2019 Conference on Implantable Auditory Prostheses

July 14-19, 2019

Granlibakken Conference Center

Lake Tahoe, CA

v1.06

2019 CONFERENCE ON IMPLANTABLE AUDITORY PROSTHESES

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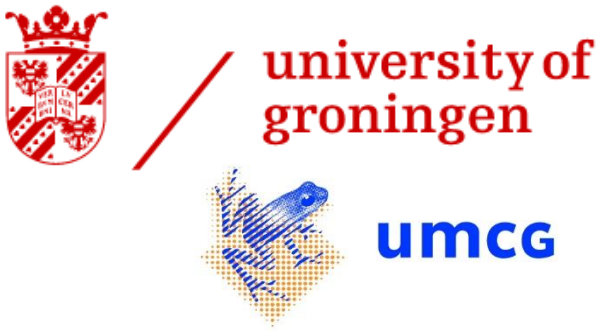

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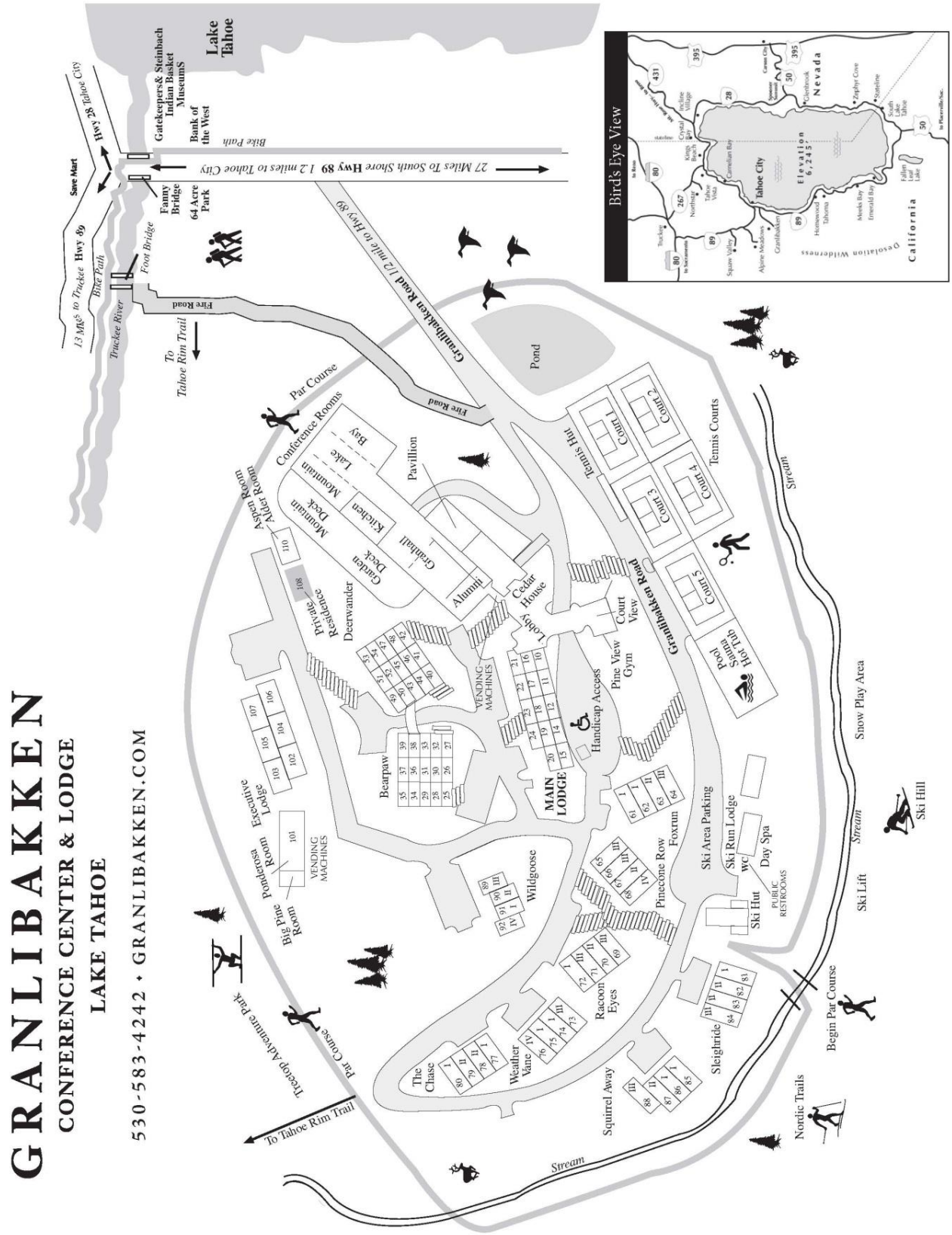
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Gatekeepers& Steinbach Indian Basket MuseumS
Bank of the West
Bike Path
27 Miles To South Shore Hwy 89 1.2 miles to Tahoe City
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64 Acre Park
Save Mart
Hwy 28 Tahoe City
13 Mls to Truckee Hwy 89
Bike Path
Truckee River
Foot Bridge
Fire Road
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Granlibakken Road 1/2 mile to Hwy 89
Pond
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Aspen Room
Alder Room
Bay
Lake
Mountain
Mountain Deck
Kitchen
Garden Deck
Pavillion
Cocktail
Alumni
Cedar House
Lobby
Court View
Deerwander
Residence
Pine View Gym
Handicap Access
Granlibakken Road
Tennis Courts
Court 1
Court 2
Court 3
Court 4
Court 5
Tahoe Rim Trail
Stream
Swimming Pool
Hot Tub
VENDING MACHINES
Executive Lodge
Ponderosa Room
Big Pine Room
Bearpaw
MAIN LODGE
Wildgoose
Pinecone Row
Foxrun
Ski Area Parking
Ski Run Lodge
WC
Day Spa
Ski Hut
PUBLIC RESTROOMS
Ski Lift
Snow Play Area
Ski Hill
Begin Par Course
Nordic Trails
Sleighride
Racoon Eyes
Squirrel Away
Weather Vane
The Chase
Par Course
Treetop Adventure Park
To Tahoe Rim Trail
Bird's Eye View
Nevada
California
Tahoe City
Elevation 6,245'
Truckee
Northstar
Tahoe Vista
Kings Beach
Crystal Bay
Incline Village
Carnelian Bay
Squaw Valley
Alpine Meadows
Homewood
Tahoma
Meeks Bay
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Zephyr Cove
Stateline
South Lake Tahoe
Fallen Leaf Lake
Desolation Wilderness
Carson City
Genoa
Cold Creek
Minden
Gardnerville
Jackpot
Topaz Lake

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PROGRAM OVERVIEW

Sunday July 14	
3:00 PM – 10:00 PM	Registration
6:00 PM – 7:00 PM	Dinner
7:00 PM – Midnight	Welcome Reception
Monday July 15	
7:00 AM	Breakfast opens
8:15 AM – 12:00 PM	Optimizing CIs: Personalization
12:00 PM – 1:00 PM	Lunch
4:00 PM – 6:00 PM	Poster Viewing
6:00 PM – 7:00 PM	Dinner
7:00 PM – 9:00 PM	Expanding use of CIs: Use in different populations
9:00 PM – Midnight	Poster Viewing and Social
Tuesday July 16	
7:00 AM	Breakfast opens
8:30 AM – 12:00 PM	Enhancing use of CIs: Perception of speech, voice, and music
12:00 PM – 1:00 PM	Lunch
1:30 PM – 4:00 PM	Company Presentations and Device workshops
4:00 PM – 6:00 PM	Poster Viewing
6:00 PM – 7:00 PM	Dinner
7:00 PM – 9:00 PM	Open session: Bilateral and Binaural
9:00 PM – Midnight	Poster Viewing and Social
Wednesday July 17	
7:00AM	Breakfast opens
8:30 AM – 12:00 PM	Supporting CIs: Harnessing auditory plasticity
12:00 PM – 1:00 PM	Lunch
1:00 PM – 3:30 PM	Mentoring Session
4:00 PM – 6:00 PM	Poster Viewing
6:00 PM – 7:00 PM	Dinner
7:00 PM – Midnight	Dance Party and Poster Viewing
Thursday July 18	
7:00AM	Breakfast opens
8:30 AM – 10:00 AM	Open session: Imaging the auditory system
10:30 AM – 11:45 AM	Facilitating use of CIs Pt. 1: Role of attention and cognition
11:45 AM – 12:00 PM	Group picture
12:00 PM – 1:00 PM	Lunch
4:00 PM – 6:00 PM	Poster Viewing
6:00 PM – 7:00 PM	Dinner
7:00 PM – 9:00 PM	Facilitating use of CIs Pt. 2: Role of attention and cognition
9:00 PM – Midnight	Poster Viewing and Social
Friday July 19	
7:00AM	Breakfast opens
8:30 AM – 12:00 PM	Open session: Auditory physiology and function
12:00 PM – 1:00 PM	Lunch
1:00PM	Conference End

CIAP 2019 Speaker Program (RED = Invited Speaker)

Monday July 15

8:30 – 12:00 Optimizing CIs: Personalizing cochlear implants for individual users

Session Chair: Astrid Van Wieringen

8:15 OPENING INTRODUCTION. Karen A. Gordon, Deniz Başkent

8:30 **P1.** USING A COMBINED ANIMAL AND HUMAN APPROACH TO BETTER UNDERSTAND HOW NEURAL FUNCTION AFFECTS COCHLEAR IMPLANT PERFORMANCE: **Kara C Schvartz-Leyzac**, Deborah J. Colesa, Alexander Arts, Donald Swiderski, Teresa A. Zwolan, Yehoash Raphael, Bryan E. Pfingst

9:00 **P2.** EARLY INTERVENTION AND CORTICAL EVALUATIONS OPTIMISE OUTCOMES FOR CHILDREN WITH HEARING LOSS: **Teresa Y. C. Ching,** Harvey Dillon, Mark Seeto, Bram Van Dun, Patricia van Buynder, Laura Button, Vivienne Marnane, Sanna Hou, Paola Incerti

9:30 **P3.** AUDITORY NEURAL HEALTH IMAGING (ANHI) USING PATIENT-CUSTOMIZED MODELS: Ahmet Cakir, Robert T. Dwyer, Katelyn A. Berg, Rene H. Gifford, Jack H. Noble

9:45 **P4.** APPROACHES FOR CUSTOMIZED NEUROTROPHIN TREATMENT IN COCHLEAR IMPLANTATION: Jennifer Schulze, Hinrich Staecker, Thomas Lenarz, Dirk Wedekind, Hildegard Buening, Axel Rossi, Axel Schambach, Athanasia Warnecke

Break 10:00 – 10:30

10:30 – 12:00 Optimizing CIs: Personalizing cochlear implants for individual users

Session Chair: Ian Bruce

10:30 **P5.** THE INTERACTIONS OF BOTTOM-UP AND TOP-DOWN INFORMATION PROCESSING DURING SPEECH RECOGNITION BY ADULTS WITH COCHLEAR IMPLANTS: **Aaron C. Moberly**

11:00 **P6.** TOWARDS OBJECTIVE AND AUTOMATIC INDIVIDUALISED FITTING THROUGH EEG-BASED MEASURES OF SPEECH INTELLIGIBILITY: **Tom Francart,** Eline Verschueren, Ben Somers

11:30 **P7.** SPEECH ENHANCEMENT BASED ON RECURRENT NEURAL NETWORKS FOR COCHLEAR IMPLANTS: ENVIRONMENT-OPTIMIZED ALGORITHM APPLIED TO NOVEL ACOUSTIC CONDITIONS: Mahmoud Keshavarzi, Robert P. Carlyon, Brian C. J Moore, Tobias Goehring

11:45 **P8.** USING MACHINE LEARNING TO ESTIMATE THE FUNCTIONAL STATUS OF THE COCHLEAR NERVE IN ADULT COCHLEAR IMPLANT USERS: Jeffrey Skidmore, Angela Pellittieri, William Jason Riggs, Shuman He

12:00 – 13:00 LUNCH

16:00 – 18:00 Poster viewing

18:00 – 19:00 DINNER

19:00 – 21:00 Expanding use of CIs: Use of cochlear implants in new populations with hearing loss

Session Chair: Jill Firszt

19:00 **P9.** RESTORING SOUND LOCALISATION IN ADULTS WITH SINGLE-SIDED DEAFNESS: REFLECTIONS FROM A MULTI-CENTRE STUDY: **Pádraig Kitterick**

19:30 **P10**. BALANCE AND HEARING: WHAT COCHLEAR IMPLANTS HAVE TAUGHT US ABOUT DEVELOPMENT OF THE VESTIBULAR SYSTEM: **Sharon L. Cushing,** Blake C. Papsin, Karen A. Gordon

Break 20:00 – 20:15

20:15 **P11.** MILD THERAPEUTIC HYPOTHERMIA PRESERVES RESIDUAL HEARING AGAINST COCHLEAR IMPLANT TRAUMA: PRECLINICAL RESULTS AND TRANSLATIONAL POTENTIAL: Suhrud Rajguru

20:30 **P12.** PROTECTION OF RESIDUAL HEARING AND REDUCED HAIR CELL LOSS AFTER COCHLEAR IMPLANTATION FOLLOWING PRE-TREATMENT BY NEAR-INFRARED-LIGHT: Dietmar Basta, Ira Struebing, Dan Jiang, Patrick Boyle, Moritz Groeschel, Arne Ernst

20:45 **P13.** TOWARDS THE OPTICAL COCHLEAR IMPLANT: OPTOGENETIC STIMULATION OF THE AUDITORY PATHWAY: Daniel Keppeler, Alexander Dieter, Eric Klein, Michael Schwaerzle, Patrick Ruther, Tobias Moser

21:00 – 24:00 Poster and Social Session

Tuesday July 16

8:30 – 12:00 Enhancing use of CIs: Perception of speech, voice, and music

Session Chair: Bob Carlyon

8:30 **P14.** HEARING VOICES ACROSS THE SPECTRUM: **Etienne Gaudrain**

9:00 **P15.** TOWARDS OBJECTIVE MEASURES OF SPEECH PERCEPTION: **Jonathan Z Simon**

9:30 **P16.** MAPPING EMOTIONAL PROSODY PROCESSING IN NORMAL AND COCHLEAR IMPLANT LISTENERS WITH fNIRS: A PILOT STUDY: Ryssa Moffat, David McAlpine, Deniz Başkent, Lindsey Van Yper

9:45 **P17.** EFFECTS OF TALKER VARIABILITY ON SPOKEN WORD RECOGNITION FOR ADULT COCHLEAR IMPLANT USERS: Terrin N. Tamati, Aaron C. Moberly

Break 10:00 – 10:30

Session Chair: Monita Chatterjee

10:30 **P18.** SPEECH PERCEPTION UNDER COCHLEAR-IMPLANT CONDITIONS: EFFECT OF AGE AND EXPOSURE TO A TONE LANGUAGE: **Laurianne Cabrera**

11:00 **P19.** THE NEUROBIOLOGY OF MUSICAL PITCH DISORDERS: IMPLICATIONS FOR COCHLEAR IMPLANT RECIPIENTS: **Isabelle Peretz**

11:30 **P20.** PERCEPTION OF DISSONANCE FOR SIMULTANEOUS MUSICAL INTERVALS BY UNILATERALLY DEAF COCHLEAR IMPLANT USERS: Emily R. Spitzer, David M. Landsberger, David R. Friedmann, John J. Galvin III

11:45 **P21.** THE SOUND OF MUSIC – TWO NOVEL EEG-PARADIGMS FOR MEASURING DISCRIMINATION OF MUSIC IN COCHLEAR IMPLANT USERS: Bjorn Petersen, Niels Trusbak Haumann, Anne Sofie Friis Andersen, Andreas Hoejlund, Martin Dietz, Soeren Kamaric Riis, Elvira Brattico, Peter Vuust

12:00 – 13:00 LUNCH

13:30 – 16:00 Company Presentations and Device workshops

16:00 – 18:00 Poster viewing

18:00 – 19:00 DINNER

19:00 – 21:00 OPEN SESSION: Bilateral/binaural

Session Chair: Chris Brown

19:00 **P22.** NEURAL CODING OF BINAURAL CUES BETWEEN ACOUSTIC AND ELECTRICAL STIMULATION IN AN ANIMAL MODEL OF SINGLE-SIDED DEAFNESS: Yoojin Chung, Bertrand Delgutte

19:15 **P23.** WHEN HAVING TWO EARS PRODUCES INTERFERENCE INSTEAD OF A SPEECH-PERCEPTION ADVANTAGE: Joshua G.W. Bernstein, Olga A. Stakhovskaya, Kenneth K. Jensen, Matthew J. Goupell

19:30 **P24.** BINAURAL SENSITIVITY IN CHILDREN WITH BILATERAL COCHLEAR IMPLANTS: THE COURSE OF DECISION-MAKING REVEALED BY EYE GAZE: Ellen Peng, Alan Kan, Ruth Y. Litovsky

19:45 **P25.** EFFECT OF PULSE RATE AND ENVELOPE ON INTERAURAL TIME DIFFERENCE DISCRIMINATION IN HEARING INEXPERIENCED CI RATS: Nicole Rosskothen-Kuhl, Alexa N. Buck, Jan W. Schnupp

Break 20:00 – 20:15

20:15 **P26.** USING DYNAMIC ITD SENSITIVITY TO MATCH ELECTRIC AND ACOUSTIC HEARING IN PATIENTS WITH UNILATERAL COCHLEAR IMPLANTS AND RESIDUAL CONTRALATERAL HEARING: LOCALIZATION AND SPEECH PERCEPTION OUTCOMES: Coral Dirks, Peggy B. Nelson, Andrew J. Oxenham

20:30 **P27.** BILATERAL COCHLEAR-IMPLANT PROCESSOR OUTPUT ILDS AS A FUNCTION OF DYNAMIC-RANGE COMPRESSION PARAMETERS AND HEAD MOVEMENT: Alan W Archer-Boyd, Robert P Carlyon

20:45 **P28.** SPEECH-IN-NOISE RECOGNITION WITH MORE REALISTIC IMPLEMENTATIONS OF A BINAURAL COCHLEAR-IMPLANT SOUND CODING STRATEGY INSPIRED BY THE MEDIAL OLIVOCOCHLEAR REFLEX: Enrique A. Lopez-Poveda, Almudena Eustaquio-Martin, Milagros J. Fumero, Jose Manuel Gorospe, Ruben Polo Lopez, Auxiliadora Gutierrez Revilla, Reinhold Schatzer, Peter Nopp, Joshua S. Stohl

21:00 – 24:00 Poster and Social Session

Wednesday July 17

8:30 – 12:00 Supporting CIs: Harnessing auditory plasticity for improved function

Session Chair: Andrej Kral

8:30 **P29.** AUDITORY-COGNITIVE TRAINING TO OPTIMIZE POST-IMPLANT OUTCOMES: **Erin Ingvalson**

9:00 **P30.** VIRTUAL REALITY-BASED EXAMINATION OF AUDIOVISUAL SPEECH PERCEPTION IN COCHLEAR IMPLANT RECIPIENTS: **Hartmut Meister,** Pascale Sandmann, Martin Walger

9:30 **P31.** NEUROMODULATION ENHANCES PLASTICITY IN A RODENT MODEL OF COCHLEAR IMPLANT USE: Erin Grace Glennon, Jasmin Multani, Mario A. Svirsky, Robert Froemke

9:45 **P32.** THE IMPORTANCE OF CONSISTENT COCHLEAR IMPLANT USE ON CORTICAL PLASTICITY IN CHILDREN WITH SINGLE SIDED DEAFNESS: Hyo-Jeong Lee, Daniel Smieja, Melissa Polonenko, Sharon L Cushing, Blake C Papsin, Karen A Gordon

Break 10:00 – 10:30

Session Chair: Ruth Litovsky

10:30 **P33.** BENEFITS OF MUSIC-BASED TRAINING FOR SUPPORTING SPEECH OUTCOMES IN CI USERS: **Frank A Russo**

11:00 **P34.** PERCEPTUAL LEARNING OF VOCODED SPEECH WITH AND WITHOUT CONTRALATERAL HEARING: IMPLICATIONS FOR THE REHABILITATION OF COCHLEAR IMPLANT SUBJECTS: Martin Chavant, Alexis Hervais-Adelman, Olivier Macherey

11:15 **P35.** REWEIGHTING OF BINAURAL LOCALIZATION CUES IN BILATERAL COCHLEAR IMPLANT LISTENERS: Maike Ferber, Bernhard Laback, Martin Lindenbeck

11:30 **P36.** INTERAURAL PITCH DISCRIMINATION IN CHILDREN WITH NORMAL HEARING, HEARING AIDS, AND COCHLEAR IMPLANTS: Morgan Eddolls, Lina Reiss, Yonghee Oh, Curtis Hartling, Alicia Johnson, Bess Glickman, Germaine Stark, Jennifer Ruiz

11:45 **P37.** LONG TERM EXPOSURE TO ITD CUES FROM BILATERAL COCHLEAR IMPLANTS RESULTS IN NORMAL ITD SENSITIVITY IN A NEONATALLY DEAFENED MODEL: Alexander Thompson, Dexter Irvine, Samuel Irving, Aasha Riordan, Nathan Bordonaro, Andrew Wise, James Fallon

12:00 13:00 LUNCH

13:00 – 15:30 Mentoring session: Ruth Litovsky

16:00 – 18:00 Poster viewing

18:00 – 19:00 DINNER

19:00 – 20:00 Posters

Wednesday 19:00 to 24:00 Social Hour + Dance Night

Thursday July 18

8:30 – 12:00 OPEN SESSION: Imaging the auditory system

Session Chair: Colette McKay

8:45 **P38.** USING fNIRS TO PREDICT SPEECH PERCEPTION IN INFANT COCHLEAR IMPLANT RECIPIENTS: Samantha C Harrison, Ian M Wiggins, Douglas E H Hartley

9:00 **P39.** COMBINED ELECTRO-OPTICAL STIMULATION OF SPIRAL GANGLION NEURONS IN A MOUSE MODEL OF AN OPTOGENETIC COCHLEAR IMPLANT: Fadhel El May, Xiankai Meng, Vivek V Kanumuri, Florent-Valéry Coen, Stephen McInturff, Osama Tarabichi, Stephanie P. Lacour, Albert S. Edge, M Christian Brown, Daniel J. Lee

9:15 **P40.** FREQUENCY FOLLOWING RESPONSE (FFR) AND SPEECH RECOGNITION BENEFIT FOR COMBINING A COCHLEAR IMPLANT AND CONTRALATERAL HEARING AID: David M Kessler, Saradha Ananthakrishnan, Spencer B Smith, Kristen DOnofrio, Rene Gifford

9:30 **P41.** AUDITORY POTENTIALS TO THE FUNDAMENTAL FREQUENCY OF THE VOICE IN COCHLEAR IMPLANT LISTENERS: Jana Van Canneyt, Tom Francart, Jan Wouters

9:45 **P42.** PHYSIOLOGIC AND PSYCHOPHYSICAL PERCEPTION OF SPECTRAL CUES IN HYBRID COCHLEAR IMPLANT USERS: Viral Tejani, Jeong-seo Kim, Alexandra Watts, Paul Abbas, Carolyn Brown

Break 10:00 – 10:30

10:30 – 12:00 Facilitating use of CIs-Part 1. The role of attention and cognition

Session Chair: Matt Goupell

10:30 **P43.** ACOUSTIC, LINGUISTIC, AND COGNITIVE FACTORS IMPACT EFFORTFUL LISTENING: IMPLICATIONS FOR COCHLEAR IMPLANT USERS: **Stefanie E Kuchinsky**

11:00 **P44.** SPEECH UNDERSTANDING AND LISTENING EFFORT IN INDIVIDUALS WITH SINGLE-SIDED DEAFNESS WHO RECEIVE A COCHLEAR IMPLANT: Tanvi Thakkar, Emily Burg, Shelly Godar, Sara Misurelli, Daniel Lee, Ruth Y Litovsky

11:15 **P45.** DECODING SELECTIVE ATTENTION IN NORMAL HEARING LISTENERS AND BILATERAL COCHLEAR IMPLANT USERS WITH CONCEALED EAR EEG: Waldo Nogueira, Hanna Dolhopiatenko, Irina Schierholz, Andreas Buechner, Bojana Mirkovic, Martin Bleichner, Stephan Debener

11:30 **P46.** DICHOTIC LISTENING PERFORMANCE AND EFFORT IN BILATERAL COCHLEAR-IMPLANT AND NORMAL-HEARING LISTENERS: Kristina DeRoy Milvae, Stefanie E. Kuchinsky, Matthew J. Goupell

12:00 – 13:00 LUNCH

16:00 – 18:00 Poster viewing

18:00 – 19:00 DINNER

19:00 – 21:00 Facilitating use of CIs-Part 2. The role of attention and cognition

Session Chair: Jan Wouters

19:00 **P47.** USING HIGH-DENSITY OPTICAL BRAIN IMAGING TO STUDY SPEECH PROCESSING WITH A COCHLEAR IMPLANT: **Jonathan Peelle**

19:30 **P48.** CHILDREN WITH IMPAIRED BINAURAL HEARING HAVE WORKING MEMORY, LEARNING AND NAVIGATION DEFICITS: EVIDENCE FROM GROUPS WITH BILATERAL COCHLEAR IMPLANTS AND UNTREATED SINGLE-SIDED DEAFNESS: Claire McSweeny, Sharon L. Cushing, Jennifer Campos, Blake C. Papsin, Karen A. Gordon

19:45 **P49.** NEURAL CORRELATES OF SELECTIVE ATTENTION PREDICT SPEECH STREAMING PERFORMANCE IN BILATERAL CI USERS: Brandon T. Paul, Mila Uzelac, Joseph Chen, Trung Le, Vincent Lin, Andrew Dimitrijevic

Break 20:00 – 20:15

20:15 **P50.** TRACKING LANGUAGE AND MUSIC PROCESSING WITH NEUROPHYSIOLOGICAL MEASURES IN CHILD AND ADULT CI-USERS: **Anja Hahne**

20:45 **P51.** DIFFUSION MODELS AS ADDITIONAL MEASURES OF COCHLEAR IMPLANT USER PERFORMANCE: Nawal El Boghdady, Florian Langner, Waldo Nogueira, Deniz Başkent, Etienne Gaudrain

21:00 – 24:00 Poster and Social Session

Friday July 19

8:30 – 12:00 OPEN SESSION: Auditory physiology and function

Session Chair: Michelle Hughes

8:30 **P52.** EVIDENCE FOR BETTER NEURAL HEALTH IN CHILDREN WITH COCHLEAR IMPLANTS RELATIVE TO ADULTS: Julie G. Arenberg, Kelly N. Jahn, Mishaela DiNino

8:45 **P53.** LATE COMPOUND ACTION POTENTIAL COMPONENTS AS MARKER FOR COCHLEAR LESIONS AT PERIPHERAL DENDRITES OR SOMATA OF SPIRAL GANGLION NEURONS: Wiebke Susanne Konerding, Julie Gayle Arenberg, Andrej Kral, Peter Baumhoff

9:00 **P54.** ELECTRODE-SPECIFIC ECAP AMPLITUDE GROWTH FUNCTIONS AND THEIR RELATIONSHIP TO LOUDNESS GROWTH: Andreas Buechner, Lutz Gaertner, Thomas Lenarz

9:15 **P55.** ESTIMATING NEURAL SURVIVAL USING A NEW VERSION OF THE PANORAMIC ECAP METHOD: Tobias Goehring, Charlotte Garcia, Stefano Cosentino, Richard E. Turner, John M. Deeks, Taren Rughooputh, Manohar Bance, Robert P. Carlyon

9:30 **P56.** INVESTIGATING THE EFFECTS OF STIMULUS POLARITY AND PULSE SHAPES IN A COMPUTATIONAL MODEL OF THE IMPLANTED HUMAN COCHLEA: Randy K. Kalkman, Jeroen J. Briaire, Johan H. M. Frijns

9:45 **P57.** NEUROPHYSIOLOGICAL MEASURES OF ELECTRODE AND MODULATION RATE DISCRIMINATION IN COCHLEAR IMPLANTS: Jaime Andres Undurraga Lucero, Lindsey Van Yper, Deborah Vickers

Break 10:00 – 10:30

Session Chair: QianJie Fu

10:30 **P58.** SINGLE-SIDED CONGENITAL DEAFNESS SUPPRESSES BUT DOES NOT PREVENT ELECTRICAL ACTIVATION OF THE DEPRIVED EAR FROM THE BRAINSTEM TO THE CORTICAL LEVEL: Peter Hubka, Monique Hajduk, Jochen Tillein, Andrej Kral

10:45 **P59.** UNILATERAL HEARING LOSS SIMILARLY DISRUPTS BINAURAL INTEGRATION IN THE JUVENILE AND ADULT GERBIL AUDITORY MIDBRAIN: Andrew Curran, Maike Vollmer

11:00 **P60.** PULSE SYMMETRY AND THE SPREAD OF EXCITATION OF COCHLEAR IMPLANTS: Gunnar L Quaß, Peter Baumhoff, Dan Gnansia, Pierre Stahl, Andrej Kral

11:15 **P61.** THE ROLE OF COCHLEAR PLACE OF STIMULATION ON VOCAL PITCH PERCEPTION: Simin Soleimanifar, Hannah E. Staisloff, Justin M. Aronoff

11:30 **P62.** PREDICTION OF INDIVIDUAL COCHLEAR IMPLANT RECIPIENT SPEECH PERCEPTION WITH THE OUTPUT SIGNAL TO NOISE RATIO METRIC: Greg D Watkins, Brett A Swanson, Gregg J Suaning

11:45 **P63.** IMPLICIT AUDITORY RULE LEARNING WITH LINGUISTIC AND ENVIRONMENTAL STIMULI IN NORMAL HEARING AND COCHLEAR IMPLANT USERS: Liat Kishon-Rabin, Shira Cohen, Ronen Perez

12:00 – 13:00 LUNCH

13:00 End of Conference

POSTER SESSION M: MONDAY – 8AM TO MIDNIGHT

M1: MACHINE LEARNING IMPLICATIONS IN COCHLEAR IMPLANTS: IDENTIFICATION OF LOMBARD SPEECH USING CNN-BASED CLASSIFICATION: Juliana N Saba, John H.L. Hansen

M2: AN ELECTRODOGRAM-TO-AUDIO WAVELET VOCODER THAT USES MACHINE LEARNING TECHNIQUES TO SOLVE INTERFERENCE PROBLEMS: Bradford C. Backus, Kamil Adiloglu, Jorg-Hendrik Bach, Tobias Herzke

M3: COCHLEAR SHAPE VARIABILITY FROM 987 COMPUTED TOMOGRAPHY IMAGES: AN ANATOMICAL STUDY: Dan Gnansia, Thomas Demarcy, Clair Vandersteen, Herve Delingette, Nicholas Ayache, Charles Raffaelli, Nicolas Chevara

M4: THE CONCEPT OF INDIVIDUALIZED COCHLEAR IMPLANTATION: Thomas Lenarz, Rolf Benedikt Salcher, Nils Kristian Prenzler, Daniel Kley, Anke Lesinski-Schiedat, Andreas Buechner

M5: MEDICAL IMAGE COMPUTING TOOLS DEDICATED TO PERSONALIZED COCHLEAR IMPLANTATION: Thomas Demarcy, Clair Vandersteen, Dan Gnansia, Herve Delingette, Nicholas Ayache, Charles Raffaelli, Nicolas Guevara

M6: ESTIMATING INTERAURAL MISMATCH TO INFORM INDIVIDUALIZED FREQUENCY MAPPING: Joshua G.W. Bernstein, Kenneth K. Jensen, Olga A. Stakhovskaya, Jack H. Noble, Michael Hoa, H Jeffrey Kim, Robert Shih, Elizabeth R. Kolberg, Matthew J. Goupell

M7: IMPLICATIONS OF SPIRAL GANGLION MORPHOLOGY AND PLACE-FREQUENCY MISMATCHES FOR COCHLEAR IMPLANT SOUND CODING: Chris J. James

M8: OPTIMIZED BIMODAL FITTING USING SELF-ASSESSMENT METHODS: Iris Arweiler, Josef Chalupper, Sven Kliesch, Andreas Buechner

M9: BDNF OVEREXPRESSING HUMAN STEM CELLS IN ALGINATE FOR COCHLEAR IMPLANT OPTIMIZATION: Verena Scheper, Silke Huegl, Anika Hamm, Michael Gepp, Andre Schulz, Peter Hubka, Christoph Pannier, Thomas Lenarz, Thomas Rau, Andrea Hoffmann, Jana Schwieger

M10: COMPUTATIONAL MODEL OF VOLTAGE DYNAMICS IN VESTIBULOCOCHLEAR NERVE FIBERS: Aravind Govindaraju, Ruth Anne Eatock, Robert Raphael

M11: ARTIFICIAL COCHLEA MODEL MATERIAL VALIDATION FOR INSERTION FORCE MEASUREMENTS: Rolf Salcher, Martina Nullmeier, Jakob Cramer, Nick Pawsey, Thomas Lenarz, Thomas Rau

M12: ON THE DEVELOPMENT OF REALISTIC ARTIFICIAL COCHLEA MODELS: Thomas Stephan Rau, Silke Huegl, Martina Nullmeier, Nick Pawsey, Omid Majdani, Thomas Lenarz, Rolf Salcher

M13: LOCALIZED ELECTRODE IMPEDANCE CHANGES WITH DELAYED-ONSET HEARING LOSS IN HYBRID COCHLEAR IMPLANT USERS: Hyejin Yang, Viral Tejani, Jeong-Seo Kim, Paul Abbas, Carolyn Brown, Jihwan Woo

M14: SUSTAINED DEXAMETHASONE RELEASING ELECTRODE COATING PROTECTS AGAINST COCHLEAR IMPLANTATION ELECTRODE INSERTION TRAUMA INDUCED HEARING LOSSES AND FIBROSIS: Dongxiu Chen, Yanjing Luo, Muqing Xu, Dong Ma, Jieqing Cai, Jie Tang, Hongzheng Zhang

M15: ANATOMICAL CORRELATES AND SURGICAL CONSIDERATIONS FOR LOCALIZED THERAPEUTIC HYPOTHERMIA APPLICATION IN COCHLEAR IMPLANTATION SURGERY: Suhrud Rajguru, Enrique Perez, Anrea Viziano, Zaid Al-Zaghal, Fred F. Telischi, Rachele Sangaletti, Curtis King, Michael Hoffer

M16: OTOPROTECTION USING A COMBINATION OF L-N-ACETYLCYSTEINE AND DEXAMETHASONE IN AN IN VITRO MODEL OF INNER EAR TRAUMA: Jeenu Mittal, Mario M. Perdomo, Dibyanshi Mishrra, Hannah Marvade, Timothy Yassa, Carolyn Garnham, Viraj Shah, Rahul Mittal, Adrien A Eshraghi

M17: EVALUATING THE USE OF BUNCHED-UP PULSES FOR OBJECTIVE DETERMINATION OF THRESHOLDS IN COCHLEAR IMPLANTS USERS: Ana Sodan, Sabine Meunier, Vincent Pean, Stephane Roman, Marion Montava, Jean-Pierre Lavieille, Olivier Macherey

M18: IS THE EFFECT OF INTERPHASE GAP ON THE ELECTRICALLY-EVOKED COMPOUND ACTION POTENTIAL CORRELATED WITH COCHLEAR NERVE SURVIVAL IN HUMAN LISTENERS? Shuman He, Jeffrey Skidmore, Lei Xu, Xiuhua Chao, Ruijie Wang, Jianfen Luo, Haibo Wang

M19: USING THE DTR MOUSE MODEL FOR DETERMINING EFFECTS OF COCHLEAR HEALTH ON COCHLEAR IMPLANT FUNCTION: Jenna Devare, Deborah J. Colesa, Lisa A. Beyer, Bryan E. Pfingst, Yehoash Raphael

M20: FUNCTIONAL MEASURES OF COCHLEAR HEALTH IN MICE WITH CHRONIC MULTICHANNEL IMPLANTS: Deborah Jean Colesa, Jenna Devare, Bryan E. Pfingst, Yehoash Raphael

M21: A NEW MOUSE MODEL FOR TESTING OUTCOMES OF GJB2-RELATED DEAFNESS: INDUCIBLE CONDITIONAL DELETION OF GJB2: Donna Martin, Jennifer Skidmore, Xiaobo Ma, Jelka Cimerman, Lisa Beyer, Donald Swiderski, Yehoash Raphael

