as a control group (no therapy or working memory only) and 3 groups as the experimental groups. The experimental groups will undergo sound-working memory therapy in which different sounds background will be assigned during sound or sound-working memory therapy session. The parents will be requested to answer ERC and Malay SGS at the beginning and end of sound or sound-working memory therapy session. The participants from both groups will undergo pre and post-intervention using ABR with Stroop Task.

**Results:** Two-way Repeated measure ANOVA will be used to compare the ABR sensory gating, ERC, and Malay SGS between experimental and control groups before and after the intervention. Multiple linear regression will be used to evaluate the relationship of all outcomes that will be measured. This study postulates that a good agreement among ABR sensory gating, ERC, and Malay SGS scales in evaluating emotion regulation among ASD children will be obtained.

**Conclusion:** Success in conducting this study will provide a better understanding of sensory gating in ASD children. ABR sensory gating also will provide a reliable and direct result that can significantly support any findings on self or parental-reported questionnaires. This allows for more accurate diagnosis and symptoms which may help in planning intervention for ASD children.

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## Effect of Gender on Cervical Vestibular Evoked Myogenic Potential

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**Keywords:** cVEMP, Gender difference, Tone burst

**Background:** Vestibular Evoked Myogenic Potentials (VEMP) is a short latency potential which is evoked by the activation of receptors of the vestibular system using sound or vibrations which is generated by modulated electromyographic signals from the sternocleidomastoid muscle for the cervical VEMP (cVEMP). The cVEMP test determines if the saccule, one portion of the otolith organs, as well as the inferior vestibular nerve and central connections are intact. Several studies have investigated the possible factors that can have an effect on the amplitude and latency of VEMP responses. Studies on cVEMP parameters affected by gender and ear tested revealed varied outcomes. Some studies have concluded that there was statistically significant differences for all cVEMP parameters as women had lower p13 latencies compared to men while some other studies have revealed that there were no significant differences revealed on gender difference in cVEMP parameters such as in mean of n1 latency, p1 latency and n1-p1 interval between males and females. As the literature reveals that the studies investigated the effect of gender and ear tested on cVEMP shows varied and contradictory outcomes, there is a need to assess the effect of gender on cVEMP responses.

**Methodology:** In the current study, gender difference for cVEMP responses was investigated in healthy young adults. For this, 30 individuals (60 ears), 15 of whom were females (30 ears) and 15 males (30 ears) were included. For VEMP test recordings, subjects were seated with the head rotated maximally to the contralateral side of the sound stimulus. The parameters used were two hundred tone bursts stimuli of 500Hz presented at 95dBnHL, using a 30Hz – 1500Hz band pass filter, at the rate of 3.1Hz. Recording were taken in 60ms window.

**Results:** cVEMP responses were collected by mono-aural stimulation of vestibular system and the obtained data was subjected to Repeated Measures of ANOVA. In VEMP tracings comparison of absolute latencies and amplitudes of P1, N1 and P2 were compared Between -Subjects and Within-Subjects. The Between-Subjects results showed no statistically significant difference for latency of P1, N1 and P2 response for left ear and right ear between males and females, Wilks' Lambda = 0.816, F(9.0, 131.572) =1.275, and p=0.257. Similarly there is no statistically significant difference for amplitude for left ear and right ear between males and females, Wilks' Lambda= 0.845, F(9.0,131.572) =1.045, and p= 0.408. The Within-Subjects results revealed no statistically significant difference for latency of P1 (p=0.528), N1 (p=0.420) and P2 (p=0.098) and amplitude of P1 (p=0.203), N1 (p=0.573) and P2 (p=0.617) responses.

**Conclusion:** The data reveals that factors such as gender and ear tested do not have an effect on the cVEMP responses. With regard to the amplitude and latencies of P1, N1 and P2 responses, no difference between left ear and right ear in males and females as well as between males and females was detected. Thus, from the current study it can be concluded that there is no effect of gender and ear tested on VEMP responses.

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## Comparison between Vestibular Evoked Myogenic Potential and Handedness

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**Keywords:** Labyrinth Vestibule, Motor Skills, Handedness

**Background:** The Vestibular Evoked Myogenic Potential (VEMP) is a myogenic potential, which waves latencies are short to mean, and triggered by strong sound intensity. VEMP assesses the vestibular nerve and the otolith organs, the saccule, and the utricle. The ocular VEMP (oVEMP) shows utriculo-ocular reflex, and the cervical VEMP (cVEMP) evaluates the sacculo-collic reflex. Musicians are constantly exposed to music in high pressure sound levels, what can lead to cochlear alterations or improve hearing abilities. Thus, our study compared oVEMP and cVEMP results and hand dominance.

**Methods:** The research was approved by the Ethical Commission of Research of the Federal University of Santa Maria (approbation number: 16728013.0.0000.5346) and authorized by a signed consent form. For this reason, 56 subjects, ranging in age from 18 to 45 years old were included. The cVEMP and oVEMP latencies, amplitudes and interamplitudes were evaluated in both sides of the ear and the handedness was assessed by the Edinburgh Handeness Inventory. The subjects had normal hearing and no comorbidities. They were divided in three groups: right-handed, left-handed and ambidexterity. The data has been analysed using Mann-Whitney U test inferential analysis and the p value considered was <0.05, with Statistic software 9.1.

**Results:** In the sample, 28 were musicians and 28 non-musicians, who were mostly right-handed (71,43%), then ambidextrous (17,86%) and left-handed (10,71%). The comparison between cVEMP results and handedness assessment results showed that P13 latency on the right ear is bigger in ambidextrous (18,48) than in left-handed (16,31), but not in the right-handed (17,45) (p = 0,04). Meanwhile oVEMP showed no significant difference between the groups. Despite that, in the general analysis cVEMP showed bigger P13 waves amplitudes and interamplitude in both sides in the left-handed group. Though oVEMP showed bigger N10 and P15 waves latencies in the right side in the right-sided group, and amplitudes and interamplitudes also bigger in both sides in the ambidextrous. To assess handedness and compare motor skills of musicians and non-musicians, Ferreira *et al*. (2014) report that musicians and non-musicians showed similar handedness, although musicians showed better quality at planning and executing actions, prevalence ambidexterity when executing fine motor skills and low difference between hands in hand actions. Still, the authors observed that most musicians were right-handed, then left-handed and ambidextrous, wich corroborates our study and show that this population presents better hand motor skills in both hands due to the musical experience.

**Conclusion:** The data showed that the P13 latency on the right ear is bigger in ambidextrous than in left-handed, but not in comparison to right-handed.

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# Using eye-tracking to measure word processing in 3-5-year-olds with hearing loss

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**Keywords:** Word processing, eye-tracking, children with hearing loss

**Introduction:** Children with hearing loss (HL) may not have access to all the acoustic cues needed to differentiate speech sounds [1], potentially causing slower word processing. This study aims to quantify these lags using eye-tracking. Word-initial stops are more acoustically salient than word-final stops [2], predicting slower processing for word-coda as opposed to word-onset contrasts.

To measure word processing, we investigated how children with HL vs. normal-hearing (NH) process minimal pair words differing in their Onset (e.g. *bin* vs. *pin*) compared to non-minimal Control pairs (e.g. *pear* vs. *bib*), and minimal pair words differing in their Coda (e.g. *mat* vs. *mat*).

**Methods:** A preliminary sample of 8 children with HL ($M_{age}$ = 4.6 years) and 28 NH children ($M_{age}$ = 4.6 years) participated in an eye-tracking study using a Looking-While-Listening paradigm. The HL sample includes children with uni- and bilateral hearing loss, and various device types (CI/HA/BAHA). Children saw 8 non-minimal pair and 30 minimal pair trials (18 onset pairs and 12 coda pairs), with voicing and place of articulation contrasts. Each trial presented two pictures (e.g. *bin* and *pin*) in silence for 2400ms, followed by ‘Look at the [target]’ (e.g. *bin*), followed by the two pictures for a further 4000ms. Differences in proportion of looks to the target over time were analysed with cluster-based permutation tests. While curves in the Control-Onset comparison were aligned at the offset of ‘the’, curves in the Onset-Coda comparison were aligned at the burst of the target word plosive (e.g., onset: ‘*b*’ in *bin* and coda: ‘*p*’ in *map*), thus correcting for the later disambiguation point in coda pairs.

**Results:** Statistical analyses performed over the NH sample did not detect any difference between Control vs. Onset looking curves (cluster: time-window = 3500-3800, p = .115), or between Onset vs. Coda curves (no clusters detected). In combination with visual inspection of the data, this suggests that NH children process words in all three conditions equally fast. The preliminary descriptive data for the children with HL indicates no difference in processing time for Onset vs. Control trials, but overall proportion of looks to target appears to be lower for Onset than Control trials. Furthermore, children with HL seem to take slightly longer to look at the target for Coda compared to Onset trials.

**Conclusions:** Results of the NH children provide a clear baseline for testing the word processing abilities of children with HL. Preliminary results from the children with HL suggest more uncertainty during the processing of minimal pair words compared to non-minimal pairs, as well as slightly slower processing for coda compared to onset minimal pairs. These results provide important preliminary insights into the real-time delays that children with HL face when processing words. This may aid the future development of interventions targeted towards overcoming processing lags, and its knock-on effects for communication and listening effort.

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# The effects of attention on the MOCS as measured by TEOAE suppression

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**Keywords:** MOCS, TEOAE suppression, attention

**Background:** Among the functions of the medial olivocochlear system (MOCS) are to protect the auditory system against excessive noise, to aid in listening in noise, and to aid in selective attention. This system can be activated by presenting acoustic suppressor signals (such as broadband noise, BBN) to the ear, and its activity can me measured using various tests, including otoacoustic emission (OAE) suppression. Previous works have suggested that attention state was affecting the OAE supression in adult (Cone, 2009). However, the effects of attention state on the measurement of OAE supression in children is poorly understood. The current study therefore aims to investigate the effects of attention on the MOCS activity via transient OAE (TEOAE) suppression measured in the inattentive versus attentive state among children.

**Methods:** 11 normal hearing school-age children (aged between 8-11) participated in this study. Contralateral TEOAE suppressions were performed in the presence of BBN at 60 dBA at 1,000, 1,400, 2,000, 2,800, and 4,000 Hz in two conditions: inattentive state and attentive state. Subjects were asked to relax and sit still during the inattentive state. In the attentive state, subjects were asked to complete several working memory modules while TEOAE suppressions were being measured. Both conditions were repeated 5 more times using 5 other acoustic suppressor signals (2 Quranic recitations and 3 nature sounds), all presented at 60 dBA.