M22: USING DETECTION THRESHOLDS TO ESTIMATE COCHLEAR HEALTH: SINGLE PULSE VS MULTIPULSE STIMULI: Bryan E. Pfingst, Deborah J. Colesa, Donald L. Swiderski, Yehoash Raphael, Kara C. Schvartz-Leyzac

M23: USING DETECTION THRESHOLDS TO ESTIMATE COCHLEAR HEALTH: EFFECTS OF ELECTRODE CONFIGURATION: Kara C Schvartz-Leyzac, Deborah J. Colesa, Donald L. Swiderski, Yehoash Raphael, Bryan E. Pfingst

M24: TOWARDS A METRIC TO QUANTIFY INFORMATION TRANSMISSION BY COCHLEAR-IMPLANT CODING STRATEGIES: Thibaud Leclere, Aswin Wijetillake, Manuel Segovia-Martinez, Enrique A Lopez-Poveda

M25: EFFECT OF SIMULATED LOW FREQUENCY RESIDUAL HEARING ON SPECTRAL RESOLUTION AND SPEECH PERCEPTION: Emily R. Spitzer, David M. Landsberger, David R. Friedmann

M26: DOES ENVIRONMENTAL SOUND PERCEPTION IMPROVE AFTER COCHLEAR IMPLANTATION? Michael S. Harris, Benjamin Hamel, Kevin McMahon, Aaron Moberly, Valeriy Shafiro

M27: OPTIMIZED STIMULI FOR MEASURING AUDITORY STEADY-STATE RESPONSES ACROSS THE ELECTRODE ARRAY IN CI USERS: Wouter David, Robin Gransier, Jan Wouters

M28: INVESTIGATION OF AUDITORY NERVE FIBERS FACILITATION EFFECT IN COCHLEAR IMPLANT RECIPIENTS: Sonia Tabibi, Andrea Kegel, Waikong Lai, Norbert Dillier

M29: INVESTIGATING THE REDUCTION OF THE FACIAL NERVE STIMULATION IN COCHLEAR IMPLANTS BY TRIPHASIC PULSES: David P. Herrmann, Randy K. Kalkman, Johannes H. M. Frijns, Andreas Bahmer

M30: EFFECTS OF ELECTRICAL PULSE POLARITY SHAPE ON INTRA COCHLEAR NEURAL RESPONSES IN HUMANS: TRIPHASIC PULSES WITH ANODIC SECOND PHASE: Katharina V. A. Kretzer, David P. Herrmann, Andreas Bahmer

M31: ULTRAFAST RED-SHIFTED OPTOGENETIC STIMULATION OF THE AUDITORY NERVE: Burak Bali, Antoine Huet, Vladan Rankovic, Tobias Moser

M32: COMPARISON OF ELECTRICAL AND OPTICAL STIMULATION OF THE COCHLEAR NUCLEUS: IMPLICATIONS FOR FUTURE AUDITORY BRAINSTEM IMPLANTS: Stephen McInturff, Osama Tarabichi, Vivek Kanumuri, Nicolas Vachicouras, Stephanie Lacour, Daniel J. Lee, Christian Brown

M33: EXPLORING RAMPED PULSE SHAPES FOR COCHLEAR IMPLANTS IN AN ANIMAL MODEL: Charlotte Amalie Navntoft, Jeremy Marozeau, Tania Rinaldi Barkat

M34: CONGENITAL SINGLE-SIDED DEAFNESS; TO TREAT OR NOT TO TREAT: Martijn J.H. Agterberg, Arjan J. Bosman, Ad F.M. Snik, Lucas Mens

M35: MEASURING LOCAL FIELD POTENTIALS IN PATIENTS WITH AUDITORY BRAINSTEM IMPLANTS: Lutz Gaertner, Thomas Lenarz, Andreas Buechner

M36: THE EFFECT OF CURRENT SHAPING ON SPECTRAL RESOLUTION WITH LATERAL WALL AND MID-SCALAR ELECTRODE ARRAYS: Monica Padilla, David M. Landsberger

M37: ASSESSMENT OF ADJUSTMENT TO ELECTRICAL THRESHOLD (T) LEVEL AND ELECTRICAL STIMULATION RATE ON IDL AND AM DETECTION AT SOFT PRESENTATION LEVEL IN ADULT CI USERS: Terry B. Nunn, Dan Jiang, Tim Green, Deborah Vickers

M38: AUTOMATED ADJUSTMENT AND EVALUATION OF ELECTRICAL HEARING THRESHOLDS IN COCHLEAR IMPLANT PATIENTS: Tobias Rader, Johannes Plesch, Sebastian Strieth

M39: SPECTRAL ALIASING IN A SPECTRAL RIPPLE DISCRIMINATION TASK: Jesse M. Resnick, Anisha R. Noble, Jay T. Rubinstein, David L. Horn

M40: CHANNEL INTERACTIONS IN COCHLEAR IMPLANTS: DO THEY REALLY INCREASE AT HIGH CURRENT LEVELS? Quentin Mesnildrey, Stephane Roman, Olivier Macherey

M41: INDIVIDUAL DIFFERENCES IN RECALIBRATING TO UPWARD SPECTRAL SHIFTS: Michael Louis Smith, Matthew Brandon Winn

M42: SPECTRAL CONTRAST EFFECTS REVEAL DIFFERENT ACOUSTIC CUES FOR VOWEL RECOGNITION IN COCHLEAR-IMPLANT USERS: Lei Feng, Heather A. Kreft, Andrew J. Oxenham

M43: EVALUATING THE EFFECT OF INCREASED SPREAD OF EXCITATION ON SPEECH-IN-NOISE PERCEPTION BY COCHLEAR IMPLANT LISTENERS: Tobias Goehring, Julie G. Arenberg, Robert P. Carlyon

M44: EFFECT OF PHASE DURATION ON JITTER DETECTION: PSYCHOPHYSICS AND COMPUTATIONAL MODELING: Olivier Macherey, Jesse M. Resnick, Jay T. Rubinstein

M45: RECOVERY FROM PRIOR STIMULATION IN ABI AND CI USERS: AN INSIGHT INTO TEMPORAL PROCESSING PERFORMANCE: Mahan Azadpour, William H. Shapiro, Mario A. Svirsky

M46: APPLYING ACROSS-CHANNEL MODULATION MASKING TO THE IDENTIFICATION OF POORER COCHLEAR IMPLANT CHANNELS: Patrick J. Boyle, Joseph Schlittenlacher, Joanna Muff, James Tysome, Sali Saleh, Deborah Vickers, Brian C.J. Moore

M47: SPREAD OF EXCITATION WITH INCREASING PULSE AMPLITUDE OR PHASE DURATION: Ning Zhou, Lixue Dong, John Galvin

M48: PITCH MATCHING: ELECTRODE LOCATION OR PROCEDURAL ARTIFACT? Kenneth Kragh Jensen, Olga A Stakhovskaya, Elizabeth Kolberg, Jack H Noble, Matt Goupell, Joshua G. W. Bernstein

M49: EFFECT OF NUMBER OF ACTIVE ELECTRODES AND CHANNEL STIMULATION RATE ON SPEECH RECOGNITION AND SOUND QUALITY: Katelyn Berg, Jack Noble, Benoit Dawant, Robert Dwyer, Robert Labadie, Rene Gifford

M50: HOW MANY CHANNELS DO PEDIATRIC COCHLEAR IMPLANT USERS NEED FOR MAXIMUM PERFORMANCE? Jourdan Taylor Holder, Linsey Watkins Sunderhaus, Rene Headrick Gifford

M51: FREQUENCY WARPING AND SPEECH INTELLIGIBILITY IN COCHLEAR IMPLANT LISTENERS: Kutay B. Sezginel, Christopher A. Brown

M52: MODULATION FREQUENCY DISCRIMINATION INTERFERENCE IN COCHLEAR IMPLANT USERS: Shaikat Hossain, Raymond Goldsworthy

M53: AMPLITUDE MODULATION DEPTH DISCRIMINATION BY COCHLEAR IMPLANT USERS: Jessica J. M. Monaghan, Robert P. Carlyon, John M. Deeks

M54: COMPARING ANALOG AND PULSATILE STRATEGIES USING PRIMARILY TEMPORAL INFORMATION: Natalia Stupak, David Landsberger

M55: USING AUTOMATIC SPEECH RECOGNITION AND SPEECH SYNTHESIS TO IMPROVE SPEECH INTELLIGIBILITY FOR COCHLEAR IMPLANT USERS IN REVERBERANT AND NOISY LISTENING ENVIRONMENTS: Kevin M. Chu, Leslie M. Collins, Boyla O. Mainsah

M56: EVALUATING INDIVIDUALIZED COCHLEAR IMPLANT PROCESSORS WHOSE SITES OF STIMULATION WERE SELECTED USING THE INTERPHASE GAP EFFECT AND A COMBINATION OF PHYSICAL AND VIRTUAL ELECTRODES: Joshua S. Stohl, Kostas Kokkinakis

M57: INDIVIDUALIZING ELECTRIC FREQUENCY FILTER ASSIGNMENTS FOR COCHLEAR IMPLANT AND ELECTRIC-ACOUSTIC STIMULATION DEVICES: NORMAL-HEARING SIMULATIONS: Margaret T. Dillon, Brendan P. O'Connell, Emily Buss, Joseph B. Hopfinger

M58: INDIVIDUALIZING ELECTRIC FREQUENCY FILTERS FOR COCHLEAR IMPLANT AND ELECTRIC-ACOUSTIC STIMULATION DEVICES: PATIENT DATA: Margaret T. Dillon, Emily Buss, Michael W Canfarotta, Meredith A. Rooth, Harold C. Pillsbury, Kevin D. Brown, Brendan P. OConnell

M59: MASK ESTIMATION MODELS FOR REVERBERANT ARTIFACT REMOVAL IN COCHLEAR IMPLANT PULSE TRAINS: Lidea Shahidi, Leslie Collins, Boyla Mainsah

M60: A REAL-TIME NOISE REDUCTION ALGORITHM BY ESTIMATING SPEECH GAP FOR COCHLEAR IMPLANT: Tzu-Lin Ong, Xinzhao Liu, Yi-Ting Tsai, Xindong Liu, Zengjun Sun, Kaibao Nie

M61: LONG-TERM EVALUATION OF SINGLE-SIDED DEAF AND ASYMMETRIC HEARING IMPAIRED CI RECIPIENTS: Susan Arndt, Pascal Challier, Frederike Hassepass, Thomas Wesarg, Antje Aschendorff, Iva Speck

M62: SOCIAL FACTORS AND INDIVIDUAL OUTCOMES IN COCHLEAR IMPLANT USERS: Erin O'Neill, John Basile, Peggy Nelson

M63: QUALITY OF LIFE FOR ADULT COCHLEAR IMPLANT RECIPIENTS WITH ASYMMETRIC HEARING LOSS AS REPORTED BY PARTICIPANTS AND THEIR SIGNIFICANT OTHERS – INITIAL RESULTS OF A CLINICAL TRIAL: Jill B. Firszt, Ruth M. Reeder, Laura K. Holden, Noel Dwyer, Tim Holden, WUSM Asymmetric Hearing Study Team

M64: ENVELOPE COMPRESSION AS A QUALIFYING FACTOR IN THE "EIGHT-CHANNEL LIMIT": Coral Erica Dirks, Matthew Brandon Winn

M65: PURE TONE AUDIOMETRY VS. SPEECH AUDIOMETRY AS INCLUSION CRITERIA FOR COCHLEAR IMPLANTATION IN ADULTS: Tirza F.K. van der Straaten, Jeroen J. Briaire, Anouk V.M. Burger, Johan H.M. Frijns

M66: CONTEXT AND USER REQUIREMENTS FOR DIGITAL SPEECH THERAPY FOR THE SEVERELY HEARING IMPAIRED – FIRST RESULTS (THERESIAH): Markus Meis, Joerg-Hendrik Bach, Andreas Becker, Kerstin Bilda, Alev Erem, Tobias Feith, Stefan Goetze, Jonna Juers, Andreas Radeloff, Benjamin Tschuschke, Laura Tuschen

M67: COMPREHENSIVE ONLINE ASSESSMENT OF AUDITORY ABILITIES IN COCHLEAR IMPLANT USERS: Valeriy Shafiro, Megan Hebb, Ying Hsiao, Kelly Brown, Chad Walker, Jasper Oh, Stanley Sheft, Kara Vasil, Aaron Moberly

M68: RELIABILITY OF VISUAL SPEECH PREDICTS NEURAL SUPPRESSION OF DEGRADED AUDITORY SPEECH: Hannah E. Shatzer, Aaron C. Moberly, Mark A. Pitt, Kara J. Vasil, Antoine J. Shahin

M69: ANALYSIS OF FRICATIVES IN SPEECH PRODUCED BY HEARING IMPAIRED INDIVIDUALS AIDED WITH DIFFERENT ASSISTIVE HEARING DEVICES: Shruthi Raghavendra, Sungmin Lee, Justine Hui, Chin-Tuan Tan

M70: DISCRIMINATION THRESHOLDS IN SELF-PRODUCED SPEECH IN COCHLEAR IMPLANT LISTENERS AND NORMAL LISTENERS: Sarah Bakst, Caroline A. Niziolek, Ruth Y. Litovsky

M71: VALIDITY AND RELIABILITY OF THE COCHLEAR IMPLANT QUALITY OF LIFE (CIQOL) PROFILE AND GLOBAL INSTRUMENTS IN COMPARISON TO LEGACY INSTRUMENTS: Theodore R. McRackan, Brittany N. Hand, Craig A. Velozo, Judy R. Dubno

TUESDAY–8AM TO MIDNIGHT

T1: CLINICAL RESULTS WITH A FULLY IMPLANTABLE ACOUSTIC PROSTHESIS; THE BENEFIT OF LISTENING WITH TWO DEVICES: Martijn J.H. Agterberg, John Noten, Cris Lanting, Jef Mulder

T2: THE QUEST FOR BINAURAL CUE PROCESSING IN COCHLEAR IMPLANT USERS' SPEECH PERCEPTION: Benjamin Dieudonne, Tom Francart

T3: THE ABILITY TO UNDERSTAND INTERAURAL ALTERNATING SPEECH IS INTACT IN BILATERAL COCHLEAR-IMPLANT LISTENERS: Ellen Peng, Matthew J Goupell, Chantal van Ginkel, Danielle Zukerman, Ruth Y. Litovsky

T4: CHRONIC BILATERAL STIMULATION THROUGH COCHLEAR IMPLANTS DURING DEVELOPMENT CAN REVERSE THE EFFECT OF EARLY-ONSET DEAFNESS ON NEURAL ITD SENSITIVITY: Woongsang Sunwoo, Bertrand Delgutte, Yoojin Chung

T5: MODELLING EXPERIENCE-DEPENDENT SOUND LOCALIZATION FOR DIFFERENT HEARING-IMPAIRMENTS: Seba Ausili, John van Opstal, Marc van Wanrooij

T6: IMPROVING BINAURAL UNMASKING BY ADJUSTING FREQUENCY MAPS IN SSD-CI SIMULATIONS: Jonathan Neukam, Mahan Azadpour, Elad Sagi, Nicole Capach, Mario Svirsky

T7: TOWARDS A CLINICAL APPROACH FOR CREATING BILATERAL COCHLEAR IMPLANT MAPS: Justin M. Aronoff, Hannah E. Staisloff, Abbigail Kirchner

T8: EFFECTS OF SPECTRAL RESOLUTION AND FREQUENCY MISMATCH ON SPATIAL RELEASE MASKING IN SIMULATED BILATERAL COCHLEAR IMPLANTS: Kevin Xu, Quinton Gopen, Qian-jie Fu

T9: INTERAURAL MISMATCHES IN INSERTION DEPTH AND SCALA LOCATION FOR BILATERAL COCHLEAR-IMPLANT USERS: Matthew J Goupell, Jack H Noble, Elizabeth Kolberg, Olga A Stakhovskaya, Kenneth K Jensen, Michael Hoa, Jeffery Kim, Joshua GW Bernstein

T10: IMPROVING SPEECH INTELLIGIBILITY OF BILATERAL COCHLEAR IMPLANT USERS WITH A BINAURAL N-OF-M SOUND CODING STRATEGY: Tom Gajecki, Waldo Nogueira

T11: ASSESSING SOUND SOURCE LOCALIZATION IN LISTENERS WITH BILATERAL COCHLEAR IMPLANTS: Sean R Anderson, Rachael Jocewicz, Alan Kan, Ruth Y Litovsky

T12: ASSESSMENT OF BINAURAL STREAMING IN CI PATIENTS: Niclas Alexander Janssen, Jeremy Marozeau, Andreas Buechner

T13: SOLVING THE COCKTAIL PARTY PROBLEM WITH THE INTERAURAL LEVEL DIFFERENCE CUE: Christopher A. Brown

T14: A VR-BASED ENVIRONMENT ENABLING BICI SPATIAL SOUND RESEARCH - DEVELOPMENT AND EXPERIMENTAL VERIFICATION: Kacper Kosikowski, Bradford C Backus, Francois Patou, Tobias Herzke, Jeremy Marozeau, Soren Kamaric Riis

T15: LATERALIZATION OF VIRTUAL SOUND SOURCES WITH A BINAURAL COCHLEAR-IMPLANT SOUND CODING STRATEGY INSPIRED BY THE MEDIAL OLIVOCOCHLEAR REFLEX: Enrique A. Lopez-Poveda, Almudena Eustaquio-Martin, Milagros J. Fumero, Joshua S. Stohl, Reinhold Schatzer, Peter Nopp, Robert D. Wolford, Jose Manuel Gorospe, Ruben Polo Lopez, Auxiliadora Gutierrez Revilla, Blake S. Wilson

T16: THE IMPORTANCE OF SOUND LEVEL IN SOUND LOCALIZATION ASSESSMENT: Hillary Snapp, Martijn Agterberg, Astrid Van Wieringen

T17: THE EFFECT OF SOUND LEVEL ON THE SPATIAL SPEECH PERCEPTION IN COMPLEX AUDITORY ENVIRONMENT FOR COCHLEAR IMPLANT USERS: Sara Akbarzadeh, Sungmin Lee, Chin-tuan Tan

T18: EFFECT OF LINKED AND “SPATIALLY AWARE” COCHLEAR-IMPLANT COMPRESSION ON SPATIAL PERCEPTION IN A REVERBERANT ROOM: Rasmus Østergaard Bendsen, Abigail Anne Kressner, Torsten Dau

T19: SYNCHRONIZED AUTOMATIC GAIN CONTROL (AGC) IN BILATERAL COCHLEAR IMPLANT RECIPIENTS YIELD SIGNIFICANT LOCALIZATION BENEFIT: Robert T Dwyer, Nichole C Dwyer, Rene H Gifford

T20: EFFECT OF (MIS)MATCHED COMPRESSION SPEED ON SPEECH INTELLIGIBILITY IN BIMODAL LISTENERS: Dimitar Spirrov, Eugen Kludt, Eline Verschueren, Andreas Buechner, Tom Francart

T21: MASKING EFFECTS IN THE PERCEPTION OF MULTIPLE SIMULTANEOUS TALKERS IN NORMAL-HEARING AND COCHLEAR IMPLANT USERS: Qian-Jie Fu, Quinton Gopen, Biao Chen, Ying Shi, Yongxin Li

T22: THE SEGREGATION OF SEQUENTIALLY INTERLEAVED SENTENCES BY NORMAL-HEARING AND COCHLEAR-IMPLANT LISTENERS USING MONAURAL LEVEL CUES. : Alan W Archer-Boyd, Robert P Carlyon

T23: MODULATION INTERFERENCE BETWEEN BILATERALLY PRESENTED STIMULI IN COCHLEAR-IMPLANT USERS: Monita Chatterjee, Aditya M Kulkarni

T24: ANODIC VERSUS CATHODIC QUADRAPHASIC PULSES: EFFECTS ON THE PERCEPTION OF INTERAURAL TIME DIFFERENCES IN COCHLEAR IMPLANT LISTENERS: Francois Guerit, Jeremy Marozeau, Suyash N. Joshi, Bastian Epp

T25: NORMAL HEARING LOUDNESS GROWTH IN BILATERAL COCHLEAR IMPLANT USERS: Adam A Hersbach, Ruth E English, Evelyn Do, Kerrie L Plant, Zachary M Smith

T26: SPECTRAL AND BINAURAL LOUDNESS SUMMATION IN SINGLE-SIDED-DEAFNESS AND BILATERAL COCHLEAR IMPLANT USERS: Hongmei HU, Laura Hartog, Stephan D. Ewert

T27: USING PARTICIPATORY DESIGN TO DEVELOP AND EVALUATE A TOOL FOR DETECTING LOUDNESS IMBALANCE ACROSS EARS IN BILATERAL COCHLEAR-IMPLANT USERS: Marina Salorio-Corbetto, Deborah A. Vickers, Lorenzo Picinali

T28: ONSET WEIGHTING OF INTERAURAL TIME DIFFERENCES IN NEONATALLY DEAFENED CI RATS IS COMPARABLE TO NORMAL HEARING RATS: Alexa Nadezhda Buck, Nicole Rosskothen-Kuhl, Kongyan Li, Lakshay Khurana, Chloe H.K Chan, Jan W Schnupp

T29: SENSITIVITY OF COCHLEAR IMPLANT USERS TO ITDS OF PURE TONES USING CLINICAL CODING STRATEGIES: Christian Wirtz, Dirk Meister, Werner Hemmert

T30: WITHIN-EAR BALANCING OF RESPONSE STRENGTH BETWEEN ACOUSTIC AND ELECTRIC STIMULATION IMPROVES NEURAL SENSITIVITY TO INTERAURAL TIME DIFFERENCES IN BIMODAL STIMULATION: Maike Vollmer, Merle Berents, Andrew Curran, Armin Wiegner

T31: IMPROVING ITD-BASED LOCALIZATION OF BILATERAL CI USERS BY SELECTED TEMPORAL MANIPULATION OF THE SOUND’S ENVELOPE: Bernhard U. Seeber, Aswin Wijetillake

T32: ARE BALANCE DEFICITS IN CHILDREN WITH BILATERAL AND UNILATERAL DEAFNESS DUE TO VESTIBULAR IMPAIRMENT ALONE? Claire McSweeny, Sharon L Cushing, Jennifer Campos, Blake C Papsin, Karen A Gordon

T33: DISRUPTED INTERHEMISPHERIC COHERENCE IN CHILDREN RECEIVING BILATERAL IMPLANTS SIMULTANEOUSLY: Daniel Smieja, Benjamin T. Dunkley, Blake Papsin, Karen A. Gordon

T34: HEAD SHADOW ENHANCEMENT TO IMPROVE SOUND LOCALIZATION AND SPEECH INTELLIGIBILITY IN NOISE FOR BIMODAL LISTENERS: Benjamin Dieudonne, Tom Francart

T35: SPATIAL HEARING OF BIMODAL EAS USERS: Snandan Sharma

T36: SPATIAL SPEECH INTELLIGIBILITY IN BIMODAL AND SINGLE-SIDED DEAF COCHLEAR IMPLANT USERS – A MODEL, SIMULATION AND PATIENT MEASUREMENT COMPARISON: Tim Juergens, Ben Williges, Ayham Zedan, Thomas Wesarg

T37: EFFECTS OF ELECTRO-ACOUSTIC STIMULATION ON HEARING IN GUINEA PIGS WITH HYBRID COCHLEAR IMPLANTS: Melissa B. Lawrence, Irina A. Omelchenko, Wenxuan He, Douglas Fitzpatrick, Michael E. Reiss, Lina A.J. Reiss

T38: EFFECT OF THE DEVICE DELAY MISMATCH ON SOUND LOCALIZATION ACCURACY IN BIMODAL LISTENERS: Stefan Zirn, Julian Angermeier, Susan Arndt, Thomas Wesarg

T39: THE BENEFIT OF CONTRALATERAL ROUTING OF SIGNALS IN CI USERS WITH RESIDUAL HEARING: H Christiaan Stronks, Jeroen J. Briaire, Johan H. M. Frijns

T40: CONTRALATERAL SUPPRESSION OF HUMAN HEARING SENSITIVITY IN SINGLE-SIDED DEAF COCHLEAR IMPLANT USERS: Waldo Nogueira, Enrique Lopez-Poveda, Benjamin Krueger, Paul Delano, Constantino Dragicevic

T41: PITCH MATCHING IN COCHLEAR IMPLANTEES WITH SINGLE-SIDED DEAFNESS: EFFECTS OF ELECTRODE POSITION AND ACOUSTIC STIMULUS TYPE: Youssef Adel, Tobias Weissgerber, Uwe Baumann, Olivier Macherey

T42: BINAURAL PITCH FUSION: COMPARISON OF ISOLATED AND TEMPORALLY FLANKED DICHOTIC STIMULI: Yonghee Oh, Lina Reiss, Frederick Gallun

T43: IMPACT OF FLAT PANEL CT-BASED COCHLEAR IMPLANT FITTINGS ON SPEECH, TIMBRE, AND PITCH PERCEPTION: Melanie L. Gilbert, Nicole T. Jiam, Patpong Jiradejvong, Daniel L. Cooke, Charles J. Limb

T44: ELECTRODE PITCH RANK ORDER IN FULL-TIME AUDITORY BRAINSTEM IMPLANT (ABI) USERS: Christine Carter, Dana Egra-Dana, Barbara Herrmann

T45: EXPLORING POLYPHONIC PITCH PERCEPTION IN COCHLEAR IMPLANT USERS: Andres Camarena

T46: THE EFFECT OF STIMULUS CARRIER RATE ON PITCH PERCEPTION AND LOUDNESS IN COCHLEAR IMPLANT USERS: Damir Kovačić, Chris James

T47: RATE PITCH DISCRIMINATION WITH DOUBLE PULSE INTERVALS OPTIMIZED USING ECAP RESPONSES: Sabrina H. Pieper, David P. Herrmann, Andreas Bahmer

T48: BENEFITS OF VARIABLE-RATE STIMULATION FOR COCHLEAR IMPLANT PITCH PERCEPTION: Ray Goldsworthy

T49: PITCH CONVEYED THROUGH ELECTRODE LOCATION AND STIMULATION RATE IN COCHLEAR IMPLANT USERS: Susan Rebekah Subrahmanyam Bissmeyer, Raymond L. Goldsworthy

T50: EFFICIENT EXTRACTION AND SPECTRAL OF TEMPORAL INFORMATION FOR PITCH CODING IN CI: Aswin Adris Wijetillake, Julian Skovgaard, Kai Dang, Manuel Segovia Martinez

T51: TEMPORAL PITCH WITH SHORT INTER-PULSE INTERVALS: AMPLITUDE MODULATION, RATE LIMITATIONS, AND PITCH-CUE DOMINANCE: Martin Lindenbeck, Sridhar Srinivasan, Bernhard Laback, Maike Ferber, Piotr Majdak

T52: MANDARIN TONE PERCEPTION WITH COCHLEAR IMPLANTS USING PRIMARY PITCH WITHOUT RELIABLE SECONDARY CUES: Qinglin Meng, Xiaoya Wang, Weiyan Guo, Fanhui Kong, Guangzheng Yu, Nengheng Zheng, Jan W. H. Schnupp

T53: CAN LISTENERS COMBINE PURELY TEMPORAL INFORMATION FROM DIFFERENT FREQUENCY REGIONS TO HEAR THE “MISSING FUNDAMENTAL” PITCH?: John M. Deeks, Hedwig E. Gockel, Robert P. Carlyon

T54: SPECTRAL SLOPE DISCRIMINATION WITH COCHLEAR IMPLANT SIMULATIONS: Xin Luo, Barierane Akeeh, Kathryn Pulling

T55: DETERMINING UNDERLYING VOCAL PITCH DIMENSIONS IN COCHLEAR IMPLANT USERS: Bailey E. Harmon, Hannah E. Staisloff, Emily Ann O'Brien, Grace H. Kim, Justin M. Aronoff

T56: VOICE PITCH CONTROL IN COCHLEAR IMPLANT USERS: Razieh Alemi, Alexane Lehmann, Mickael Deroche

T57: DO LISTENERS UTILIZE VOICE CUES IN NOISE AS IN QUIET FOR A SPEAKER DISCRIMINATION TASK? : Yael Zaltz, Feigi Grinvald, Liat Kishon Rabin

T58: HOW AGING AND LISTENING EXPERIENCE AFFECT VOICE-GENDER DISCRIMINATION AND SPEECH RECOGNITION IN NOISE IN ADULT COCHLEAR IMPLANT LISTENERS: Kara C. Schvartz-Leyzac, Teresa A. Zwolan, Bryan E. Pfingst

T59: DISSOCIATED DEVELOPMENT OF VOICE PERCEPTION ACROSS GENDER CUES IN NORMAL-HEARING AND COCHLEAR IMPLANT CHILDREN: Leanne Nagels, Etienne Gaudrain, Debi Vickers, Petra Hendriks, Deniz Başkent

T60: SINGING PROFICIENCY IN CHILDREN WITH BIMODAL HEARING AND BILATERAL COCHLEAR IMPLANTS: Jing Yang, Rosalie M. Uchanski, Emily Hahn, Xianhui Wang, Lisa S. Davidson, Li Xu

T61: EFFECT OF ACOUSTIC BANDWIDTH ON BIMODAL BENEFIT FOR MUSIC PERCEPTION AND APPRECIATION: Kristen D'Onofrio, Spencer Smith, Rene Gifford

T62: MELODIC CONTOUR IDENTIFICATION COMPARABLE IN EARLY-DEAFENED, LATE-IMPLANTED AND POST-LINGUALLY DEAFENED COCHLEAR IMPLANT USERS: Christina D. Fuller, Deniz Başkent, Rolien H. Free

T63: PERCEPTION OF SEQUENTIAL MUSICAL INTERVALS BY UNILATERALLY DEAF COCHLEAR IMPLANT USERS: Emily R. Spitzer, John J. Galvin III, David R. Friedmann, David M. Landsberger

T64: OBJECTIVE MEASUREMENTS OF MUSIC DISCRIMINATION IN INDIVIDUAL COCHLEAR IMPLANT USERS: Bjorn Petersen, Niels Trusbak Haumann, Anne Sofie Friis Andersen, Andreas Hoejlund, Martin Dietz, Soeren Kamaric Riis, Elvira Brattico, Peter Vuust

T65: AN ON-LINE ALGORITHM FOR SPECTRAL COMPLEXITY REDUCTION OF MUSIC SIGNALS FOR COCHLEAR IMPLANT LISTENERS: Johannes Gauer, Ekaterina Krymova, Christiane Voelter, Denis Belomestny, Rainer Martin

T66: THE OPAL STRATEGY IMPROVES COCHLEAR IMPLANT PITCH AND MELODY PERCEPTION: Andrew E. Vandali, Brett A. Swanson, Anna O'Brien, Evelyn Do, Dakota Bysouth-Young, Rachelle Hassarati, Robert Cowan

POSTER SESSION W: WEDNESDAY –8AM TO MIDNIGHT

W1: DESIGNING SHAPE MEMORY ALLOY ACTUATORS TAILORED TO THE HUMAN COCHLEA GEOMETRY: Nuha Suzaly, Silke Huegl, Thomas S. Rau, Thomas Lenarz

W2: DEVELOPMENT OF AN IMPLANTABLE MEMS SENSOR FOR HEARING DEVICES: Guilherme Miron, Andre Gesing, Fabio Alves, Stephan Paul, Julio Cordioli

W3: COMPARISON OF MULTI-COMPARTMENT CABLE MODELS OF HUMAN AUDITORY NERVE FIBRES: Siwei Bai, Richard Bachmaier, Joerg Encke, Miguel Obando-Leiton, Werner Hemmert

W4: DEVELOPMENT/ESTABLISHMENT OF IN VITRO MODEL TO UNDERSTAND THE EFFECT OF ELECTRICAL STIMULATION ON INNER EAR: Adrien A. Eshraghi, Zaid Al-Zaghal, Mario M. Perdomo, Stefanie A. Pena, Jeenu Mittal, Carolyn Garnham, Elijah J. Horesh, Christopher Otoole, Jorge Bohorquez, Rahul Mittal

W5: REPLICATION AND USE OF A LADDER NETWORK OF RESISTORS FOR MODELLING INTRA-COCHLEAR VOLTAGE MEASUREMENTS: Francois Guerit, Simone de Rijk, Manohar Bance, Robert P. Carlyon

W6: THE ANATOMICAL NEURAL FRAMEWORK SUPPORTING AUDITION IS PRESERVED IN DEAF CATS: Blake E. Butler, Stephen G. Lomber

W7: SPATIAL DECONVOLUTION OF INTRACOCHLEAR POTENTIALS SUPPORTS ECTOPIC ELECTRICAL STIMULATION HYPOTHESIS: Charles C. Finley, Laura K. Holden, Timothy A. Holden, Jill B. Firszt

W8: ELECTRODE MISDIRECTION INTO THE SUPERIOR SEMICIRCULAR CANAL: COMPLICATION OF COCHLEAR IMPLANTATION BY ROUND WINDOW APPROACH: Minbum Kim

W9: SIMULATING THE EFFECTS OF “M-CURRENT” POTASSIUM CHANNELS IN COCHLEAR IMPLANT EXCITATION OF AUDITORY NERVE FIBERS: Ian C. Bruce, Laura Green, Babak V-Ghaffari, Mark A. Rutherford

W10: MODELLING ELECTRICALLY EVOKED COMPOUND ACTION POTENTIALS AND SINGLE NEURON RESPONSES TO PREDICT POLARITY AND PULSE SHAPE EFFECTS ON SPIRAL GANGLION NEURONS UNDER ELECTRO-STIMULATION: Matthieu Recugnat, Jaime Undurraga, David McAlpine

W11: EVALUATION OF A NEW ALGORITHM TO OPTIMIZE AUDIBILITY IN COCHLEAR IMPLANT RECIPIENTS: Laura K. Holden, Jill B. Firszt, Ruth M. Reeder, Noel Y. Dwyer, Amy L. Stein, Leo M. Litvak

W12: PRELIMINARY EVALUATION OF THE SOUNDBITE BONE-CONDUCTION DEVICE FOR CHINESE SSD ADULTS: Xin Xi, Xian Hua Zhang, An Ran Pang, Shuo Shou Kang, Yu Su, Yong Yi Yuan, Quan Shi, Hui Zhao

W13: BENCHMARK OF HEALTH-RELATED QUALITY OF LIFE QUESTIONNAIRES IN BIMODAL HEARING SYSTEM SUPPLY: Mareike Grundmann, Karsten Plotz, Andreas Radeloff, Gisela Schulze, Markus Meis

W14: A CODING STRATEGY TO REMOVE TEMPORALLY MASKED PULSES AND ITS EFFECT ON SPEECH PERCEPTION IN COCHLEAR IMPLANT USERS: Wiebke Lamping, Tobias Goehring, Abigail A. Kressner, Jeremy Marozeau, Robert P. Carlyon

W15: WORD LEARNING IN ADULTS WITH COCHLEAR IMPLANTS: EXAMINING THE INFLUENCE OF TALKER VARIABILITY AND AUDIOVISUAL SPEECH: Jasenia Hartman, Jenny Saffran, Ruth Litovsky

W16: THE EFFECT OF AGE ON COCHLEAR-IMPLANT USERS’ RECOGNITION OF CONSONANT CONTRASTS THAT VARY IN DISCRETE TEMPORAL CUES AT DIFFERENT STIMULATION RATES AND ENVELOPE MODULATION RATES: Maureen J. Shader, Sandra Gordon-Salant, Bomjun Kwon, Matthew J. Goupell

W17: ACHIEVING EQUIVALENT COCHLEAR IMPLANT SPEECH RECOGNITION IN VIRTUAL AND REAL SOUND BOOTHS: Chen Chen, Amy L Stein, Hayley R. Morris, Daniel Zeitler, Leonid M. Litvak

W18: SPEECH RECOGNITION IN NOISE IN SINGLE-SIDED DEAF COCHLEAR IMPLANT CHILDREN WITH APPLICATION OF DIGITAL WIRELESS ADAPTIVE MICROPHONE TECHNOLOGY: Thomas Wesarg, Iva Speck, Susan Arndt, Tanja Mueller, Konstantin Wiebe, Frederike Hassepass, Till Fabian Jakob

W19: DECODING THE AUDITORY NERVE. IMPLICATIONS FOR COCHLEAR IMPLANT TECHNOLOGY: Jacques Andre Grange, John Francis Culling

W20: THE MOST ACCURATE ACOUSTIC MODEL OF A COCHLEAR IMPLANT DIFFERS ACROSS INDIVIDUALS: THE INFLUENCE OF ELECTRODE INSERTION DEPTH AND AUDITORY PLASTICITY: Nicole Hope Capach, Mahan Azadpour, Elad Sagi, Jonathan D Neukam, Rene Gifford, Robert T Dwyer, Artur Lorens, Marika Kruszynska, Mario A Svirsky

W21: DETECTING EXTRACOCHLEAR ELECTRODES WITH TRANSIMPEDANCE MEASUREMENTS IN COCHLEAR IMPLANTS: A HUMAN CADAVER STUDY: Simone Rosalie de Rijk, Manohar Bance

W22: IMPEDANCE DEVELOPMENT AFTER IMPLANTATION OF HYBRID-L24 ELECTRODES: Simon Konrad, Andreas Buechner, Thomas Lenarz, Gerrit Paasche

W23: QUANTIFYING CHILDREN'S "REAL WORLD" SOUND ENVIRONMENTS: A COMPARISON BETWEEN SPEECH PROCESSOR DATALOGGING AND HUMAN CODER CLASSIFICATIONS: Hillary V. Ganek, Deja Forde-Dixon, Sharon L Cushing, Blake C. Papsin, Karen A. Gordon

W24: SELECT AND CONVEY SOUNDS INFORMATION: THEIR EFFECTS IN VOCODED NORMAL HEARING LISTENERS: Pierre Stahl, Marianna Vatti, Manuel Segovia Martinez, Kai Dang, Dan Gnansia

W25: OBJECTIVE AND SUBJECTIVE ANALYSIS OF A FRONT-END AGC WITH A BACK-END MULTI-BAND DYNAMIC COMPENSATION SYSTEM: Florian Langner, Andreas Buechner[DB1], Waldo Nogueira

W26: THE IMPACT OF LOW RATE STIMULATION ON SPEECH UNDERSTANDING AND SOUND PERCEPTION USING THE ACE STRATEGY: Eugen Kludt, Thomas Lenarz, Andreas Buechner

W27: SOUND EVENT DETECTION AND CLASSIFICATION BASED ON WOLA SPECTRAL FEATURES FOR COCHLEAR IMPLANTS: Feifan Lai, Kaibao Nie

W28: OTICON MEDICAL BRAINHEARING: TOWARDS PUPILLOMETRY AS CLINICAL TOOL FOR COCHLEAR IMPLANTS: Ariane Laplante-Levesque, Romane Demullier, Michel Hoen, Marine Ardoint, Isabelle Mosnier, Christophe Vincent

W29: SURGICAL SAFETY AND CLINICAL EFFICIENCY OF THE OTICON MEDICAL NEURO COCHLEAR IMPLANT SYSTEM: Ariane Laplante-Levesque, Richard Bussieres, Joseph Chen, Nael Shoman, Tony Batten, Per Caye-Thomasen, David Schramm

W30: ACCURACY OF DRILL DEPTH CONTROL OF AN IMAGE-GUIDED MICRO-STEREOTACTIC TARGETING SYSTEM DEDICATED TO COCHLEAR IMPLANTATION SURGERY: Thomas Stephan Rau, Tobias Blum, Marcel Kluge, Samuel John, Lueder Alexander Kahrs, Tobias Ortmaier, Max Froehlich, Omid Majdani, Thomas Lenarz

W31: A BINAURAL CI RESEARCH PLATFORM FOR OTICON MEDICAL IMPLANTS ENABLING ITD/ILD AND VARIABLE RATE PROCESSING – AN UPDATE: Bradford C Backus, Adama Treguier, Fabien Berrettoni, Tobias Herzke, Kamil Adiloglu, Soren Kamaric Riis

W32: CCI-MOBILE: SAFETY AND PERFORMANCE EVALUATION: Ram Charan Mudha Chandra Shekar, John H. L. Hansen

W33: CCI-MOBILE: MOVING TOWARDS EXPLORING ADVANCED RESEARCH PARADIGMS FOR COCHLEAR IMPLANT AND HEARING AID USERS: Ria Ghosh, Juliana N. Saba, Nursadul Mamun, Ramcharan Chandra Shekhar, Avamarie Brueggeman, Hussnain Ali, John H. L. Hansen

W34: CCI-MOBILE: ENVIRONMENT-SPECIFIC SPEECH ENHANCEMENT WITH COCHLEAR IMPLANT LISTENERS USING CONVOLUTIONAL NEURAL NETWORK: Nursadul Mamun, Soheil Khorram, John H. L. Hansen

W35: CCI-MOBILE: INDIVIDUAL CHANNEL BOOSTING OF CONSONANT AND VOWEL SEGMENTS IN N-OF-M STRATEGIES FOR COCHLEAR IMPLANTS: Juliana N. Saba, Hussnain Ali, John H. L. Hansen

W36: CCI-MOBILE: OPEN-SOURCE APP DEVELOPMENT FOR REAL-TIME COCHLEAR IMPLANT PARAMETER ADJUSTMENT USING THE CCI-MOBILE RESEARCH PLATFORM: Avamarie Brueggeman, Hussnain Ali, John H. L. Hansen

W37: CCI-MOBILE: A PORTABLE, FLEXIBLE, REAL-TIME SOUND PROCESSING PLATFORM FOR COCHLEAR IMPLANT RESEARCH: Mahan Azadpour, Mario A. Svirsky

W38: CCI-MOBILE: EVALUATING EFFECTS OF PULSE RATE ON TEMPORAL PROCESSING AND SPEECH PERCEPTION IN CI USERS: Mahan Azadpour, Mario A. Svirsky

W39: CCI-MOBILE: DEVELOPMENT OF SOFTWARE BASED TOOLS FOR SPEECH PERCEPTION ASSESSMENT AND TRAINING WITH HEARING IMPAIRED BRAZILIAN POPULATION: Bernardo H. P. Murta, Rafael A. Chiea, Gustavo L. Mourao, Maria M. C. Pinheiro, Julio A. Cordioli, Stephan Paul

W40: LATERALIZATION OF INTERAURAL TIME DIFFERENCES MEASURED WITH THE CCI-MOBILE RESEARCH PLATFORM: Stephen R. Dennison, Alan Kan, Ruth Y. Litovsky

W41: A BINAURAL ADVANCED COMBINATION ENCODER STRATEGY FOR SOUND LOCALIZATION WITH THE CCI-MOBILE RESEARCH PLATFORM: Stephen R. Dennison, Alan Kan, Ruth Y. Litovsky

POSTER SESSION TH: THURSDAY –8AM TO MIDNIGHT

TH1: MONITORING OF THE INNER EAR FUNCTION DURING AND AFTER COCHLEAR IMPLANT INSERTION USING ELECTROCOCHLEOGRAPHY: Sabine Haumann, Max E. Timm, Marina Imsiecke, Andreas Buechner, Thomas Lenarz, Rolf B. Salcher

TH2: CHARACTERIZATION OF EAS INTERACTION THROUGH ECOCHG AMPLITUDE GROWTH FUNCTIONS: Benjamin Krueger, Andreas Buechner, Waldo Nogueira

TH3: RELATIONSHIP BETWEEN INTRA-OPERATIVE ECOCHG MONITORING AND HEARING PRESERVATION: Gunnar Geissler, Andreas Buechner, Rolf Salcher, Michael Bardt, Thomas Lenarz

TH4: ACOUSTICALLY EVOKED COMPOUND ACTION POTENTIAL USING THE POSTOPERATIVE ELECTROCOCHLEOGRAPHY FROM EAS/HYBRID COCHLEAR IMPLANT USERS: A PRELIMINARY STUDY: Jeong-Seo Kim, Viral Tejani, Paul Abbas, Carolyn Brown

TH5: POLARITY SENSITIVITY AND REFRACTORY RECOVERY OF THE ELECTRICALLY EVOKED COMPOUND ACTION POTENTIAL: Michelle L. Hughes

TH6: POLARITY SENSITIVITY OF THE ELECTRICALLY EVOKED COMPOUND ACTION POTENTIAL: EFFECTS OF PULSE PHASE DURATION: Michelle L. Hughes, Sangsook Choi

TH7: EFFECTS OF AGING AND DURATION OF DEAFNESS ON NEURAL FUNCTION OF THE ELECTRICALLY-STIMULATED COCHLEAR NERVE: Jeffrey Skidmore, Angela Pellittieri, William Jason Riggs, Shuman He

TH8: SHORT-TERM OVERSTIMULATION AFFECTS ECAP- AND EABR-THRESHOLDS IN GUINEA PIGS: Susanne Schwitzer, Moritz Groeschel, Horst Hessel, Arne Ernst, Dietmar Basta

TH9: RESPONSE STRENGTH AND RESPONSE SPREAD IN PRIMARY AUDITORY CORTEX AS TOOLS TO FIND THE "BEST/OPTIMAL/EFFICIENT" STIMULATION STRATEGY: Victor Adenis, Pierre Stahl, Dan Gnansia, Jean-Marc Edeline

TH10: EVALUATING AND COMPARING BEHAVIOURAL AND ELECTROPHYSIOLOGICAL ESTIMATES OF NEURAL SURVIVAL: Tim Brochier, John Deeks, Manohar Bance, Robert Carlyon

TH11: INTER-SCALAR SHIFT DETECTION FOR THE HIFOCUS MID-SCALA ELECTRODE ARRAY THROUGH INTRACOCHLEAR ELECTRICAL FIELD IMAGING: Yu Dong, Jeroen J Briaire, Michael Siebrecht, Johan H.M Frijns

TH12: BAND-LIMITED CHIRP-EVOKED COMPOUND ACTION POTENTIALS IN GUINEA PIGS: FEASIBILITY FOR COCHLEAR IMPLANTATION MONITORING: Youssef Adel, Jochen Tillein, Tobias Weissgerber, Uwe Baumann

TH13: METHODS FOR MEASURING AUDITORY CORTICAL CHANGES IN FELINE MODEL OF COCHLEAR IMPLANTATION: Kwame Kutten, Peter Hubka, Lea Sollmann, Laurent Younes, Andrej Kral, J Tilak Ratnanather

TH14: CONGENITAL AUDITORY DEPRIVATION AFFECTS CORTICAL FIELDS DIFFERENTLY – COMPARISON OF THE PRIMARY AUDITORY FIELD AI AND THE POSTERIOR AUDITORY FIELD PAF: Jochen Tillein, Peter Hubka, Andrej Kral

TH15: EFFECTS OF PULSE PHASE DURATION ON THE ELECTRICALLY-EVOKED COMPOUND ACTION POTENTIAL IN CHILDREN WITH COCHLEAR NERVE DEFICIENCY AND CHILDREN WITH NORMAL-SIZED COCHLEAR NERVES: Shuman He, Jeffrey Skidmore, Lei Xu, Xiuhua Chao, Jianfen Luo, Ruijie Wang, Haibo Wang

TH16: SPECTROTEMPORAL RIPPLE DENSITY DISCRIMINATION IN INFANTS AND ADULTS WITH NORMAL HEARING: EFFECT OF CARRIER RATE: Anisha R. Noble, Jesse M. Resnick, Mariette Broncheau, Stephanie Klotz, Jay T. Rubinstein, Lynne A. Werner, David L. Horn

TH17: PERCEPTION AND PRODUCTION ACCURACY AND ERROR PATTERNS IN NORMAL HEARING AND CHILDREN USING COCHLEAR IMPLANTS: Olga Peskova, Vahid Montazeri, Peter Assmann

TH18: CAN AURAL PREFERENCE DEVELOP IN AN OLDER CHILD AND THEN REVERSE AFTER HEARING RECOVERY IN ADULTHOOD?: A RARE SINGLE CASE STUDY: Jaina Negandhi, Blake Papsin, Robel Alemu, Karen A Gordon

TH19: EFFECT OF AURAL PREFERENCE ON CORTICAL BILATERAL ADVANTAGE IN CHILDREN WITH BIMODAL HEARING: Melissa J Polonenko, Daniel Smieja, Blake C Papsin, Karen A Gordon

TH20: LANGUAGE AND AUDITORY DATA OF CHILDREN WITH SINGLE-SIDED DEAFNESS AND A COCHLEAR IMPLANT: Tine Arras, Christian Desloovere, Jan Wouters, Astrid van Wieringen

TH21: TOWARDS AN OBJECTIVE MEASURE OF PAEDIATRIC COCHLEAR IMPLANT OUTCOME: OUR SEARCH FOR AN AUDITORY BASELINE FOR SPEECH PROCESSING: Faizah Mushtaq, Ian M. Wiggins, Padraig T. Kitterick, Carly A. Anderson, Douglas E. H. Hartley

TH22: A NEW METHOD FOR INVESTIGATING SOCIAL-COGNITION IN DEAF INFANTS WITH COCHLEAR IMPLANTS: Claire Monroy, Chi-hsin Chen, Chen Yu, Derek Houston, Irina Castellanos

TH23: WHAT CAN SPEECH ACQUISITION DATA TELL US ABOUT COCHLEAR IMPLANT DEVICE LIMITATIONS? ANALYZING ACCURACY, ERROR PATTERNS, AND SPECTRAL FEATURES OF CHILDREN'S /T/ AND /K/ PRODUCTIONS: Allison Ann Johnson, Jan R Edwards, Benjamin Munson, Danielle M Bentley

TH24: THE EFFECTS OF EARLY ACOUSTIC HEARING ON SPEECH PERCEPTION AND LITERACY ABILITIES OF PEDIATRIC COCHLEAR IMPLANT RECIPIENTS: Lisa Davidson, Rosalie Uchanski, Heather Grantham, Ann Geers, Jill Firszt

TH25: LONG-TERM EFFECTS OF EARLY COCHLEAR IMPLANTATION: A SUCCESS STORY?: Stefanie Krijger, Paul Govaerts, Martine Coene, Ingeborg Dhooge

TH26: AUDIO-VISUAL SENTENCE IDENTIFICATION IN EARLY-DEAFENED, LATE-IMPLANTED COCHLEAR IMPLANT USERS: Christina D Fuller, Dana Kort, Rolien H Free, Deniz Başkent

TH27: VISUAL DISTRACTION DIMINISHES SPEECH UNDERSTANDING IN COCHLEAR-IMPLANT LISTENERS: Anna R Tinnemore, Sandra Gordon-Salant, Matthew J Goupell

TH28: RATE DISCRIMINATION AND SENTENCE RECOGNITION IN YOUNG AND ELDERLY NORMAL HEARING ADULTS USING VOCODED SPEECH: Lendra M. Friesen, Monita Chatterjee

TH29: AGE-RELATED DEFICITS IN AUDITORY CORTICAL PROCESSING IN COCHLEAR-IMPLANT USERS: Zilong Xie, Olga Stakhovskaya, Matthew J. Goupell, Samira Anderson

TH30: ENHANCED CORTICAL PLASTICITY IS RELATED TO BETTER COCHLEAR IMPLANT OUTCOMES: Andrew Dimitrijevic, Brandon Paul, Joseph Chen

TH31: EVERYDAY LISTENING WITH COCHLEAR IMPLANTS: A WORKOUT FOR THE BRAIN?: Ian M Wiggins, Francisca Perea Perez, Graham Naylor, Adriana Zekveld, Douglas Hartley

TH32: DOES DEGREE OF SPEECH ASYMMETRY MODULATE BILATERAL SPEECH INTELLIGIBILITY AND LISTENING EFFORT IN ADULTS WITH BILATERAL COCHLEAR IMPLANTS AND ADULTS WITH NORMAL HEARING?: Emily Burg, Matthew Winn, Tanvi Thakkar, Shelly Godar, Ruth Litovsky

TH33: THE IMPACT OF PITCH CUES ON LISTENING EFFORT IN A WORD RECALL TASK FOR NORMALLY HEARING AND COCHLEAR IMPLANTED LISTENERS: Yue Zhang, Alexandre Lehmann, Mickael Deroche

TH34: USING OBJECTIVE MEASURES TO REVEAL LISTENING EFFORT IN COCHLEAR IMPLANT LISTENERS: Xin Zhou, Emily Burg, Alan Kan, Ruth Y Litovsky

TH35: INVESTIGATION OF DYNAMIC METRICS AND PUPILLOMETRY DATA IN TARGET LOCALIZATION TRAINING WITH BICI SIMULATION IN A VR ENVIRONMENT: Pierre-Yves Hasan, Kacper Kosikowski, Francois Patou, Soren Kamaric Riis

TH36: DECREASED WORKING MEMORY CAPACITY IN CI USERS TESTED IN A VISUAL TASK IN SILENCE AND NOISE: Tobias Weissgerber, Uwe Baumann

TH37: RELATION BETWEEN SUBJECTIVE LISTENING EFFORT AND SPEECH INTELLIGIBILITY IN CI USERS: Melanie Krueger, Michael Schulte, Kirsten C. Wagener, Markus Meis

TH38: THE EFFECT OF SPEAKING RATE ON CI USERS' LISTENING EFFORT AND ACCESS TO SENTENCE CONTEXT: Matthew Brandon Winn

TH39: DISRUPTION OF THE BENEFIT OF SENTENCE CONTEXT IN LISTENERS WITH COCHLEAR IMPLANTS: Steven P Gianakas, Matthew B Fitzgerald, Matthew B Winn

TH40: SEMANTIC CUE AND EAR EFFECTS ON PERCEPTUAL RESTORATION OF SPEECH IN ADULT COCHLEAR-IMPLANT USERS: Brittany N. Jaekel, Rochelle S. Newman, Matthew J. Goupell

TH41: PERCEPTUAL ADAPTATION TO FORMANT CHANGES ASSOCIATED WITH VOWEL CATEGORIES OR VOCAL TRACT LENGTH: IMPLICATIONS FOR SPEECH PERCEPTION IN COCHLEAR IMPLANT USERS: Olivier Crouzet, Etienne Gaudrain, Deniz Başkent

TH42: FOREIGN-ACCENTED SPEECH PERCEPTION BY COCHLEAR IMPLANT USERS: EFFECTS OF TALKER VARIABILITY: Michelle R. Kapolowicz, Vahid Montazeri, Phillip Tran, Melissa M. Baese-Berk, Fan-Gang Zeng, Peter F. Assmann

TH43: THE "TWO-SENTENCE PROBLEM": COMMUNICATION REQUIRES UNDERSTANDING SPEECH BLOCKS LONGER THAN A SINGLE SENTENCE: Nicole Hope Capach, Jonathan D Neukam, Mahan Azadpour, Elad Sagi, Arthur Wingfield, Mario A Svirsky

TH44: WORD AND NONWORD READING FLUENCY IN POSTLINGUALLY DEAF ADULT COCHLEAR IMPLANT USERS: Terrin N. Tamati, Aaron C. Moberly, Kara J. Vasil, William G. Kronenberger, David B. Pisoni, Christin Ray

TH45: EFFECTS OF SPECTRAL RESOLUTION OF AUDITORY FEEDBACK ON VOWEL PRODUCTION: Xin Luo, Ayoub Daliri

TH46: DEVELOPMENT OF AN FNIRS-BASED OBJECTIVE MEASURE OF SPEECH PERCEPTION IN PAEDIATRIC COCHLEAR IMPLANT RECIPIENTS: Faizah Mushtaq, Ian M. Wiggins, Padraig T. Kitterick, Carly A. Anderson, Douglas E. H. Hartley

TH47: CROSS-MODAL ACTIVITY IN AUDITORY AND VISUAL CORTICES AND SPEECH RECOGNITION OUTCOMES IN POST-LINGUAL COCHLEAR IMPLANT USERS: A FUNCTIONAL NEAR-INFRARED SPECTROSCOPY (FNIRS) STUDY: Amanda Fullerton, Catherine M. McMahon, Robert Luke, Heivet Hernandez-Perez, Deborah Vickers, Jessica J.M. Monaghan

TH48: USE OF FNIRS FOR OBJECTIVE PROGRAMMING OF COCHLEAR IMPLANTS: Colette M McKay, Stefan Weder, Shoushtarian Mehrnaz, Hamish Innes-Brown

TH49: USE OF FNIRS FOR IMPROVED PROGNOSIS FOR COCHLEAR IMPLANT CANDIDATES: Colette McKay, Shoushtarian Mehrnaz, Hamish Innes-Brown

TH50: CORTICAL CORRELATES OF SPEECH INTELLIGIBILITY MEASURED USING FUNCTIONAL NEAR-INFRARED SPECTROSCOPY (FNIRS): Rachael J Lawrence, Ian M Wiggins, Douglas EH Hartley, Carly A Anderson, Jodie Davies-Thompson

TH51: EVALUATING THE EFFECT OF FOCUSSED STIMULATION ON EXCITATION PATTERNS IN HUMANS AND CATS: PSYCHOPHYSICS AND DEVELOPMENT OF AN EEG PARADIGM: Francois Guerit, Andrew J. Harland, John C. Middlebrooks, Robin Gransier, Matthew Richardson, Jan Wouters, Robert P. Carlyon

TH52: RECORDING EEG FROM COCHLEAR IMPLANT ELECTRODES: Ben Somers, Christopher Long, Tom Francart

TH53: SINGLE-TRIAL EEG ALPHA RHYTHMS TRACK CHANGES OF LISTENING EFFORT IN COCHLEAR IMPLANT USERS DURING SPEECH IN NOISE PERCEPTION: Brandon T. Paul, Andrew Dimitrijevic

TH54: NEURAL REPRESENTATIONS OF ENVELOPE INTERAURAL TIME DIFFERENCES: Lindsey N Van Yper, Jaime A Undurraga, Juan Pablo Faundez, David McAlpine

TH55: NEURAL ENCODING OF EMOTION AND GENDER IN SPEECH: Emily Graber, Brandon Paul, Emmanuel Chan, Varia Sajeniouk, Joseph Chen, Andrew Dimitrijevic

TH56: NEURAL TRACKING TO SPEECH PROCESSED BY SINUSOIDAL SYNTHESIS MODEL FOR COCHLEAR IMPLANT USERS: Sungmin Lee, Sara Akbarzadeh, Dat Quoc Ngo, Chin-tuan Tan

TH57: INVESTIGATION OF THE AUDITORY PATHWAY IN ASYMMETRIC HEARING IMPAIRED PATIENTS WITH [18F]FDG PET: Iva Speck, Susan Arndt, Johannes Thurow, Antje Aschendorff, Ganna Blazhenets, Philipp T. Meyer, Lars Frings

TH58: DEVELOPING A MODEL OF MAGNETOENCEPHALOGRAPHY (MEG) SCAN FOR COCHLEAR IMPLANT RECIPIENTS: Roni-Judith Kahana Zweig, Jaime Undurraga, Qingqing Meng, Yves De Deene, David McAlpine, Catherine McMahon

TH59: EFFECT OF MODULATION DEPTH ON THE 40-HZ AUDITORY STEADY-STATE RESPONSE AND AUDITORY CHANGE COMPLEX IN CI USERS AND NORMAL-HEARING LISTENERS: Robin Gransier, Wouter David, Francois Guerit, Matthew Richardson, John M Middlebrooks, Robert P Carlyon, Jan Wouters

TH60: AUTOMATED INTER-SCALAR SHIFT DETECTION FOR THE HIFOCUS MID-SCALA FROM CT SCANS: Michael Siebrecht, Jeroen J Briaire, Johan H M Frijns

TH61: INFLUENCE OF ANGULAR INSERTION DEPTH AND THE DEFAULT ELECTRIC FREQUENCY FILTER ASSIGNMENTS ON FREQUENCY-TO-PLACE MISMATCH IN COCHLEAR IMPLANT AND ELECTRIC-ACOUSTIC STIMULATION DEVICE USERS: Michael W. Canfarotta, Margaret T. Dillon, Emily Buss, Harold C. Pillsbury, Kevin D. Brown, Brendan P. OConnell

TH62: PRE-OPERATIVE PROMONTORY STIMULATION AND CORTICAL RECORDING IN DIFFICULT CI CANDIDATES: Giacomo Mandruzzato, Marek Polak

TH63: CLASSIFICATION OF ELECTROPHYSIOLOGIC RESPONSES TO SPEECH PROCESSED THROUGH AN ACOUSTIC SIMULATION OF A COCHLEAR IMPLANT: Matthew Fitzgerald, Vivian Lou, Steven Losorelli, Blair Kaneshiro, Gabriella Musacchia, Nikolas Blevins

TH64: TWIST AND SHOUT – A CASE SERIES OF CI, MRI AND SURGICAL INTERVENTIONS: Sara M. Friauf, Sebastian Hoth, Mark Praetorius

SPEAKER ABSTRACTS

P1: USING A COMBINED ANIMAL AND HUMAN APPROACH TO BETTER UNDERSTAND HOW NEURAL FUNCTION AFFECTS COCHLEAR IMPLANT PERFORMANCE

Kara C. Schvartz-Leyzac, Deborah J. Colesa, Alexander Arts, Donald Swiderski, Teresa A. Zwolan, Yehoash Raphael, Bryan E. Pfingst
University of Michigan, Ann Arbor, MI, USA

A growing body of literature suggests that spiral ganglion neuron density and/or function contributes, at least in part, to post-operative performance in cochlear- implanted listeners. Collectively, studies in animals and humans suggest that specific electrophysiological and psychophysical measures reflect neural conditions in the implanted cochlea. Animal studies from our lab and others have demonstrated that specific characteristics of the electrically-evoked compound action potential (ECAP) and psychophysical measures of multipulse integration (MPI) are related to neural status in electrically-stimulated guinea pig cochleae. Related studies also demonstrate that these same measures reflect speech recognition performance in cochlear-implanted humans. This work is promising for improving outcomes in cochlear implant patients, and we and others have conducted experiments in which electrical stimulation sites are selected or removed based on these measures of neural health. However, these studies often have mixed results underscoring the variability in functional measures and performance that are often present in cochlear implanted humans. This variability in humans could be attributed to non-neural factors that affect neural health measures (e.g., distance from the electrode to the stimulated neural fibers) and/or diverse central and cognitive processing abilities across cochlear implanted patients. This talk will review animal and human data from our lab examining how specific ECAP and psychophysical measures relate to cochlear histology, and how other potential, non- neural factors might also contribute to these findings. Preliminary results for application of ECAP measures using a site-selection approach will be discussed.

P2: EARLY INTERVENTION AND CORTICAL EVALUATIONS OPTIMISE OUTCOMES FOR CHILDREN WITH HEARING LOSS

Teresa Y. C. Ching, Harvey Dillon, Mark Seeto, Bram Van Dun, Patricia van Buynder, Laura Button, Vivienne Marnane, Sanna Hou, Paola Incerti
National Acoustic Laboratories, Australia

Introduction. Permanent childhood hearing loss has a significant negative impact on children's development. With implementation of universal newborn hearing screening programs, it is now possible to detect and treat hearing loss early in life. The effect of early intervention for improving outcomes of children with hearing loss is quantified in the Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) study, a prospective population-based study in Australia.

Methods. The LOCHI cohort comprises 450 children, 163 of whom first received their cochlear implants (CIs) before 3 years of age. Of these, about half received their implants before 12 months of age. Demographic and audiological characteristics, including CI maps were collected, and speech and language outcomes were assessed using standardized tests and custom-designed tests in a prospective manner. Multiple regression analyses were used to determine the factors, including age at implantation, on language outcomes at 5 years of age. The influence of aetiology and age at implantation on CI characteristics was examined.

Results. The study found that children who received early implantation had better language outcomes. On average, children who received CIs at 24 months had poorer language than those implanted at 6 months (-21.4; 95% CI: -33.8 to -9.0). Whereas children who received CIs between 12 and 36 months achieved optimal CI maps within 6 months of implantation, those who received CIs at a younger age took longer. Drawing on findings from a related study, we propose that measurements of cortical auditory evoked potentials be used to optimize CI maps and monitor progress after implantation in young children.

Conclusion. The findings guide evidence-based management of children born with severe or profound degrees of hearing loss. Timely intervention and cortical evaluations of the effectiveness of hearing devices are key to maximising outcomes.

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P3: AUDITORY NEURAL HEALTH IMAGING (ANHI) USING PATIENT-CUSTOMIZED MODELS

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Studies have shown that hearing outcomes with cochlear implants (CIs) are dependent on several factors, including the health of the auditory nerve fibers. We have developed a model-based approach for estimating the health of auditory nerve fibers as it varies along the length of the cochlea. Our models include a physics-based patient-specific electro-anatomical model (EAM) of current spread induced by the electrodes coupled with auditory nerve fiber (ANF) activation models. ANF models permit estimating which groups of fibers each electrode activates and facilitate estimating the health of those neural fibers, which to the best of our knowledge has never been done for CI patients.

Our EAMs are geometrically customized using patient CT images, and the electrical properties are customized using electric field imaging measurements. ANF models are created similarly to Rattay et al. 2001. Using these models, we can simulate any electric stimulus delivery as well as acquisition of objective measurements, such as electrically evoked compound action potential (ECAP) amplitude growth functions (AGFs). We estimate the health of the ANFs by: (1) parameterizing our ANF models according to neural health; and (2) using a constrained optimization algorithm to tune the neural health of the ANFs in order to minimize the sum of squared differences between simulated and the measured ECAP AGFs. We refer to this process of estimating neural health for fibers along the length of the cochlea as Auditory Neural Health Imaging (ANHI).

We have evaluated our ANHI approach with 3 patients, revealing at least one region of poor health for each patient. Since a comparison of monopolar and tripolar thresholds has been proposed as a surrogate for neural health, linear regression models (LRMs) were created in order to determine the correlation of clinically measured tripolar thresholds with electrode distance, monopolar thresholds, and ANHI. Data plots revealed a small but consistent shift (~1.3 mm) in the ANHI data relative to the tripolar thresholds, likely due to small inaccuracies in how the model permits flow of electrical current through the round window. These shifts were corrected in the ANHI data prior to the following analyses. LRMs revealed monopolar thresholds to be uncorrelated with tripolar thresholds. However, electrode distance and ANHI were both found to be significantly associated with tripolar thresholds with nearly perfect LRM average correlation of R=0.92 across the 3 cases. The correlation between electrode distance alone and tripolar thresholds is R=0.68 on average.

This work represents the first clinical validation of our patient-specific models. Our results demonstrate the validity of our ANHI estimates and support that tripolar thresholds contain neural health information. However, unlike raw tripolar threshold data, ANHI provides an estimate of which specific fiber bundles are healthy. Further, our models can estimate which fiber bundles are activated for any electric stimulus, permitting comprehensive CI simulation. For example, the models can be used to estimate the spectral smearing between different neighboring electrode pairs—data which will be presented at the conference. Ultimately, we envision these models will not only permit design and implementation of novel patient-customized programming strategies, but also may provide further insight into factors that affect patient outcomes.

P4: APPROACHES FOR CUSTOMIZED NEUROTROPHIN TREATMENT IN COCHLEAR IMPLANTATION

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Introduction: Protection of auditory neurons from degeneration by neurotrophins has been demonstrated in several in vitro and in vivo studies. Therefore, the administration of neurotrophins is a promising pharmacological approach in cochlear implantation. Endogenous production of neurotrophins, however, is highly regulated and exogenous application may disturb this homeostasis. The aim of this study is to understand the expression profile of BDNF and its receptors and to use gene delivery for sustained low-dose BDNF delivery to minimize disturbances by non-physiological exogenous BDNF application.

Methods: The expression of both BDNF forms and their receptors in the murine cochlea was analysed by immunocytochemical antibody staining. Additionally, BDNF was delivered to mice using a supporting cell specific adenenoviral vector for the sustained delivery of low-dose neurotrophins to the inner ear.

Results: Both forms and their corresponding receptors are expressed in the organ of Corti and in the spiral ganglion of adult cochleae. Treatment with Ad28-BDNF and Ad28-NT3 was successful in transfection of inner ear supporting cells. Quantification of neurotrophin release showed low-dose neurotrophins at physiological levels.

Conclusion: These results suggest that a cell-specific low-dose delivery of neurotrophins to the inner ear is possible and may match more precisely the physiological conditions in the cochlea.

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P5: THE INTERACTIONS OF BOTTOM-UP AND TOP-DOWN INFORMATION PROCESSING DURING SPEECH RECOGNITION BY ADULTS WITH COCHLEAR IMPLANTS

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To successfully recognize and understand degraded speech, such as through a cochlear implant (CI) or when spectrally degraded by noise-vocoding, the listener must combine the bottom-up sensory evidence in the signal input with top-down linguistic knowledge and neurocognitive skills. Moreover, bottom-up (auditory sensitivity) and top-down (linguistic and neurocognitive) processes likely interact in a complicated fashion across listeners, who bring to the table varying degrees of bottom-up sensory fidelity and top-down predictive coding skills. This presentation will review a series of studies over the past three years of speech recognition by postlingual adults with CIs and normal-hearing (NH) peers listening to noise-vocoded stimuli. First, data will be presented demonstrating the contributions to speech recognition performance of several key top-down neurocognitive skills – information-processing speed, inhibitory control, working memory capacity, and nonverbal reasoning – both cross-sectionally in experienced CI users and NH peers as well as longitudinally in new CI users. Second, data will be shown regarding the contributions of a number of bottom-up auditory sensitivity measures – static and dynamic spectral resolution and temporal resolution – to speech recognition by CI users. Third, preliminary analyses will be reported that test the hypothesis that the quality of bottom-up input moderates the effects of top-down processes on speech recognition. That is, patients with both very good bottom-up input (extremely clear, well-specified signals) and those with very poor bottom-up input (extremely degraded signals) will rely minimally on top-down predictive processing to recognize speech, whereas patients with intermediate bottom-up input will rely heavily on top-down predictive processing. Clinical implications will be discussed, including the development of novel clinical assessment batteries to predict CI outcomes before surgery, to explain poor CI outcomes after implantation, and to develop new rehabilitative interventions to optimize speech recognition outcomes for CI users who may be at high risk of a poor outcome following implantation.

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P6: TOWARDS OBJECTIVE AND AUTOMATIC INDIVIDUALISED FITTING THROUGH EEG-BASED MEASURES OF SPEECH INTELLIGIBILITY

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For optimal communication, cochlear implant fitting and signal processing needs to be fine-tuned to the specific listener and listening circumstances. This requires fundamental changes to the current paradigm of fixing the fitting in infrequent sessions in the clinic: fitting adjustment needs to be fully automatic, preferably done on the sound processor itself, and therefore the sound processor needs input about the consequences of electrical stimulation. We address this problem by developing an objective measure of speech intelligibility, using natural ecological speech as picked up by the microphone as stimulus, and by recording the corresponding EEG from implanted electrodes.

We recently developed an EEG-based objective measure of speech intelligibility using fully natural speech, which is strongly correlated with the behaviourally measured speech reception threshold [Vanthornhout et al, JARO, 2018]. However, measuring EEG in response to continuous stimuli with cochlear implants is not straightforward, because large artefacts due to the electrical stimulation by the cochlear implant contaminate the signal. We will present a novel method to avoid such artefacts, based on periodic blanking of the signal, and the results of a study investigating the relation between speech understanding and neural envelope tracking in CI users.

The objective measure of speech intelligibility is based on neural tracking of the speech envelope. We decode the speech envelope from the EEG signal and compare it with the actual speech envelope. This comparison is a measure of neural coding of the speech envelope, and assuming normal function of the auditory system beyond the periphery, by extension a measure of speech intelligibility. We validated the method by recording EEG in 8 CI users while they listened to natural speech (a story). Speech understanding was varied by changing the intensity of the presented speech. The speech envelope was reconstructed from the EEG using a linear decoder and then correlated with the envelope of the speech stimulus as a measure of neural envelope tracking, which was compared to actual speech understanding. We found that neural envelope tracking increased with increasing speech understanding in every participant. Furthermore, behaviourally measured speech understanding was correlated with participant-specific neural envelope tracking results. This shows the potential of neural envelope tracking as an objective measure of speech understanding in CI users.

To record EEG in real-life circumstances, unobtrusive recording electrodes are needed. One possibility would be to record EEG from the cochlear implant electrodes. We investigated this possibility in a small population of subjects implanted with a percutaneous connector, allowing direct access to the electrode leads. The results will be presented.