**Results:** A large effect size (indicated by the partial eta squared ($\eta^2$) value of 0.18) was found between the TEOAE suppressions obtained in the inattentive and the attentive states. Descriptive analyses showed more enhancement effects in the inattentive condition compared to the attentive condition, especially at the higher frequencies. TEOAE suppression magnitudes were larger for all suppressor signals at all tested frequencies during the attentive condition than the inattentive condition.

**Conclusion:** The higher OAE suppressions were observed during the attentive state than during the inattentive state indicates that attention could enhance the MOCS activity. The attention state of the subject has to be taken into account when measuring TEOAE suppressions.

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# The effects of nature sounds and Quranic recitation on the MOCS as measured by TEOAE suppression

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**Keywords:** MOCS, TEOAE suppression, nature sounds, Quranic recitation

**Background:** Otoacoustic emission (OAE) suppression is among the tests used to measure the medial olivocochlear system (MOCS) function. Previous works have shown the effectiveness of BBN as a suppressor signals to activate the MOCS due to its large bandwidth (Kalaiah, Nanchirakal, Kharmawphlang & Noronah, 2017). However, the effects of broadband-like nature sounds and Quranic recitations as suppressor signals to activate the MOCS have yet to be investigated. The current study therefore aims to investigate the effects of nature sounds and Quranic recitation as suppressor signals on the MOCS activation as measured by suppression transient OAE (TEOAE) among children.

**Methods:** 11 normal hearing school-age children (aged between 8-11) participated in this study. TEOAE suppressions were performed in the presence of contralateral BBN, three nature sounds (ocean, rain, and waterfall), and two Quranic recitations (Al-Fatihah and Yasin) at 60 dBA at 1,000, 1,400, 2,000, 2,800, and 4,000 Hz. The subjects' attention states were kept constant by asking them to complete several working memory modules while the TEOAE suppressions were being measured.

**Results:** A large effect size (partial eta squared, $\eta^2 = 0.14$) was found between the TEOAE suppressions obtained at the 5 frequencies, indicating an effect of frequency. Further descriptive analysis showed larger TEOAE suppressions at 1,000 Hz and 1,400 Hz in 4 out of 6 suppressor signals. At 1,000 Hz, all 6 suppressor signals were as effective as one another at triggering the MOCS. At 1,400 Hz, a moderate effect size ($\eta^2 = 0.066$), was observed for TEOAE suppressions obtained using the 6 suppressor signals, indicating that some suppressor signals were moderately more effective than others. The top 3 most effective suppressor signals – Waterfall (2.35 dB $\pm$ 5.23), BBN (2.00 dB $\pm$ 5.22), and Al-Fatihah (1.65 dB $\pm$ 4.86) – were similarly effective in triggering the MOCS (indicated by small effect size, $\eta^2 = 0.016$ for the comparison of TEOAE supression between the three noises).

**Conclusion:** Waterfall sound and Al-Fatihah were as effective as BBN in activating the MOCS, as indicated by the amount of TEOAE suppressions obtained. Our findings suggest that nature sounds as well as Quranic recitations have the potential to be used as suppressor signals in future MOCS studies, as well as the stimulus to be used in sound therapy.

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# Suppression Distortion Product Otoacoustic Emission (Suppression DPOAE) using Various Contralateral Suppressors among Autism Spectrum Disorder Children

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**Keywords:** Autism Spectrum Disorder (ASD), Sensory Gating, Suppression DPOAE

**Background:** Auditory sensory gating deficits is an abnormality in Autism Spectrum Disorder (ASD) patient that leads to sensory processing difficulty. It is particularly difficult for ASD children to discriminate multiple auditory stimuli, which hinders them to focus on one auditory stimulus and separating unnecessary sounds. Suppression DPOAE is a tool used to identify sensory gating deficit in the general population and specifically in ASD children. This paper aims to investigate the suppression effect among ASD children using various types of sounds suppressors in order to address the inability of ASD children in filtering unnecessary information.

**Methods:** A total of 20 children with 10 ASD children and 10 normal developing children aged 6-12 years old will be recruited. The DPOAE is elicited from one accessible ear by presenting two pure tones frequencies (with an f2/f1 ratio of 1.22) at 1kHz, 2kHz, 4kHz, 6kHz. and 8kHz. Meanwhile, suppressor sounds will be presented on another ear. Several types of sounds have been chosen as contralateral suppressor including white noise, environmental sounds, natural sounds, Quranic recitation, and piano sounds. The amount of DPOAE suppression will be determined by identifying the difference between DPOAE amplitude baselines without masker and with the presentation of masker in dB sound pressure level for all sound types.

**Results:** Sound with the highest suppression effect was determined using effect size calculation and RM ANOVA. A high suppression effect may suggest high sensory gating performance while low suppression may indicate low sensory gating performance.

**Conclusion:** This study provides a better understanding of the alternative sound stimuli to assess sensory gating deficit among ASD children besides the standard white noise tone. Sound with a high suppression effect has the potential to be used for sound therapy intervention among ASD children as part of rehabilitation and therapy.

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## Electrophysiological and psychophysical measures of dynamic interaural phase differences

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**Keywords:** Acoustic Change Complex (ACC), frequency modulation, temporal fine structure (TFS)

**Background:** A behavioural test of temporal fine structure (TFS) processing is frequency modulation (FM) detection for low-rate modulators that are out-of-phase across ears. This measure gauges sensitivity to dynamic interaural phase differences (IPDs). The test has been used to gain insights into developmental and ageing effects in TFS processing (Kane et al., 2020). The purpose of this study was to develop an electrophysiological analogue of this test that can provide a parallel objective measure of TFS processing based on the acoustic change complex (ACC) evoked by FM.

**Methods:** Participants were young adults with normal hearing. For behavioural testing, FM detection thresholds were measured using a 3-alternative, forced-choice procedure for rates from 4 – 32 Hz carried by a 500-Hz tone. The sinusoidal modulator was either the same across ears (diotic FM) or was inverted (dichotic FM), resulting in dynamic IPDs. For electrophysiological testing, a 500-Hz tone carried a fixed depth of FM that was behaviorally sub-threshold for diotic FM but supra-threshold for dichotic FM. The carrier tone was steady except for 250-ms segments of FM that occurred pseudo-randomly every 2.5 seconds. The FM during these segments was either diotic or dichotic, and the modulator frequency was randomly selected without replacement from the 5-rate set (4, 8, 16, 24, and 32 Hz); this set was continuously replenished upon exhaustion. A trigger pulse synchronized to the onset of each FM segment provided an event marker that was stamped onto the continuously acquired, single-channel electroencephalogram (EEG). The trigger code was unique to each rate of FM allowing the continuous EEG to be partitioned into epochs associated with each FM rate. EEG recording continued until 220 samples were acquired for each FM rate. After averaging, standard metrics were used to determine the presence and parameters of the averaged P1-N1-P2 ACC complex.

**Results:** The behavioural results showed relatively constant FM detection thresholds across the range 4 – 32 Hz for diotic FM. For dichotic FM, thresholds were better by almost an order of magnitude at 4 Hz but declined with increasing rate. By 32 Hz, dichotic thresholds had converged with diotic thresholds. The electrophysiological results showed a parallel pattern. As expected, no ACC was elicited at any diotic FM rate since the fixed depth of FM was behaviourally sub-threshold. For dichotic FM, however, a robust ACC was elicited by the 4-Hz FM, and there was a systematic reduction in amplitude and increase in latency of the ACC as the rate of FM increased. No ACC was evident for the highest rate of 32 Hz.

**Conclusion:** These results demonstrate that the ACC elicited by dynamic IPDs shows a parallel effect of FM rate as observed behaviourally. This suggests that the electrophysiological measure can provide an objective assessment of TFS processing.

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## The Lateralized Readiness Potential as a measure to resolve functional hearing loss

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**Keywords:** functional hearing loss, Lateralized Readiness Potential, ABR

**Background:** The Lombard sign, the Stenger test and various objective measures have been used to detect nonorganic functional hearing loss. This paper describes two studies that address the applicability of the Lateralized Readiness Potential (LRP) to the clinical situation where patients feign hearing loss. Both involve an audiometric test situation where subjects were instructed to simulate hearing loss by selectively not responding to stimuli. Study 1) investigated whether the LRP could be recorded within a single block of testing, while study 2) investigated the use of low intensity near threshold auditory stimuli as this is relevant to situations where hearing loss is willfully exaggerated.

**Methods:** In both studies subjects were instructed to respond according to the side of stimulation with a key press during Go trials and no response in NoGo trials. In this way responses to the NoGo trials were akin to simulating a hearing loss. In the first study (n=10) we compared responses recorded in a test condition with only Go trials, to one in which an intensity difference in 1000 Hz tones cued responses (Go 79 dB HL; NoGo 73 dB HL). In the second study (n=10) 500 and 4000 Hz tones were used at near-threshold intensities. We also included 4000 Hz tonebursts in order to investigate the possibility of simultaneously recording Auditory Brainstem Responses (ABR). In the first study electroencephalography was recorded with a 32-channel whole head setup (Neuroscan) while in the second study a 16-channel montage (Biosemi) was used with electrodes clustered around C3 and C4 scalp locations.

**Results:** In study 1) group averaged waveforms show that suppressed responses, cued by NoGo stimuli, diverge from the performed Go responses at approximately 300 msec poststimulus. LRPs were comparable when Go responses were recorded in a separate condition in which participants responded to all stimuli, and when Go and NoGo trials were included in the same condition. Study 2) showed that the amplitude of the LRP did not differ between the three stimuli used to elicit the response ($F_{(27)}=0.017$, $p=0.98$). Single-trial electrode data from Go and NoGo trials were submitted to supervised binary classification and a logistic regression model gave a mean accuracy of close to 0.7. The Jewett wave V latencies of the resultant ABRs from some subjects were observed to increase between the high (Go) and low (NoGo) intensity tonebursts.

**Conclusion:** These results show that recording within a single testing block with stimuli that is near auditory threshold has a negligible influence on the LRP. Furthermore, auditory stimulus frequency (500, 1000 and 4000 Hz) and type (continuous and transient) have little effect on the amplitude of the LRP. It can also be recorded with transient stimuli which means that it is possible to simultaneously record other confirmatory measures, like ABR. Given these attributes of the response, the LRP may be a useful addition to the battery of tests that investigate suspected nonorganic hearing loss.

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## Ear-specific hemispheric asymmetry in unilateral deafness revealed by auditory cortical activity

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**Keywords:** Unilateral deafness, hemispheric asymmetry, auditory spatial processing

**Background:** Unilateral deafness reduces the ability to localize sounds achieved via binaural hearing. Furthermore, unilateral deafness promotes a substantial change in cortical processing to binaural stimulation, thereby leading to reorganization over the whole brain. Although distinct patterns in the hemispheric laterality depending on the side and duration of deafness have been suggested, the neurological mechanisms underlying the difference in relation to behavioral performance when detecting spatially varied cues remain unknown.

**Methods:** To elucidate the mechanism, we compared N1/P2 auditory cortical activities and the pattern of hemispheric asymmetry of normal hearing, unilaterally deaf, and simulated acute unilateral hearing loss groups while passively listening to speech sounds delivered from different azimuth angles including +60, +15, 0, -15, and -60. The behavioral performances of the participants concerning sound localization were measured by detecting sound sources in the azimuth plane. The spatial, speech, and quality of hearing questionnaire were also obtained from unilaterally deaf patients.

**Results:** The results reveal a delayed reaction time in the right-sided unilaterally deaf group for the sound localization task and prolonged P2 latency compared to the left-sided unilaterally deaf group. Moreover, the right-sided unilaterally deaf group showed more extensive cortical reorganization evidenced by increased responses in the hemisphere ipsilateral to the intact ear for individuals with better sound localization whereas left-sided unilateral deafness caused contralateral dominance in activity from the hearing ear. The brain dynamics of right-sided unilateral deafness indicate greater capability of adaptive change to compensate for impairment in spatial hearing. In addition, cortical N1 activities in unilateral deaf people were inversely related to the duration of deafness in the area encompassing the right auditory cortex, indicating that early intervention would be needed to protect from maladaptation of the central auditory system following unilateral deafness.

**Conclusion:** In summary, we provided new information that right-sided unilateral deafness incurs greater deafness-driven reorganization compared to left-sided unilateral deafness, as evidenced by stronger activity ipsilateral to the hearing ear. This notion is further supported by the finding that contralateral hemispheric lateralization of RUD people shifts toward the ipsilateral hemisphere with better behavioral localization and perception, suggesting that neural adaptive changes strengthen the ipsilateral auditory pathway to compensate for decreased spatial sensitivity. In addition, simulated acute unilateral hearing loss decreased the behavioral localization accuracy as well as the normal contralateral dominance for spatial processing. Finally, neuroplasticity in the auditory cortex of UD adults is more prominent in people with a longer duration of monaural deprivation, indicating that early intervention for unilateral deafness may change the degree of unilaterally driven reorganization that is closely linked to the spatial sensitivity for sound localization.

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## Pre-stimulus baseline differences in Active and Passive listening

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**Keywords:** Pre-stimulus, Attention, CAEP

**Background:** The effects of attention on Cortical Auditory Evoked Potentials (CAEPs) have commonly been reported as an increase in component amplitudes or earlier component latencies. However, these metrics do not provide information regarding the 'preparedness' of the auditory system when an individual is attending to an auditory stimulus. Such preparedness can be uncovered by exploring the differences in the 'pre-stimulus' baselines of the CAEPs. Previous studies have shown differences in the brainwave activity (particularly alpha wave) as indices of attention-related preparedness. However, the strength (amplitudes) of the pre-stimulus EEG activity has been largely unexplored.

**Methods:** In the current study we compared the RMS amplitude in the pre-stimulus time regions while participants were either actively attending to the auditory stimuli or ignoring it. CAEPs were recorded in 26 participants in response to a bisyllabic word in the Kannada language, 'gadi', using a 256-channel EGI equipment. The stimuli were presented binaurally and the EEG was recorded in two attention conditions – active and passive. While the participants simply watched a muted video during the passive condition, they were instructed to press appropriate buttons during the active condition, they. The raw EEG of both active and passive attention for each participant was pre-processed offline to remove bad channels, segments and components, and was epoched between -1000 ms and 2000 ms with reference to the stimulus onset. The RMS amplitude of the pre-stimulus (-1000 to 0 ms) time region was estimated for each participant for the 'Cz region of interest' as well as the GFP.

**Results:** Paired t-tests showed that the RMS amplitudes for both Cz ROI and the GFP were significantly higher ($p < 0.01$) for the active attention condition compared to the passive condition. Additionally, mean topographic plot of the pre-stimulus time showed a strong positivity in the central (around Cz ROI) for the active attention condition, which was not observed for the passive attention condition. Further, paired t-tests also showed that the N1 peak amplitudes for the active condition were significantly greater than those observed in the passive attention condition.

**Conclusion:** Previous research (Barry et al., 2000) has suggested that increased pre-stimulus alpha activity was strongly associated with amplitude of the ERP components. The results of our study further enhance this observation by showing that the EEG activity prior to the stimulus onset was higher for the active attention condition. This is likely a 'preparedness' response by the cortex in anticipation of the auditory stimulus. Higher baseline activity could indicate better preparedness and higher sensitivity for the approaching stimulus. The higher baseline activity could be comparable to an anticipatory increase in the activity as observed in CNV.

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# Revisiting Dichotic Listening Paradigm using Event Related Potential - A Neuropsychophysiological study

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**Keywords**: Dichotic listening, Ear Advantage, Learning Disability

**Introduction:** Dichotic listening is an experimental paradigm where two different stimuli are presented to the right and left ear simultaneously. DL has been using in assessing auditory processing deficits and lateralisation defects in children with developmental deficits like learning disability. Evoked potentials are electrical signals generated by the nervous system in response to a stimulus. There are very few studies in the literature that have explored the neurodynamics of dichotic listening using passive electrophysiological paradigm. Preliminary evidence suggests that, for speech stimuli, in free recall condition, N1 component of LLR have shown left hemispheric dominance. However such neurophysiological changes have not been established for forced recall condition. Further modulation of LLR in dichotic listening for all the three condition has not been established in children with learning disability. Hence the main aim of the study is to compare both behavioural and electrophysiological correlates of DL in healthy children and children with learning disability.

**Method:** The study was carried out at the Department of Speech & Hearing, Manipal College of Health Professions, Manipal. The study recruited 25 healthy right handed children (10-15 yrs) and 18 children with learning disability (10-15 yrs). The traditional behavioural dichotic digit test – Kannada (Bhat et al 2020) was administered on all the participants in free and forced recall condition. A novel dichotic neuropsychophysiological paradigm was developed which would simultaneously record both behavioural and electrophysiological measures, using three Kannada numbers (6, 3 and 7). The validity of the behavioural scores for the novel was established in normal adults by comparing the normalised ear scores with the gold standard dichotic digit test. The novel test was administered in free recall (Perceptual asymmetry), forced right (Attention process) and forced left condition (Executive function). Cortical auditory evoked potentials were recorded using Brain vision 32 channels ERP recording system. Brain Electrical Source Analysis software was used to analyse ERP waveforms. The ear scores for both traditional and novel test and the electrophysiological measures (Latency and amplitude) of N1 and P2 components obtained from all the three condition were statistically analysed to establish the group difference.

**Result:** Behavioural findings indicated a significant group difference between healthy children and children with learning disability in both traditional and novel test, where LD children showed consistently poor scores than controls in all the three condition. Moreover, healthy children showed a significant right ear advantage in free recall condition whereas LD children failed to show any ear advantage. Similar correlates were obtained for CAEPs where the left hemispheric dominance (indicated shorter N1 latency and larger N1 amplitude) exhibited by normal children were not seen in children with learning disability. Moreover there was a significant interaction effect between condition and group where the modulation of P2 as a function of attention where only seen in normal children.

**Conclusion:** The current study established the use of both behavioural and electrophysiological correlates of dichotic listing test in identifying both top down and bottom up deficits in children with learning disability. This combination of tests could be a valuable asset in diagnosing children with LD if the findings are established on larger population.

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# Determining frequency and spectral ripple discrimination thresholds using the auditory change complex: a comparison with psychophysical discrimination

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**Keywords:** ACC, auditory discrimination threshold, frequency, spectral ripples

**Background:** It is well known that auditory discrimination is necessary for understanding speech. Frequency and spectral ripple discrimination have both been shown to correlate with speech understanding. To date, discriminatory capacities are often investigated using psychophysical methods. Obtaining data using these methods is not always possible in e.g. infants. In this study, the auditory change complex (ACC) is applied as an objective measure to assess the relationship between psychophysical and electrophysiological frequency and spectral ripple discrimination thresholds. The ultimate goal is to use these stimuli to obtain (e)ACCs for use as a predictor of speech and/or signal processing.

**Methods:** Ten normal hearing subjects and CI patients participated in this study. To assess psychophysical frequency and spectral ripple discrimination thresholds, a single-interval paradigm was used (Won et al., 2011). Psychometric curves were fitted to determine thresholds. Besides psychophysical (behavioral) frequency resolution thresholds (pFDT), also electrophysiological (objective) frequency resolution thresholds (eFDT), obtained by (e)ACCs, were determined in the sound field. The same was determined for spectral ripple discrimination thresholds. Normalized N1P2 (P-P) amplitudes of the ACC were calculated. Stimuli were exactly same for both psychophysical and electrophysiological experiments: a stimulus of 1000 Hz was used as reference tone with varying acoustic changes of 0.2 to 10% ($f_{base}+\Delta f$) 600 ms after onset (total duration of 1240 ms). For spectral ripples discrimination of phase inversions were tested for varying densities from 0.25 to 11.314 ripples/octave. Absolute auditory psychophysical and electrophysiological discrimination thresholds and correlations are analyzed.

**Results & (preliminary) conclusions:** Preliminary data show that it is feasible to use (e)ACC in normal hearing subjects and CI users. Until now, results show (NB. data acquisition is still running due to COVID19 postponement at moment of abstract submission) a promising relation between subjective and objective variables of (e)ACC. Most recent outcomes will be addressed.