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P7: SPEECH ENHANCEMENT BASED ON RECURRENT NEURAL NETWORKS FOR COCHLEAR IMPLANTS: ENVIRONMENT-OPTIMIZED ALGORITHM APPLIED TO NOVEL ACOUSTIC CONDITIONS

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Cochlear implant (CI) users encounter difficulties understanding speech in noisy environments, especially with non-stationary backgrounds such as competing speech and traffic noise. In previous studies, algorithms based on machine learning methods like deep neural networks were shown to improve the intelligibility of speech in noise but they relied on a priori information about the target speech, the background noise, or both. Recent evidence indicates that the generalization performance of deep neural networks to unseen speakers or backgrounds is improved by using recurrent neural network (RNN) architectures with temporal memory. Here we used a single-microphone RNN-based algorithm, optimized for a specific class of background noises (environment-optimized by using either multi-talker or traffic noise recordings), to process speech in multi-talker babble and in traffic noise, and assessed its benefits in terms of speech intelligibility and perceptual quality. Most importantly, we used realistic testing scenarios that included a different speaker, different signal-to-noise ratios and different noise recordings than those used for training the algorithm. We evaluated whether benefits in speech perception were predicted by objective measures, and whether they were obtained by CI users and/or normal-hearing listeners using CI simulations.

Objective measures of speech intelligibility (SI), including STOI and NCM, were used to evaluate the performance of the algorithm for unseen multi-talker babble with varying numbers of competing talkers. Both measures predicted better SI for stimuli processed with the RNN algorithm than for unprocessed stimuli in cases with 4 or more competing talkers. This was the case for both acoustic and noise-vocoded stimuli.

The effect of the RNN algorithm on SI was further assessed with two groups of subjects. In experiment 1, 10 normal-hearing subjects listened to speech-in-babble stimuli through headphones and using a CI simulation based on noise-vocoded signals. The results confirmed the predictions of the objective measures and yielded a substantial mean benefit in speech reception threshold (SRT) of 2.9 dB. In experiment 2, 10 experienced users of Advanced Bionics CIs listened to speech in multi-talker babble and traffic noise. The results indicated significant improvements in SRT of 3.4 dB for speech in babble and 2 dB for speech in traffic noise. Furthermore, speech quality assessed using a rating procedure was significantly higher for the processed than for the unprocessed stimuli for the CI subjects.

This work was funded by Action on Hearing Loss (UK, grant 82 and Flexi Grant F92) and supported by a travel award from Advanced Bionics (US).

P8: USING MACHINE LEARNING TO ESTIMATE THE FUNCTIONAL STATUS OF THE COCHLEAR NERVE IN ADULT COCHLEAR IMPLANT USERS

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Background: Cognitive impairment is highly prevalent in older CI users (e.g., Mosnier et al., 2015, 2018). Obtaining reliable behavioral responses and subjective descriptions of how electrical stimulation is perceived from these patients can be challenging or infeasible. Therefore, it is desirable to develop objective tools for optimizing CI programming settings for implanted patients with declined cognitive functions. As the initial step to achieve this long-term goal, this study applied machine learning techniques to create an objective predictive model for assessing the functional status of the cochlear nerve (CN) in adult CI patients. Because neurophysiological evidence shows significantly poorer CN function in children with cochlear nerve deficiency (CND) than in children with normal-sized CNs (He et al., 2018), results measured in these two patient populations can serve as a perfect training set for the model. This model created an index for the functional status of the CN based on independent variables derived from the electrically-evoked compound action potential (eCAP) input/output (I/O) function and the eCAP refractory recovery function.

Methods: To date, 21 children with CND, as well as 18 children and 9 adults with normal-sized CNs, have been recruited and tested for this study. All subjects were implanted with a Cochlear® Nucleus™ device in the test ear. For each subject, the eCAP I/O function and eCAP refractory recovery function were measured at multiple electrode locations across the electrode array. Both functions were measured with a charge-balanced, cathodic leading, biphasic electrical pulse. Data from children with CND and children with normal-sized CNs were used as the training dataset for a Linear Discriminant Analysis (LDA) algorithm to find a linear predictor function that maximized the separation in CN function between these two patient populations. Data from the adult CI users were then used in the predictive model to generate an index for the functional status of the CN for each adult subject.

Results: The LDA algorithm successfully created a linear function that predicts the functional status of the CN, as evidenced by two distinct distributions of index values for children with CND and children with normal-sized CNs. The predicted functional status of the CN for adult CI users varied along the linear function, with index values ranging from moderate to excellent neural function. Our results also showed that independent variables from the eCAP refractory recovery function had more weight in the predictor model than those from the eCAP I/O function.

Conclusions: We created a preliminary model that predicts the functional status of the CN for adult CI users. The preliminary results also suggested that CN temporal responsiveness might be heavily dependent on its functional status.

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P9: RESTORING SOUND LOCALISATION IN ADULTS WITH SINGLE-SIDED DEAFNESS: REFLECTIONS FROM A MULTI-CENTRE STUDY

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Acquired unilateral severe-profound sensorineural hearing loss, or single-sided deafness, can have a severe detrimental impact on an individual's quality of life. This impact often appears to be disproportionate to their degree of impairment, given that they still have access to one normally-hearing ear. The total or near-total loss of binaural cues has a hugely disruptive effect on listening in and navigating everyday environments. Cochlear implantation holds great promise as an intervention that could address the difficulties that these individuals face, by restoring bilateral access to sound. Previous studies have demonstrated that cochlear implantation reduces localisation error in these adults. I will present data from a prospective multi-centre study of cochlear implantation in adults with single-sided deafness whose aim was to better understand the nature of that improvement in spatial hearing. The localisation abilities and self-reported listening difficulties of adults with acquired unilateral severe-profound sensorineural hearing loss were assessed at baseline and after being implanted unilaterally. Sound localisation was assessed in an anechoic chamber before and 9 months after implantation using a 48-loudspeaker array that was capable of recreating the patterns of reverberation that arise in a variety of listening environments. Detailed information on their listening performance, device programming, device usage, and the extent to which they listened to training materials through the implant alone were recorded. I will present analyses of their localisation performance and identify what factors influenced whether a patient receives spatial benefit, and discuss the implications for candidature and rehabilitation. I will also discuss the extent to which the benefits to spatial hearing observed in the laboratory could be generalised to benefits in everyday life.

P10: BALANCE AND HEARING: WHAT COCHLEAR IMPLANTS HAVE TAUGHT US ABOUT DEVELOPMENT OF THE VESTIBULAR SYSTEM

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Background: Congenital bilateral hearing loss provides a framework for studying the impact of sensory deprivation on the brain. Restoration of hearing through the use of bilateral cochlear implantation also allows us to study brain development in children. It is common for children with deafness to have concurrent deficits of vestibular function which may further impact brain development and influence their functional outcomes.

Objectives: 1) To examine the impact of combined cochleovestibular loss on the development and function of children who receive bilateral cochlear implants. 2) To determine the benefit of providing enhanced spatial information through the use of head referenced cochlear implant stimulation on balance in these children.

Methods: Brain development as measured by brainstem and cortical potentials, evoked by cochlear implants will provide the framework for review of behavioural and functional measures including spatial navigation and balance in children with a variety of configurations of sensory loss including bilateral and unilateral combinations of cochleovestibular loss. The use of head referenced cochlear implant stimulation as a means of improving balance in children with combined cochleovestibular deficits will be explored.

Results: Children with congenital sensory deprivation related to any configuration of cochleovestibular loss will have abnormal brain development. This abnormal developmental trajectory leads to deficits in spatial awareness and balance among others. Balance is improved by the provision of bilateral auditory input through implants. This improvement can be amplified by providing head referenced stimulation.

Conclusions: When examining outcomes in children with congenital sensory deficits such as deafness one must also consider the impact of concurrent vestibular loss. While the provision of hearing through bilateral cochlear implants improves outcomes beyond hearing alone, deficits in balance and spatial navigation remain and may benefit from supplemental information provided through head referenced stimulation.

P11: MILD THERAPEUTIC HYPOTHERMIA PRESERVES RESIDUAL HEARING AGAINST COCHLEAR IMPLANT TRAUMA: PRECLINICAL RESULTS AND TRANSLATIONAL POTENTIAL

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More than half a million patients, including children, have benefitted significantly from the remarkable technological breakthrough that are cochlear implants (CI). An increasing number of cochlear implant subjects have some level of residual hearing at the time of implantation and can benefit from bimodal electro-acoustic devices. Surviving hair cell activity and as a result a functioning organ of Corti and neural substrate has recently been linked to speech perception outcomes. However, trauma to the sensitive inner ear structures during CI leads to inflammation and oxidative stress exacerbating the loss of residual hearing. A successful translation of therapeutic interventions to limit this trauma and protect residual hearing have yet to be achieved. Here, we will review efforts to develop an application of localized, mild therapeutic hypothermia for protection of hair cells and the neural substrate following CI. We have developed a custom-probe and system to locally deliver mild hypothermia to the inner ear during CI surgery and preclinical results in a rodent model show significant improvement in survival of hair cells and preservation of residual function post-CI. We show that therapeutic hypothermia delivered to the inner ear is safe and does not adversely affect function. We used RNA-sequencing (RNA-Seq) and real-time PCR (rt-PCR) techniques to characterize molecular mechanisms underlying the protective effects of therapeutic hypothermia in CI-traumatized cochlear sensory epithelia from rats. Gene expression changes were confirmed at multiple time points between control, euthermic and hypothermia-treated implanted cochleae. Mild therapeutic hypothermia reduced inflammation and oxidative stress and increased activity of anti-apoptotic pathways, while preserving the blood labyrinth barrier. Moreover, flow cytometric analysis shows that hypothermia treatment significantly reduces the number of activated microglia, macrophages and leukocytes when compared with euthermic conditions. On-going research in our group is focused on identifying potentially synergistic therapeutics for combination with hypothermia and translating this technique to enhance protection of residual hearing and cochlear sensory epithelia.

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P12: PROTECTION OF RESIDUAL HEARING AND REDUCED HAIR CELL LOSS AFTER COCHLEAR IMPLANTATION FOLLOWING PRE-TREATMENT BY NEAR-INFRARED-LIGHT

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The protection of residual hearing is becoming increasingly important in cochlear implant (CI) surgery. Various drug-based approaches have been investigated for the prevention of cochlear apoptosis/necrosis, so far without much success. An alternative to drugs may be near-infrared light (NIR). Specific wavelengths within the NIR spectrum are known to influence cytochrome-c-oxidase activity which leads in turn to a decrease of apoptotic mechanisms. It has been shown previously that NIR can decrease the cochlear hair cell loss significantly if applied daily after noise exposure. Recently, studies by our group indicated that even a single NIR-pre-treatment has the ability to reduce auditory threshold shifts and rescue cochlear sensory tissue when applied immediately before loud sound exposure. Therefore, the present study investigated the efficacy of a single NIR pre-treatment before cochlear implantation in an animal model.

During a cochlear implant surgery, normal hearing adult guinea pigs had one cochlea pre-treated with NIR-light for 15 minutes. Immediately after light exposure, a CI electrode array, specifically designed for guinea pigs, was inserted through a cochleostomy into the scala tympani of the first cochlear turn. The contralateral ear received a similar treatment (insertion) but was sham-exposed only.

Four weeks after implantation, outer hair cell loss was determined in histological cochlear samples and data were compared between the two ears (with or without NIR pre-treatment) in each animal.

The data demonstrate that hair cell loss was significantly reduced (approx. 40 %) in NIR-pre-treated ears compared to the contralateral side (implanted only). Moreover, the hearing loss was significantly reduced (20 dB on average) by the pre-treatment within the investigated frequency range.

Our results suggest that a very effective protection of cochlear structures is possible during cochlear implantation by a single NIR pre-treatment.

This study was supported by Advanced Bionics GmbH, Hannover, Germany.

P13: TOWARDS THE OPTICAL COCHLEAR IMPLANT: OPTOGENETIC STIMULATION OF THE AUDITORY PATHWAY

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When hearing fails, cochlear implants (CIs) provide open speech perception to most of the currently half a million CI users. CIs bypass the defective sensory organ and stimulate the auditory nerve electrically. The major bottleneck of current CIs is the poor coding of spectral information, which results from wide current spread from each electrode contact. As light can be more conveniently confined, optical stimulation of the auditory nerve presents a promising perspective for a fundamental advance of CIs. In this study we established reliable expression of the ultra-fast channelrhodopsin Chronos in spiral ganglion neurons (SGNs) and demonstrated its support of high temporal fidelity in the auditory nerve. Further, we developed multichannel optical CIs based on microfabricated light-emitting diode (LED) arrays. We characterized them for optical stimulation of channelrhodopsin-2 (ChR2)-expressing SGNs in transgenic rats or gerbils using optical auditory brainstem responses (oABR) stimulated by individual or multiple LEDs. Positioning of the probes and atraumatic implantation was validated with micro-CT imaging. Multielectrode array recordings along the tonotopic axis of the inferior colliculus (IC) indicate spectral selectivity of optical stimulation closer to acoustic than electrical stimulation. This contribution will summarize the current state of optogenetic stimulation of the auditory pathway and report on recent breakthroughs on achieving high temporal fidelity, frequency resolution and establishing multichannel optical CIs.

The research leading to these results has received funding from the German Research Foundation (DFG) through the Cluster of Excellence BrainLinks-BrainTools (EXC 1086), the Collaborative Research Center 889, Cluster of Excellence Multiscale Bioimaging and the Leibniz program, from the Federal Ministry of Education and Research (BMBF) via the project Optical Cochlear Implant (No. 13N13728) as well from the European Research Council (ERC Advanced Grant OptoHear).

P14: HEARING VOICES ACROSS THE SPECTRUM

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When two people talk at the same time, it becomes challenging to follow what they say if their voices sound similar. The ability to discriminate voices seems crucial in cocktail party situations. However, the relationship between the ability to detect a small difference between two voices and the benefit one may derive from this voice difference to understand two competing talkers is not straightforward. The acoustic cues associated with voice differences are indeed complex, and intertwined with acoustic cues associated with linguistic information. The ability to detect and exploit voice differences thus results from a cognitive process that slowly develops over childhood. By studying populations with special hearing abilities, like musicians or cochlear implant users, recent studies have shed some light on this intimate relationship between form and content in speech perception. These findings also offer new perspectives for the improvement of hearing to multiple speakers with cochlear implants.

P15: TOWARDS OBJECTIVE MEASURES OF SPEECH PERCEPTION

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Significant progress has been made using non-invasive neurophysiological tools, especially electroencephalography (EEG) and magnetoencephalography (MEG), to investigate the neural processing underlying different aspects of speech perception. Recent successes may even point the way towards neurophysiologically based "objective" measures of speech perception. In this talk I will discuss specific examples of such measures, including the determination of which of several speakers a listener is attending to, the determination of whether or not the acoustic signals of noisy speech are further processed into linguistically-based phonemes, and more examples of related neural correlates of speech intelligibility.

P16: MAPPING EMOTIONAL PROSODY PROCESSING IN NORMAL AND COCHLEAR IMPLANT LISTENERS WITH FNIRS: A PILOT STUDY

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Emotional prosody recognition is vital for successful verbal communication. Cochlear implant (CI) recipients with good speech recognition perform below normal hearing (NH) peers on emotional prosody recognition tasks. To compensate for the poor transmission of spectral cues by CIs, recipients rely on temporal and intensity cues, as evidenced by behavioural studies. To date, little is known about the brain mechanisms underlying emotional prosody recognition in CI hearing. The present study investigates whether functional near-infrared spectroscopy (fNIRS) can provide insight into central processing of emotional prosody in CI and NH listeners.

At CIAP, we will present pilot data from 8 normal hearing (NH) adults who participated in a behavioural forced-choice listening task and a fNIRS passive listening task. Six-syllable sentences with pseudo content words and real function words were used in both tasks (e.g., "the larfle is himber"). The stimuli were recorded in a neutral, happy, sad, fearful and angry prosodies. To examine each group's reliance on acoustic cues, we modulated the stimuli into five conditions: a) natural, b) flat - pitch contour flattened, c) rate - pitch and intensity cues equalised, d) intensity - pitch and rate cues equalised, and e) pitch - rate and intensity cues equalised. In the forced-choice listening task, participants identified the emotion conveyed in each stimulus (N=125). During the passive listening fNIRS task, participants heard 10 blocks of each emotion-condition pair (N=25). Comparisons were made between prosodies, as well as within and between acoustic conditions. Metabolic responses were correlated with behavioural responses for each prosody-condition pair. This method offers insight into the neurophysiological basis for the perception of emotion-related acoustic cues in NH listeners, which provides the groundwork for understanding emotional prosody processing in CI hearing. This is key for the development of strategies targeting emotional prosody in therapy and classroom settings.

P17: EFFECTS OF TALKER VARIABILITY ON SPOKEN WORD RECOGNITION FOR ADULT COCHLEAR IMPLANT USERS

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Cochlear implants (CIs) have been highly successful in providing a restored sense of hearing to profoundly deaf individuals. However, while adult, postlingually deaf CI users are generally able to obtain high levels of speech recognition in favorable conditions, such as a quiet lab or clinic booth, their real-world speech communication skills seem to vary greatly. Real-world listening environments are often adverse to successful speech communication, involving noise, competing talkers, reverberation, as well as different sources of acoustic variability (e.g., talker variability). Listeners must not only communicate with familiar individuals, but also understand many new talkers, with different voices and accents, which can be challenging. Normal-hearing (NH) listeners show less accurate and slower word recognition in multiple-talker compared to single-talker conditions, and devote processing resources to accommodate changes in talkers' voices. However, previous research suggests that spectro-temporal degradations by noise-vocoding limit NH listeners' ability to detect and accommodate changes in talkers' voices. While CI users seem to be sensitive to some talker information (e.g., differences between male and female voices), given varied findings in prior studies, it is still unclear how talker variability affects spoken word recognition in this population, as well as the extent to which talker variability effects are mediated by perceptual limitations in the detection of talker changes.

The goal of the current study was to examine the effects of talker variability, and the perception of talker differences, on spoken word recognition by experienced, postlingually deaf adult CI users. Word recognition accuracy and response time were obtained in single- and multiple-talker conditions, which varied by talker gender (female, male, mixed) and pre-stimulus talker information (i.e., cueing to the particular talker). Talker discrimination was also assessed for female, male, and mixed talker pairs, and a questionnaire on real-world communication difficulties was administered. In a preliminary analysis, single-talker performance was highly variable and depended on the specific talker. Word recognition accuracy was lower in multiple-talker conditions, particularly in multiple-talker mixed conditions with male and female talkers, whose voices were overall more discriminable. While response times did not vary substantially by talker condition, CI users gave faster and more accurate responses when the talker was cued. Finally, CI users reported more difficulty in communicating with talkers with fast speaking rates or a regional or foreign accent, unfamiliar talkers, and multiple talkers in a group. Data collection is ongoing, and CI performance will be compared to age-matched NH listeners.

Preliminary findings suggest that talker variability may play a role in CI users' real-world communicative difficulties. Results from the word recognition task showed that individual talker characteristics (e.g., voice quality, speaking rate) had a large impact on recognition accuracy in single-talker conditions. In addition, a detrimental effect of talker variability was observed on CI users' ability to accurately recognize spoken words, especially when differences in talkers' voices were greater and also better detected. While response times did not vary substantially by talker condition, faster and more accurate word recognition when talker information was provided immediately pre-trial indicates that CI users may have been devoting resources to monitoring for talker changes in the other conditions. Thus, talker variability may reduce spoken word recognition in adult CI users, but the extent of its effects may be influenced by CI users' ability to perceive talker differences. Comparisons to aged-matched NH listeners will shed light on these findings and further allow us to investigate the contributions of hearing impairment and age on listeners' ability to accommodate talker variability in spoken word recognition.

P18: SPEECH PERCEPTION UNDER COCHLEAR-IMPLANT CONDITIONS: EFFECT OF AGE AND EXPOSURE TO A TONE LANGUAGE

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The ability of the auditory system to process the spectro-temporal modulations of sounds play a crucial role in our ability to perceive speech and learn a language. For tone languages, pitch variations of the voice, conveyed by fine spectro-temporal modulations, manifest the lexical meaning of syllables. One of the current challenges for cochlear implant (CI) technology is to better encode this information in order to improve speech perception for listeners using tone languages. Indeed, Mandarin-speaking adults using CIs experience more difficulties in perceiving lexical tones than consonants. This perceptual advantage may result from the fact that CIs provide relatively sufficient temporal envelope information for consonant perception in quiet, but do not convey the fine spectro-temporal information considered to be necessary for accurate pitch perception. Another possibility is that post-lingually hearing-impaired Mandarin speakers have developed language-specific use of these acoustic cues impeding lexical tone processing under CI conditions.

In a series of experimental studies, we explored whether exposure to a tone language could influence the use of the fine spectro-temporal modulations for speech perception. First, simulation studies using vocoders with normal-hearing (NH) listeners showed that reliance on the fine spectro-temporal modulations is affected by language exposure. Mandarin-speaking NH adults rely more on the fine spectro-temporal cues, as they are more affected by its degradation when discriminating lexical tones compared to French-speaking NH adults. This cross-linguistic difference is also observed early during development, that is, by 10 months of age but not at 6 months. This observation suggests that the duration of exposure to the native language influences the use of the acoustic information available in the speech signal.
Second, the case of children who are pre-lingually hearing-impaired and thus, rely on an impoverished speech signal to learn a tone language was investigated. Contrary to our expectations, Mandarin-speaking children using CIs showed more difficulties when discriminating between native consonants compared to native lexical-tone contrasts. This suggests that Mandarin-speaking children using CIs may have developed efficient perceptual strategies for lexical-tone perception as a result of being exposed to degraded acoustic information while acquiring their native tone language.

P19: THE NEUROBIOLOGY OF MUSICAL PITCH DISORDERS: IMPLICATIONS FOR COCHLEAR IMPLANT RECIPIENTS

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The last decade of research has provided compelling evidence that musical engagement is a fundamental human trait, and its biological basis is increasingly scrutinized. In this endeavor, the detailed study of individuals who have “congenital amusia”, an umbrella term for lifelong musical pitch disabilities that cannot be attributed to intellectual disability, lack of exposure, or brain damage after birth, is instructive for cochlear implant recipients. Here, I review key points that have emerged during recent years regarding the neurobiology of congenital pitch disorders, focusing on the importance of recurrent processing between the right inferior frontal cortex and the auditory cortex for conscious monitoring of musical pitch and how it relates to emotions, learning, and speech communication.

P20: PERCEPTION OF DISSONANCE FOR SIMULTANEOUS MUSICAL INTERVALS BY UNILATERALLY DEAF COCHLEAR IMPLANT USERS

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Background: Simultaneous musical intervals contribute to the emotional response to music. In normal-hearing (NH) listeners, some simultaneous music intervals may sound more dissonant (e.g., minor 2nd, tritone) than others (e.g., major 3rd, perfect 5th). Because of limited spectral resolution, pitch perception is generally poor in cochlear implant (CI) listeners; as such, perception of musical intervals is impaired. However, it is unclear whether CI users are sensitive to the relative dissonance across simultaneous intervals. In this study, dissonance ratings for simultaneous intervals were measured in 11 CI patients with single-sided deafness (SSD), in whom dissonance ratings with the CI ear could be precisely compared to those with the NH ear. We hypothesized that dissonance ratings would be much better with the NH ear, much poorer with the CI ear, and similar between NH+CI and the NH ear alone.

Methods: Dissonance ratings for two-note simultaneous intervals played by piano samples were collected with the NH ear (via headphone), the CI ear (via direct audio input, or DAI), and with both ears. Ratings for 13 simultaneous intervals (ranging from unions to a perfect octave) were collected for two “root notes” [the lowest component frequency for any interval: F3 (175 Hz) or C4 (262 Hz)] and for simple (within an octave) and compound intervals (separated by an octave). During testing, an interval would be presented and subjects were asked to rate pleasantness by clicking on line with extreme anchors “least pleasant” and “most pleasant.” Ratings for the different root note, simple/compound ranges, and listening conditions were tested within each test block.

Results: Overall pleasantness ratings were much poorer with the CI ear than with the NH ear; ratings for NH+CI were slightly but significantly poorer than with the NH ear alone, suggesting some degree of binaural interference. With the NH ear, the minor 2nd, tritone, and major 7th were rated least pleasant and the unison, major 3rd, perfect 5th and perfect octave were rated most pleasant, consistent with previous studies. While overall ratings were poorer with the CI, intervals ratings were highly correlated between the NH ear and the CI ear for all root note and simple/compound spacing conditions. For all listening conditions, ratings were also highly correlated all root note and simple/compound spacing conditions. A follow-up experiment with a subset of stimuli showed that most subjects were able to replicate ratings measured with the larger stimulus set.

Discussion: While overall ratings were much poorer with the CI (consistent with our hypothesis), relative dissonance ratings across intervals were similar between acoustic and electric hearing. For all listening conditions, ratings were consistent across the root note and simple/compound interval conditions. Note that the simultaneous intervals were presented acoustically; as such, the degree of temporal envelope “beating” in the input waveform may have driven the pattern of results. Contrary to our hypothesis (and to previous studies with SSD CI subjects), a slight but significant binaural interference for NH+CI was observed for dissonance ratings over the NH ear alone. While relative dissonance across intervals may be preserved with electric hearing, much work needs to be done to improve overall quality ratings and to improve binaural enhancement with combined acoustic and electric hearing.

P21: THE SOUND OF MUSIC – TWO NOVEL EEG-PARADIGMS FOR MEASURING DISCRIMINATION OF MUSIC IN COCHLEAR IMPLANT USERS

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Introduction. Music listening with a cochlear implant is challenging due to the lack of temporal fine structure and a limited dynamic range in the CI signal. Hence, a number of ongoing efforts aim to improve music perception with a CI. For this purpose, objective and feasible music tests are in demand. Thus, the aim of this study is to design and validate two novel musical EEG-paradigms for use in future CI research.In a wider perspective, the study aims to investigate whether a novel sound processing strategy implementing output compression may be beneficial for music listening with a CI, as compared to front-end automatic gain control strategies.

Methods. EEG paradigms: 1. The CI Musical Multifeature Mismatch negativity (MMN) -paradigm integrates a new approach in which no standard stimuli are presented. Deviants in pitch, timbre, intensity and rhythm are embedded in an Alberti bass pattern and presented randomly at four levels of magnitude. 2. The Free-listening paradigm uses the Music Information Retrieval toolbox. Hereby, it is possible to investigate the relation between musical features and ERP responses. Here, participants listened to an excerpt of the tango piece Adios Noñino. Neither of the two approaches have previously been tested on CI-users.

Participants. Eleven experienced CI-users and 14 normal hearing controls underwent EEG-recording while listening to the paradigms. In addition, they completed a behavioural test for discrimination of the music features and levels also presented in the MMN-paradigm.

Results.The CI paradigm elicited significant responses to all deviants in both experimental groups, across levels. This indicates both the paradigm's potential to measure CI-users' discrimination of details in music and the success of the CI in transmitting them. However, overall MMN responses of CI-users were significantly smaller compared to NH listeners. While NH listeners showed MMN responses that were in accordance with the deviation level magnitude, CI users' MMN amplitudes were less consistent with level hierarchy, mainly driven by undifferentiated responses to the levels of change in pitch. In the behavioral test, CI-users scored above chance, but significantly below the NH group in discrimination of all deviants, except rhythm. Hit rates corresponded well with levels of magnitude.

Free-listening paradigm analyses showed significant N1 og P2 ERPs to increases in spectral flux and loudness in NH controls, but not in CI-users. For spectral flux, however, the N1 response of CI-users was not significantly smaller than that of NH, suggesting basic detection of changes in timbral features of "real music". The lack of a significant response to increases in loudness may be explained by the strongly reduced dynamic range of the CI sound transmission.

Conclusion. These results are encouraging indications of the potential of the two novel EEG-paradigms as tools for objective measurements of music discrimination. Despite high complexity, the CI Mumufe MMN paradigm is both accurate and feasible and may provide strong evidence of CI users' musical discrimination abilities and thresholds. Free-listening paradigm results suggest that inferences of CI-users' music perception are possible under conditions that are comparable to their everyday music experience. However, more participants and more analyses are needed to make firm conclusions.

P22: NEURAL CODING OF BINAURAL CUES BETWEEN ACOUSTIC AND ELECTRICAL STIMULATION IN AN ANIMAL MODEL OF SINGLE-SIDED DEAFNESS

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Cochlear implant (CI) users increasingly have significant acoustic hearing in the non-implanted ear and continue to use a hearing aid (HA) in the non-implanted ear. In addition, CIs have become a treatment option for people with single-sided deafness (SSD). These populations of CI users can potentially enjoy the benefits of binaural hearing such as improved sound localization and speech reception in noise by utilizing binaural cues present between the two modes of stimulation. Here, we investigated the sensitivity of midbrain auditory neurons to interaural time differences (ITD) with bimodal stimulation to understand how the binaural cues are represented in the central auditory pathway and identify the most effective stimulation parameters for delivering these cues.

Single-unit recordings were made from the inferior colliculus (IC) of an unanesthetized Dutch-belted rabbit that was deafened and implanted in one ear and had normal hearing in the opposite ear. Periodic trains of acoustic clicks and electric pulses at low repetition rate (20-80 Hz) were used to characterize bimodal ITD sensitivity of the IC neurons.

In many neurons, the temporal discharge pattern showed strong responses to both stimuli for large ITDs, either acoustic leading or electric leading. The acoustic response latency was longer than the electric latency reflecting the additional biological delay of the sound traveling through the external, middle and inner ear. For smaller delays near zero-ITD after adjusting for the difference in response latencies, IC neurons showed clear binaural interaction to the bimodal stimuli in that the firing rate could be either increased or decreased relative to the rate for stimulation in either mode. We observed similar shapes of ITD tuning curves such as peak and trough types as previously observed in response to pairs of acoustic clicks or electrical pulses. Neural ITD discrimination thresholds lay in a similar range as thresholds observed in IC neurons of bilaterally deafened and implanted animals.

The results show that neurons in the auditory midbrain can be sensitive to binaural cues in combined acoustic and electric stimulation and suggest that binaural benefits with bimodal hearing could be improved by providing better access to binaural cues in SSD/CI users and HA-CI users.

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P23: WHEN HAVING TWO EARS PRODUCES INTERFERENCE INSTEAD OF A SPEECH-PERCEPTION ADVANTAGE

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While head-shadow advantages improve speech understanding in noise for bilateral (BI) and single-sided-deafness (SSD) cochlear-implant (CI) listeners, it is unclear how well bilateral input can facilitate the perceptual organization of a complex auditory scene. A series of studies examined the bilateral integration process with different groups of BI-CI and SSD-CI listeners, all using the same contralateral-unmasking paradigm. In the monaural condition, target and interfering speech were presented to one ear. In the bilateral condition, a copy of the interfering speech was also presented to the other ear. This allowed an evaluation of how listeners were able to bilaterally integrate the interfering speech to perceptually separate it from the target.

The results of these studies have revealed tremendous differences across listener groups and individuals in the extent to which the second auditory input influenced performance. In some cases, adding the second ear improved speech-perception performance (contralateral unmasking). Contralateral unmasking was most likely to occur when the target speech was presented to an acoustic or electric ear with good monaural intelligibility. In other cases, adding the second ear reduced speech-perception performance (contralateral interference), sometimes so dramatically as to nearly extinguish any speech perception in the target ear. Contralateral interference was most likely to occur when the target ear had relatively poor monaural intelligibility or the contralateral ear had a high monaural intelligibility. For example, this was the case for SSD-CI listeners attending to their CI ear, or for BI-CI listeners with a long duration of deafness in the target CI ear. Furthermore, there was a strong correlation between SSD-CI listener age and the magnitude of the interference, regardless of duration of deafness or monaural intelligibility score. This suggests that possible age-related changes in attentional control or cognition resulted in an inability to ignore the better ear.

Overall, these results suggest that while some CI listeners can benefit from having two ears to perceptually organize the auditory scene, some BI-CI and SSD-CI listeners are instead susceptible to contralateral interference effects. In everyday communication settings, this means that while having two ears may provide a head-shadow benefit, the interference could reduce this advantage when multiple people are speaking. BI-CI and SSD-CI listeners might benefit from targeted rehabilitation approaches aimed at improving performance in the poorer ear and enhancing the ability to selectively attend to one ear.

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P24: BINAURAL SENSITIVITY IN CHILDREN WITH BILATERAL COCHLEAR IMPLANTS: THE COURSE OF DECISION-MAKING REVEALED BY EYE GAZE

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Children with severe-to-profound deafness are receiving bilateral cochlear implants (BiCI) at a growing pace world-wide. However, they are fitted with two independent devices, and mapping is done separately in each ear. Although they typically benefit from having two CIs vs. a single CI, their spatial hearing skills are significantly worse than normal-hearing peers. To understand whether binaural sensitivity is a limiting factor for functional abilities, we have typically measured binaural just-noticeable difference (JND) thresholds by presenting stimuli through research interfaces. As such, specific pairs of electrodes in the two ears can be selectively activated, with tight control of interaural time and level differences (ITDs and ILDs). Because this approach uses single pairs of electrodes, it is not strongly linked to the way sound processors typically function in everyday listening.

Here we developed a novel paradigm with acoustic signals designed to measure ITD and ILD JNDs when signals were presented directly to the children's clinical processors via the audio input port. The stimuli were designed to activate a fixed set of eight electrodes in each ear, allowing a larger overlapping region along the cochlea between two ears. To further understand the perceptual time-course of binaural processing, we also recorded children's eye gaze during the task. This approach provides data about supra-threshold decision-making process, as well as ITD and ILD JND thresholds.

Cochlear Nucleus processors which employ the Advanced Combined Encoder (ACE) strategy were used. ACE typically stimulates the eight electrodes with highest sound intensity. To target stimulations on electrodes 4-11 in each ear, we designed a complex of eight transposed tones with center frequencies matching the targeted electrodes based on the clinical map in each processor. A 30 Hz amplitude modulation was superimposed on the acoustic complex. Electrodograms confirmed good envelope encoding of the acoustic signal in targeted electrodes and minimum stimulation on electrodes outside of the chosen range. ITD and ILD cues were introduced by either time-shifting or intensity scaling the whole waveform in either ear. Since sound processors stimulate at over 900 pulses/s, the ITD cue was only available in the envelope, which is the only viable ITD cue that can potentially be received from these sound processors in real-world listening.

In 10 children tested to date, ILD JNDs were between 0.7-6.0 dB, all well within the physiologically relevant ILD range. ITD JNDs range between ~200-1000 μs; 8/10 children had measurable JNDs within the physiologically relevant ITD range. Analysis of eye gaze data suggested that, for cue magnitudes above JND thresholds, latency decreased as the binaural cue magnitude increased and became more salient, even though both accuracy and response time from mouse-click reached a high asymptote. These novel findings demonstrated that children with BiCIs have ITD sensitivity when listening through specially designed stimuli that maximize envelope ITD cues delivered through clinical processors. Further, the novelty of the eye gaze paradigm revealed the importance of cue saliency for decision-making on binaural tasks.

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P25: EFFECT OF PULSE RATE AND ENVELOPE ON INTERAURAL TIME DIFFERENCE DISCRIMINATION IN HEARING INEXPERIENCED CI RATS

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Sound localization is one of the major challenges for bilateral cochlear implant (CI) users. To date, their ability to use binaural cues, and especially interaural time differences (ITDs), fall far below that of their normal hearing peers. While it is widely suspected that the issue lies in the lack of early sensory input, our recent study on neonatally deafened, CI implanted rats has shown that, at least at low pulse rates (pps), very good ITD sensitivity can be developed even in the absence of early sensory input if the bilateral CIs are synchronized. Here, we follow up on these results to investigate the dependence of ITD sensitivity on pulse rates and stimulus envelope in neonatally deaf rats.

Deafness in rats was induced neonatally by kanamycin and verified by measuring auditory brainstem responses. In young adulthood (~p60), CI electrodes were chronically implanted into both cochleae. Sensitivity to onset and ongoing ITD of binaural, biphasic pulse train stimuli at different pulse rates (50 to 900 pps) was studied by training CI implanted rats on a two-alternative forced choice lateralization task.

When presented with precise ITD cues covering the rats' physiological range (~±130 µs) from the start of first stimulation, all neonatally deafened CI rats showed sub-millisecond ITD sensitivity within a matter of a week of training. For stimuli with rectangular windowed pulse trains, good ITD sensitivity was observed at all pulse rates tested with maximum performance observed at 300 pps. For Hanning windowed pulse train stimuli, CI rats were still able to discriminate sub-millisecond ITDs. However, providing stimuli with weaker onset cues particularly at higher pulse rates resulted in a general decline in performance but the difference was only significant at 300 pps.

In conclusion, an inexperienced, adult auditory system can develop precise ITD sensitivity within the physiological range if given synchronized CI stimulation immediately after bilateral CI implantation. CI stimulation rates of up to 900 pps should not prevent the development of ITD discrimination, but greatest ITD sensitivity was found at lower pps rates. Furthermore, CI stimulation can provide usable ITD information even if CI pulse trains have very gentle rising slopes, indicating that precise "envelope onset timing cues" are not necessary, and that the auditory system of neonatally deafened CI rats therefore appears capable of processing ongoing ITDs of the CI pulse trains.