The use of frequency and spectral ripple discrimination paradigms using the (e)ACC would warrant further research in difficult to test patients. Near future clinical relevance lies in possible application of (e)ACC to investigate auditory discrimination in pediatric CI users.

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## The P300 auditory evoked potential: an objective measurement of listening effort?

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**Keywords:** P300, listening effort

**Background:** Listening effort is defined as the attentional and cognitive effort to understand speech [1, 2]. Subjective, behavioural, and objective measurements of listening effort have been reported, though only weak correlations between these measurements were found. Hence, it was suggested that each measurement might evaluate different aspects of listening effort, supporting the argument that listening effort involves multiple dimensions [3]. To establish the underlying dimensions of these listening effort measurements, it was suggested to first investigate whether each individual measurement, such as objectively measured listening effort, systematically change according to listening demands [3]. Therefore, this study aimed to examine the effect of diverse listening conditions on the P300 as objective listening effort measurement.

**Methods:** Twenty young-adults (mean age: 24.65 y) and twenty older-adults (mean age: 58.90 y) with age-appropriate hearing were included. The P300 was recorded at Fz, Cz, and Pz referenced to the nose using an oddball paradigm with the Flemish monosyllabic digits one and three as frequent and infrequent stimuli, respectively. This oddball paradigm was conducted in three listening conditions: (1) quiet, (2) a favourable noise condition at +4 dB SNR, and (3) an unfavourable noise condition at -2 dB SNR. The P300 was only evaluated for trials in which the infrequent stimulus was correctly identified. To assess possible differences between listening conditions, a repeated-measures 3 (quiet, favorable and unfavorable noise condition) x 3 (amplitude, absolute latency, and interpeak latency) analysis of variance (ANOVA) was conducted for each channel.

**Results:** Preliminary descriptive results on P300 latency revealed an increase in absolute latency with increasing task difficulty. Further, ANOVA analyses will investigate changes in P300 amplitude, absolute latency, and interpeak latency related to task difficulty. All of these results will be presented during IERASG 2021.

**Conclusion:** It is hypothesized that the P300 amplitude, absolute, and interpeak latency will increase with increasing task difficulty, suggesting that these changes might reflect objectively measured listening effort.

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## A proposal of phonological auditory electrophysiological hearing assessment

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**Keywords:** Event-Related Potential; N400; Dyslexia.

**Background:** The Specific Reading Disorder is a disorder that covers the areas involved in learning, among them, mainly, reading and writing and also, another very important aspect, the discrimination of sounds. Children with Specific Reading Disorder have a deficit due to a deficiency in the processing of speech sounds and therefore have difficulties regarding discrimination, memory and auditory perception, aspects directly linked to auditory processing. Auditory discrimination is responsible for grouping sounds according to similarity or difference, auditory memory is responsible for storing or retrieving auditory information, while auditory perception is responsible for receiving and interpreting the combined sounds and the perception of words. ). The LLAEP records the electrical cortical activities that occur in the face of acoustic stimuli during this processing. These potentials are directly linked to higher cortical functions such as brain attention to sound, auditory discrimination, immediate memory and decision making and reasoning intrinsic to cognition. N400, object of study of this research, is a response of the neuroelectric activity given in a negative deflection that has the formation of its peak around 400 ms after the beginning of the stimulus This component is related to the auditory-linguistic integration of a word within a semantic context. propose a new form of phonological auditory electrophysiological assessment to investigate the late neural component N400 of PRE in adults and children, with and without dyslexia using a technological tool.

**Methods:** The study was developed in 2 phases, the first step being the scientific elaboration and technical creation of a mobile APP to carry out two tasks: Congruent and Incongruent in phonological aspects, the second phase was the performance of the auditory-linguistic task by means of frequent (/ba/) and rare (/da/) acoustic stimulus and co-occurrence with the syntactic-semantic linguistic task generated in the APP. In the first stage, a bibliographic survey of the list of words and not words was carried out and the list was elaborated, and then the mobile application associated with reading, phonological integration of the sound, letter-sound relationship and access to lexical memory. This phase includes the data collection stage. The study was divided into three groups. The Study Group: (EG): was composed of 10 students from 9 years to 10 years and 11 months, of both sexes, with an interdisciplinary diagnosis of dyslexia. The Child Control Group: (GC-i) composed of 5 students without an interdisciplinary diagnosis of dyslexia, from 9 years to 10 years and 11 months, of both sexes. The Adult Control Group: (GC-a) composed of 10 adults, of both sexes, from 20 years to 24 years and 2 months, with no diagnosis of any learning disorder. All subjects were submitted to the application and registration of potentials related to an event with binaural stimulation in an oddball paradigm, concomitant to the accomplishment of the congruent and incongruous tasks presented in the APP. The wave peaks and potential latency related to the N400 event were analyzed from the results obtained using the Biologic's Evoked Potential System (EP) equipment in two moments: during the congruent task and, in the other moment, during the incongruous task.

**Results:** Regarding latency, the results showed a significant difference between the average of the GE and GC-a groups for the incongruous task. The GE presented increased latency in relation to the GC-a for the same task. The results referring to latency also showed that only the GC-a showed a significant difference between factors, the incongruence factor showed a decrease in latency. Regarding the amplitude, there was a significant difference only between the congruence and incongruence factors for the GC-a, where an increase in amplitude was observed in the incongruous task.

**Conclusion:** The APP with the semantic, congruent and incongruous syntactic task was able to elicit and highlight the event-related potential **-** N400 in the three groups. It was also possible to observe that N400 was generated with a shorter latency in the adult group compared to dyslexic children and with normal development. Such findings can be explained by his superior ability to distinguish linguistic tasks and perform them more easily due to his greater experience of language and maturation of the nervous system.

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## Study of Long Latency Auditory Evoked Potentials in children with reading and writing disorders: Speech and Tone Burst stimulus

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**Keywords:** auditory evoked potentials, electrophysiology, children, learning

**Background:** Reading and writing disorders (RWD) are characterized by difficulties in the acquisition and/or development of written language by children who have deficits both in phonological decoding and in understanding oral and/or written language. Studies show that children with RWD may be delayed in the development of auditory skills, preventing the adequate processing of information. This study had like objective to investigate the central auditory pathway of children with RWD through the components P2, N2 and P300 of the Long Latency Auditory Evoked Potential (LLAEP) with Tone Burst and Speech stimulus, comparing with a control group.

**Methods:** In this study, 20 children with RWD (study group - SG), aged between 8 and 11 years, and 20 children with typical development (control group - CG), matched by gender and age, were evaluated. All children underwent basic audiological evaluation, the LLAEP, using an odd-ball task, with Tone Burst (1KHz for the frequent stimulus and 2KHz for the rare) and with Speech (with the syllable /ba/ for the frequent stimulus and /da/ to the rare) and reading and writing assessment tests (Written Narrative Dicourse and Dictation of words and pseudo-words). In addition, all children underwent neuropsychological assessment using the Wechsler Intelligence Scale for Children 4th Edition - WISC-IV to measure the intellectual quotient (IQ). All individuals had an IQ above 80 and a normal level of verbal comprehension.

**Results:** The mean latency values of P2, N2 and P300 for the Tone Burst were greater in the SG than in the CG, but no statistically significant differences were found in the comparison between them. For the Speech stimulus, statistically significant differences were found between SG and CG only for P300 ($p = 0.040$). A significant difference was found for the mean amplitude values of N2-P300 between the SG and CG ($p = 0.042$), but it was not found for the P2-N2 with Tone Burst stimulus. For Speech stimulus, were found of statistical difference between SG and CG for the N2-P300 amplitude values.

**Conclusion:** In the analysis of the P2, N2 and P300 components among children with RWD (SG) and children with typical development (CG), it was found that the P300 component, both for the analysis of latency and amplitude, proved to be efficient in the identification of children with RWD. Furthermore, children with RWD had worse responses to the Speech stimulus than with the Tone Burst stimulus. The study agrees with the presence of possible changes in the perception of auditory information in children with RWD and suggests the possibility of using P300 for early identification and therapeutic monitoring.

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## Hearing loss is associated with delayed neural responses to continuous speech

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**Keywords:** Neural tracking, hearing loss, speech processing

**Background:** Even with hearing aids, hearing impaired persons still experience speech understanding difficulties in noisy environments. In this study, we investigate the differences in neural responses to continuous speech between normal hearing and hearing impaired participants.

**Methods:** We investigated the impact of hearing loss on the neural processing of speech. All participants listened to a story presented in silence and a story presented in 5 different levels of background speech-weighted noise. Using a forward modelling approach, we compared the neural responses to continuous speech of 14 adults with sensorineural hearing loss with those of age-matched normal-hearing peers.

**Results:** Compared to their normal-hearing peers, hearing-impaired listeners had increased neural tracking and delayed neural responses to continuous speech in quiet. The latency also increased with the degree of hearing loss. As speech understanding decreased, neural tracking decreased in both population; however, a significantly different trend was observed for the latency of the neural responses. For normal-hearing listeners, the latency increased with increasing background noise level. However, for hearing-impaired listeners, this increase was not observed.

Our results support the idea that the neural response latency indicates the efficiency of neural speech processing. Hearing-impaired listeners process speech in silence less efficiently than normal-hearing listeners. Our results suggest that this reduction in neural speech processing efficiency is a gradual effect which occurs as hearing deteriorates. Moreover, the efficiency of neural speech processing in hearing-impaired listeners is already at its lowest level when listening to speech in quiet, while normal-hearing listeners show a further decrease in efficiency when the noise level increases.

**Conclusion:** From our results, it is apparent that sound amplification does not solve hearing loss. Even when intelligibility is apparently perfect, hearing-impaired listeners process speech less efficiently.

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# The effects of extended silent pauses between words in continuous speech stimulus on cortical responses

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**Keywords:** Cortical responses, Continuous speech, Stimulus reconstruction, EEG

**Background:** Cortical responses to continuous speech can be examined using a stimulus reconstruction approach, or the decoding model (Crosse *et al.*, 2016). This is an inverse problem, where the model attempts to reconstruct the speech envelope using the recorded electroencephalogram (EEG). Stronger correlation between the reconstructed and actual speech envelope implies stronger responses. However, since evoked responses are stronger following sound onset than for ongoing stimuli (Wang *et al.*, 2005; Hamilton, Edwards and Chang, 2018), and also increase when interstimulus-intervals in periodic stimuli (e.g. tone pips) are longer (Davis *et al.*, 1966). Onsets following pauses in continuous speech may therefore enhance speech evoked responses.

Motivated by these studies, the objectives of the current work are to test if an increase in the duration of pauses between words in the continuous speech stimulus increases the correlation between the reconstructed and actual envelope.

**Methods:** In this study, we modified a speech stimulus by inserting short (0.25 seconds) and long (0.5 seconds) silent pauses between each word. Participants listened to stimuli under three conditions: normal speech, speech containing extended short silent pauses, and long silent pauses between words. EEG and speech envelopes were filtered and decoded in the delta (1 – 4 Hz) and theta (4 – 8 Hz) frequency bands. In addition, we segmented the modified speech envelopes to focus analysis on the onset and non-onset segments following each pause to investigate how different segment of speech contributes to the stimulus reconstruction.

**Results:** speech envelope reconstruction improves (correlation increases from 0.092 to 0.243 in the delta band ($p \leq 0.001$), and 0.063 to 0.103 in the theta band ($p \leq 0.001$)) when participants listened to speech stimuli with extended pauses. Correlation between the reconstructed and actual speech envelope is lowest when participants listened to normal speech, and highest when listened to speech added with long silent pauses. The stimulus envelope reconstruction was found to be dominated by the onset segments of the envelope rather than the non-onset segments.

**Conclusion:** Our findings are further evidence that evoked responses to continuous speech are strongly influenced by acoustic onsets (Hamilton, Edwards and Chang, 2018; Howard and Poeppel, 2010). Extended pauses in speech may provide more time for the auditory cortex to recover and generate stronger onset responses after each word (Davis et al., 1966). The continuous speech stimulus with extended silent pauses between words could provide a potential clinical benefit in improving the detection of cortical responses to speech.

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## Dichotic listening deficits in amblyaudia are characterized by aberrant neural oscillations in auditory cortex

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**Keywords:** Auditory processing disorders (APD); event-related brain potentials (ERPs); gamma/beta band response; hemispheric asymmetries; phase-locking; time-frequency analysis

**Background**: Children diagnosed with auditory processing disorder (APD) show deficits in processing complex sounds that are associated with difficulties in higher-order language, learning, cognitive, and communicative functions. Amblyaudia (AMB) is a subcategory of APD characterized by abnormally large ear asymmetries in dichotic listening tasks.

**Method**: Here, we examined frequency-specific neural oscillations and functional connectivity via electroencephalography (EEG) in children with and without AMB during passive listening of nonspeech stimuli.

**Result**: Inter-trial phase-locking (ITPL) maps of these "brain rhythms" revealed stronger phase-locked beta-gamma (~35 Hz) oscillations in AMB participants within bilateral auditory cortex for sounds presented to the right ear, suggesting a hypersynchronization and imbalance of auditory neural activity. Brain-behavior correlations revealed neural asymmetries in cortical responses predicted the larger than normal right-ear advantage seen in participants with AMB. Additionally, we found weaker functional connectivity in the AMB group from right to left auditory cortex, despite their stronger neural responses overall. Our results reveal abnormally large auditory sensory encoding and an imbalance in communication between cerebral hemispheres (ipsi- to -contralateral signaling) in AMB.

**Conclusion**: These neurophysiological changes might lead to the functionally poorer behavioral capacity to integrate information between the two ears in children with AMB.

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# The spectral shape of stimuli, using for aided free field ASSR: real ear measurements

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**Keywords:** ASSR, free field stimulation, hearing aids.

**Background:** ASSR (Auditory Steady-State Response) - an objective hearing diagnostics method, based on the registration of auditory evoked potentials in response to modulated stimuli with their automatic analysis. The main benefit of this method is the frequency specificity, which increases its importance in pediatric audiology. The interest to electrophysiological methods has increased recent years because of necessity for the objective evaluation of amplification outcomes in infants and children with additional disabilities. Methods of aided ASSR registering in the free field were particularly proposed. For increasing the sensitivity of such methods it's important to get information about the spectral shape of ASSR stimuli, their changes in open ear and after hearing aid (HA) processing.

**Methods:** In present study we evaluated modulated tones with the 40 Hz modulation frequency. For 0.5 kHz carrier frequency we choose the exponential modulation ($AM^2$), for 1 kHz - $AM^2$ and frequency-specific Chirp, for 2 kHz and 4 kHz - frequency-specific Chirp. Stimulus intensity in free field was 55 dB HL. Stimulation was provided using "Neuro-Audio" system, real ear measurements - using Interacoustics Affinity 2.0 system. Three steps of measurements were performed:
1. Measurement of the source signal in the referent point of free field.
2. Open ear measurements were performed for children between 1 and 7 ages.
3. Measurements of stimuli after HA processing. Three HA fitting modes were evaluated: *a*) WDRC, digital noise reduction is switch off; *b*) linear gain, digital noise reduction is switch off; *c*) WDRC, digital noise reduction is switch on. Omnidirectional microphone mode had been selected in each case.

**Results:** 1. Measurements in the free field. $AM^2$-stimuli characterized by narrow shape and the sharp peak, which was accurately appropriate to the career frequency. Chirp tones had more wide shape, and there was a plato or slight rising to the higher frequencies at the most amplitude region. The central part of plato (or rising) was centered at the career frequency. 2. Open ear measurements. Observed changes were typical for all children. For the 0.5 kHz - peak movement to 0.6 Hz without the shape changing. For 1 kHz - 5 dB amplitude increasing ($AM^2$) and 3 dB decreasing (Chirp). For 2 kHz - peak movement to 2,4 kHz, its' sharpening and 3 dB amplitude increasing. There weren't significant changes of stimulus at 4 kHz. 3. Measurements after HA processing. Changes for 0.5 kHz: the same amplitude in *a* and *b* modes, 6 dB less in *c* mode; the least noise amplitude was in *b* mode ($p<0,05$). Changes for 1 kHz ($AM^2$): difference in peak amplitude didn't exceed 2 dB between modes; less noise amplitude was in *a* and *b* modes ($p>0,05$). Changes for 1 kHz (Chirp): difference in peak amplitude didn't exceed 2 dB between modes; the least noise amplitude was in *b* mode ($p>0,05$). Changes for 2 kHz: difference in peak amplitude didn't exceed 3 dB between modes; the least noise amplitude was in *b* mode ($p<0,05$). Changes for 4 kHz: the same peak amplitude in *a* and *b* modes and 4 dB less in *c* mode; the less noise amplitude in *a* mode ($p>0,05$).

**Conclusion:** Stimuli used during free field ASSR tend to be changed in the child's ear canal. The optimal HA parameters during free-field ASSR recording with mentioned stimuli are: switched off noise reduction, linear gain at 500, 1000 and 2000 Hz, WDRC at 4000 Hz. These parameters allow to avoid reduction of amplitude of stimuli at career frequency and decrease amplitude at non-testing frequency region.

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## Measuring electrically evoked Mismatch Negativity in cochlear implant users

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**Keywords:** Electrically evoked Mismatch Negativity **(**eMMN), Cortical Potentials, Cochlear implant (CI) users, pitch, loudness

**Background:** Mismatch Negativity (MMN) can be elicited in normal-hearing listeners and cochlear implant (CI) users due to changes in the auditory stimulation. In CI users, electrically evoked MMN (eMMN) has been recorded as a response to a change of the electrode configuration and the stimulation length (Ponton and Don 1995; Wable et al. 2000). Eliciting an MMN using two adjacent electrodes (pitch cue) and a change in the stimulation amplitude (loudness cue) would potentially be applicable as an objective measure for the performance of CI users. Therefore, it might be suitable to optimize the fitting procedure, especially for non-cooperative patients like children or mentally handicapped persons.

**Methods:** In this work, MMN was electrically evoked in users of a MI1200 CI electrode (Med-El, Innsbruck, Austria). In an oddball paradigm the stimulation electrode and the stimulation amplitude were changed. Particularly, the electrode pairs (3, 4) and (9, 10) as well as two stimulation amplitudes (most-comfortable level (MCL), MCL minus 50 % dynamic range) for electrode 6 were presented as standard and deviant conditions (and vice versa). The stimulation sequence was generated using the Psyworks 5 software (Med-El, Innsbruck, Austria) and presented via the telemetry coil, that received the sequence from the max programming interface (Med-El, Innsbruck, Austria). EEG was recorded between the vertex (active electrode) and referenced to the linked mastoids, where the ground electrode was positioned on the forehead. After baseline-correction and bandpass-filtering, the MMN amplitudes and latencies were averaged for standard and deviant epoch combinations. During the measurement, the patients were seated in an armchair in a sound- and electrically insulated room and were instructed to not pay attention to the stimuli during watching a silent movie. The speech perception was evaluated using the Freiburg monosyllable word test.

**Results:** The preliminary results for 15 patients will be presented. MMN amplitudes and latencies will be reported and discussed.

**Outlook:** We expect a dependence of the MMN presence, amplitudes, and latencies on the varied stimulation parameters. Therefore, we propose that the elicitation of an MMN by adjacent electrodes and a difference in the stimulation amplitude can reflect the pitch and loudness discrimination abilities of the CI users and by this it might contribute to optimizing the fitting procedure.

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# Benefits of the hearing aid associated with musical auditory training in elderly with presbycusis

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**Keywords:** Auditory Evoked Potentials. Hearing Aids. Presbycusis/rehabilitation

**Background:** Hearing deprivation in the elderly has a fundamental impact on the organization and functioning of the auditory cortex, influencing neural reorganization and functional deficits, such as the difficulty of speech recognition in noise. Musical Auditory Training was developed as a new proposal for auditory training aimed at stimulating the central auditory skills of elderly hearing aid users. However, understanding the effects of this training on the central hearing mechanisms that interfere with hearing adaptation and rehabilitation processes in the elderly is still a challenge. Objective: To analyze the effectiveness of Musical Auditory Training associated with the adaptation of hearing aids to elderly with presbycusis.