P26: USING DYNAMIC ITD SENSITIVITY TO MATCH ELECTRIC AND ACOUSTIC HEARING IN PATIENTS WITH UNILATERAL COCHLEAR IMPLANTS AND RESIDUAL CONTRALATERAL HEARING: LOCALIZATION AND SPEECH PERCEPTION OUTCOMES

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Current cochlear implant (CI) fitting strategies aim to maximize speech perception through the CI by allocating all spectral information across the electrode array without regard to tonotopic placement of each electrode along the basilar membrane. For patients with considerable residual hearing in the non-implanted ear, this approach may not be optimal for binaural hearing. This study aims to explore fitting procedures in which CI maps better complement information from the acoustic ear by reducing the frequency mismatch between ears. We investigate the mechanisms of binaural temporal-envelope beat sensitivity in patients with unilateral deafness and CIs as a function of spectral overlap using bandpass filtered pulse trains. Results in eight CI listeners show sensitivity to beats and “tuning” such that sensitivity to beats depends on the relationship between the spectral content of sound in each ear. This information was used to remap eight listeners who had at least six months of listening experience prior to frequency remapping. Results suggest that frequency-matched maps perform as well or better than clinical maps in tests of localization and spatial speech understanding tasks, including the precedence effect, throughout a period of 6 months of listening experience. Subjective performance metrics and anecdotal reports suggest that frequency remapping can produce noticeable, immediate changes in perceived spatial awareness, speech, and quality of hearing. The outcomes of this study will provide new information on binaural interactions in patients with a CI in one ear and significant residual hearing in the contralateral ear and guide methodology for frequency-matching remapping efforts.

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P27: BILATERAL COCHLEAR-IMPLANT PROCESSOR OUTPUT ILDS AS A FUNCTION OF DYNAMIC-RANGE COMPRESSION PARAMETERS AND HEAD MOVEMENT

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Dynamic-range compression is used in cochlear implants (CIs) to compensate for the greatly reduced dynamic range of CI listeners. Previous work (Archer-Boyd & Carlyon, in press) has shown that the interaction between head movement and slow-acting, unlinked compressors produces highly distorted interaural level differences (ILDs).

We investigated the effect of altering dynamic-range compression parameters on the ILDs produced during head movement. These parameters included: attack/release times, compression ratio, threshold, number of independent channels, and unlinked/linked gain. Moving signals were created by combining static behind-the-ear hearing aid microphone impulse responses at successive angles with speech-shaped noise. This method has been perceptually verified in normal-hearing (NH) listeners to produce the perception of a smoothly moving signal (Brimijoin et al. (2013)). The CI processor simulation was initially based on the specifications and output of the Advanced Bionics Bionic Ear Programming System Plus (BEPS+) MATLAB simulation.

The results showed that changes to all compressor parameters altered the output ILD profile during head movements. Short attack/release times produced profiles similar in shape to the natural ILD profile, with static ILDs that were reduced in size, dependent on the compression ratio. Long attack/release times produced profiles that did not resemble the natural ILD profile, and could result in the ILD continuing to change to change after the movement had stopped. Changing the attack time had a larger effect on the level profile of the initially contralateral ear (level increasing), while changing the release time had a larger effect on the ipsilateral ear (level decreasing). Though linked compressors could preserve ILDs, they could also induce unnatural unilateral level changes, and could reduce the audibility of sound sources at the contralateral ear. Multi-channel compressors affected the spectral shape of the ILDs, and could, using suitable parameter settings, reduce the spectral distortion of ILDs inherent in broadband, single-channel compressors.

The results will be used to estimate the possible psychophysical effects of altering compression parameters on both localization and speech intelligibility using parameter settings similar to those currently implemented in CIs from each CI manufacturer.

References: Archer-Boyd and Carlyon (in press). J. Acoust. Soc. Am.; Brimijoin et al. (2013). PLoS One 8(12).

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P28: SPEECH-IN-NOISE RECOGNITION WITH MORE REALISTIC IMPLEMENTATIONS OF A BINAURAL COCHLEAR-IMPLANT SOUND CODING STRATEGY INSPIRED BY THE MEDIAL OLIVOCOCHLEAR REFLEX

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Objectives: Cochlear implant (CI) users continue to struggle understanding speech in noisy environments with current clinical devices. We have previously shown that this outcome can be improved by using binaural sound processors inspired by the medial olivocochlear (MOC) reflex, which involve dynamic (contralaterally controlled) rather than fixed compressive acoustic-to-electric maps. The present study aimed at investigating the potential additional benefits of using more realistic implementations of MOC processing.

Design: Nine users of bilateral CIs and two users of unilateral CIs participated in the study. Speech reception thresholds (SRTs) for sentences in competition with steady-state noise were measured in unilateral and bilateral listening modes. Stimuli were processed through a standard (STD) strategy, involving two independently functioning sound processors with fixed compression (the current clinical standard); the originally proposed MOC1 strategy with fast contralateral control of compression; a MOC2 strategy with slower control of compression; and a MOC3 strategy with slower control of compression and greater effects in the lower than the higher frequency channels. Performance with the four strategies was compared for multiple simulated spatial configurations of the speech and noise sources, including specific configurations where the original MOC1 strategy was expected to be disadvantageous relative to the STD strategy.

Results: In unilateral listening and when the implant ear had the worse acoustic signal-to-noise ratio, the mean SRT was 4 dB worse for the MOC1 than for the STD strategy (as expected) but it became equal or better for the MOC2 or MOC3 strategies than for the STD strategy. In bilateral listening, mean SRTs were 1.8 dB better for the best MOC strategy (MOC3) than for the STD strategy across all spatial configurations tested, including a condition with speech and noise sources co-located at front where the MOC1 strategy was slightly disadvantageous relative to the STD strategy. All strategies produced significantly better SRTs for spatially separated than for co-located speech and noise sources. A statistically significant binaural advantage (i.e., better mean SRTs across spatial configurations and participants in bilateral than in unilateral listening) was found for the MOC2 and MOC3 strategies but not for the STD or MOC1 strategies.

Conclusions: Overall, performance was best with the MOC3 strategy, which maintained the benefits of the originally proposed MOC1 strategy over the STD strategy for spatially separated speech and noise sources and extended those benefits to additional spatial configurations. In addition, the MOC3 strategy provided a significant binaural advantage, which did not occur with the STD or the original MOC1 strategies.

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P29: AUDITORY-COGNITIVE TRAINING TO OPTIMIZE POST-IMPLANT OUTCOMES

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Many older adults complain of difficulties perceiving speech in noisy situations, understanding foreign-accented talkers, and understanding speech produced by a talker with a motor speech disorder. Older adults are often less successful perceiving difficult speech than younger adults, and success is often linked to working memory capacity. Even when older and younger adults are equally successful at perceiving difficult speech, older adults rely on a larger number of cognitive supports than do younger adults. As many of these older adults have normal hearing, amplification is not a viable therapy to improve their speech perception. Alternatively, difficulties perceiving speech in noise are a common complaint for cochlear implant (CI) and hearing aid users that current technologies are not able to completely address. Behavioral training is therefore a promising avenue to improve listeners' perception of difficult speech. Our lab's interest is in targeting the link between working memory capacity and difficult speech perception performance as a possible behavioral intervention to improve performance. This work has demonstrated that working memory training may lead to speech perception in noise gains. We have also demonstrated short-term speech-in-noise training may lead to gains perceiving speech in noise for postlingually deafened adults who use CIs. More recently, we've expanded our training paradigms to include prelingually deafened children who use CIs. Our data indicate that providing children with working memory and/or phonological awareness training may lead to language gains.

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P30: VIRTUAL REALITY-BASED EXAMINATION OF AUDIOVISUAL SPEECH PERCEPTION IN COCHLEAR IMPLANT RECIPIENTS

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Speech perception in daily life relies on multimodal information. Cochlear Implant (CI) recipients are often particularly skilled at using visual speech cues. This may be due to the need to overcome the relatively limited cues provided by the electrical stimulation thereby supporting the outcome of the CI. Hence, audiovisual speech plays an especially crucial role in CI users and is linked to several aspects such as learning, plasticity and fitting. Moreover, assessing audiovisual perception has high ecological validity.

At least in many European countries audiovisual speech is only considered rather unsystematically with cochlear implantation. This is at least partly due to the fact that appropriate audiovisual material and methods are lacking. An innovative approach is the use of virtual reality (VR) to overcome some of these restrictions. It allows visualization of arbitrary speech stimuli by means of avatars or so-called “talking heads”. VR is promising for studying multisensory integration because it combines realistic settings with precise control of stimulus presentation.

This talk gives insight into the methods and opportunities of VR-based audiovisual speech assessment. It shows research needs related to CI-mediated speech perception and outcome from ongoing studies.

P31: NEUROMODULATION ENHANCES PLASTICITY IN A RODENT MODEL OF COCHLEAR IMPLANT USE

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Rates of auditory perceptual learning and asymptotic speech perception performance with cochlear implants are highly variable across patients (Blamey et al. Audiol Neurootol 2013). Adaptation to cochlear implants is believed to require neuroplasticity within the central auditory system (Fallon et al. J Neural Eng 2009). However, mechanisms by which behavioral training enables plasticity and improves outcomes are poorly understood. Here we investigate the hypothesis that neural mechanisms that promote plasticity in the rodent auditory system are key to optimizing cochlear implant usage, and might be especially helpful in cases of poor performance. We focus on noradrenergic modulation of rat auditory cortex by the locus coeruleus, which can enable robust and long-lasting neural and behavioral changes (Manunta and Edeline J Neurophysiol 2004; Martins and Froemke Nat Neurosci 2015; Sara Curr Opin Neurobiol 2015; Glennon et al. Brain Res 2018)

We developed a new surgical approach for cochlear implantation in adult rats (King et al. J Neurophysiol 2016). Our approach allows insertion of an 8-channel electrode array covering up to 360 degrees in the cochlea and allows rats to freely behave while using the implant to perform auditory tasks. Rats are trained on a go/no-go task, and self-initiate trials to respond to a target tone. Previously, we showed in normal hearing animals that this task requires auditory cortex, and that this task is sensitive to cortical modulation and plasticity (Froemke, Carcea et al. Nat Neurosci 2013; Carcea et al. Nat Commun 2017).

Here we examined the effect of pairing locus coeruleus stimulation with an auditory stimulus on auditory learning when the animal has to relearn a tone identification task using a cochlear implant. Initial training was done using acoustic stimuli and without locus coeruleus-auditory pairing in normal hearing animals. Animals were then bilaterally deafened and unilaterally cochlear-implanted. The animals were then retrained on the auditory task with the new target delivered by intracochlear electrical stimulation. Prior to each daily behavioral training session for the new target, one group of rats underwent a 5-10 min pairing session. Pairing accelerated learning with cochlear implants compared to animals that did not receive it. We then conducted multi-unit recordings in the auditory cortex to assess activation of the cortex by the cochlear implant. Animals that had been trained with the cochlear implant had more effective activation of the cortex, and those that underwent pairing had a sharper representation of the target cochlear implant channel. We used fiber photometry to monitor neural activity of noradrenergic locus coeruleus neurons, showing strong responses to novel auditory stimuli and noxious stimuli. During auditory learning, normal hearing animals display dynamic locus coeruleus activity, specifically during the acquisition of the new meaning of reward relevant tones. These studies indicate that neuromodulation can play a powerful role in shaping outcomes with cochlear implant use and training. Furthermore, native variability in cochlear implant use outcomes might reflect a difference in level of engagement of neuromodulatory systems across subjects.

P32: THE IMPORTANCE OF CONSISTENT COCHLEAR IMPLANT USE ON CORTICAL PLASTICITY IN CHILDREN WITH SINGLE SIDED DEAFNESS

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Objective: 1) To assess the effects of consistency of CI use on cortical plasticity in children with single sided deafness who receive a cochlear implant.

Background and rationale: Cortical development is directed by hearing experience in early childhood. Cross-modal plasticity occurs in the absence of auditory input and, in asymmetric hearing loss, input from the better ear is abnormally strengthened. Both of these effects increase with longer duration of deprivation. In children with single sided deafness (SSD), a neuroprotective effect of providing a cochlear implant at young ages was found in a small cohort of toddlers. In the present study, we examined cortical effects of cochlear implantation in a cohort of 19 children with both pre and post-lingual onset of SSD who received a cochlear implant.

Methods: Multi-channel electroencephalography (EEG) was measured in 19 children with SSD who received a cochlear implant at 1.1 to 16 years of age (mean ± s.d. = 7.3 ± 5.2). Twelve of the children had congenital unilateral SSD and seven had sudden onset of acquired SSD at 3.6-14.2 years of age (mean ± s.d. = 11.07 ± 4.0). The duration of deafness was limited (mean ± s.d. = 2.1 ± 1.4). EEGs were evoked by unilateral presentations of 36ms acoustic clicks trains delivered at 250 Hz via an insert earphone to the normal hearing ear and trains of electric biphasic pulses (36 ms) delivered at 250 Hz via an L34 processor to an apical electrode (#20) in the implanted ear. Recordings were completed at the time of acute cochlear implant use (1d-2 weeks) and then repeatedly with chronic cochlear implant use for up to 43 months (mean ± s.d. = 18.0 ± 12.7). The time-restricted artifact and coherent source suppression (TRACS) beamformer was used to locate the cortical sources underlying peak amplitude of EEG responses measured at the surface of the head. Maximum dipole moment (nAm) and corresponding latency were extracted from the voxels in left and right auditory cortices with the largest signal-to-noise ratio (highest pseudo-Z). Cortical lateralization to all stimuli as well as aural preference of each cortex to the unilateral stimuli were measured. The consistency of daily CI usage was determined from the device datalog at each test session.

Results: Evidence of aural preference was found at early stages of cochlear implant use. Within the first 12 months of CI experience, representation of input from the implanted ear emerged, normalizing cortical lateralization to all stimuli. A reversal of preference for the normal hearing ear was found in some children after long term use of implant. Average daily CI use spanned from 1.1 to 10.2 hours (mean ± s.d. = 5.9 ± 2.9). The degree of reversal from aural preference recorded ≥4 months post-implant activation was significantly correlated to the average hours of daily CI use.

Conclusions: Both the duration and consistency of CI use are important determinants of cortical development from the deaf ear in children with single sided deafness.

P33: BENEFITS OF MUSIC-BASED TRAINING FOR SUPPORTING SPEECH OUTCOMES IN CI USERS

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This presentation will consider the efficacy of music-based training to support speech outcomes in CI users. Beyond music itself, the obvious targets in this type of training are aspects of speech perception and production that are mediated by pitch. These include the perception and production of speech prosody, the perception of voice gender, and the perception of speech in noise. All of these aspects appear to be impaired in CI users, and the limited evidence available suggests that they may be improved through music-based training. While the focus of this presentation will be outcomes in CI users, I will also integrate the broader pool of evidence that becomes available when considering correlation, cross-sectional and experimental studies that have investigated music training effects on speech outcomes in older adults with age-related hearing loss and young adults with normal hearing under spectro-temporally degraded conditions.

P34: PERCEPTUAL LEARNING OF VOCODED SPEECH WITH AND WITHOUT CONTRALATERAL HEARING: IMPLICATIONS FOR THE REHABILITATION OF COCHLEAR IMPLANT SUBJECTS

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An increasing number of cochlear implant (CI) candidates show residual acoustic hearing, usually in their contralateral ear. A small proportion of them even has normal or quasi-normal hearing. This patient population may react very differently to CI implantation compared to bilaterally-deaf patients, mainly because they may not rely mostly on their CI to understand speech. From their first activation, they are receiving very different information in each ear, and there is currently no data on the type of training or rehabilitation strategy they should follow: do they need to spend some time listening to their CI alone, without contralateral hearing to maximize their performance? Or, on the contrary, does their residual hearing help them train to recognize speech with their CI more quickly?

To get a first insight into this question, we tested 60 normal-hearing listeners in an auditory perceptual learning experiment. Each subject was randomly assigned to one of three groups of 20 referred to as NORMAL, LOWPASS and NOTHING. The experiment consisted of two test phases separated by a training phase. In the test phases, all subjects were tested on recognition of monosyllabic words passed through a six-channel “PSHC” vocoder presented to a single ear (Mesnildrey et al., 2016). In the training phase, all subjects were also presented with the same vocoded speech in one ear but the signal they received in their other ear differed across groups. The NORMAL group was presented with the unprocessed speech signal; the LOWPASS group with a low-pass filtered version of the speech signal (filter cut-off of 250 Hz) and the NOTHING group with no sound at all. These three groups aim to simulate groups of CI subjects having normal contralateral hearing, residual low-frequency hearing and no residual hearing, respectively. The training phase consisted of listening to a 30-minute audio book with subtitles displayed on a computer screen.

A mixed-effect ANOVA showed a significant effect of training. All subject groups performed better after than before the training phase. Furthermore, there was a significant interaction between training and group. Further analysis showed that the amount of improvement was significantly smaller for the NORMAL than for the LOWPASS and NOTHING groups.
This shows that having normal contralateral hearing reduces or slows down perceptual learning of vocoded speech but that having instead an unintelligible contralateral signal does not have this effect. Potential implications for the rehabilitation of CI patients with partial or full contralateral hearing will be discussed.

Mesnildrey Q, Hilkhuysen G, and Macherey O (2016) “Pulse-spreading harmonic complex as an alternative carrier for vocoder simulations of cochlear implants.” J Acoust Soc Am 139:986-991.

P35: REWEIGHTING OF BINAURAL LOCALIZATION CUES IN BILATERAL COCHLEAR IMPLANT LISTENERS

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For spatial hearing within the horizontal plane, normal-hearing (NH) listeners rely primarily on the two binaural cues interaural time difference (ITD) and interaural level difference (ILD). They apply frequency-dependent weights when combining these cues to determine the perceived azimuth of a sound source. Low-frequency fine structure ITD cues are generally considered to be most salient. Cochlear implant (CI) listeners, however, rely almost entirely on ILDs, while ITDs contribute only little or not at all. This has two main reasons: 1) Current envelope-based CI stimulation strategies using constant-high-rate pulse trains do not encode fine structure ITDs and available envelope ITD cues are not sufficiently salient. 2) Even when presenting highly controlled fine structure ITDs using a research interface and the most sensitive pulse rate, CI listeners' sensitivity is lower and much more variable across listeners compared to NH listeners' fine structure ITD sensitivity. A recent study in our lab showed that NH listeners changed their ITD/ILD weighting when one of the cues was reinforced through visual feedback. Such ITD/ILD reweighting could be a factor contributing to the low ITD sensitivity of CI listeners, since in daily experience with current CI-systems, ILDs consistently indicate the sound source locations while ITDs provide no robust localization cues.

We adapted our NH experiment to bilateral CI listeners stimulated with a research interface. The experiment was conducted in a virtual environment and consisted of a pretest to establish the initial ITD/ILD weights, a multi-day training, in which visual feedback reinforced the ITD locations, and a posttest to measure the effect of training on the weights. We additionally measured just noticeable differences (JNDs) for ITD and ILD before and after training. ILDs corresponding to a range of azimuthal locations were derived individually in a separate pretest and combined with naturally occurring ITDs in various spatially inconsistent combinations, using a maximum azimuthal inconsistency of 24°. Participants' task was to lateralize 100-pps and 300-pps pulse trains presented at a single interaurally place-matched electrode pair. Feedback consistent with the ITD location was provided.

The data collection is still ongoing; however, preliminary results are promising and suggest an increase in ITD weights, especially in the 300-pps condition. So far, increased post-training ITD weights in lateralization do not seem to be reflected in corresponding post-training changes of ITD and ILD JNDs.

Based on our previous results with NH listeners, we propose a mechanism potentially contributing to CI listeners' low ITD sensitivity. Additionally, the present results are promising in terms of making fine structure ITDs better usable for CI listeners using future CI-systems that better convey ITD information.

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P36: INTERAURAL PITCH DISCRIMINATION IN CHILDREN WITH NORMAL HEARING, HEARING AIDS, AND COCHLEAR IMPLANTS

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Children with hearing loss potentially have central auditory processing abilities that differ from their normal-hearing (NH) peers due to disruption of auditory input and/or abnormal stimulation from hearing devices during development. Recent data suggests that hearing device combination affects the development of binaural pitch fusion, which determines the range of pitch differences over which dichotic stimuli are fused. Hearing device combination may affect other abilities, such as interaural pitch discrimination. In this study, we measured interaural pitch match functions in 25 NH, 10 hearing aid (HA), 11 bimodal cochlear implant (CI), and 18 bilateral CI children ranging in age from 6 to 10 years old.

A 2-interval, 2-alternative forced choice method of constant stimuli procedure was used to measure pitch match functions. Depending on device combination, acoustic tones were presented through headphones and/or electric pulse trains were presented to single electrodes. In each trial, the reference ear was stimulated with a fixed stimulus (frequency or electrode), and the contralateral, comparison ear stimulus was stimulated sequentially and varied in frequency or electrode. The child was asked to choose which of the two stimuli sounded higher in pitch, and a pitch match function was generated over several trials as a function of contralateral stimulus.

Successful completion of the task was defined as being able to bracket the pitch match, i.e. consistently rank some comparison stimuli as lower in pitch and another set of stimuli as higher in pitch than the reference stimulus. Overall, in the first year, 96% of NH children, 70% of HA children, 33.3% of bimodal CI children, and 50% of bilateral CI children were able to complete the task. For those who completed the task, interaural pitch match discrimination ability was measured as the pitch match range between the 25%-75% points of the pitch match function; pitch match range is a measure of the steepness of the function slope, with narrow ranges indicating steep slopes and wide ranges indicating shallow slopes and poor interaural pitch discrimination. NH children had narrower pitch match ranges compared to the hearing-impaired groups. When results were compared with data collected previously in equivalent adult groups, NH children had significantly broader pitch match ranges than NH adults. No other differences were seen. Longitudinal data collected annually over three years showed significant improvements in pitch match completion rates and decreases in pitch match ranges over time. The findings suggest the importance of device combination and experience with auditory stimulation for central auditory processing abilities in children during development.

P37: LONG TERM EXPOSURE TO ITD CUES FROM BILATERAL COCHLEAR IMPLANTS RESULTS IN NORMAL ITD SENSITIVITY IN A NEONATALLY DEAFENED MODEL

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Introduction: Performance with bilateral cochlear implants is superior to that with a unilateral implant; however, bilateral implantees still have poor performance in sound localisation and in speech discrimination in noise compared to normal hearing subjects. Long periods of profound deafness, with or without clinical bilateral cochlear implant use, results in reduced sensitivity to interaural time differences (ITDs). To test if long-term exposure to salient ITDs would result in improved ITD sensitivity, we developed a custom sound processor to deliver ITDs for chronic intra-cochlear electrical stimulation in a profoundly deaf animal model.

Method: Four groups of cats were used: acutely deafened controls (NH, n=2), neonatally profoundly deafened unstimulated (NDUS, n=2) and two groups there were neonatally profoundly deafened and received approximately 6 months of bilateral intra-cochlear electrical stimulation. Stimulation was from either clinical cochlear implants and speech processors (NDS, n=6) or from our custom-made sound processor and stimulator (NDITDS, n=8). One NH, two NDS and six NDITDS cats were trained on an automated go/no-go food reward sound lateralisation task. In acute experiments on cats at approximately 8 months of age, single-unit responses to electric bilateral stimulation with a range of ITDs were recorded from the central nucleus of the inferior colliculus bilaterally, using 32-channel silicon arrays.

Results: The NH animal was readily able to discriminate between two tones played from one speaker or moving between two speakers positioned 50 cm apart, reaching criteria performance by 10 days, while the NDS and NDITDS cats were unable to perform the task even after 60 days. Neuronal sensitivity to ITDs was significantly poorer in the NDS (n = 137) and NDU (n = 55) groups compared to the NH group (n = 110) (KW, $p < 0.01$), while the NDITDS group (n = 91) had significantly higher sensitivity than the NDS group (KW, $p < 0.01$) and was not significantly different than the NH group.

Conclusion: Long term exposure to salient ITDs from bilateral cochlear implants prevented or reversed the degradation in ITD processing that occurs following long-term deafness from a young age.

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P38: USING fNIRS TO PREDICT SPEECH PERCEPTION IN INFANT COCHLEAR IMPLANT RECIPIENTS

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Congenitally deaf children often receive their cochlear implants (CIs) in their first year to optimise their language development. However, language outcomes following implantation vary widely, even amongst children who are implanted at a similar age, leaving some children lagging behind. Long before it is possible to assess speech perception abilities behaviourally, objectively measured biomarkers may help clinicians predict which children might struggle with their CIs. In order to characterise a suitable biomarker, an important first step is to establish how speech perception develops in normally-hearing infants and how these processes differ amongst deaf infants who receive CIs. This longitudinal study aimed to use functional near infrared spectroscopy (fNIRS), a neuroimaging technique that is safe for repeated use with infants with CIs, to identify cortical activation in response to visual and auditory stimuli that may prove useful as a biomarker to predict future language outcomes.

To date, 13 participants aged 6-18 months have completed testing sessions at 1 month pre-implantation and at 1 and 6 months post-implantation (or a time-equivalent for controls), with further test sessions planned at the 12 month post-implantation mark. Participants were exposed to auditory speech, visual speech and non-speech stimuli in a block design whilst undergoing fNIRS imaging.

Our results suggest that it is possible using fNIRS to record cortical activation in temporal brain regions to visual and auditory speech and non-speech stimuli in infants.
By developing our understanding of how the auditory cortex develops in normally-hearing and deaf infants before and after cochlear implantation, we aim to develop biomarkers that may help predict subsequent speech and language development. These biomarkers may prove useful to help direct rehabilitation resources to CI recipients who need them most.

P39: COMBINED ELECTRO-OPTICAL STIMULATION OF SPIRAL GANGLION NEURONS IN A MOUSE MODEL OF AN OPTOGENETIC COCHLEAR IMPLANT

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Introduction: In developing a next-generation cochlear implant (CI), optical stimulation may address limitations of electrically-based devices, as light can be more spatially focused to create a greater number of independent channels. Light-driven stimulation of the cochlea is now feasible using optogenetics, which relies on the introduction of light-sensitive transmembrane ion channels to modulate spiral ganglion neuron (SGN) activity. At first, an optical CI will likely be a hybrid device combining both electrical and optical modalities to provide redundancy. However, the interaction between electrical and optical stimulation has not been well studied. Here, using a transgenic mouse model, we explore the effect of combined electrical and optical stimulation of SGNs on evoked auditory brainstem responses (ABRs) and neural activity in the inferior colliculus (IC).

Methods: Animal models were Bhlhb5 transgenic mice (n=10 mice) expressing channelrhodopsin-2 (ChR2) in spiral ganglion neurons driven by Cre-recombinase enzyme. Littermates with no ChR2 expression were used as controls and showed no response to light. Prior to surgery, we first assessed acoustically evoked ABRs through subdermal needle electrodes positioned at the pinna, vertex and below the ear. We then performed a cochleostomy distal to the round window niche using a postauricular approach and inserted either: 1) a silver wire through the cochleostomy and a return silver wire through the round window, or 2) a conformable micro-electrode array (fabricated at École Polytechnique Fédérale de Lausanne). To record IC neural multi-unit activity, we performed a craniotomy and inserted a 16-electrode multichannel shank along the tonotopic axis of the contralateral IC. Stimulation was biphasic electrical pulses (with alternating polarity) and blue light (488nm) pulses produced by a laser and conveyed by an optical fiber. We examined the effect of different co-stimulation paradigms and combinations on electrically-evoked ABR (eABR) waveforms and on IC activity.

Results: Transgenic mice expressing ChR2 showed ABR and IC activity to either electrical or optical stimulation alone. Light pulses 1 ms before suprathreshold electrical stimulation resulted in an increase in both eABR peak 1 amplitudes and IC activity for light that was suprathreshold, but not for light that was subthreshold. The increase observed in eABR P1 amplitudes approximated the sum of those obtained from each stimulation modality alone. The increase observed in IC activity was less than the simple sum computed from each stimulation modality alone, which may result from saturation of IC neurons as the level is increased. Our data suggest that a hybrid electro-optical cochlear implant might be more effective than a device using just one modality.

P40: FREQUENCY FOLLOWING RESPONSE (FFR) AND SPEECH RECOGNITION BENEFIT FOR COMBINING A COCHLEAR IMPLANT AND CONTRALATERAL HEARING AID

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Introduction: Multiple studies have shown significant speech recognition benefit when acoustic hearing is combined with a cochlear implant (CI) for a bimodal hearing configuration. However, this benefit varies greatly between individuals, with some patients receiving significant benefit and others receiving little-to-no benefit. There are currently no available clinical measures that can predict bimodal benefit; as such, clinical decision making regarding which ear to implant or whether a patient should pursue one or two implants is not only difficult, but it is not evidence based. The frequency following response (FFR) is an auditory-evoked potential that provides an objective way to quantify auditory neural processing of periodicity and temporal fine structure (TFS) of an acoustic stimulus. Although studies have found correlations between FFR spectral amplitudes with speech recognition tasks for adults with normal hearing (Anderson et al., 2011; Parbery-Clark et al., 2009; Song et al., 2011), no studies have investigated the FFR and bimodal benefit in adults who use a CI and a hearing aid (HA) in the non-implanted ear. Thus, the purpose of the current study was to replicate and expand on previous studies that have investigated the relationship between bimodal benefit and various aspects of auditory function, including the FFR, in the non-implanted ear. We hypothesized that FFR spectral amplitude at the stimulus fundamental frequency (F0) and first formant (F1) in the non-implanted ear—indices of periodicity and TFS auditory processing—would be significantly correlated with bimodal benefit.

Methods: Participants included 14 unilateral CI users (Mean age = 57.78 years, range = 25 to 79.4 years) who wore a HA in the non-implanted ear and had unaided audiometric thresholds less than or equal to 80 dB HL at 250 Hz in the non-implanted ear. Participants completed three speech recognition measures: CNC words in quiet and Az-Bio sentences at +5 dB SNR (S0N0 and S0N45-315) with the CI-alone and in the bimodal condition (i.e., CI + HA). An FFR was measured in the non-implanted ear using a 170-ms /da/ stimulus at a fixed intensity level of 90 dB SPL. Additional testing included spectral modulation detection, a quick method for measuring psychophysical tuning curves, and amplitude modulation detection in the non-implanted ear.

Results: 1) There was a significant positive correlation between FFR spectral amplitudes at F0 and bimodal benefit for all three speech recognition measures (CNC: $r = 0.86$, $p < 0.001$; AzBio +5 S0N0: $r = 0.59$, $p = 0.042$; AzBio +5 S0N45-315: $r = 0.75$, $p = 0.005$). There was, however, no correlation between FFR spectral amplitudes at F1 and bimodal benefit, likely due to reduced or absent TFS representation at F1 (700 Hz). 2) Neither low frequency audiometric thresholds nor measures of spectral or temporal resolution in the non-implanted ear were correlated with bimodal benefit.

Conclusions: The FFR holds potential as an objective tool to better explain variability in bimodal benefit frequently observed in populations of bimodal listeners. It is possible that this information may eventually be used for clinical decision making, such as guiding bilateral CIs vs. bimodal candidacy decisions or determining which ear to implant, particularly in difficult-to-test populations such as young children. Further study of the FFR and bimodal benefit is warranted.

P41: AUDITORY POTENTIALS TO THE FUNDAMENTAL FREQUENCY OF THE VOICE IN COCHLEAR IMPLANT LISTENERS

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Cochlear implant patients have considerable difficulty with voice gender recognition and intonation perception. Both these speech characteristics are strongly linked to the fundamental frequency of the voice.

In a first experiment, we studied how cochlear implant listeners perceive frequencies in the range of the fundamental frequency of the voice. We used EEG to measure auditory steady-state potentials (ASSRs) to modulated pulse trains (bipolar, 900 pps) with modulation frequencies equal to 100, 200 and 300 Hz. We found that, for modulation frequencies above 100 Hz, ASSRs have very small amplitudes and can often not be measured above background noise. This contrasts with findings in normal hearing subjects, where significant ASSRs can be found up to at least 450 Hz. Similarly, A similar drop in performance above 100 Hz was found in studies on behavioral modulation detection in cochlear implant listeners. These findings indicate that cochlear implant listeners struggle to perceive amplitude modulations above 100 Hz, explaining their troubles with interpreting the fundamental frequency of the voice.

ASSRs have the limitation that they require the stimulus frequency to be steady, which is highly unnatural for the fundamental frequency of the voice. In a second experiment, we aim to study the auditory processing of the naturally varying fundamental frequency of the voice in cochlear implant patients with frequency following responses (FFR). Before setting up experiments with cochlear implant listeners, we explored the effect of three important stimulus parameters in normal hearing individuals. First of all, we studied how response SNR varies with the complexity of the stimulus, i.e. from simple modulated tones, over Klatt synthesized vowels, to natural vowels. Second, we compared response SNRs across different frequency regions, i.e. around 100, 150 or 200 Hz. Third, we studied how direction of variation of the fundamental frequency, i.e. upward, flat, or downward, affects the response SNR. The results of this exploration will be presented at the conference.

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P42: PHYSIOLOGIC AND PSYCHOPHYSICAL PERCEPTION OF SPECTRAL CUES IN HYBRID COCHLEAR IMPLANT USERS

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Today, many surgeons are using atraumatic electrode arrays and surgical techniques to preserve residual acoustic hearing in the implanted ear. For these individuals, low-frequency sounds are processed naturally and combined with high-frequency sounds that are conveyed electrically (e.g. Cochlear Nucleus Hybrid CI; Roland et al, 2016). These individuals outperform traditional CI users, particularly on speech perception in background noise (Gantz et al, 2017). This report will describe results of a series of physiological and psychophysical experiments that were undertaken to explore how spectral cues transmitted acoustically and electrically are processed by Hybrid CI users.

Acoustic Processing: Intracochlear electrocochleography (ECoG) allows one to measure cochlear microphonic (CM) and auditory nerve neurophonic (ANN) potentials from an intracochlear electrode in response to acoustic stimulation (e.g. Abbas et al, 2017; Tejani et al, 2019). We used ANN responses and a forward masking paradigm to construct physiologic tuning curves (Gorga & Abbas, 1981). The probe was a 500 Hz tone burst. The masker frequency was varied from one octave below to one octave above the probe frequency.

Electric Processing: Two experimental 6-channel MAPs that differed on electrode spacing were created. One MAP used six adjacent electrodes (electrodes 12-17). The other used wider spacing (electrodes 7, 10, 13, 16, 19, and 22). We reasoned that closer spacing of the electrodes in the MAP would lead to more channel interaction. Electrically evoked compound action potentials (ECAP) were utilized to measure channel interaction. A Channel Separation Index (CSI; Hughes 2008, Scheperle & Abbas, 2015) was calculated to quantify the degree of channel interaction. Spondee recognition in quiet and noise, as well as spectral ripple depth detection, was assessed for each subject using both MAPs. Performance was assessed in three listening modes: acoustic-only, electric-only, and combined acoustic+electric.

Acoustic + Electric Processing: Intracochlear ECoG responses were measured using an acoustic tone burst that was presented with and without simultaneous presentation of continuous electrical pulse trains. The electrical stimulation suppresses ECoG responses, indicating a form of electric-acoustic interaction (Koka & Litvak, 2017). We also measured electric-acoustic interactions psychophysically, where perpetual thresholds for acoustic tone bursts were assessed with and without an electrical pulse train masker (Koka & Litvak, 2017; Kruger et al, 2017).

Preliminary Results: Acoustic tuning curves measured from Hybrid CI users vary widely. Additionally, electrical channel interaction functions indicate better channel separation for the widely spaced experimental MAP. This MAP also yielded better performance on speech recognition measures. Lastly, greater suppression of acoustic responses was observed physiologically (via ECoG) rather than psychophysically. Data collection is ongoing, but the final aim is to use multiple regression analysis to ascertain the contribution of acoustic processing (tuning curves), electric processing (channel interactions), and acoustic+electric processing (electric-acoustic interactions) on outcome measures (speech recognition) in Hybrid CI users

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P43: ACOUSTIC, LINGUISTIC, AND COGNITIVE FACTORS IMPACT EFFORTFUL LISTENING: IMPLICATIONS FOR COCHLEAR IMPLANT USERS

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Recent surveys have revealed that the vast majority of individuals with hearing loss report exerting more effort when listening to speech than their normal-hearing peers. Listening effort is thought to arise as individuals compensate for declines in the bottom-up, auditory signal (as a result of hearing loss or other adverse listening conditions) by engaging more extensive top-down mental resources (e.g., executive functions). When compensation is successful, there may be minimal decrements in speech recognition accuracy despite potentially large increases in how hard the individual had to work to achieve that level of performance. As a result, fewer mental resources may remain to support other sensory, motor, and cognitive functions that are important for daily life activities.

Identifying the mechanisms that contribute to effortful listening may be critical for comprehensively assessing and mitigating the challenges faced by individuals with speech recognition difficulties. Neuroimaging studies have proven incredibly useful in this endeavor. However, many commonly used methods (e.g., fMRI) are not appropriate for some clinical populations of interest, including cochlear implant (CI) users. In this talk, I will summarize a series of studies that have examined the extent to which behavioral and physiological measures, namely pupillometry, can be used to assess the acoustic, linguistic, and cognitive factors that contribute to effortful listening in normal-hearing and hearing-impaired individuals. I will describe my neuroimaging work that aims to validate such measures by linking them to the engagement of specific sensory and executive function neural systems. Finally, I will conclude by discussing the implications of this research by highlighting ongoing collaborations with researchers investigating the impact of acoustic and attentional demands on listening effort in adult CI users.

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P44: SPEECH UNDERSTANDING AND LISTENING EFFORT IN INDIVIDUALS WITH SINGLE-SIDED DEAFNESS WHO RECEIVE A COCHLEAR IMPLANT

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Patients with severe-to-profound hearing loss in one ear and normal hearing in the other, known as single-sided deafness (SSD), have recently opted to obtain a cochlear implant (CI) in their deaf ear. Little is known about how a CI and a normal hearing ear impact a listener's ability to perceptually separate concurrent talkers originating from different spatial locations. Additionally, listening effort is a relevant issue for patients with SSD. Listening with one ear can be taxing, resulting in increased levels of listening effort in noisy situations. Furthermore, tinnitus is a common concern in this population, exacerbating this effect and leading to decreased quality of life. Here we aimed to investigate the impact of cochlear implantation in patients with SSD. We hypothesized that having electric hearing one ear and acoustic hearing in the other would promote spatial release from masking and reduce listening effort in SSD patients, due to having access to the second ear.

Eight listeners with SSD, recruited as part of a clinical trial, participated in speech-in-noise testing at two visits: a pre-CI and post-CI visit (took place 1 year after activation). We measured changes in pupil dilation (PD) to quantify listening effort for three spatial conditions during both visits: a target sentence in quiet presented at 0° azimuth, co-located speech and maskers at 0° azimuth, and ± 90° spatially separated target and maskers, all at 0 dB signal-to-noise ratios. Listeners were instructed to attend to the target talker and repeat the sentence that was heard; this was scored as a percentage of correctly repeated words. Target sentences were male-talker IEEE sentences and maskers were two different male AzBio talkers. Maximum PD during a two second period following stimulus offset was used to index listening effort.

Group data revealed that in the pre-CI visit, listeners exhibited the highest intelligibility scores in quiet (mean: 98.7%). Lowest scores were obtained in the co-located condition (mean: 52.2 %) and there was a slight improvement in the spatially-separated condition (mean: 63.5%), suggesting a release from masking. Listening in quiet yielded the smallest PD and the co-located condition yielded the largest. When comparing masker conditions, there was a small decrease in PD in the spatially-separated condition compared to the co-located. This implies that, in addition to the release from masking, there was a slight release from effort from the co-located to spatially-separated conditions. Results from the post-CI visit, compared to the pre-CI visit, show improved speech intelligibility scores in all conditions, quiet: 99.7%, spatially-separated: 79.3%, and co-located: 67.3%. Maximum PD was smallest in the quiet condition, while an even higher PD was measured in the masking conditions, compared to the pre-CI visit.

Results demonstrated that CIs can facilitate improved speech understanding in noise for patients with SSD. Overall, there was an increase in PD in every listening condition from the pre-CI to post-CI visit. For the masker conditions, this may be explained by an increase in engagement in the task, since speech intelligibility improved from the pre-CI to post-CI visit. This has implications for understanding the integration of electric and acoustic inputs for patients with SSD.

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P45: DECODING SELECTIVE ATTENTION IN NORMAL HEARING LISTENERS AND BILATERAL COCHLEAR IMPLANT USERS WITH CONCEALED EAR EEG

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Electroencephalography (EEG) data can be used to decode an attended speech source in normal-hearing (NH) listeners using high-density EEG caps, as well as around-the-ear EEG devices. The technology may find application in identifying the target speaker in a cocktail party like scenario and steer speech enhancement algorithms in cochlear implants (CIs). However, the worse spectral resolution and the electrical artifacts introduced by a CI may limit the applicability of this approach in CI users. This work investigates if selective attention can be decoded in CI users in the course of two experimental studies.

In the first study, speech from two audio books, one uttered by a male and one by a female voice, was presented to 12 NH listeners and 12 CI users. Participants were instructed to attend to one of the two concurrent speech streams, presented dichotically, while a 96-channel EEG was recorded. Speech envelope reconstruction from the EEG data was obtained by training decoders using a regularized least square estimation method. Decoding accuracy was defined as the percentage of accurately reconstructed trials for each subject. The experiment was repeated in NH listeners using a vocoded version of two audio books to reduce spectral resolution and to simulate speech perception with a CI in NH listeners. The overall results showed a decoding accuracy of 80.9% using the original sound files in NH listeners. The performance dropped to 73.3% in the vocoded speech condition and to 71.2% in the group of CI users. In sum, although the accuracy drops when the spectral resolution becomes worse, the results prove the feasibility to decode an attended sound source in NH listeners using a vocoder simulation. Furthermore, even in CI users the attended speech source can be decoded, albeit more training data are needed.

In the second study, the decoding of selective attention was investigated using a high-density scalp EEG and an around-the-ear EEG system (cEEGrid), using the same selective attention paradigm based on the envelope tracking algorithm. 10 NH listeners and 10 bilateral CI users participated in the study. Participants again were instructed to attend to one out of the two concurrent speech streams, while data were recorded simultaneously by a 96-channel scalp EEG and an 18-channel cEEGrid setup. Reconstruction performance was performed exactly in the same manner as in the previous study. Results from the second study confirm that it is possible to decode selective attention in NH listeners with high decoding accuracies, using a high-density scalp EEG. However, the decoding accuracy was significantly lower with the cEEGrid. Furthermore, the study could show that it is possible to decode selective attention in CI users despite the introduced electrical artifact. Results on the single-subject level showed that in several CI users selective attention could be successfully decoded with the cEEGrid system.

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P46: DICHOTIC LISTENING PERFORMANCE AND EFFORT IN BILATERAL COCHLEAR-IMPLANT AND NORMAL-HEARING LISTENERS

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Adults who seek bilateral cochlear implantation are often implanted sequentially. This practice can lead to differences in the functionality of the two ears, which may limit binaural benefits and make listening more cognitively demanding. Functional differences could be caused by a number of possible factors, including those related to peripheral encoding (e.g., effective spectral resolution). Measures of speech understanding on binaural tasks are typically used to characterize binaural benefits. The addition of pupillometry as an index of listening effort, the auditory and cognitive resources exerted to perform those tasks, provides additional information beyond a single performance measure. This experiment investigates the role of interaural differences on speech understanding and listening effort for the simple binaural task of selective attention to an ear during dichotic listening. Bilateral cochlear-implant (BCI) listeners with a range of interaural asymmetries were tested. Symmetric and asymmetric ears were also simulated in normal-hearing (NH) listeners by varying the spectral resolution with vocoded speech. We hypothesized that attending to relatively degraded speech in the presence of relatively clear speech would require more listening effort than the opposite case.

BCI and NH listeners performed a monotic and dichotic digit listening task with attention directed toward one ear. BCI listener ear asymmetry was measured by performance differences in monaural speech understanding. For listeners with larger functional differences across ears, the quality of the signal of the target and interfering speech varied with changes in attended ear. For NH listeners, the quality of the target and interferer were varied by changing the number of vocoded channels in each ear. Digit recall accuracy and pupil dilation were measured throughout the experiment to evaluate performance and listening effort, respectively. To investigate the relationship between cognition and performance on this task, non-auditory inhibition and working memory tests were completed in all listeners.

Preliminary results show higher digit recall accuracy for monotic conditions compared to dichotic conditions. In addition, larger pupil size was observed during dichotic conditions in comparison to monotic conditions. In 11 young NH listeners, higher spectral resolution of the interfering digits was associated with faster growth in pupil size over time. Listener performance in 12 BCI listeners was more varied than the NH listener performance. Special cases for BCI also occurred; a highly asymmetric listener showed similar pupil size for monotic and dichotic conditions when attending to the better ear, supporting the idea that the poorer ear may not be perceived in dichotic listening with a large ear asymmetry. The relationship between cognitive measures and these results will be discussed.

In the NH listeners, effort increases with increasing spectral resolution of interfering speech without significant differences in digit recall for dichotic conditions, which supports the main hypothesis that interaural asymmetries can cause increases in listening effort. In the BCI listeners, preliminary results suggest that interaural asymmetries can lead to poorer performance for both monotic and dichotic listening than predicted by differences in spectral resolution in the NH listeners. This may indicate that asymmetries in the BCI listeners involve more than an interaural spectral resolution difference and reflect additional peripheral encoding factors or more central changes to the auditory system. By studying both listening performance and the cognitive resources involved, we can facilitate a more complete understanding of cognitive demands to cochlear implant listening and attain a more holistic view of BCI perception than is attained with behavioral measures alone.

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P47: USING HIGH-DENSITY OPTICAL BRAIN IMAGING TO STUDY SPEECH PROCESSING WITH A COCHLEAR IMPLANT

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How does acoustic challenge affect the way our brains process speech? I will report results from our studies using high-density diffuse optical tomography (HD-DOT), a type of optical brain imaging, to study the brain networks supporting speech comprehension. We scanned adult listeners with and without cochlear implants while they listened to speech in quiet while measuring brain activity in occipital, temporal, and frontal lobes using source-reconstructed neuroimaging. We find that, as a group, listeners with cochlear implants engage regions of frontal cortex associated with executive processing more than listeners without, consistent with increased cognitive demand during listening. I will also talk about our efforts to link individual differences in brain activity to outcome measures such as speech intelligibility in quiet and noise.

P48: CHILDREN WITH IMPAIRED BINAURAL HEARING HAVE WORKING MEMORY, LEARNING AND NAVIGATION DEFICITS: EVIDENCE FROM GROUPS WITH BILATERAL COCHLEAR IMPLANTS AND UNTREATED SINGLE-SIDED DEAFNESS

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Objectives: (1) To identify deficits in spatial perception, working memory, awareness, and academics in children with hearing loss, and (2) To determine relationships between these functional abilities.

Background: Binaural/spatial hearing is impaired in children with hearing loss. Binaural cues are unavailable to children with untreated single-sided deafness (SSD) and are inaccurate/inconsistent in children using bilateral cochlear implants (BCIs). Hearing loss also negatively affects cognitive processes, which could appear as working memory and learning deficits in these groups of children.

Methods: A battery of functional measures were completed in 32 children who received BCIs simultaneously (mean age (SD)=8.94(2.88) years), and 20 children with untreated SSD (mean age(SD)=10.73(4.17) years). Results were compared to 36 children with normal hearing (mean age(SD)=10.03(3.25) years). The test battery focused on hearing ability (PBK speech perception test, Speech and Spatial Qualities of hearing questionnaire-SSQ), spatial perception (subjective visual vertical), spatial navigation (triangle completion task), verbal working memory (digit span), spatial working memory (Corsi block tapping test, dot matrix test), academics (WIAT-III sub-tests) and language (CELF). Hypotheses were tested using principal components analyses of these measures.

Results: Principal components analyses identified 4 main clusters of data across the 3 groups: PC1: memory and learning; PC2: self-perceived hearing ability; PC3: hearing and spatial navigation; PC4: balance and spatial navigation. ANOVAs to assess group differences, accounting for age, revealed that children with BCIs had significantly lower memory/learning (PC1) and self-perceived hearing (PC2) than the other 2 groups ($p<0.05$). Children with SSD also showed impaired memory/learning (PC1) compared to normal hearing peers ($p=0.005$) and had more challenges with their hearing, balance and spatial navigation (PC3 and PC4) compared to the other groups ($p<0.05$).

Conclusion: Despite good self-perceived hearing, children with untreated SSD exhibit cognitive and learning deficits and poor balance and spatial navigation. Providing children with BCIs does not entirely remediate cognitive deficits that result from periods of auditory deprivation in development but may provide improvement in balance relative to untreated SSD to support spatial navigation. Together, the findings reiterate the importance of providing children with binaural input as early as possible.

P49: NEURAL CORRELATES OF SELECTIVE ATTENTION PREDICT SPEECH STREAMING PERFORMANCE IN BILATERAL CI USERS

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Objective. Cochlear implant (CI) users find it difficult to listen to one talker in a multi-talker environment, a phenomenon known as auditory streaming. To reveal physiological correlates behind disrupted auditory streaming, this study determined whether neural signatures of perceptual stream segregation could be quantified in bilaterally-implanted CI users and whether this measure predicted performance. Previous work in normal hearing (NH) adults has shown that selective attention to one talker in a two-talker paradigm is associated with two neural markers in the electroencephalogram (EEG): 1) increased “neural tracking” to the attended stream compared to the ignored stream and 2) alpha (8-12 Hz) event-related synchronization (ERS) ipsilateral to the attended side, which may suppress cortical processing to the ignored side. Here we examined these two signatures in groups of bilateral CI users and NH adults.

Methods. Two free-field speakers positioned at +/- 45° and at 1 meter away from participants concurrently presented 4 to 7 pairs of spoken numbers (or digits) by the same female voice. Prior to each trial, a cue indicated the side to which the participant was to attend. The number of digits and side of attention varied randomly across trials. Participants reported the last digit presented on the cued side. The 64-channel EEG was recorded during the task. Neural tracking for attended and ignored stimuli was quantified using linear encoding models that cross correlate the EEG and the speech envelope. Time-frequency analysis was separately performed to look at ignore-stream suppression.

Results. Performance on left/right digit identification in 13 CI users (80%) was poorer than for 8 NH controls (93%, $p = 0.03$). Notably, performance in CI users also closely correlated with clinical speech perception scores ($r = 0.91$). Neural tracking was better for the attend stream compared to the ignore stream in both groups. However, in the CI group, those with better speech tracking of the attended stream had better performance ($r = 0.60$, $p = 0.03$). Although we observed alpha ERS ipsilateral to the ignored stream in both groups, ERS did not predict behaviour or correlate to performance. Thus, attention and suppression mechanisms during auditory streaming may be independent.

Conclusion. Neural signatures of selective attention in CI users can predict their speech streaming performance and can be a marker of patient outcome.

P50: TRACKING LANGUAGE AND MUSIC PROCESSING WITH NEUROPHYSIOLOGICAL MEASURES IN CHILD AND ADULT CI-USERS

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Though the cochlear implant (CI) is generally successful in allowing its users to perceive and understand language, the electric stimulation differs substantially from conventional acoustic stimulation and we still have not fully grasped the consequences for language comprehension and other cognitive functions. In contrast to the many studies examining the basal/basic mechanisms of hearing with a CI, the goal of our lab is a more detailed understanding of higher cognitive processes beyond the auditory cortex.

In my talk, I will present a series of studies using late event-related brain potentials (ERPs) and functional near-infrared spectroscopy (fNIRS) to examine language and music processing. One such project concentrates on young, early implanted children that rely on the CI for language acquisition. In an EEG study, we could show that prelingually deafened children with a CI were surprisingly fast word learners who despite the late and poorer input need less hearing experience than typically hearing children to establish robust semantic relationships (visible as an N400). We suggest that this is due to their greater age and hence their more matured cognitive faculties when encountering language for the first time. Current studies shall examine this further.

Other projects focus on primary school children and adolescents for which we saw large developmental effects in prosodic and syntactic sentence processing over time.
In the music domain, we examine both the processing of specific features as well as abstract music comprehension. I will present an ongoing study with adult CI users which considers how different aspects of music is processed depending on 1) hearing status (deaf/single-side deafness/typical hearing), 2) onset of deafness (pre-/perilingual vs. postlingual) and 3) time of implantation (childhood vs. adulthood). The results show an interesting fine-grained picture, which sharpens our eyes for critical details when thinking of music processing with a CI.

P51: DIFFUSION MODELS AS ADDITIONAL MEASURES OF COCHLEAR IMPLANT USER PERFORMANCE

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Seldom are real-life acoustic scenes free of background interfering talkers. Unlike normal hearing (NH) listeners, who understand speech well in these scenarios (perception of speech-on-speech; SoS), cochlear implant (CI) users find such settings quite challenging. These difficulties were shown in earlier studies to potentially be related to the difficulties in the perception of two fundamental voice cues, namely, the voice pitch (F0) and the vocal tract length (VTL) of the speaker.

Measuring sentence comprehension provides an indication of real-life communication scenarios (Best et al., 2016), in which listeners attempt to extract meaningful information from the entire sentence as a whole. This differs from traditional intelligibility measures that are based on individual word identification. Cochlear implant processing inevitably distorts some of the essential cues required to draw meaning from the entire sentence, thus affecting overall sentence comprehension. The Sentence Verification Task (SVT) has been used in multiple settings to measure sentence comprehension speed (response times; RTs) and accuracy in both NH and CI listeners. However, interpreting RTs and accuracy scores in isolation could be misleading, since participants may sacrifice accuracy for speed or vice-versa. To address this speed-accuracy trade-off, and define a unified performance measure, diffusion models were proposed and widely validated in a number of auditory and visual discrimination tasks with NH listeners. Nevertheless, applying such models to CI data, especially in the context of SoS and voice cue perception, remains largely unexplored.

In this study, we explored the use of drift rate as a combined measure of SoS comprehension RTs and accuracy. Larger values of the drift rate indicate better information accumulation over the time course of the stimulus and vice-versa. SoS comprehension RTs and accuracy, in addition to SoS intelligibility (word identification), were measured in three experiments as a function of increasing the F0 and VTL difference between two competing talkers: a target speaker and a background masker. Participants were asked to indicate whether the target sentence was true or false. In experiment 1, NH listeners (unvocoded) and CI users using their own speech processors were tested. For NH listeners, results showed an increase in comprehension drift rate as a function of increasing F0 and VTL between the two competing talkers, although this effect was not significant. On the contrary, results for the CI listeners showed a significant decrease in comprehension drift rate (quality of information gathered) as a function of increasing F0 and VTL. The data for both NH and CI groups corroborated results observed in the more traditional SoS intelligibility task. In experiments 2 and 3, the effects of increased channel interaction and spectral contrast enhancement (SCE; Nogueira et al., 2016), respectively, on SoS intelligibility and SoS comprehension were measured in CI users using experimental processors. Data from experiment 2 revealed a significant drop in SoS intelligibility scores with increased channel interaction. However, this drop in performance with increased channel interaction did not appear either in the SoS comprehension speed or accuracy measures, nevertheless, it was significantly present in the drift rate data. Finally, data from experiment 3 revealed that while increased SCE improved SoS intelligibility for the CI users tested, this effect was not present in either of the three SoS comprehension measures (RTs, accuracy, or drift rate). Together, these findings demonstrate that SoS comprehension measures, especially when analyzed using diffusion models, may provide powerful methods of analyzing CI users' performance in adverse listening conditions.

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P52: EVIDENCE FOR BETTER NEURAL HEALTH IN CHILDREN WITH COCHLEAR IMPLANTS RELATIVE TO ADULTS

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Although cochlear implants (CIs) are highly successful at providing children and adults with access to speech in quiet listening environments, many struggle to understand speech in noise and to appreciate music. Little is known about the effects of cochlear implant stimulation during human auditory system development. Some investigations with animal models have shown that stimulation might preserve the health of the target spiral ganglion neurons (SGNs). Thus far, research in our lab has demonstrated that children who receive CIs early in life have lower behavioral thresholds than adult-deafened and implanted listeners, suggesting that children might have a larger population of healthy spiral ganglion neurons. We next used the polarity effect, a measure believed to reflect SGN peripheral process integrity, to determine if children may have a greater number of peripheral processes than adults. We found no difference between children and adults, which may indicate that children and adults have similar peripheral dendrite health. Finally, in the present study, we used several metrics from the electrically-evoked compound action potential (ECAP) to quantify potential differences in SGN density between child- and adult-implanted listeners. ECAP responses were obtained in 24 child-implanted ears and 23 adult-implanted ears with either Advanced Bionics (n = 18 ears, 13 participants) or Cochlear Ltd. (n = 29 ears, 22 participants) devices. The average age at implantation for the child-implanted ears was 4.3 years. The average age at implantation for the adult-implanted ears was 54.0 years. Stimuli were 25 us/phase pulses with interphase gaps (IPGs) of either 0 (AB only), 7, or 30 us. We quantified ECAP peak amplitude, threshold, and growth function slope on a subset of electrodes in response to each IPG. Consistent with prior studies, older listeners had shallower growth function slopes than younger listeners. The IPG effect for amplitude, or the difference in peak amplitude as a function of IPG, also decreased with increasing age. IPG effects for slope and threshold were not related to age, but were related to the channel of stimulation. Channels with high focused behavioral thresholds had steeper slopes and higher ECAP thresholds in the subjects with AB implants and basal channels had higher thresholds in the subjects with the Cochlear device. These results and those of previous studies demonstrate that early-implanted children likely have better neural health than post-linguistically deafened and implanted adults. The findings may suggest a need for different program optimization methods in children and adults.

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P53: LATE COMPOUND ACTION POTENTIAL COMPONENTS AS MARKER FOR COCHLEAR LESIONS AT PERIPHERAL DENDRITES OR SOMATA OF SPIRAL GANGLION NEURONS

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When electrically stimulating the deaf ear with cochlear implants (CIs), the outcome may critically be hampered by patchy degeneration of the spiral ganglion neurons (SGNs). These progressive processes from peripheral to central parts of the SGN may ultimately lead to 'hearing holes', i.e. regions less or nonresponsive to electrical stimulation. The present study addresses the possibility to detect local SGN degeneration via electrophysiological markers. Therefore, we performed micro-lesions targeting either peripheral dendrites or somata of SGNs and recorded electrically-evoked compound action potentials (eCAPs).

The experiments were performed in 6 normal hearing Dunkin-Hartley guinea pigs (N=9 cochleae). We used a micro-electrode to lesion the SGNs through a cochleostomy in the basal turn. The cochleotopic position of the lesion was identified by acoustically-evoked CAP (aCAP) audiograms and the lesion site (i.e. peripheral or soma) was histologically identified via µCT imaging and 3D autofluorescence confocal microscopy of optically cleared cochleae. After lesioning, the cochleae were pharmacologically deafened by an intra scalar perfusion with Neomycin-sulfate solution. The deafened cochleae were electrically stimulated through custom 6-contact CIs (MedEl, Innsbruck) and eCAPs were recorded in response to monopolar, biphasic, charge balanced pulses (50 µs per phase).

So far, 5 cases were histologically identified as primarily lesions of SGN somata and 4 at the peripheral dendrites. The micro-lesions resulted in focal aCAP threshold shifts for frequencies above 8 kHz with a mean spread of 1.3 octaves (n=5). We analyzed the two stimulus polarities separately. The late components of the eCAP, the N2 and its subcomponents N2a (mean peak latency: 1.1 ms) and N2b (1.3 ms), revealed a differential effect, based on the lesion site: The amplitudes (upper asymptote of the N2a sigmoidal fit; N2a and N2b amplitude at 3 dB above threshold) were larger for soma lesions as compared to peripheral lesions. Furthermore, the relative amplitude of the two components was lower (i.e. smaller N2a) for stimulation close to the lesion, as compared to apical stimulation. Both effects were more pronounced for cathodic-leading stimulation.

We established a method to histologically and electrophysiologically assess focal micro-lesioning, targeting peripheral dendrites or somata of the SGNs in the guinea pig cochlea. The results revealed distinct changes in late eCAP components based on the lesion site. These markers may be suited to detect 'hearing holes' in the degenerated cochlea.

This project was supported by the MedEl Company (Innsbruck) and the MHH-plus Foundation of the Hannover Medical School.

P54: ELECTRODE-SPECIFIC ECAP AMPLITUDE GROWTH FUNCTIONS AND THEIR RELATIONSHIP TO LOUDNESS GROWTH

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Background and significance. In each cochlear implant patient, the electrical dynamic range needs to be determined for each electrode contact, defined by the threshold (T-level) and the most comfortable level (M-level). An instantaneous compression curve maps the filter outputs to currents within this electrical dynamic range. The same compression curve, however, is being used for all electrode contacts alike, not accounting for possible differences in the loudness growth functions (LGF) in different regions of the cochlear [1]. Above that, considering the very narrow electrical dynamic range, an individualized adaptation of the compression curve might be advantageous, particularly in difficult listening environments. However, it is hard to imagine that audiologists would be able to spend hours to psychophysically determine the LGF for each individual electrode. Inspired by [2], we designed a study investigating the correlation between the subjectively perceived LGF and the evoked compound action potential amplitude growth function (ECAP AGF). In case there was a good correlation between the two, an automatically determined ECAP AGF might be used to predict the shape of the loudness growth curve of each individual channel allowing for an automated individualization of the compression curves.

Material and methods. 20 MedEl CI subjects with fully inserted long electrode arrays (standard 31mm or Flex 28) have been recruited for the study. The study implies one acute visit where ECAP AGFs and loudness growth functions across all electrodes are being determined. ECAPs are measured using the AutoART function within the clinical fitting software Maestro, while the LGFs are determined using the psychophysical software suite PsyWorks, presenting 7 linearly distributed stimulation currents across the electrical dynamic range of all electrodes in a randomized order, with each of the stimuli occurring three times. Subjects have to indicate the perceived loudness of each stimulus on a continuous scale from “inaudible” to “too loud”. While the ECAP measurements are obtained at a stimulation rate of 80 Hz, loudness is determined at different rates, i.e. 1200 pps, 600 pps, 300 pps and 150 pps. The profile and the steepness of the ECAP AGF and the LGF are being compared with each other.

Results. At present, eight complete datasets are available. The slope of the ECAP AGFs as well as the subjective LGFs were found to be subject and electrode specific. Both curves become shallower towards the base of the cochlear, indicating a place dependency. For selected electrodes, we found a significant correlation between the steepness of the subjective LGF and the ECAP AGF. LGFs measured on the same electrode but at different rates had similar progressions and slopes, while the stimulation currents needed for equal loudness percepts were higher for the lower rate stimuli.

Conclusion. Our preliminary outcomes speak in favor of an individualized compression function for each individual channel in cochlear implant systems which might in fact be achievable using an objective ECAP-AGF based approach.

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P55: ESTIMATING NEURAL SURVIVAL USING A NEW VERSION OF THE PANORAMIC ECAP METHOD

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Ideally the neural excitation produced by each electrode of a cochlear implant (CI) should be restricted to neurons close to that electrode. Exceptions to this optimal scenario can arise from variations in neural survival along the cochlea and in factors, such as lateral electrode position, that influence current spread. Cosentino et al (2015) developed an objective method for measuring neural spread of excitation and identifying those exceptions, using the forward masking paradigm described by Brown et al (1990) to measure the electrically evoked compound action potential (ECAP). This panoramic ECAP (PECAP) method first obtained a measurement matrix consisting of ECAPs for every possible combination of masker and probe electrode, and then used a nonlinear optimisation algorithm to derive excitation patterns on the assumption that each ECAP reflects the overlap between masker and probe excitation patterns. The procedure converts the estimated excitation patterns into the ECAPs that they would produce, and varies those patterns to obtain the best fit between the predicted ECAPs and the measurement matrix. This fitting procedure initially assumed unimodal excitation patterns centred on the stimulating electrode, and then, if the fitting error exceeded a criterion value, relaxed these assumptions so as to improve the fit.

Here we present a new version of PECAP (PECAP2) that separately models the neural survival profiles and current spread from each electrode, and combines them to estimate the neural excitation patterns. An advantage over both PECAP1 and a similar method proposed by Biesheuvel et al (2016) is that changes to the neural survival parameter influence the excitation patterns from multiple adjacent electrodes in a biologically plausible way. Furthermore, knowledge of how neural survival and current spread vary along the cochlea may influence clinical decisions and fitting procedures. We show that, like PECAP1, PECAP2 is able to reconstruct a wide range of simulated excitation patterns, even when the simulated ECAP matrices generated by those patterns are degraded by noise. We also show that when the data from DeVries et al (2016) are processed via PECAP2, the variations in predicted neural survival along the electrode array correlate significantly with detection thresholds obtained with focussed (quadrupolar) stimulation. Finally we evaluate various factors, other than the underlying excitation patterns, that might influence the measurement matrix and degrade the accuracy of PECAP2. These include (i) variations in refractoriness along the cochlea, checked by comparing measurements along the matrix diagonal using the forward-masking and alternating-polarity methods, (ii) effects of recording electrode, checked by recording from multiple separate electrodes and considering electrode impedances, and (iii) noise in the ECAP recordings, checked by measuring multiple subsets of runs so as to estimate the reliability of each ECAP.

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P56: INVESTIGATING THE EFFECTS OF STIMULUS POLARITY AND PULSE SHAPES IN A COMPUTATIONAL MODEL OF THE IMPLANTED HUMAN COCHLEA

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Electrophysiological and psychophysical studies with cochlear implant users have shown that the sensitivity of human auditory neurons to electrical stimulation depends on stimulus polarity, with most studies reporting that anodic pseudomonophasic pulses require less current to achieve maximum comfortable loudness level than pseudomonophasic cathodic pulses (Undurraga et al. 2013, Macherey et al. 2017, Carlyon et al. 2017). The exact reason for this polarity sensitivity is still unclear, but a better understanding of it may help in optimising cochlear implant stimulation strategies.

To investigate the effects of stimulus polarity, a previously published computational model of the human cochlea was used to simulate electrical stimulation with different pulse shapes, phase durations and multipolar configurations (Kalkman et al. 2014, 2015). The model consisted of a volume conduction part based on the Boundary Element Method, coupled with a deterministic active electrical double cable model of the auditory nerve fibres. The volume conduction part of the model uses five different three-dimensional geometries of human cochleae, which could each be combined with several electrode array geometries representing different electrode types and intrascalar positions. The nerve fibre model was based on the human-derived Schwarz-Reid-Bostock neural kinetics scheme (Schwarz et al., 1995). Simulations were done for symmetric biphasic, monophasic and pseudomonophasic pulses, for a range of different phase durations, in monopolar and (partial) tripolar stimulus configurations, at different electrode positions in the cochlea.

Results show that different parts of the simulated auditory neurons are sensitive to different phase polarities, which is mainly a consequence of spatial factors in the model (i.e. fibre trajectory, cochlear anatomy, electrode position and multipolar stimulus configuration). However, relative threshold levels of different stimulus polarities are also greatly influenced by temporal factors (i.e. phase durations and pulse shape), as well as modelled nerve fibre morphology. In cochleae with intact neurons, electrical stimulation in the basal region generally shows lower thresholds for anodic stimuli than for cathodic, consistent with experiments in literature. However, in the middle and apical regions model results frequently show the opposite polarity sensitivity. When modelling neurons with missing peripheral processes, the polarity sensitivity is reversed throughout the cochlea. The results also suggest it may be possible to exploit polarity sensitivity of the auditory neurons to enhance the effectiveness of multipolar stimulation strategies, by using pseudomonophasic pulses to effectively suppress secondary regions of excitation close to contacts that are stimulating at a polarity opposite to that of the main electrode contact.

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P57: NEUROPHYSIOLOGICAL MEASURES OF ELECTRODE AND MODULATION RATE DISCRIMINATION IN COCHLEAR IMPLANTS

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Background. The auditory change complex (ACC) is a cortical response that can be elicited by any change in an ongoing stimulus. In a previous study, we demonstrated that electrically-evoked ACC responses (eACC) varied for electrode discrimination following cochlear implant (CI) activation. Specifically, we observed different rates of change over time in the presence of and the amplitude of the response.
The current work explores a range of stimulus parameters to determine whether -electrical steady state responses, as well as transient responses can be recorded in cochlear implant users with the same stimuli, indicating the discrimination abilities at different stages along the auditory pathway.

Objectives. To determine if both the steady state and transient responses could be measured simultaneously for the same stimuli in CI-users. To determine how/if at all this differed from normal hearing listeners

Methods. Six normal hearing listeners were tested acoustically and five adult post-lingually deaf CI-users with Nucleus 24 devices were tested using direct stimulation to explore responses to changes in stimulus frequency. Discrimination tasks with the same stimuli were conducted to determine if stimuli that were discriminable behaviourally also produced a detectable electrophysiological response. For implant users this was conducted on the six most apical electrodes together with other measures of electrode discrimination.
Stimuli were constantly switched (electrode or modulation rate) without gaps to maximise the estimate of the change response. A range of parameters were explored to understand the limits of electrical hearing and to make comparisons with normal hearing abilities. Two switching rates (6.4 and 2 Hz) were used.

Results. Preliminary findings suggest that for normal hearing listeners both steady state and transient responses were present for both the fast and slow switching conditions. However, in CI-users, responses were observed only for the slower switching rate (2Hz). Further details of the exploration of the parameter set will be presented.

Conclusions. A potential interpretation of the findings is that the neural generators of the steady-state response may be adapted by electrical stimulation, which is not observed for normal hearing listeners.

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P58: SINGLE-SIDED CONGENITAL DEAFNESS SUPPRESSES BUT DOES NOT PREVENT ELECTRICAL ACTIVATION OF THE DEPRIVED EAR FROM THE BRAINSTEM TO THE CORTICAL LEVEL.

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Single-sided congenital deafness leads to developmental reorganization of the auditory pathways resulting in overall hearing ear preference and suppression of the auditory input originating from the inexperienced ear. It is, however, not fully understood where this functional disadvantage for the inexperienced ear initiates and how it progresses along the auditory pathways. Here, we have approached this problem by studying electrically evoked auditory brainstem responses (eABR) and cortical activation in a natural model of congenital deafness – uni- and bilaterally congenitally deaf cats.

In the present study, 4 hearing control, 4 bilaterally congenitally deaf cats (bCDC) and 4 unilaterally congenitally deaf cats (SSD) were used. All animals were bilaterally electrically stimulated by cochlear implants (CI). For eABRs, single biphasic electric pulses (200 µs/phase) were delivered to CI in wide bipolar configuration. Cortical responses were evoked by a train of 3 biphasic electric pulses (200 µs/phase, 500 Hz). Intensities up to 12 dB above ABR threshold were used. The ABRs were recorded using Ag-AgCl subcutaneous wire electrodes placed caudo-ventrally from the respective pinna and at the head vertex. Local cortical activations (local field potentials and multiunit activities) were recorded using 16-channels linear multichannel arrays covering all layers of the primary auditory cortex. The overall morphology, peak amplitudes, activation latencies and relation to binaural cues (interaural time and level differences – ITD and ILD, respectively) were evaluated.

In SSD, eABRs revealed smaller peak amplitudes to electric stimulation of the deaf ear in comparison to the hearing ear. This reduction in the brainstem activation cannot be explained by auditory deprivation alone since no difference in the peak amplitudes of eABR signals was found between bCDCs and hearing controls. Cortical responses showed a shift in favor of the hearing ear irrespective of the recorded cortical hemisphere. As a consequence, ITD responses were dominated by a response to the hearing ear irrespective of binaural time shifts resulting in weakly modulated ITD functions. ILD functions were dominated by the intensity function of the hearing ear with small effects of the deaf ear input.

The present results show a weaker response to stimulation of the deprived ear compared to the experienced ear already at the level of the brainstem. Electric activation of the deprived auditory nerve, however, evoked responses up to the level of the primary auditory cortex. Nevertheless, ITD and ILD data demonstrate that abnormal incongruent representations of binaural spatial cues prevented their integration in the unilaterally deprived auditory system.

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P59: UNILATERAL HEARING LOSS SIMILARLY DISRUPTS BINAURAL INTEGRATION IN THE JUVENILE AND ADULT GERBIL AUDITORY MIDBRAIN

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Subjects with single-sided deafness (SSD) increasingly undergo cochlear implant surgery (SSD-CI users) to obtain binaural hearing benefits, such as directional hearing. However, asymmetric hearing may disrupt the hemispheric balance of central auditory circuits that support spatial hearing. In an animal model of unilateral deafness, we test whether binaural integration in auditory midbrain neurons is differently impacted by unilateral hearing loss during development or during adulthood.