**Methods:** Single-blind randomized clinical trial, approved by the research ethics committee under number 02848918.2.0000.5406. Eight elderly people, new users of hearing aids, aged between 65 and 80 years, participated in the study, divided into two groups: Hearing Aid Group: which only used hearing aids; and Auditory Training Group: use of hearing aids and musical auditory training. The trainning consisted of 30-minute 16 sessions with the objective of working on the auditory temporal processing skills (resolution and temporal ordering), localization, auditory closure and selective attention. The training could be accessed online, with versions in Portuguese and English. All participants performed the cortical auditory evoked potential tests with verbal stimulus and HHIE-S Handicap Inventory for the Elderly – Screening version self-assessment questionnaire. The tests were carried out in two moments: Initial assessment, carried out before the adaptation of hearing aids and auditory training; and after three months, final assessment at the end of auditory training. All participants were adapted bilaterally, with mini retroauricular hearing aids, from the same manufacturer and with the same digital signal processing and NAL-NL2 method, with open adaptation, adjusted according to their individual audiograms. Descriptive analysis was performed (mean and standard deviation) and mixed ANOVA of repeated measures was performed to analyze the main effect of the group and time, and the interaction between them.

**Results:** The groups were homogeneous, considering the variables age, sex, education, time of hearing deprivation and average hours of hearing aid daily use. For the electrophysiological test, there was a significant decrease in the latency of the P3a component in the Auditory Training Group when comparing initial and final assessements. For the HHIE-S questionnaire, there was a statistically significant difference for the total and subtotal social score for the Auditory Training Group when comparing the initial and final assessments. When using the classification regarding the perception of handicap, we have that the two groups evolved from light / moderate perception of the handicap to without perception of the handicap.

**Conclusion:** Musical Auditory Training associated with the use of hearing aids is a innovate methodology that promove benefits for the ederly with presbycusis wich proved to be effective hearing heabilitation by generating neural changes, evidenced by the decrease in P3a, and reduction of the hearing loss impact in the restriction of daily living activities for the elderly with presbycusis.

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## Açaí's Effect on Long Latency Auditory Evoked Potential

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**Keywords:** Antioxidant; Communication; Auditory Evoked Potential.

**Background:** Açaí (Euterpe oleracea), composed of anthocyanins and antioxidants, has an inhibitory effect on oxidation processes generated by free radicals and oxidative stress [1]. Scientific evidences (2,3) demonstrates the benefits of the fruit on the human physiological system. Thus, they suggest that the antioxidant effects of açaí are also able of influencing the processing of auditory information. The Long Latency Evoked Potential assesses the functioning of the central auditory pathway at the level of the cerebral cortex, its response occurs in response to a cognitive task requiring involvement in the discrimination of target sounds [4.]

**Methods:** The study was approved by the Comitê de Ética e Pesquisa (CEP) nº 3.417.226. Twenty female individuals between 18 and 30 years of age were selected who did not present attentional, neurological problems and audiometric thresholds within the normal range. The procedures were carried out in the same laboratory, in two days with an interval of seven days between measurements, through a randomized process controlled by a third researcher in which he was responsible for the delivery and content of the capsules (açaí or placebo) denominating them as intervention. and placebo. The responsible researcher and the volunteers were not aware of the contents of the capsules, in which were delivered by the third researcher and should be ingested after the first registration of the LLAEP. The LLAEP examination took place before and after thirty minutes of capsule ingestion. Biologic's Evoked Potential System equipment with 2 channels was used, ground electrode positioned in Fpz, active electrodes: Fz and Cz and reference electrodes: A1 / A2; followed the following parameters: tone burst stimulus with 20 ms plateau and 5 ms rise / fall, at 70 dB of intensity, presented in a binaural way, presentation rate 0.9 stimuli / second, alternating polarity, filter between 1-30 Hz, and sampling of 200 stimuli (80% frequent at 1000Hz and 20% rare at 2000Hz), recorded in a 500 ms window. Participants were instructed to remain alert to identify rare stimuli and name it "fine". On the second day the same procedures were performed, however, the third researcher checked the protocol applied previously and the capsule not ingested on the first day for application of the new protocol. For statistical analysis, the latencies and amplitudes of the components of the long latency potential were compared before and after ingestion of the capsules; normality test, descriptive statistics and T test ($p <0.05$).

**Results:** There was a significant difference between the measures of amplitude of the P2 component that increased after ingestion of the capsule in the açaí protocol, which did not occur in the placebo group. Averages of latency and amplitude values, respectively, before and after ingestion of the açaí capsule: P1 (52,93; 50,06) (1,60; 1,56); N1 (90,46; 93,63) (- 2,87; -2,57); P2 (152,72; 155,05) (4,68; 5,54); N2 (223,41; 225,10) (-2,93; -2,62 ); P3 (276,25; 269,36) (3,30; 3,12).

**Conclusion:** The ingestion of açaí produced changes in the auditory evoked potential and confirmed the benefits of the fruit in the functioning of the central auditory function and in the processing of auditory information.

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## Spatial Release from Masking Represented in Cortical Auditory Evoked Potentials

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**Keywords:** CAEP, speech in noise, spatial release from masking

**Background:** It has been well established that spatially separating speech from competing noise improves detection and discrimination of the speech. To date, there has been little investigation to reveal potential neurophysiological correlates to this perceptually observed effect of spatial release from masking (SRM). This question holds theoretical relevance, as it would deepen our knowledge of the neurophysiological mechanisms of binaural processing of speech in noise. This also holds clinical relevance as the results could lead to objective measures of SRM benefit, which could be used as a tool in measuring benefit of therapies such as hearing aid use and auditory training.

**Methods:** The effect of SRM within the auditory cortex was investigated using cortical auditory evoked potentials (CAEPs). Twenty-seven normal hearing adults between 20 and 36 years of age were tested. CAEPs in response to consonant-vowel tokens (/ta/, /da/ or /di/) in the presence of a 10-talker babble (all delivered in sound field) were recorded. A fixed level paradigm was used: tokens were presented at 60 dB SL (re: token threshold in quiet) at 0° azimuth and the babble was presented at 2 different SNRs (+10 and 0), either co-located at 0° azimuth or spatially separated at +90° azimuth. Latencies and amplitudes of P1, N1, and P2 were compared across co-located (Co) and spatially separated (R) conditions, and an overall SRM effect was calculated for each CAEP component by calculating the percent change from Co to R.

**Results:** CAEP component latencies and amplitudes demonstrated systematic shifts as a function of noise location; spatially separating the babble from the token resulted in decreased latencies and increased amplitudes of the P1-N1-P2 response components. In +10 dB SNR, N1 and P2 latencies decreased and N1P2 amplitudes increased as the babble was spatially separated. Similar results were found for 0 dB SNR, with the addition of a decreased P1 latency with spatial separation of the babble. The magnitude of change in CAEPs between co-located and spatially separated conditions were similar between the two SNR conditions except for P1 latency showing a larger SRM effect in 0 dB SNR.

**Conclusion:** The data strongly suggest that the effects of spatial release from masking are represented in the auditory cortex through CAEP components P1, N1, and P2. With spatially separating the babble +90° from the token, CAEP component latencies and amplitudes decreased and increased, respectively. While most SRM benefit was seen in the N1 and P2 components, a more difficult SNR led to an observed SRM effect at P1 as well. This study has shown a cortical representation of how the central auditory system squelches background noise using binaural cues (i.e., interaural level and timing differences), and has provided a baseline for future work in this area as well as a promising start for an objective measure of SRM benefit.

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## A digit-based behavioral and electrophysiological test battery for assessing different speech processing abilities

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**Objectives:** Effective communication requires good speech perception abilities. Speech perception can be assessed with behavioral and electrophysiological methods. Relating these two types of measurements to each other can provide insights into the underlying cortical processes. The current study aimed (1) to develop a digit-based test battery suited for eliciting different speech-evoked cortical responses, and (2) to relate the speech-evoked cortical responses to behavioral measures of speech detection, discrimination, and comprehension.

**Design:** Thirty young normal-hearing native Danish speakers with normal or corrected-to-normal vision participated. The digit-triplet lists from the Dantale-I speech corpus were used as stimulus material. All measurements were carried out in the presence of stationary speech-shaped noise at 67 dB(C) SPL. The behavioral measurements included speech detection thresholds (SDTs), speech recognition thresholds (SRTs) and speech comprehension scores (SCSs). For the electrophysiological measurements, multi-channel electroencephalography (EEG) recordings were performed. N100 and P300 responses were evoked using an active auditory oddball paradigm. N400 and Late Positive Complex (LPC) responses were evoked using congruent and incongruent digit sequences that were presented using audio-only or audio-visual paradigms.

**Results:** All cortical EEG components could be evoked successfully. While no correlations between the SDT and SRT measurements and the N100 and P300 responses were found, the SCSs were correlated with the EEG responses to the congruent and incongruent digit sequences ($r = -0.5$, $p < 0.05$). Regarding the N400 and LPC measurements, there were significant amplitude differences between the congruent and incongruent digit conditions within the same paradigm ($p < 0.05$) but not across the two paradigms.

**Conclusions:**The developed test battery was found to be usable and to produce reliable data. Because the audio-visual paradigm produced N400 and LPC responses very similar to those of the audio-only paradigm, it is expected to facilitate measurements of speech comprehension in clinical populations with severe hearing losses. Follow-up studies with hearing-impaired individuals will provide further insights into the consequences of hearing loss on cortical speech processing.

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## Assessment of auditory function in elderly presbycusis patients with and without mild cognitive impairment

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**Keywords:** Aging, Cognition, hearing

**Background:** Aging is a natural phenomenon to living beings related to time and marked by specific biopsychosocial changes for each individual. From these changes, it is observed elderly people with hearing loss due to aging (presbycusis) and / or with dementia processes that generate complications in communication, expression, capture and understanding of information. The cortical auditory evoked potential is an instrument used to assess the cognitive processes of hearing, providing information about the integrity of the central auditory pathways correlated to language and communication. Age and mental integrity are factors that influence the responses of the PEAC. The Montreal Cognitive Assessment test (MoCA), another instrument used in the assessment of cognitive functions, assesses a wide range of functions (executive, visual and spatial skills, naming, memory recovery, digits, sentence, abstract reasoning and orientation) and contributes for the diagnosis of dementias and other mental disorders. This research aims to evaluate and compare auditory function in elderly presbycusis patients with and without mild cognitive impairment.