Single unit recordings were performed in the inferior colliculus of Mongolian gerbils. First, basic response parameters to unilateral and bilateral acoustic stimuli (pure tones and clicks) were characterized in normal hearing (NH) juveniles (postnatal days P15-23) to identify critical periods for binaural integration. Second, juvenile (P15, P19, P23) and adult (~P65) animals were unilaterally deafened. After 15 days of deafness, animals received bilateral round window electrodes, and responses to monaural and binaural biphasic electric pulses were recorded. NH adult gerbils served as controls. Parameters of binaural integration included: interaural response strength dominance, interaural receptive field alignment, and interaural time difference (ITD) coding.

In hearing animals, mature-like responsiveness to transient stimuli (clicks, pulses) was observed around P19. ITD sensitivity and ITD discrimination thresholds matured around P23, while interaural receptive field alignment at this age was still immature.
In SSD animals, independent of age at deafness onset, hemisphere-specific degradations in population ITD coding and increases in ITD discrimination thresholds were observed. Response strength to ipsi- and contralateral electric stimulation of the deaf ear was weaker compared to the hearing ear. Moreover, a lower incidence of ITD sensitive neurons was observed, and the shapes of ITD functions were often unclassifiable. Nevertheless, ITD sensitive neurons from SSD animals displayed a similar degree of ITD sensitivity and ITD discrimination thresholds to electric pulses when compared to age-matched NH controls, independent of age at SSD onset.

In summary, although ITD coding matures relatively late during development (~P23), binaural signal integration in auditory midbrain neurons was similarly impacted by unilateral hearing loss during development and adulthood. Even though a small fraction of neurons in SSD animals demonstrate general ITD sensitivity to electric stimulation, the observed asymmetric changes in population ITD coding between hemispheres and the increased ITD discrimination thresholds may contribute to poor directional hearing in SSC-CI users. Moreover, it remains speculative whether similar intervention strategies would be effective in restoring binaural hearing in both juvenile and adult SSD-CI users.

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P60: PULSE SYMMETRY AND THE SPREAD OF EXCITATION OF COCHLEAR IMPLANTS

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One major issue in the loudness coding with cochlear implants is that increasing the stimulation current leads to a higher spread of excitation in the auditory nerve (Kral et al., 1998, Hear Res). This increases the channel interactions and limits the number of effective channels a cochlear implant user can use. Loudness coding can alternatively be achieved by an increase in pulse duration instead of an increase in pulse amplitude (Zeng et al., 1998, Neuroreport). A stimulus that couples asymmetric pulses with phase duration loudness coding could reduce the current spread while still providing a coding of stimulus intensity, possibly alleviating the channel interaction effects.

We implanted 6 channel cochlear implants (Oticon) in 10 acutely deafened white guinea pigs of either sex and used a 2x16 channel Neuronexus probe located in the inferior colliculus to record neural responses along the tonotopic gradient while stimulating with either of 2 different pulse shapes: a symmetric, biphasic, charge balanced pulse of 50 µs phase duration and a 1:1 phase duration ratio increasing in amplitude, or an asymmetric, biphasic, charge balanced pulse of 50 µs first phase duration with a 1:5 phase duration ratio increasing in phase duration. All stimuli at equal levels thus delivered the same charge. To estimate the spread of excitation, we presented all stimuli at channels 2 and 5 on the cochlear implant, and compared the overlap of the activated neuronal populations in the inferior colliculus. We further simultaneously presented interleaved pulse trains of different frequencies at suprathreshold levels via different channels on the cochlear implant, allowing us to evaluate the brain's capability to resolve and differentiate between the two stimuli by extracting the vector strength of the response to the different frequencies.

There was significant overlap of the activated neuronal populations for both stimulus shapes when operated in monopolar configuration that decreased in bipolar configuration. The mean dynamic range was 3 4 dB depending on the place of stimulation for monopolar symmetric stimuli, and significantly lower for monopolar asymmetric stimuli (2.6 3.8 dB). Overall, the differences in the collicular responses to the different stimuli were weak but discernable.

When presented alone using the monopolar configuration, the mean vector strength increased monotonically with increasing stimulus level for both stimuli. The mean vector strength of the two stimuli presented at 19 Hz or 37 Hz were not different at threshold level (~0.4), at threshold -6 dB (~0.25) or at threshold +6 dB (~0.65). However, a simultaneous presentation of pulse trains at high current levels (threshold +6 dB) with an additional second channel led to a reduction in the mean vector strength to 0.2 (19 Hz) and 0.4 (37 Hz) for symmetric pulses, demonstrating an interaction of the two stimulation channels. The reduction was significantly smaller when stimulation level was coded by increasing the phase duration (asymmetric pulses) instead of increasing the amplitude (symmetric pulses), down to 0.4 (19Hz) and 0.5 (37 Hz), demonstrating that the channel interaction at high stimulation levels is lower with phase duration coding.

Our results show that the brain's ability to resolve two individual streams of overlapping information at a subcortical level improves when asymmetric stimuli combined with phase duration loudness coding are used.

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P61: THE ROLE OF COCHLEAR PLACE OF STIMULATION ON VOCAL PITCH PERCEPTION

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Cochlear implant (CI) users have difficulties in vocal pitch discrimination and perception because of the distortion of F0 and the distortion of harmonic structure. However, it is unclear what cues these individuals are using to understand vocal pitch. In this study, we aimed to investigate the role of cochlear place on perceiving different vocal pitches. To minimize the subjective nature of pitch judgments, we used a method that relies on the relationship between perception and production.

Four bilateral CI users participated in this study, which involved a within-subject design. In order to shift the pitch of auditory feedback, either four apical or four basal electrodes were deactivated. Data were collected for three vocal tasks: sustained vocalization, singing “Happy Birthday,” and reading “The Rainbow Passage.”

The preliminary result suggest that participants’ F0 compensated for changes in the place of stimulation. Vocal pitch was higher when the place of stimulation was shifted apically.

Although mechanisms of vocal auditory feedback are still unclear in CI users, this study suggests that place of stimulation has a noticeable effect on vocal pitch production. This suggests that place of stimulation is a cue that CI users are using to determine vocal pitch.

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P62: PREDICTION OF INDIVIDUAL COCHLEAR IMPLANT RECIPIENT SPEECH PERCEPTION WITH THE OUTPUT SIGNAL TO NOISE RATIO METRIC

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A cochlear implant (CI) implements a variety of sound processing algorithms to improve speech intelligibility. Typically, only a small number of parameter combinations are evaluated with recipients. The optimal configuration may be different for each recipient. The current study evaluates a novel methodology which uses the Output Signal to Noise Ratio (OSNR) to predict complete psychometric functions for individual CI recipients.

Speech scores from sentence-in-noise tests in a “reference” condition were mapped to OSNR and a psychometric function was fitted. The reference variability was defined as the root mean square error (RMSE) between the reference scores and the fitted curve. To predict individual scores in a different condition, OSNRs in that condition were calculated and the corresponding scores read from the reference psychometric function. In a retrospective experiment, scores were predicted for each condition and subject in three existing data sets of sentence scores. The prediction error was defined as the RMSE between observed and predicted scores. In data set 1, sentences were mixed with 20 talker babble (20TB) or speech weighted noise (SWN) and presented at 65 dB sound pressure level (SPL). An adaptive input Signal to Noise Ratio (ISNR) procedure was used. Sound processing was ACE and ACE with Ideal Binary Mask (IdBM) processing with five different gain threshold (GT) settings. In data set 2, sentences were mixed with SWN, street-side city noise or cocktail party noise and presented at 65 dB SPL. An adaptive ISNR procedure was used. Sound processing was ACE and ACE with two different noise reduction schemes. In data set 3, sentences were mixed with 4 talker babble (4TB) at two ISNRs and presented at levels of 55 to 89 dB SPL. Sound processing was three different automatic gain control configurations.

For data set 1, the median of individual prediction errors across all subjects, noise types and conditions, was 13 percentage points and equal to the reference variability. The OSNR prediction method was inaccurate for the specific condition GT = +10 dB (errors of 57 and 77 points for 20TB and SWN). For data set 2, the median of individual prediction errors was 17 points and the reference variability was 11 points. For data set 3, the median prediction error was 11 points and the reference variability was 6 points.

The results supported the hypothesis that the OSNR prediction method could accurately predict individual recipient scores for a range of algorithms and noise types, for all but one condition. The medians of the individual prediction errors for each data set were always within 6 percentage points of the reference variability. Further investigation of predictions for IdBM processing with positive values of GT is planned.

Overall, the novel OSNR based prediction method shows promise as a tool to assist researchers and clinicians in the development or fitting of CI sound processors.

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P63: IMPLICIT AUDITORY RULE LEARNING WITH LINGUISTIC AND ENVIRONMENTAL STIMULI IN NORMAL HEARING AND COCHLEAR IMPLANT USERS

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Background: Evidence accumulated over three decades has shown that the large variation in performance of cochlear implant (CI) users can be only partially explained by demographic factors, such as age at implantation, duration of deafness, and residual hearing. It has been suggested that much of the unexplained variance in performance may be attributed to cognitive factors, especially basic implicit learning and memory abilities, which are considered important to language acquisition and speech processing. To date, however, only few studies addressed this issue in CI users and have done so using non-auditory stimuli. We argue that because the primary mode for speech and language acquisition and development is via the auditory modality, implicit learning in CI users should be assessed in the auditory modality. Thus, the purpose of the present study was to assess implicit auditory rule learning (ARL) using linguistic and non-linguistic stimuli in normal hearing (NH) and in CI users.

Method: Participants included 20 NH (M=26 years) and 15 prelingually deafened CI users (18-31 years old) who varied in their years of implantation (1.5-18 years). A similar unique double- condition rule was applied to two sets of natural auditory stimuli: environmental sounds (dog barking, bird singing, door knocking and bell ringing) and linguistic sounds (/sa/, /ta/, /si/ and /ti/). ARL for each type of stimuli consisted of three sessions. In each session, participants listened to 16 sequences (3 stimuli in a sequence) according to the rule. After each sequence, participant keyed what they heard (active learning). Then they heard another set of sequences of which only half were according to the rule and were required to judge correct/incorrect. The final task in each session was to complete the last sound in a sequence. In the third session, judgement and completion tasks were repeated in novel sequences to assess generalization of the rule. Sound presentation and response scoring (in percent correct and reaction time) were software controlled. Prior to testing, it was confirmed that CI users identified correctly all sounds. CI users were also tested on speech perception and additional cognitive tests.

Results: All NH adults demonstrated faster ARL for the speech stimuli compared to the environmental sounds although (almost) complete learning was achieved by the last session for both sounds. Generalization was observed for both sets of stimuli by the end of training. In contrast, preliminary evidence with four CI users (data collection will be completed in the next 2 months), suggests large variability between CI: only one CI learned the rule. All tested CI users were high functioning in quiet; however, the best performer had residual hearing in the non-implanted ear and showed the best performance in speech perception in noise.

Conclusions: The data thus far provide novel insight to the ramifications of an early period of auditory deprivation on implicit learning in the auditory modality. These may explain some of the difficulties CI users have in performing under difficult listening conditions as well as in demonstrating poor high-level linguistic skills where encoding, processing and learning of rules from the stream of speech sounds are necessary.

MONDAY POSTER ABSTRACTS

M1: MACHINE LEARNING IMPLICATIONS IN COCHLEAR IMPLANTS: IDENTIFICATION OF LOMBARD SPEECH USING CNN-BASED CLASSIFICATION

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The natural response of a speaker to alter the production of speech due to the acoustic environmental conditions is referred to as the 'Lombard Effect.' Speech modifications as a result of the Lombard Effect (LE) can be identified with changing glottal slope, formant frequencies, duration of vowels, and emphasis on key consonants. LE is used as an attempt to increase speech intelligibility within noisy environments where communication can be more difficult. Prior studies have investigated and identified the key components of Lombard produced speech and analyzed their individual effects on intelligibility [1-4]. In this study, a machine learning approach was used to classify Lombard speech to determine implications of increased speech intelligibility for cochlear implant (CI) users. A convolutional-neural-network (CNN) was trained using the UT-SCOPE-LE database consisting of TIMIT sentences spoken from 29 different speakers in neutral and Lombard-conditions [4]. Human speech was recorded in an ASHA-certified sound booth from listeners exposed to three different noise types: large crowd, highway (car), and pink for three different SNR levels via open-ear headphones [4]. A two-tier, classification scheme was formulated to detect if speech was produced under Lombard or neutral style as well as the level of noise exposure. Qualitative subjective analysis was used to determine if CI users were equally able to identify Lombard speech. CI users were asked to determine the speaker condition as either neutral or Lombard (noise-exposed) and to record the decision confidence level on a 1-5 rating scale. Analysis of CNN model accuracy, Lombard discrimination by CI users, and the practical implications of using machine learning for future CI signal processing will be discussed.

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M2: AN ELECTRODOGRAM-TO-AUDIO WAVELET VOCODER THAT USES MACHINE LEARNING TECHNIQUES TO SOLVE INTERFERENCE PROBLEMS

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We introduce a gammatone wavelet vocoder that can take an electrodogram and a CI user's fitting data and produce an audio output for normal hearing users. The vocoder generates a single gammatone-shaped wavelet for each pulse in the electrodogram and then combines these into a continuous sound output, similar to the function of the Bräcker vocoder [1]. The goal was to develop a 'universal' vocoder that could take any electrodogram input and mimic as much as possible a particular CI user's experience and performance—and work in real time. The main challenges with this type of vocoder are: (1) achieving correct loudness percepts when wavelets constructively and destructively overlap, (2) being able to simulate electrical current spread, (3) dealing with the place and temporal pitch cues which are always coupled by the action of the basilar membrane for NH listeners but are not coupled for CI users.

Loudness was adjusted by first assigning the magnitude of the wavelets to the intensity of their corresponding pulses in the electrogram. Since the output loudness can be reduced by destructive overlaps of consecutive wavelets, this effect was corrected using a combination of phase rotations and gains adjustments computed by a machine learning approach based on Gaussian process regression [2]. This is a new approach.

Since each wavelet was attributed to a pulse on a specific electrode, current spread could be controlled by changing the spectral bandwidth of all wavelets assigned to that electrode. The more current spread, the wider the wavelet bandwidth--and the less overlap of wavelets.

For electrodograms with a fixed stimulation rate, the vocoder produces a pitch percept corresponding to the stimulation rate. We found that by adding jitter, we could degrade this pitch percept. It was possible to add enough jitter to achieve similar pitch performance to CI users, albeit via manipulating a combination of mechanisms—primarily via the basilar membrane--that are not available to CI users.

Finally, we attempt to compare the strengths and weaknesses of this wavelet vocoder to other classes of vocoder.

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M3: COCHLEAR SHAPE VARIABILITY FROM 987 COMPUTED TOMOGRAPHY IMAGES: AN ANATOMICAL STUDY

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The cochlea shows a great variability in size and morphology. An improved knowledge of its shape is not only essential for diagnosis of shape abnormality, atraumatic surgery planning and postoperative insertion assessment but it also provides better anatomical understanding for electrode design improvements. The goal of the present study was to analyze cochlear anatomic features in in-vivo human temporal bones to study the variability and the correlation between cochlear size measurements and sex, age and body side.

The dataset consisted of 987 clinical Computed Tomography (CT) images with a voxel size of 187.5x187. 5x250 μm^3, with images from 429 males and 554 females, between 10 and 97 years of age with 448 left and 535 right sides. Automatic segmentation methods were used to analyze the CT images and the variation in cochlear base (typical A and B-axis), height and volume were assessed. This automatic segmentation used a joint shape and appearance model-based segmentation method, the scala tympani and the scala vestibuli could then be precisely localized from CT images. Image isotropic resampling and rigid registration was first performed to orient the cochlea in the cochlear coordinate system centered on a smaller region of interest. The use of such cochlear shape fitting with a local appearance model allowed subpixel accuracy segmentation.

Anatomic features such as the volume, the width, the length and the longitudinal profile of the cochlea were statistically studied with the large dataset. The parameter modeling the longitudinal profile of the cochlea was found to be bimodal (following a mixture of the two normal distributions) while most of the parameters followed roughly a normal distribution. The first mode (N = 306) generates a cochlear shape with a straight longitudinal course, while the second mode (N = 681) generates a cochlear shape with a pronounced "rollercoaster" longitudinal course. The bilateral symmetry in cochlear anatomy was quantified: if the interpatient cochlear shape variability is greater than the intrapatient bilateral variability, the study showed that the symmetry is not obvious. Finally, the relation between A distance and cochlear duct length was estimated to be poorly correlated, suggesting that cochlear duct length indirect estimation from A distance measure introduces important error.

To the best of our knowledge, it is the first time that tridimensional cochlear shape reconstruction and variability study is reported on such a large dataset.

M4: THE CONCEPT OF INDIVIDUALIZED COCHLEAR IMPLANTATION

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Background: Individualized Cochlear Implantation - meaning an individual selection of electrode insertion depth and stimulation modality (electric-acoustic stimulation (EAS) or electric stimulation (ES)) - aims for the best possible hearing outcome for every patient. Important factors to take into account are hearing preservation and an optimal cochlear coverage. Shorter electrodes show better hearing preservation results and very good speech perception results in EAS. Longer electrodes show a higher cochlear coverage and better speech perception results in ES, but show worse hearing preservation results.
The concept of partial insertion could overcome this trade-off. If a longer electrode is partially inserted for EAS, it gives the option for a further adaption for ES in case of progressive hearing loss.

Methods: N=20 patients were treated with a partial insertion and an individual selected insertion depth. Using statistical models, the postoperative residual hearing and electrode location in the cochlea were individually predicted and supported the surgeon to select best suitable electrode insertion depth. In n=6 cases a 24 mm long electrode was partially inserted with an average insertion depth of 20.2 mm and in n=14 cases a 28 mm long electrode was partially inserted 20.7 mm in average. To document the patient outcomes pre- and postoperative hearing thresholds and speech perception in noise were determined.

Results: The median hearing loss at first activation was 21.5 dB (n=6) for a partially inserted electrode of 24 mm length and 16 dB (n=13) for a partially inserted electrode of 28 mm length and improved to 13 dB (24 mm long electrode; n=4) and to 11 dB (28 mm long electrode; n=10) to 6 months. N=14 patients used their low-frequency hearing for EAS and achieved in median 74% with the HSM sentence test in noise at 10 dB SNR at 3 months and improved to 86% at 6 months. Two patients did not use an acoustic amplification and achieved 24% in noise in ES.

Conclusion: The concept of individualized cochlear implantation allows for a patient specific choice of electrode insertion depth and modality. Taking cochlear geometry and the prediction of postoperative residual hearing into account, an optimal cochlear coverage, optimal hearing preservation results and the best individual outcomes can be achieved. Patients treated with partial insertion can benefit from EAS. If hearing is progressive over time, partial insertion allows for further, patient specific adaptation of the insertion depth.

M5: MEDICAL IMAGE COMPUTING TOOLS DEDICATED TO PERSONALIZED COCHLEAR IMPLANTATION

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Cochlear implant surgery is performed with limited patient-specific planning, setup, and post-implantation insertion assessment. Yet pre- and postoperative imaging is performed routinely. Medical images are nowadays underexploited since clinically relevant information could be extracted using computerized tools.

A set of modular model-based image computing tools is proposed. Each method comes within a mathematical framework with sparse representation so that it yields interpretable “white box” systems. The different clinical needs are tackled using the following considerations: 1) parametric generative models, models designed to generate (confabulate) new images based on given parameters; 2) parameters estimation methods, methods to fit the parameters of the generative model to an observed image; 3) postprocessing computation to extract clinically relevant information; and 4) visualization to convey interactively the results.

The four generic steps to go from images to personalized clinical information are applied to the following data: preoperative images, postoperative images and image fusion (same patient at different time points).

Preoperative (fan or cone beam) CT images analysis: A parametric shape model of the cochlea was designed. Shape parameters are estimated using standard optimization procedures or machine learning algorithms (e.g. neural networks). Model complexity is adaptable to the targeted speed-accuracy tradeoff. Results can be manually adjusted. Postprocessing allows to extract automatically, among others, the cochlear duct length and the modiolar axis and to display the unrolled cochlea with the cross-sections of its internal structures. To the best of our knowledge, the proposed methods go beyond the “state of the art”. As a result, a three-dimensional reconstruction of the scala tympani and the scala vestibuli is overlaid on the preoperative images.

Postoperative (fan or cone beam) CT images analysis: Post-implantation scanning produces metallic artifacts whose locations in the image are constrained by several parameters of the electrode array: length, electrodes number, pitch, diameter and conformation. Given an electrode array design and a postoperative image, the position of the electrode array is accurately estimated. Inserted electrode arrays are visualized in polar coordinates which allows insertion depth and overall quality (basal kink, tip fold-over) quantification. The position of each electrode expressed along the modiolar axis with respect to the basilar membrane allows a fully automatic in vivo quantification of electrode array insertion trauma, so far restricted to post-mortem studies.

Intrapatient modality fusion: A rigid transformation model is considered. The six parameters are estimated by maximizing the similarity between pre- and postoperative images. Modality fusion allows the combined visualization of three-dimensional reconstructions from pre- (anatomical structures) and postoperative images (inserted electrode array).

Each information automatically retrieved from medical images is validated using the most adapted gold standard (manually labeled high-resolution µCT, microdissection and histology). Given the careful modeling, the mean measurement and reconstruction errors are lower than the resolution of the images.

M6: ESTIMATING INTERAURAL MISMATCH TO INFORM INDIVIDUALIZED FREQUENCY MAPPING

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By providing input to both ears, bilateral (BI) cochlear implants (CIs) and CIs for individuals with single-sided deafness (SSD) – a new population recently under consideration for implantation – can improve speech understanding in noise and sound localization. These advantages are limited, however, because CIs do not restore the full magnitude of binaural-hearing benefit that acoustic hearing can provide. In normal-hearing listeners, binaural-hearing benefits arise from frequency-matched information computed in the brainstem. Standard BI-CI and SSD-CI programming considers each ear separately rather than as a pair of frequency-matched inputs to the binaural system. The resulting interaural mismatch in cochlear place of stimulation likely limits binaural benefit. The best strategy for CI users with bilateral auditory input may be a personalized approach that allocates frequencies to minimize this mismatch.

A comprehensive series of experiments was carried out for 20 BI-CI and 17 SSD-CI listeners to determine the most efficient and accurate way to evaluate interaural place mismatch to inform an individualized mapping approach. We compared three methods: sequential pitch discrimination (7-11 electrodes in each CI), interaural-time-difference (ITD) discrimination (3-5 reference electrodes per listener), and computed-tomography (CT) scans (all electrodes). Pitch matching, the most commonly used approach in the field, is susceptible to methodological biases and possible adaptation effects. ITD discrimination more directly evaluates binaural function, but is difficult to impossible for some listeners and is extremely time consuming. CT scans are efficient and readily identify electrode location, but address only physical location and not necessarily function.

The results generally showed much more interaural place mismatch for the SSD-CI listeners (mean ± SD absolute interaural insertion-angle difference: 231 ± 205°) than for the BI-CI listeners (61 ± 67°). Despite this important difference, both groups revealed a similar relative pattern across the three measures. The ITD and CT measures yielded similar estimates of mismatch, whereas the pitch estimates were more variable and less correlated to the other measures. Overall, these results suggest that CT scans, but not pitch matching, may provide a reliable estimate of the best frequency allocation to improve binaural hearing. This raises the possibility that CT scans could provide an accurate and efficient individualized approach to remapping that does not depend on exhaustive psychophysical testing to optimize binaural function.

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M7: IMPLICATIONS OF SPIRAL GANGLION MORPHOLOGY AND PLACE-FREQUENCY MISMATCHES FOR COCHLEAR IMPLANT SOUND CODING

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Variations in insertion depths for cochlear implant (CI) electrodes, with the ensuing variations in contact positions, produce considerable variations in frequency-place mismatches across subjects and across the sound coder frequency bandwidth. For example, Landsberger et al. [Ear Hear 2015] reported insertion depth angles for electrode arrays ranging from 260° to 710°, with systematic differences found between electrode types. Deeper insertions would tend to reduce frequency-place mismatches (basal ward shifts) all other things being equal, but is this the most desirable state of affairs?

In our recent study of slightly more than 100 CI recipients [James et al., Ear Hear 2018], we encountered a minimum insertion depth of 315°, ranging up to greater than 500° for Nucleus® perimodiolar and straight electrodes, and up to 720° for other devices. According to the data of Stakhovskaya et al. [JARO 2007] these angles correspond to frequencies on the spiral ganglion (SG) of approximately 1000 Hz, 450 Hz and 60 Hz respectively; or a range of 4 octaves. However, comparing the sound coder frequency bands to SG frequencies for 360°, 270°, 180° and 90° resulted in mismatches of zero to only one-and-a-half octaves across all devices: One finding in our study was that sentence recognition scores at 1 month after activation were actually negatively correlated with insertion depth, such that subjects with ~360° insertions obtained the best outcomes, and therefore they more rapidly accommodated to cochlear implantation despite the mismatch of about one octave. A similar negative relationship between insertion depth and CNC word scores had previously been found by Holden et al. [Ear Hear 2013] for a similarly large group size. We hypothesized that SG morphology and cell-density variations may produce much less selective channels for electrode positions >360°, thereby resulting in poorer speech recognition.

Before further exploring the effects of frequency-place mismatches and their interaction with spiral ganglion morphology, it is important to understand how variations in insertion depths for specific electrode designs influence mismatches. We review contact position data from different studies involving various CI electrode designs; including different perimodiolar and straight arrays. Place mismatches were computed using default sound coder band frequencies for shallow, medium and deep insertions for given electrode designs. Basal ward shifts were most often seen and fairly constant in the first turn across a range of insertion depths, with more variation for the most apical channels. However, there were some cases where frequency-place mismatches varied considerably across the array. We also noted some apparent errors in the literature in how frequency-place mappings were calculated, leading to potentially erroneous conclusions.

Finally, we consider optimum CI electrode designs and contact spacing, and alternative sound coder frequency band definitions which would take into account the empirical electrode contact position data, as well as the effects of restricting electrode insertion depth to approximately one full turn.

M8: OPTIMIZED BIMODAL FITTING USING SELF-ASSESSMENT METHODS

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A bimodal fitting usually requires a CI and a hearing aid (HA) specialist to accurately adjust the settings of both devices. For the bimodal CI users this often means visiting a clinic for the fitting of the CI and a hearing aid dispenser for the fitting of the HA. If the bimodal fitting is done at a single site, it is usuallay time consuming because two devices with different HW interfaces and SW applications have to be adjusted. In the following study an approach to combine user-centered and expert-centered fitting methods was investigated that allows the CI user to actively participate in the fitting process and the expert to efficiently perform a bimodal fitting.

A research software was developed which allowed the 15 bimodal participants to self-assess their thresholds (T) and most comfortable levels (M) on a tablet. For the CI, tone bursts and noise bursts were presented via a Naida CI Q90 sound processor and for the HA pulsed warble tones were presented via a NaidaLink HA. The procedure was intuitive for all participants and all of them were able to perform the task. Self-assessed HA thresholds corresponded well to the Insitu Audiogram measured by the Audiologist. Self-assessed M's for the CI were usually lower than the M's from the clinical map.

In a second part of the study an automated loudness balancing procedure was evaluated. The same bimodal participants performed a loudness scaling (ACALOS) separately for their CI and their HA with narrowband noises presented via loudspeaker. Likewise, they self-assessed their T's and M's with the tablet application for narrowband noises presented via loudspeaker. Based on the loudness scaling results, the loudness growth functions for the CI and the HA were matched by suggesting gain changes for the HA and the CI. T's and M's were derived for each participant from the loudness scaling and compared to the self-assessed T's and M's at the corresponding frequencies to investigate if the time-consuming loudness scaling procedure could be replaced by the shorter self-assessment procedure. Again, self-assessed T's corresponded well to the loudness scaling results whereas self-assessed M's were at a lower level than derived from the loudness scaling.

Integrating self-assessment methods in the clinical routine is a viable intervention to make bimodal fittings more efficient. As shown here, they can be applied for a first fitting as well as for fine tuning procedures later in the fitting process.

M9: BDNF OVEREXPRESSING HUMAN STEM CELLS IN ALGINATE FOR COCHLEAR IMPLANT OPTIMIZATION

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Background: BDNF (brain-derived neurotrophic factor) has a protective effect on SGN (spiral ganglion neurons) and can potentially help to increase the success of a Cochlear Implant (CI). A long-term supply with BDNF is desirable to establish a clinically relevant chronic growth factor therapy. Long-term administration of BDNF can be achieved by genetically modified human mesenchymal stem cells (hMSCs). This concept requires protection of the hMSCs from immune responses of the recipient organism and prevention of uncontrolled proliferation and migration of these cells. Alginate may serve as a matrix for the BDNF-producing cells, so that these requirements can be fulfilled. Therefore we investigated the feasibility of using stably BDNF-overexpressing hMSCs embedded in an alginate-matrix and either injected into the scala tympani or coated on the CI for optimizing cochlear implant therapy.

Methods: Electrical stimulation (ES) in vitro: BDNF-overexpressing hMSCs were encapsulated in alginate gels and electrically stimulated in vitro for 24 hours using a custom made stimulation chamber. ES was performed at 1 kHz using bi-phasic 800 µs pulses with 400s per phase and 120µs interpulse gap at different current levels (2, 1, 0.88, 0.66 or 0.33 mA). Alginate gel stability as well as cell survival and BDNF bioactivity were evaluated. Insertion forces: hMSC in alginate were applied as viscous solution or electrode coating in an artificial human sized cochlea model and the insertion forces and coating stability were analyzed on custom-made electrode arrays. Impedance: The effect of the alginate gel coating on electrode impedance was investigated in vitro and in vivo using the Maestro-system. Effect on residual hearing, neuronal protection and fibrosis: Systemically deafened guinea pigs were A) implanted with a CI, or B) implanted with an alginate-hMSC-coated CI or C) injected by alginate-embedded hMSCs into the scala tympani followed by CI insertion and alginate polymerisation. Normal hearing animals receiving bilateral CI and unilateral injection of alginate-hMSCs served as control group. Hearing thresholds were determined before surgeries and before sacrificing the animals using acoustically evoked auditory brainstem response measurements. Electrode impedances were measured weekly. Four weeks after implantation animals were sacrificed, temporal bones were harvested with the implant in situ, decalcified, immunohistochemically stained and cleared. The SGN density and fibrosis were analyzed by confocal laser scanning microscopy.

Results: The alginate-hMSC combination was not affected by electrical stimulation mimicking the situation in CI patients in vitro. The insertion forces of coated arrays were significantly reduced by 75 % of an uncoated reference. In contrast, filling the cochlear model with non-crosslinked alginate-cell solution slightly increased the insertion forces. A good stability of the coating was observed after first insertion but abrasion increased after multiple insertions. Electrode impedance was not affected by alginate gel coating in vitro and impedances in vivo did not differ between hMSC-alginate injected, coated or uncoated CI treated ears. Additionally, no difference in fibrosis was detectable between experimental groups. Coating of the electrode array with BDNF-producing hMSCs embedded in alginate resulted in neuronal protection. The gel coating was superior to injection of an alginate-hMSC suspension which did not affect the SGN and which resulted in an increased loss of residual hearing compared to cochlear implantation alone in normal hearing animals.

Conclusion: Coating of the electrode array with BDNF-overexpressing hMSCs embedded in alginate gel protected SGN from degeneration in systemically deafened animals. The alginate-hMSC coating of CI is superior to intracochlear alginate-hMSC injection. The alginate-hMSC coating is stable after moderate electrical stimulation for a short time period and significantly reduces insertion forces as a welcome side effect.

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M10: COMPUTATIONAL MODEL OF VOLTAGE DYNAMICS IN VESTIBULOCOCHLEAR NERVE FIBERS

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It is critical to understand the electrophysiological properties of primary afferent neurons in order to design optimal stimulation paradigms for cochlear and vestibular implants. In the past decade, electrophysiological experiments have provided additional data on the physiology and function of ion channels and pumps within the primary neurons of the inner ear. While models exist for the auditory nerve, the vestibular nerve has received less attention. Vestibular type-I hair cells possess cup-shaped synaptic terminals (calyces) and recent work has shown that type I hair cells transmit to calyces by two mechanisms: (1) conventional release of glutamate from vesicles ("quantal") and (2) unconventional flow of ions from the hair cell into the cleft and the postsynaptic calyx ("non-quantal"). Details of this complex transmission remain unknown, and the relevant compartments (cells and synaptic cleft) are hard to access, hindering the measurement of ion concentrations and potentials. The objective of this study is to create a biophysical model of the vestibular hair cell-calyx synapse (VHCC) with the goal of predicting and accounting for both quantal and non-quantal transmission modes. The VHCC model incorporates the specific location and surface density of ion channels (MET, HCN, Kv, NaV) and pumps (Na-K ATPase, KCC) expressed in hair cells and calyces and along the vestibular nerve at nodes of Ranvier, along with measurements of cell and calyx geometry from electron micrographs. The dynamic behavior of the system is determined from measured or estimated open probabilities, conductances, and activation time constants of the channels. The VHCC model is implemented in COMSOL and Matlab using a variant of the cable equation along with K+ and Na+ electrodiffusion in the cleft, simplified Hodgkin-Huxley-style ion currents, and stochastic vesicle release along an axisymmetric parametric surface. The overall result of this study is that the predictions of the VHCC model are consistent with experimental recordings from the vestibular hair cell synapse. The model is able to quantify how increases in extracellular K+ in the cleft contribute to non-quantal transmission and makes the novel prediction that there is a significant Na+ concentration gradient within the cleft from apex to base. The model is also able to make quantitative predictions on how alterations in ion channel density in both the hair cell and the calyx alter the ultimate pattern of firing in the vestibular nerve. These latter predictions raise important considerations for the design of vestibular implants, especially in cases where the calyx may have degenerated. The model is also able to predict the pattern of firing as a function of stimulus frequency and account for experimental observations of the gain and phase during different modes of neurotransmission. These predictions indicate how knowledge of ion channel deficiencies can inspire the design of stimulation protocols in both vestibular and cochlear implants via comparative models of the auditory nerve.

M11: ARTIFICIAL COCHLEA MODEL MATERIAL VALIDATION FOR INSERTION FORCE MEASUREMENTS

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The investigation of insertion forces in an artificial cochlea model (ACM) is a standard procedure in characterizing cochlear implants. These ACMs are used to have a controlled and reproducible test setup. Often, they are fabricated out of a smooth and easy to process material like polytetrafluoroethylene (PTFE) and used with various lubricants. However, it has not yet been demonstrated that such models are an appropriate representation of the conditions inside the living cochlea. This study is about the validation of PTFE based ACMs as a realistic cochlea model in respect to friction properties.

As the friction conditions inside a living cochlea are not easily measurable this study is a comparison of insertion forces measured in fresh cochlea specimen and ACMs. Fresh never frozen porcine cochlea specimens were used in the study, due to their similar geometry to the human, the straightforward surgical access and the ease of availability. For the comparison two-dimensional ACMs with matching size, shape and orientation were milled out of PTFE. This was done based on the CBCT scans of each porcine specimen followed by an in-house established segmentation and modeling method.

The insertion force measurements in the porcine cochlea specimens and in the corresponding ACMs were done with non-functional dummy electrode based on the Cochlear Slim Straight electrode. The insertions were repeatedly performed at a speed of 0.5 mm/s and up to a depth of 15 mm. Different lubricants like saline solution, Healon, and soap solution were to some extent combined and added to the ACM. The fresh cochleae were only filled with saline solution to prevent changes in the surface texture due to drying.

PTFE as an ACM in combination with saline solution used for insertion force measurements appears to be a valid model. A good correlation of the forces between the fresh specimen and the ACMs could be found in a number of sets. However, there are also specimen with a poorer correlation match to forces in the corresponding PTFE model. The reason for this is under investigation at the moment.

M12: ON THE DEVELOPMENT OF REALISTIC ARTIFICIAL COCHLEA MODELS

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Development of new electrode arrays of cochlear implants (CI) requires thorough evaluation of different design concepts. Of particular interest is measurement of insertion force, which is believed to be predictive of insertion trauma and ability to preserve residual hearing. Human temporal bone specimens remain the 'gold standard' for evaluation of CI electrode arrays, however they suffer from several drawbacks: limited availability, anatomical variability and limited or single use. Therefore, the use of artificial cochlea models (ACM) is well-established and widespread. However, reliability of decisions made within the development process directly depends on the reliability of the results obtained with these ACMs. Therefore, there is a high demand for realistic replications of the human inner ear in terms of geometry and frictional properties. In order to reduce the gap between fresh human temporal bone specimens (which are considered as best match of a living cochlea) and artificial models fabricated out of engineering materials, different methods of imaging, segmentation, computer-aided modeling, and manufacturing are being developed or applied as described in the following.