**Methods:** This is an analytical and cross-sectional study. Twelve individuals aged ≥ 60 years, with bilateral symmetrical sensorineural hearing loss, with tonal audibility threshold between 30 and 70 dBHL at high frequencies (considering 4, 6 and 8 kHz) and ≤ 25 dBHL in the frequencies participated in the pilot study. of 0.25, 0.50, 1 and 2 kHz, characterizing presbycusis. The individuals were divided into two groups: Group mild cognitive impairment (GMCI): composed of 6 individuals, of both sexes, who failed the MoCA test (score <26); Control Group (CG): composed of 6 individuals, of both sexes, who have not failed the MoCA test (score> 26). The data collection procedure that comprised the auditory function test battery was the Cortical Auditory Evoked Potential. For the research of potentials, the stimuli were presented in an intensity that guaranteed at least 30dBNS, by headphones in acoustic speech stimulus / ba / (frequent), / da / (infrequent). The Montreal-Basic Cognitive Assessment test (MoCA-B) was applied after the PEAC exam to avoiding interfere with the test results. To compare the results, a paired T test and a Cohen’s D test were used to analyze the sample effect.

**Results:** After performing the t-test, it was possible to observe that, despite the waves in the CCL group showing increased latency values compared to the CG, there was no statistically significant difference in the responses of the PEAC wave latencies between the control and CCL groups: Lat P1 (p = 0.68 ± 22.98; effect size = 0.17), Lat N1 (p = 0.86 ± 24.14; effect size = 0.36), Lat P2 (p = 0.84 ± 33 , 9; effect size = 11.9), Lat N2 (p = 0.75 ± 43.5; effect size = 0.74) Lat P3 (p = 0.59 ± 34.23; effect size = 0.22 ). The present study is ongoing, new results may arise from the increase in the number of patients.

**Conclusion:** From the samples obtained so far, it was possible to observe that there was no difference in the hearing function of elderly presbycusis patients with and without mild cognitive impairment.

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## Auditory Evoked Potentials and P300 in Young Female Adults who Perceive Temporary Tinnitus after a Brief Period of Silence

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**Keywords:** ALR, tinnitus, P300

**Background:** Research has shown that more than 50% of adults with no prior history of tinnitus or ear pathology report the perception of temporary tinnitus when exposed to sustained silence (Del Bo et al., 2008; Heller & Bergman, 1953; Tucker et al., 2005). Studying the perception of tinnitus in silence could improve our understanding of why it is present in some people and absent in others with similar thresholds. The purpose of this study is to document neural activity in a group of females who experience emergent temporary tinnitus while in silence and compare them to a group of females who do not experience tinnitus in silence, using Auditory Late Responses (ALRs) and P300. Thus, this study will examine the Network theory of tinnitus generation and broaden the present understanding of the differences in auditory and non-auditory cortical responses that may underlie the tendency of some people to perceive tinnitus.

**Methods:** Female participants between the ages of 18 to 35 years with normal pure tone hearing thresholds and no history of persistent tinnitus were recruited for this study. The approval for the study was obtained from the IRB of UNCG. ALR and P300 waveforms were recorded using the oddball paradigm. Participants were exposed to 10 minutes of silence after the first ALR and P300 recording and completed a Qualtrics questionnaire to report their experience in silence. The ALR and P300 was recorded again after the exposure to silence. Absolute N1, P2 and P300 waveform amplitudes and latencies were identified and were compared Pre- and Post- Silence between the group that experienced tinnitus in silence (Group 1) and the group that did not report temporary tinnitus in silence (Group 2) using ANOVA test in SPSS. Information was obtained documenting the time of tinnitus emergence, location of tinnitus perception, and types of tinnitus sounds that were perceived.

**Results:** So far 17 participants have met the criteria for inclusion in this study. The mean age of the participants was $22.5 \pm 3.7$ years. Seven (41.2%) perceived temporary tinnitus in silence. A comparison of Pre- and Post-silence P300 waveforms showed a decrease in mean P300 amplitude after exposure to silence and an increase in mean P300 latency following exposure to silence. The mean Pre-silence N1 amplitude for Group 1 was $4.04 \pm 3.4$, while Group 2 had a mean N1 amplitude of $3.99 \pm 2.4$. Post silence Group 1 N1 amplitude was $3.2 \pm 2.1$, while that of Group 2 was $3.7 \pm 2$. Mean pre-silence P2 amplitude was $5.74 \pm 2.6$, for Group 1 and $7.04 \pm 3.7$ for Group 2, mean post-silence P2 amplitudes were $5.9 \pm 2.7$ for Group 1 and $6.7 \pm 3.5$ for Group 2. Mean N1 and P2 differences in amplitude and latency were not significant when both groups were compared ($p>0.05$). Group 1 had longer pre-silence ($282 \pm 35.3$ vs $258 \pm 31.5$) and post-silence ($286.1 \pm 37.8$ vs $260.9 \pm 35.3$) P300 latencies, they also had smaller mean P300 amplitudes pre-silence ($10.4 \pm 5$ vs $12.3 \pm 7.7$) and post-silence ($8.8 \pm 6.6$ vs $10.8 \pm 6.5$). However, these differences were not statistically significant ($p>0.05$).

**Conclusion:** The data implies that exposure to silence results in a decrease in the strength and speed of the neural responses that contribute to the P300 from the auditory and non-auditory cortical regions that mediate auditory attention, memory and response inhibition. There appears to be a tendency for those who perceive temporary tinnitus in silence to show slower and less robust P300 response, which might indicate a difference in cortical response to infrequent stimuli. Further research is needed to understand the processing differences that may predispose some people to the emergence of tinnitus.

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## Behavioural and Electrophysiological measures of attention in continuous subjective tinnitus

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**Keywords:** Tinnitus, Attention, Event-Related Potentials (ERPs), Attentional Network Task (ANT).

**Background:** Attention plays a key role in the persistence and maintenance of the auditory phantom sound, tinnitus. Albeit evidence suggesting an overall dysfunctional attention system in individuals with tinnitus, there are a few studies reporting an unimpaired and/or a differential impact on the sub-types of attention. Studies in literature have utilised either a behavioural paradigm or an electrophysiological paradigm to assess attention in tinnitus. The current study is aimed at exploring the alerting, orienting, selective and executive attention in individuals with tinnitus using both behavioural and electrophysiological measures.

**Methods:** Ten individuals with continuous subjective tinnitus were age and gender matched with ten control participants with no history of tinnitus. All participants underwent complete audiological testing, tinnitus evaluation, P300 (Go-No-go) and Attentional Network Task (ANT). The paradigms were run through e-prime (version 3.0) and the ERPs were recorded using Brain vision recorder. Behavioural measures (reaction time & accuracy) and electrophysiological measures (latency and amplitude of P300 and N100) were obtained, and statistical analysis was performed using SPSS V.16.

**Results:** Go-No-Go task resulted in statistically significant difference in P3b latency ($t\ (df=18) = -2.314$ ; $p = 0.033$) and amplitude ($t(df=18) = -2.115; p=0.045$). There was no significant difference in P3a amplitude or latency. Behavioural results of ANT showed significant difference in executive ($t(df=18) = 2.090; p=0.051$). But, the orienting and alerting measures were unaffected. ERP correlates of ANT showed no statistically significant difference in P3 and N1 latency and amplitude. It was observed that the response inhibition for the tinnitus group was less in comparison to the control group however, this difference did not reach statistical significance. There was a significant positive correlation between the response inhibition in P3 and the behavioural executive attention in the healthy participants. However, the same was not statistically significant in the tinnitus group.

**Conclusion:** The orienting and alerting measures remained unaffected in both the behavioural and electrophysiological tests. However, the executive function measured using the cognitive P3 and the response inhibition measured using ANT were affected and correlated with the behavioural findings. These results suggest that tinnitus specifically impairs executive attention while other types of attention seem to be unaffected. In addition, the lack of correlation between the behavioural and electrophysiological measures of executive functions could be attributed to an altered response inhibition in individuals with tinnitus. Future studies can focus on executive attention as a key factor that influences tinnitus.

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## Auditory evoked potentials: a comparative analysis of the registration of the mediated sum with the sum of the weighted average

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**Keywords:** Auditory Evoked Potentials, hearing, electrophysiology.

**Background:** Cortical auditory evoked potentials are electrophysiological tests applied to the investigation of auditory function in children[1]. Despite being an objective test, the application in the young population can produce unreliable results due to the variation in behavior. The control of the child's condition prior to the mediating of the electrical signal guarantees a more reliable response and a safer application of the test. In addition, unweighted summation after the registration of good quality traces can be an alternative to have an examination record with good morphology in a sufficient time that ensures the child's collaboration during the test.

**Methods:** This is a retrospective documentary study that consulted the records of exams of cortical evoked potentials of healthy children. The wave records generated by the AEP Biologic Natus software were used, used to measure the components P1, N1 and P2 of these potentials in the Objective Hearing Assessment Laboratory at CEES (Education and Health Studies Center). Twelve examinations of children were selected for analysis of the Calculated and Uncalculated measures. For the mediation, the results were extracted by the ASCII Biologic Natus software and converted to numerical data in text file format by the ASC II software.

**Results:** In the analysis of the results it was possible to observe that there was no significant difference between the latency values of the components of the calculated measures in comparison with the non-calculated measures. However, the use of the calculated measures technique as the weighted sum presents a better quality of visualization of the wave morphologies, therefore, this processing resource can favor obtaining more reliable measures for diagnosis in child populations.

**Conclusion:** There were none of the measures calculated compared to the measures not calculated.

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## Minimum levels of cortical and behavioral auditory responses in children and adolescents with hearing loss

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**Keywords:** Auditory Threshold; Hearing Loss; Auditory Evoked Potentials

**Introduction:** For the early diagnosis of hearing loss, electrophysiological and behavioral tests are essential. The Cortical Auditory Evoked Potential, for objectively providing data on the functionality of the auditory cortical structures and maturation of this system, is one of the tools used in this diagnosis. To assist in this process, The Ling 6 HL Test is also used, as it provides the detection thresholds for six speech sounds. Given the above, the study sought to verify whether there is a correlation between the minimum level of cortical and behavioral auditory response (NMR) in children and adolescents with hearing loss. In addition to identifying whether audiological variables, sensory deprivation, degree of hearing loss, installation of hearing loss and reported time of use of the hearing aid, influence the responses of the studied population

**Methods:** 22 children and adolescents with bilateral, symmetrical, mild to severe sensorineural hearing loss, aged between three and 18 years, participated in the study. All of them were hearing aid users for at least one year. The procedures performed were the recording and analysis of the Cortical Auditory Evoked Potential and The Ling 6 HL Test, which were present in a pre-recorded way. The stimulus used to obtain the electrophysiological NMR was the syllable /ba/, presenting through insert earphones, monaurally in the presentation rate of 1.9ms, using the descending-ascending technique. NMR was considered to be the lowest intensity at which the subject presented the P1 component. In order to obtain the behavioral NMR, the six sounds of Ling were presented in a sound field, at supraliminary intensity and the subjects were positioned at 0º azimuth of the speaker box. The descending-ascending technique was used, and the behavioral NMR considered was the lowest intensity at which the subjects detected each of the sounds that make up the test. An adequate statistical analysis was performed for the study of each researched variable.

**Results:** An average of 53.63 dBnHL was obtained for cortical NMR. As for behavioral NMR, the averages for the sounds /m/, /u/, /a/, /i/, /ʃ/ and /s/ were, respectively, 34.40 dBHL, 36.68 dBHL, 44.95 dBNA, 39.91 dBNA, 47.56 dBNA and 47.02 dBNA. We observed moderate correlation between the cortical and behavioural NMR when the phoneme /a/ was presented. As for the degree of relation between the audiological variables studies and their impacts, sensory deprivation and the installation of hearing loss, presented statistically significant numerical data through the sounds /m/, /u/, /a/ and /i/. When correlating the cortical and behavioral NMR with the period of installation of the hearing loss, we found statistically significant difference in the correlation between the sounds /m/, /u/, /a/ and /i/ and the electrophysiological findings in the group with pre-lingual hearing loss.

**Conclusion:** There was a correlation between the cortical NMR and the behavioral threshold of the phoneme /a/. Installation of hearing loss and period of deprivation were the variables that influenced auditory behavior through the Sounds of Ling. There was a correlation between cortical and behavioral NMR for most sounds, when considering the period of installation of hearing loss.

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## Cortical compensation for hearing loss, but not age, in neural tracking of the fundamental frequency of the voice

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**Keywords:** f0-tracking; continuous speech; cortical compensation; hearing impairment; age;

**Background:** The human auditory system has a remarkable capacity to adapt and compensate for damage that occurs through ageing, trauma and disease. Therefore, auditory processing in people of advancing age or people with hearing loss may differ from typical auditory processing in young normal hearing subjects. However, the underlying mechanisms are still unclear. In this study, we aimed to investigate the effects of age and hearing loss on temporal processing of naturalistic stimuli in the auditory system. We focused particularly on the neural encoding of the fundamental frequency of the voice (f0). A preprint of this study is available on BioRxiv (Van Canneyt et al. 2021).

**Methods**: We employed a recently developed objective measure for neural phase-locking to the f0, called f0-tracking, which is based on linear decoding and encoding models. This novel technique allowed to analyse response for continuous speech stimuli, which are more natural and ecologically valid than the repetitive stimuli used in traditional paradigms, e.g. frequency following responses. F0-tracking responses from 54 normal hearing and 14 hearing impaired adults of varying ages were analysed. The responses were evoked by a Flemish story with a male talker and contained both subcortical and cortical contributions.

**Results:** The results indicated that over-all f0 response strength significantly decreased with age for normal hearing adults. Furthermore, with advancing age the cortical contributions to the response diminished and even disappeared. For hearing-impaired subjects, response strength was significantly larger compared to age-matched normal hearing controls. The response enhancement in hearing impaired subjects was related to additional cortical response contributions in the 38-50 ms latency range, which were not present in normal hearing controls. Moreover, the response strength was significantly related to the degree of hearing loss of the subject, with stronger responses for more severe hearing loss.

**Conclusion:** The results of this study indicate an age-related decrease in neural phase-locking ability at frequencies in the range of the f0, possibly due to decreased inhibition in the auditory system. Conversely the results reveal increased cortical processing in participants with hearing loss. This is suggestive of hearing-loss induced recruitment of additional neural resources to aid in speech perception.

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## Neural correlates of visual stimulus encoding and verbal working memory differ between cochlear implant users and normal hearing controls

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A common concern for individuals with severe-to-profound hearing loss fitted with cochlear implants (CIs) is difficulty following conversations in noisy environments. Recent work has suggested that these difficulties are related to individual differences in brain function, including verbal working memory and the degree of cross-modal reorganization of auditory areas for visual processing. However, the neural basis for these relationships is not fully understood. Here, we investigated neural correlates of visual verbal working memory and sensory plasticity in 14 CI users and age-matched normal-hearing (NH) controls. While recording high-density electroencephalography (EEG), participants completed a modified Sternberg visual working memory task where sets of letters and numbers were presented visually and then recalled at a later time. Results suggested that CI users had comparable behavioral working memory performance compared to NH. However, CI users had more pronounced neural activity during visual stimulus encoding, including stronger visual-evoked activity in auditory and visual cortices, larger modulations of neural oscillations, and increased frontotemporal connectivity. During memory retention of the characters, CI users, in contrast had descriptively weaker neural oscillations and significantly lower frontal-temporal connectivity. These results reveal differences in neural correlates of visual encoding and working memory in individuals with CIs.

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## Cortical evoked potentials in children using cochlear implants: early and late-implanted.

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**Keywords:** Cortical evoked potentials, Cochlear implants, Age of implantation

**Introduction**: Cochlear implants (CI) aim to achieve adequate access to hearing and speech language in children who have insufficient benefit from acoustic amplification. However, multiple factors affect the prognosis after cochlear implantation such as age of implantation. Earlier studies have indicated that age of implantation has an effect on the cortical encoding of speech sounds, thus resulting in progressive changes in latency and amplitude of responses (Eskicioğlu et al., 2020; Sharma, Dorman, & Spahr, 2002). Cortical auditory evoked potentials (CAEPs) provide an objective visualization of synchronized electroencephalographic activity in response to sounds stimuli, thus enabling evaluation of benefit of the hearing device used.

Sharma and colleagues (2002) reported a difference in maturation of cortical of CAEPs in children implanted before and after the age of 3.5 years. The current study aimed to explore such differences are observed in children fitted with unilateral cochlear implants in our cochlear implant clinic.

**Method**: 12 children with unilateral cochlear implants were classified into two equal groups based on their age of implantation as early implanted (EI) and late implanted (LI) group. The children were matched in terms of implant age (i.e number of months since CI switch on) and thus formed six pairs of subjects having IE and LI respectively. The study was carried out following ethical rules of Bharati Vidyapeeth (deemed to be University). CI assisted CAEPs were recorded in all 12 children using speech stimuli /ta/ presented at conversation level (70 dB nHL) via calibrated loudspeakers. Bio-Logic navigator Pro AEP system with single channel recording was used, in which the non-inverting electrode was placed at the vertex (Cz) and the inverting electrode at the contralateral mastoid (opposite to CI ear). Precautions were taken to reduce interference during recording. The waveforms thus obtained were analyzed by two experienced audiologists for marking of responses – P1, N1, P2 and N2 as applicable.

**Results**: Each case was analyzed for detectability and morphology of P1-N1 responses, and detectability of P2 and N2 potentials. Waveforms were also observed for unusual morphology suggestive of deprivation-induced plasticity changes as reported in previous studies (Dorman, Sharma, Gilley, Dorman, & Baldwin, 2007; Eskicioğlu et al., 2020). The response latency and amplitude were plotted graphically for comparison.

It was observed that P1 and N1 latencies were longer in children in the LI group as compared to their counterpart in the EI group in four out of six pairs. P1-N1 amplitude was lesser in the LI group as compared to the EI group in all six pairs. Responses in four out of six children in both groups (total 8/12) showed a sharp negative peak in the 10-50 ms region before P1 response. N2 was detected in only two children (one child in each group), and P2 was detected in 8 out of 12 children (four out of six in each group).

**Discussion**: Amplitude of P1-N1 response which is believed to be a Bio-marker for auditory cortical detection mechanism (Aparecida et al., 2017) was found to be lower in the LI group in all ages suggesting that long term effects of auditory deprivation persist after implantation in this group. It has been reported that children in the LI group developed morphology and latency similar to their age-matched early-implanted peers at a later chronological age causing them to miss out on critical language acquisition period (Sharma et al., 2002). The children of LI group of the present study need to be followed up to check if the latency and amplitude of children match those of the early implanted children at a later age.

**Conclusion**: This clinical data adds to the evidences regarding the effects of age of implantation so as to improve the advocacy and implementation of early intervention. However, the study needs to be carried out on a larger population for confirming these evidences.

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## Electrophysiological correlates of subjective cognitive demand in cochlear implant users during listening in noise

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**Keywords:** EEG, cochlear implants, speech tracking, alpha oscillations, listening effort

**Background:** Although cochlear implantation is a generally successful avenue of hearing restoration, there is still considerable variability and differences for speech recognition outcomes for cochlear implant (CI) listeners which cannot be explained. A potential factor that may affect outcome variability is the poor degree that clinical testing environments and stimuli reflects listening in real-world environments, which demands a greater amount of cognitive resources serving working memory and attention compared to listening in a quiet and controlled sound booth. The current study examines neural speech tracking of natural audiovisual conversations in the presence of multi-talker background noise.

**Methods**: Video and audio segments from a dialogue-based television show were presented to 15 adult CI listeners in high (SNR+5 dB), moderate (SNR+10 dB), and low (SNR+15 dB) levels of background noise while electroencephalography (EEG) was concurrently recorded. Neural tracking to the speech envelope was measured using temporal response functions, and self-reported ratings of cognitive demand for each listening condition were collected using the NASA Task Load Index. Change in alpha oscillations from the low background noise condition was correlated with change in cognitive demand.

**Results**: Preliminary findings reveal that while self-reported demand decreases as background noise levels decrease ($p < 0.01$), no significant differences in the early component of speech tracking was found between conditions. Change in right auditory cortical alpha power from the Low-Noise condition was moderately correlated to change in cognitive demand for the High-Noise condition ($r = 0.633$, $p = 0.011$) and the Audio-Only condition ($r = 0.568$, $p = 0.026$).

**Conclusion**: Current data suggests that the addition of visual cues assists in speech recognition and the inhibition of background noise, with changes in auditory cortical alpha power correlating to changes in demand. These results suggest that meaningful information about the cochlear implant listening experience can be extracted from brain responses using “ecological” stimuli such as a normal conversation.

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