Quality of the geometry depends on the imaging and segmentation method. In our lab best results have been achieved using an in-house developed experimental 3D histological imaging method as well as micro computed tomography (µCT). Clinical x-ray computed tomography was used when need of individual data or fast specimen processing outweighed requirements for spatial resolution and soft tissue differentiation. Segmentation in parallel slices was performed to generate models of the whole lateral skull base including the posterior tympanotomy. Within these anatomical models, trajectories were planned describing the surgically chosen access directions.

In contrast, for highly accurate segmentation of the spiral shaped inner ear a special visualization and segmentation software was developed, featuring a rotating slice plane around the modiolus. This dedicated software provides a sequence of midmodiolar views with adjustable angular step wide along the angular length of the inner ear. In these rotating sectional views the intracochlear structures, such as the shape of scala tympani (ST) can be segmented. Post-processing of these data was performed using computer-aided design (CAD) software including: projection of the ST's inner and outer wall into a plane for derivation of 2D models, and modeling the spatial shape of the ST as a loft of subsequent profiles for 3D models. In addition, the previously mentioned trajectory can be incorporated into the anatomical model as surgical insertion axis serving as a realistic reference for future studies on the impact of varying entry angles.

For manufacturing of the ACMs several 3D printing technologies as well as conventional CNC (computer numerical control) machining have been tested. Although continuing progress in 3D printing could be observed over the last years, unsuitability of available materials and the unavoidable stepped nature of the surfaces still limit replication of vital friction conditions. In contrast, preliminary results with ACMs milled out of a polytetrafluoroethylene (PTFE) plate are promising in terms of realistic friction conditions when compared to fresh temporal bone specimens.

However, synthetic replication of soft tissue, intracochlear compliance, and rupturable structures for more realistic ACMs is still a completely unsolved issue. It may be overcome by advanced multi-material 3D printing in the future.

M13: LOCALIZED ELECTRODE IMPEDANCE CHANGES WITH DELAYED-ONSET HEARING LOSS IN HYBRID COCHLEAR IMPLANT USERS

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Changes in electrode array design and surgical techniques have allowed for preservation of acoustic hearing in some cochlear implant (CI) users. These individuals use both acoustic and electrical stimulation in the implanted ear (e.g. Nucleus Hybrid L24 CI). Most patients lose 10-15 dB of acoustic hearing immediately from surgical trauma, however, a percentage experience a partial or complete loss of residual hearing several months after surgery. The cause of this "delayed-onset" hearing loss is not known. However, increases in electrode impedance at the time of hearing loss have been reported from our clinic (Scheperle et al, 2017) and elsewhere (Choi et al, 2017), which could reflect physiological changes in the cochlea. In both studies, electrode impedances were obtained using Custom Sound (commercial software used to program Nucleus CIs), and only reflect total impedance. Total impedance consists of access resistance and polarization impedance. Access resistance reflects the environment between stimulating and return electrodes (e.g. buildup of fibrous tissue); polarization impedance represents the electrode-electrolyte interface of the electrode (Tykocinski et al., 2005). We hypothesized that these two components would provide different insights into cochlear status at the time of hearing loss. We also explored whether impedance changes were localized to specific locations along the electrode array.

Access resistance, polar impedance, and total impedance were measured using EVT (electrode voltage telemetry) software from 46 adult Nucleus Hybrid L24 CI users, who were implanted at the University of Iowa between 2009 and 2019. Impedance data was collected at each clinical appointment, starting with initial activation, and analyzed in three electrode sections: basal (electrodes 5-10), middle (electrodes 11-16), and apical (electrodes 17-22). Average impedance was computed across electrodes in each section for each time point. (E1-4 are disabled in the clinical MAP for all Hybrid L24 users). Participants were categorized into a group with stable hearing and a group with delayed-onset hearing loss in the implanted ear. The pure-tone average (PTA) of audiometric thresholds at 125, 250, and 500 Hz at each time point was used to calculate PTA changes. Those with thresholds within 10 dB of initial activation were categorized as stable hearing. Those who lost > 10 dB and the rate of loss was 5 dB / month were categorized as having a precipitous loss.

Total impedance increased in the delayed-onset hearing loss group, consistent with past literature (Scheperle et al., 2017; Choi et al, 2017). Specifically, access resistance significantly increased relative to initial activation in the delayed-onset hearing loss group compared to the stable hearing group ($p<0.001$), whereas changes in polarization impedance were similar in both groups ($p=0.127$). Preliminary analysis indicates no location effect ($p=0.778$), meaning access impedances increased for all electrodes in the delayed-onset hearing loss group. Increased access resistance may suggest delayed-onset hearing loss could be associated with increasing layers of fibrous tissue forming around the electrodes.
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M14: SUSTAINED DEXAMETHASONE RELEASING ELECTRODE COATING PROTECTS AGAINST COCHLEAR IMPLANTATION ELECTRODE INSERTION TRAUMA INDUCED HEARING LOSSES AND FIBROSIS

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Dexamethasone is widely used to treat cochlear electrode insertion trauma (EIT), but its spread in the inner ear after systemic administration is limited. A Dexamethasone (DXM) loading Polycaprolactone (PCL) electrode coating was developed. The therapeutic effect of this drug-loaded coating on EIT-induced increases in hearing thresholds and fibrosis was evaluated by a rat model.

In vitro, L929 fibroblasts were co-cultured with the coating PCL and the cell densities were calculated and also a drug releasing test from the coating PCL was carried out.

In vivo, a rat model of EIT-induced hearing losses and fibrosis was used to test electrodes coating PCL that contained either 20%, or 0% levels of DXM. These two types of electrode and naked electrode without coating were implanted into the scala tympani via round window and left in place for 4 weeks. Hearing thresholds were determined by auditory brainstem response (ABR) in response to a series of defined pure tone stimulation (i.e. 2–32 KHz) and click. Fibrosis was measured in hematoxylin-eosin staining cross-sections through the organ of Corti. Midmodiolar cross-sections of cochlear were immunostained for TGF-β1 signal passway at the same time.

The results showed that the cell densities co-cultured with PCL did not decrease and controlled dexamethasone release of more than 10 weeks could be demonstrated in vitro with cumulative release of DXM reaching 0.748 mg occupying 27.7% of the total drug carried by PCL. Expected release time can reach one year.

In vivo experiments presented that 20% DXM releasing PCL coating electrodes protected against EIT-induced hearing losses with ABR threshold decreased by 10 dBSPL at lower frequencies (i.e. 2, 4,8 KHz) and click. Expression of TGF-β1 the total and volume of fibrous tissue were reduced.

0% DXM releasing coating PCL electrodes had neither better nor worse influence on EIT-induced hearing loss, fibrosis and the expression of TGF-β1.

In conclusion, the DXM-PCL electrode coating shows a promising application in CI surgery and has great potential in preventing hearing loss and fibrosis by inhibiting the expression of TGF-β1 with fine biological compatibility, sustained DXM delivery for target anti-inflammatory without degrading itself, and simplicity of electrode coating process maintaining the stability of the electrode itself. This new drug-loaded electrode has the potential to help EAS-mode cochlear implant recipients retain residual hearing for better results.

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M15: ANATOMICAL CORRELATES AND SURGICAL CONSIDERATIONS FOR LOCALIZED THERAPEUTIC HYPOTHERMIA APPLICATION IN COCHLEAR IMPLANTATION SURGERY

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Electrode insertion during cochlear implantation (CI) surgery can result in hair cell damage and may result in a loss of residual low-frequency hearing. Amongst hearing preservation strategies, local application of therapeutic hypothermia has shown promising results. Using a custom-designed probe and system, our group has demonstrated the feasibility of delivering controlled hypothermia to the inner ear without requiring modifications in the surgical approach. However, anatomical variations and suitability of different surgical approaches, including the standard facial recess (FR) approach versus a transtympanic approach need to be further investigated. The aim of the present study is to utilize anatomical and radiologic measurements and experimental outcomes from cadaveric human temporal bones to investigate the feasibility of delivering local hypothermia. Ten human adult cadaveric temporal bones were scanned with micro-CT. By means of software analysis, distances between the chorda tympani and the facial nerve and FR height were measured and total FR area was derived. Further measurements predicting RW visibility were recorded. Each bone was drilled and a standard FR approach was developed. The St. Thomas classification (STC) was then used to record degree of RW visibility. This grading was repeated following further drilling for optimizing visualization of the RW or independent cochleostomy and placement of the cooling probe through the FR or myringotomy. Following previously published protocols, hypothermia was delivered through both approaches and temperatures recorded by thermistors placed inside the RW (Apex), at RW niche, over the lateral semicircular canal (LC) and the supero-lateral mastoid edge (M). The average FR area was 13.87 mm2 (SD 5.52) ranging from 8.44 to 24.28 mm2. Regarding STC grading, the introduction of the cooling probe through either approach did not impede full visualization of the RW or cochleostomy. The average maximum temperature decrease, using the FR approach, was 4.57 °C (SD ± 1.68) for RW and 3.42 °C (SD ± 1.12) for Apex, while a transtympanic approach produced a mean decrease of 4.11 °C (SD ± 0,98) for RW and 3.22 °C (SD ± 0.95) for Apex. No significant differences were found between the two probe approaches. Results show that local hypothermia delivery during CI surgery, using a customized probe, can be efficiently achieved both through a FR and transtympanic approach regardless of anatomical constraints and without limiting optimal surgical visualization.

(Supported by Cochlear Research Grant)

M16: OTOPROTECTION USING A COMBINATION OF L-N-ACETYLCYSTEINE AND DEXAMETHASONE IN AN IN VITRO MODEL OF INNER EAR TRAUMA

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Background: The inner ear trauma caused by cochlear implant electrode insertion trauma (EIT) initiates multiple molecular mechanisms in hair cells or support cells resulting in initiation of programmed cell death within the damaged tissues of the cochlea which leads to loss of residual hearing. In earlier studies L-N-acetylcysteine (L-NAC) (an antioxidant), and dexamethasone (Dex) (a steroid) have been shown independently to protect the HCs loss against different types of inner ear trauma. Dexamethasone is a glucocorticoid with anti-inflammatory and anti-apoptotic characteristics. L-NAC is a free radical scavenger, as well as a precursor to the antioxidant glutathione. Glutathione is an important step in the clearance of reactive oxygen species. These molecules have different otoprotective effects. The goal of this study is to test the efficacy of a combination of these molecules to enhance the otoprotection against EIT.

Methods: OC explants were dissected from P-3 rats and placed in serum-free media. Explants were divided into control and experimental groups. Control group: 1) untreated controls 2) EIT. Experimental groups: 1) EIT+ L-NAC (different concentrations) 2) EIT+ Dex (different concentrations) 3) EIT+ L-NAC+ Dex. In EIT Groups, a 0.28-mm diameter monofilament fishing line was introduced through the small cochleostomy located next to the round window area, allowing for an insertion of between 110° and 150°. After EIT was caused, explants were cultured in media containing L-NAC alone, or Dex alone at decreasing concentrations. Concentrations of L-NAC and Dex that showed 50 percent protection of hair cell loss individually were used as a combination in the experimental group 3. After incubation, the explants were fixed and stained with FITC-phalloidin, imaged by fluorescence microscopy, and viable HCs were counted.

Results: There was decrease of total hair cell count in the EIT explants compared with control group. We identified the dosage of L-NAC, and Dex for survival of 50% protection of hair cells in vitro. This combination therapy may be beneficial in other type of inner ear trauma that can result in hair cell loss.

Conclusion: EIT involves oxidative stress and lipid peroxidation early on after the implantation. L-NAC, and Dex are effective alone in protecting the sensory cells in vitro at high doses. A combination containing L-NAC, and Dex at much lower doses of each compound, is effective in protecting sensory cells. These compounds can be combined with synergistic effect allowing a decrease of potential side effects of each compound.

M17: EVALUATING THE USE OF BUNCHED-UP PULSES FOR OBJECTIVE DETERMINATION OF THRESHOLDS IN COCHLEAR IMPLANTS USERS

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While eCAP and eABR thresholds for low-rate pulse trains correlate strongly with behavioral thresholds measured at the same rate, the correlation is much weaker with behavioral thresholds measured at higher rates, such as used clinically. This implies that eCAPs and eABRs cannot be reliably used for objective programming of threshold levels in CI users. This weak correlation is probably due to the fact that short-time constant temporal processes influence detection thresholds when stimulating at high rates while they do not at lower rates. We recently introduced bunched-up-pulses (BUPS) as an alternative stimulus to measure eABRs in CI subjects in order to capture some of these temporal processes. BUPS stimuli consist of groups of n "bunched-up" pulses repeated at a low frame rate of 31 Hz. When n=1, the stimulus is equivalent to a low-rate pulse train, which is typically used to measure eABRs. We showed in a previous study that the correlation between BUPS behavioral thresholds and clinical thresholds (i.e. 1000-pps pulse trains) increased as a function of n.

Here we evaluate the hypothesis that eABR thresholds obtained for a BUPS stimulus with n=12 could be used as a predictor of clinical thresholds (n=12 was selected based on our preliminary results).

15 MED-EL cochlear implant recipients were tested on two electrodes: the most apical and one medial. For each electrode, behavioral thresholds were measured for the clinical stimulus, and for BUPS stimuli with n=1 and n=12. eABR growth functions were then measured for the two BUPS stimuli only and eABR threshold was assumed to correspond to a wave V amplitude of 0.18 µV

So far, results show that eABR thresholds are significantly closer to clinical psychophysical thresholds for n=12 compared to n=1. This suggest that eABRs to BUPS capture some aspects of short-time temporal integration.

The across-subject correlations between eABR BUPS thresholds and clinical thresholds were also significant for both electrodes and for both types of stimuli (n=1 and n=12). However, the correlation does not appear to be stronger for n=12.

This suggests that although part of the short-term temporal integration processes may occur at a stage of the auditory system before or at the generation site of wave V, some additional processes occur more centrally, thereby preventing the eABR waves to provide a good prediction of clinical thresholds.

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M18: IS THE EFFECT OF INTERPHASE GAP ON THE ELECTRICALLY-EVOKED COMPOUND ACTION POTENTIAL CORRELATED WITH COCHLEAR NERVE SURVIVAL IN HUMAN LISTENERS?

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Background: Neural survival of the cochlear nerve (CN) is believed to be important for cochlear implant (CI) outcomes. Currently, the field lacks a clinical tool for assessing CN neural survival in individual CI patients. Children with cochlear nerve deficiency (CND) can be considered as a human model for poor CN survival, which provides an opportunity for identifying such clinical tools for implanted patient populations. Sensitivity of the electrically-evoked compound action potential (eCAP) to changes in the interphase gap (IPG) duration of a biphasic pulse has recently been shown to be associated with neural survival of spiral ganglion cells in guinea pigs (Prado-Guitierrez et al., 2006; Ramekers et al., 2014). Specifically, degenerated CNs show reduced IPG effects on eCAP amplitude, eCAP threshold and slope of the eCAP Input/Output (I/O) function compared to healthy CN fibers. The amount of reduction in the IPG effect is highly associated with the degree of neural degeneration, with greater reductions observed in neurons with more severe degenerations (Prado-Guitierrez et al., 2006; Ramekers et al., 2014). To date, this important finding has not been confirmed in typical CI users, presumably due to the unpredictable neural survival pattern in these patients. To confirm this important finding, this study compared the effect of increasing IPG duration on the eCAP between two groups of implanted children who differed in CN neural survival: children with CND and children with normal-sized CNs.

Methods: Study participants included 30 children with CND and 30 children with normal-sized CNs. All subjects were implanted with a Cochlear® Nucleus™ device with the internal electrode array 24RE[CA] in the test ear. The stimulus was a charge-balanced, cathodic leading, biphasic pulse with a pulse-phase duration of 50 μs. For each subject, the eCAP I/O function was measured for six IPGs (i.e., 7, 14, 21, 28, 35 and 42 μs) at three electrode locations across the electrode array. Dependent variables (DVs) were the maximum eCAP amplitude, eCAP threshold and slope of the eCAP I/O function. Generalized Linear Mixed effect Models (GLMMs) with subject group, electrode location and IPG duration as the fixed effects and subject as the random effect were used to compare these DVs and the size of the IPG effect on these DVs.

Results: Children with CND showed smaller maximum eCAP amplitudes, higher eCAP threshold and flatter slopes of eCAP I/O function than children with normal-sized CNs. Increasing the IPG duration resulted in increased maximum eCAP amplitude, decreased eCAP threshold and steeper slope of eCAP I/O function at all three electrode locations in both study groups. Compared to children with normal-sized CNs, children with CND showed larger IPG effects on both maximum eCAP amplitude and slope of the eCAP I/O function, which is contrary to findings reported in animal models. However, children with CND showed a smaller IPG effect on eCAP threshold than children with normal-sized CNs.

Conclusions: Overall, our findings suggest that results from animal studies cannot be directly applied to human listeners. Maximum eCAP amplitude and slope of the eCAP I/O function measured in human listeners with poorer CN survival are more sensitive to changes in the IPG. In contrast, eCAP threshold in listeners with poorer CN survival is less sensitive to increases in IPG duration. Further studies are warranted before this eCAP testing paradigm can be used as a clinical tool for evaluating neural survival of the CN in individual CI patients.

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M19: USING THE DTR MOUSE MODEL FOR DETERMINING EFFECTS OF COCHLEAR HEALTH ON COCHLEAR IMPLANT FUNCTION

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BACKGROUND: The use of animal models for chronic cochlear implant (CI) research has been limited by the fact that the condition of the spiral ganglion neurons (SGNs) is closely tied to inner hair cell (IHC) survival. The deafened diphtheria toxin receptor (DTR) mouse presents a unique opportunity to preserve SGNs while completely eliminating IHCs. In non-implanted DT-deafened mice, near 100% SGN survival can be achieved. SGN survival can then be manipulated by CI insertion trauma or other means to study effects of SGN density independent of IHC influences.

METHODS: Non-deafened wild type (WT) mice, non-deafened DTR mice, and DT-deafened DTR mice were implanted with a single platinum/iridium ball electrode in the scala tympani. Mice were implanted at 14 weeks of age on average and survived 40 days post-implantation on average, up to 108 days in the longest-surviving mouse. Electrically-evoked auditory brainstem responses (EABRs) were recorded under anesthesia weekly to assess the stability and trajectory of responses following implantation. Additionally, ensemble spontaneous activity (ESA) levels were tested in each population to assess differences in spontaneous neural activity. After functional data collection, cochlear sections were obtained, and SGN densities and IHC assessments were compared to functional responses. Results in mice were compared to results from stable long-term implanted guinea pigs.

RESULTS: Histology confirmed complete IHC loss in DT-deafened DTR mice. In some non-deafened DTR and WT mice, IHC loss was observed in the region of the implant, but IHCs were preserved apically. SGN loss was also observed in the region of the implant in some non-deafened and deafened mice, likely related to implant insertion trauma. A majority of CIs remained functional for at least 1 month following implant surgery. Animal survival was dependent on tolerance to repeated anesthetics. Vestibular side effects in some mice appeared after electrical stimulation. On average, EABR N1 to P2 differences were larger in non-deafened mice than in DT-deafened mice of comparable SGN densities and at similar time points post-implantation. Slopes of EABR amplitude growth functions (AGFs) over time demonstrated variable patterns of recovery and were very individual for each mouse, irrespective of treatment group. Mice with low SGN densities had shallow EABR AGF slopes, consistent with EABR AGFs in guinea pigs of comparable SGN densities. ESA levels for both non-deafened and deafened DTR mice were within the range of levels previously found in guinea pigs, although the distinct peak seen at 900 Hz in guinea pigs was not as distinct in mice.

CONCLUSIONS: A chronic mouse CI model was successfully created using the DTR mouse for selective IHC elimination, and demonstrated electrophysiological results similar to those seen in stable long-term chronic guinea pig models of comparable SGN densities. Further manipulation of the SGNs and IHCs, as well as implantation in mouse models of hereditary deafness, will allow for a better understanding of how cochlear health impacts CI function.

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M20: FUNCTIONAL MEASURES OF COCHLEAR HEALTH IN MICE WITH CHRONIC MULTICHANNEL IMPLANTS

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INTRODUCTION. Mice are an important model for chronic cochlear implant (CI) studies due to their ability to be genetically modified to represent many auditory conditions that are effectively treated with cochlear implantation. To date research in cochlear implanted mice has utilized mainly short-term studies, but longer-term studies are needed to evaluate function and perception under stable conditions and determine their relationship to cochlear health. Because many mice have problems with frequent anesthetic administration, a chronic CI model that can be tested in the awake condition is desirable. Electrically-evoked compound action potentials (ECAPs) recorded with multichannel CIs are a useful functional measure because they can be obtained daily without anesthesia. In this study, we assess changes and stability of ECAP data over time after implanting mice with multichannel implants and assess the relationship of the ECAP data to histological conditions in the implanted cochlea.

METHODS. Non-deafened CBA/CaJ mice were implanted in the scala tympani with a cochlear implant comprised of 3 platinum/iridium electrodes. ECAPs were obtained in the awake condition every 2 to 4 days. Electrically-evoked auditory brainstem responses (EABRs) and ensemble spontaneous activity (ESA) levels were recorded weekly under anesthesia. Animal survival times were dependent on functional longevity of the implants, percutaneous connector stability, and tolerance to repeated anesthetics. At these time points, animals were euthanized and histological analysis was performed to assess spiral ganglion neuron (SGN) densities and inner hair cell (IHC) survival for comparison to functional responses. Mouse data were also compared to data from long-term stable chronically-implanted guinea pigs to determine if the chronic CI mouse model results were similar to those previously obtained in the well-established guinea pig model.

RESULTS. Functional data collected for up to 42 days post-implantation have been obtained in multiple mice. ECAP and EABR amplitude growth functions (neural response magnitude versus stimulus current level) and ESA levels for mice showed changes in sensitivity over time after implantation with some animals declining and recovering to a steady state, and some stabilizing at lower levels. Stable data for all measures were within the range reported for long-term CI guinea pigs with comparable cochlear health. SGN densities throughout the cochlea were near normal for most mice with one case of low SGN density in the area of the implant. IHC survival in the area of the implant varied from near normal to absent with either a flat epithelial layer or remaining supporting cells. Apical to the implant, all mice had surviving IHCs. Functional data collection ended earlier than planned due to one of several complications: implant breakage, anesthetic death (after EABR and ESA recording), or percutaneous connector instability.

CONCLUSIONS. While CI research in mice is possible and important, the technique can be challenging. The use of ECAPs for long-term frequent testing in the awake state can improve outcomes and allow for effective monitoring of changes over time and stabilization of function post-implantation. Improvements in the model are needed to extend the length of the experiments. Once this has been accomplished, further studies can be done to determine the relationship that long-term stable function and perception have with various cochlear conditions.

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M21: A NEW MOUSE MODEL FOR TESTING OUTCOMES OF GJB2-RELATED DEAFNESS: INDUCIBLE CONDITIONAL DELETION OF GJB2

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Individuals with GJB2 (Connexin26)-related hearing loss exhibit near-normal organ of Corti morphology and spiral ganglion neurons (SGNs). This suggests the mechanisms of hearing loss for these patients do not involve major disruptions in morphology of the auditory epithelium or nerve. In accordance with their well-preserved neural substrates, many individuals with mutations in GJB2 perform well with a cochlear implant (CI). However, in some cases, further improvement of CI outcomes is needed.

We have designed and tested a mouse model for loss of Gjb2 where SGNs survive for several months or more, allowing stimulation by a CI. This tamoxifen-inducible mouse model uses Sox10iCre to specifically delete Gjb2 in the supporting cells of the developing mouse cochlea or in mature ears. Here we report results from mice injected with tamoxifen at post-natal day (p) 1 or p14 and assayed one or three weeks later. To test effects of Gjb2 loss on hair cell function, we analyzed hearing using ABR audiometry. We examined the underlying auditory structure using histology stains for hair cells and neurons. Deletion of Gjb2 at p1 or p14 resulted in reduced Cx26 staining in non-sensory cochlear cells and no changes in hair cell organization. Gjb2 deletion resulted in decreasing hearing and endocochlear potentials over the next three weeks. We are now assessing long-term survival of SGNs in these Sox10iCreERT2;Gjb2flox/flox mice. Our results suggest that these mice are a good model for testing CI function in ears with deficient gap junction as well as assessing new CI technologies and methods for enhancing outcomes.

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M22: USING DETECTION THRESHOLDS TO ESTIMATE COCHLEAR HEALTH: SINGLE PULSE VS MULTIPULSE STIMULI

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INTRODUCTION: Clinically measured detection thresholds (T levels) for electrical pulse trains vary from one cochlear implant electrode to the next and serve as a basis for setting stimulation levels in the speech processor. However, these thresholds might reveal additional useful information, such as the neural status near each electrode, which could be used to optimize the implant fitting for individual patients. In this poster we examine the hypothesis that psychophysical detection thresholds for monopolar (MP) stimulation of individual electrodes predict the health of the cochlea in localized regions near the electrodes.

METHODS: Data were taken from several previous experiments with a total of 58 guinea pigs. Cochlear health was defined in terms of spiral ganglion neuron (SGN) density and inner hair cell (IHC) survival near the electrode that was used for threshold measurement. Diversity in cochlear health across the subject population was created by using various treatments before cochlear implantation. Psychophysical detection thresholds for single 25 µsec/phase biphasic pulses and for 200 msec trains of these pulses at various pulse rates (10 to 5000 pps in steps of doubling) were measured using MP stimulation. For comparison, multipulse-integration (MPI) slopes (rates of threshold decrease as a function of pulse rate) were calculated for pulse rates below 1000 pps. For each subject, thresholds were obtained from a single electrode located in the basal turn of the scala tympani in a region where there was little room for variation in the electrode position with respect to the neural population. Thresholds for this study were obtained during a period when thresholds over time were stable until the time of euthanasia and were compared to SGN densities and IHC survival assessed in the region closest to the electrode used for the threshold measurements.

RESULTS: Thresholds for single 25 µsec/phase biphasic pulses did not reflect across-subject differences in SGN density. However, for pulse trains, percent of the variance in detection thresholds accounted for by SGN density increased from 7% at 39 pps to 19% at 313 pps and then remained fairly constant up to 5000 pps, averaging 20.4%. By comparison, 45% percent of the variance in MPI slopes was accounted for by SGN density.

CONCLUSIONS AND IMPLICATIONS: Detection of single short-duration electrical pulses was not affected by the number of neurons available or by the presence of hair cells. Integration of pulse trains to produce lower detection thresholds did depend on the number of available neurons and/or the presence of IHCs or some other correlated variable. Across-site variation in T levels, which are typically measured with high-rate pulse trains, is likely to reflect, in part, across-site differences in cochlear health, particularly in cases where the medial-lateral electrode position in the scala tympani is relatively consistent. Thus, these T levels could alert the audiologist to possible regions of poor cochlear health, which could then be examined further using more sensitive measures and thus could be the first step in implementing site selection procedures or other rehabilitative measures. Thresholds for single biphasic pulses might be helpful for parsing contributors to threshold variation by reflecting variables that are not related to SGN density.

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M23: USING DETECTION THRESHOLDS TO ESTIMATE COCHLEAR HEALTH: EFFECTS OF ELECTRODE CONFIGURATION

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INTRODUCTION: Studies in humans have shown that psychophysical detection thresholds vary as a function of electrode site, and that more focused electrode configurations often results in greater variance in across-site patterns when compared to monopolar electrode configurations. It has been hypothesized that focused current configurations might better reflect local features of the electrical-neural interface, such as the condition of the adjacent spiral ganglion neurons (SGNs), but to date, this question has not been directly addressed using an animal model. The current study assessed the relationship between SGN density and psychophysical detection thresholds measured with tripolar and monopolar electrode configurations in cochlear-implanted guinea pigs.

METHODS: Cochlear health was diversified across chronically-implanted guinea pigs by applying various treatments. Sixteen animals were implanted in an untreated, hearing ear; 4 animals were deafened with a local injection of neomycin into the implanted ear; 5 animals were deafened with neomycin, then treated with a neurotrophin prior to implantation. Psychophysical detection thresholds were obtained for 200 ms trains of 25 µs/phase pulses presented in either monopolar (MP) or tripolar (TP) electrode configurations. Thresholds were assessed using six different pulse rates (156 – 5000 pps), given that previous studies have hypothesized different mechanisms for pulse rates above and below 1000 pps (Pfingst et al., 2011). The thresholds were then compared to SGN densities and inner hair cell (IHC) survival assessed in a region closest to the center of the electrodes used for the threshold measurements (Profile A) at a location more apical to the stimulated electrode (Profile C).

RESULTS: Across all animals and all pulse rates, detection thresholds were lower when measured with the MP (-25.81 dB re: 1mA) compared to the TP (-20.17 dB re: 1mA) electrode configuration. When comparing threshold levels across all animals with SGN densities in Profile A, there was no clear effect of electrode configuration. Specifically, when examining data across all animals for each pulse rate, the least square linear regression coefficients were comparable when for the TP and the MP electrode configurations. However, when examining results within the implant-only group of animals (n=16), where SGN densities were highest and there were surviving IHCs, results generally showed larger coefficient of determination values for the MP compared to the TP electrode configurations suggesting that SGN densities accounted for a greater proportion of variance in MP detection thresholds compared to the TP detection thresholds. For MP electrode configurations and a low pulse rate (156 pps), detection thresholds accounted for 47% and 36% of the variance in SGN density in Profile A and C, respectively. A similar finding was observed for 313 pps, but not at higher pulse rates. For TP electrode configurations, threshold detection for 156 pps stimuli accounted for 27% of the variance of SGN densities in Profile A but were not significantly related to those in Profile C. For TP thresholds, this pattern was true for all pulse rates evaluated.

CONCLUSIONS AND IMPLICATIONS: The data reported here did not support the hypothesis that thresholds assessed using a TP electrode configuration would account for a higher proportion of the variance in SGN densities adjacent to the stimulation electrode when compared to thresholds measured using an MP configuration. This might be because the MP configuration achieves a better (broader) sample of the neural population, at least as the neural population was sampled in this study. There are tenuous data in this study suggesting that detection thresholds measured using a TP configuration are more focused on SGN densities local to the stimulated electrodes, at least for ears with higher SGN densities and at lower pulse rates. Additional data are needed in a larger group of animals with low and intermediate SGN densities to better understand this relationship.

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M24: TOWARDS A METRIC TO QUANTIFY INFORMATION TRANSMISSION BY COCHLEAR-IMPLANT CODING STRATEGIES

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Processing strategies in cochlear implants (CI) aim to transmit information from the acoustic input signal to the auditory nerve via electrical pulsatile sequences with the most fidelity. For hardware, surgical, or physiological reasons, important acoustic cues may not be well encoded and transmitted to auditory nerve fibers, resulting in an important behavioral gap between CI and normal hearing listeners observed in many aspects (speech understanding in noise, localization, pitch perception, etc…). Instead of running psychophysical tests on CI users to determine the potential benefit of a strategy, the efforts in improving CI-user performance could be aided by computational models that could predict outcomes of CI users. While many models already exist for normal hearing listeners to predict performance from the acoustic stimulus (e.g. speech intelligibility, binaural hearing, pitch and loudness discrimination …), equivalent models dedicated to CI listeners are not as advanced and need to be further developed. As a first step to predict psychophysical data for CI listeners, the present study intends to develop a method to objectively quantify how much information is present in the auditory nerve of an individual CI user for a given sound processing strategy. Models of electrode-nerve interface were combined with adapted-version of existing phenomenological models of the auditory nerve in order to generate the output spike trains evoked by a population of auditory nerve fibers when receiving an input electric current from the electrode array. Several models (e.g. Biphasic Leaky Integrate and Fire, Point-process) and metrics (e.g. mutual information, cross-correlation) are presented and discussed as potential candidates to describe the information transmission between acoustic and neural representations.

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M25: EFFECT OF SIMULATED LOW FREQUENCY RESIDUAL HEARING ON SPECTRAL RESOLUTION AND SPEECH PERCEPTION

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Background: There are many potential advantages to combined electric and acoustic stimulation (EAS) with a cochlear implant (CI) including benefits for hearing in noise, localization, frequency selectivity, and music enjoyment. As such, attempts at preserving hearing has become a priority for patients with residual acoustic hearing. However, even when hearing preservation is successful, patient performance on these outcome measures are highly varied and the residual acoustic hearing may not be beneficial for all patients. As such we propose that a measure of spectral resolution might be more predictive of the usefulness of the acoustic component in acoustic-electric hearing. In the following experiment, we measure baseline performance on a spectral resolution and speech comprehension tasks in normal hearing individuals with using low-pass filters to simulate typical audiograms of CI candidates. As this simulates audibility of a hearing-impaired listener without any of the corresponding distortions of a hearing-impaired system, the data collected for this experiment represents best-case baseline data for evaluating hearing impaired individuals with similar audiograms.

Methods: We recruited normal hearing subjects for the study. Three low-pass FIR filters with passbands beginning at 125 Hz and stopbands at 250, 500, and 750 Hz were implemented to simulate typical audiograms of CI users with preserved low frequency residual hearing. The filters sharply attenuate to 80 dB SPL at the stopband frequency in order to approximate the steeply sloping hearing loss typically seen in these patients. Spectral resolution was measured using the SMRT (Aronoff & Landsberger, 2013) for the four versions of SMRT: unfiltered and filtered with each of the three filters. These same participants also performed speech recognition using AzBio sentences in the same four conditions, both in quiet and at a +5 dB SNR. Performance was assessed at two levels (60 dBA and 40 dBA) in order to simulate high and low levels of audibility.

Results: Preliminary results suggest that performance for filtered SMRT remains equal to performance for unfiltered SMRT for the 500 and 750Hz filters but drops significantly when all information above 250Hz is removed. Performance was equal for both presentation levels. Similar to SMRT, removing spectral information above 250 Hz resulted in poor performance on AzBio sentences in quiet but had no effect for the wider filters. In noise however, a systematic degradation in performance was seen as spectral information was removed.

Discussion: These results will be used to design a protocol to prospectively measure spectral resolution, speech perception, and music enjoyment in CI patients with residual low frequency acoustic hearing. While our simulation mimics the spectral information received through a CI, we do not account for the loss of cochlear non-linearities caused by the damage to outer hair cells. The broadening of auditory filters will likely lead to distorted, and therefore poorer spectral resolution for CI patients despite similar audiograms to the simulated hearing loss NH patients received. By presenting similar spectral information to both groups of patients, we hope to explore the effects of sensorineural hearing loss on spectral resolution and speech perception.

M26: DOES ENVIRONMENTAL SOUND PERCEPTION IMPROVE AFTER COCHLEAR IMPLANTATION?

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Improvement in environmental sound perception is an anticipated benefit of cochlear implants (CI) among many clinicians and patients. Previous studies consistently demonstrate that environmental sound perception remains lower in CI users than in normal-hearing (NH) listeners. It is generally assumed that environmental sound perception improves pre- to post-implantation. We examined this assumption by testing whether the ability to identify common environmental sounds would be higher in CI users than in listeners with hearing loss who qualify for CIs but are awaiting surgery.

First, we examined identification of common environmental sounds in a group of 39 experienced adult postlingually deaf CI users and a similar group of 20 adults with hearing loss who met criteria for implantation. Participants in both groups were tested using a previously developed Familiar Environmental Sound Test-Identification sound subset (FEST-I) which examines identification of 25 environmental sounds using a closed-set response format. On each trial, after hearing a sound, participants selected one of 25 response options. Results revealed no significant differences in average identification accuracy among CI users and CI candidates, 59.9% (14.3) vs. 54.7% (26.4), respectively. Due to cross-sectional study design, however, it was conceivable that unexplored differences between the groups led to similar environmental sound performance. Thus, in a second study, FEST-I was re-administered six months post-activation to the 14 CI candidates who had elected to undergo implantation. A comparison between pre-CI and post-CI scores also revealed no significant differences in environmental sound performance between pre-CI and 6 months post-CI, 64.3% (15.0) vs. 66.3% (15.5), respectively. Moderate correlations were observed between the amount of change in pre-to-post FEST-I scores and each of the following: pre-CI thresholds, participants' chronological age age, and age at estimated onset of hearing loss.

The present findings indicate a lack of improvement in environmental sound identification following implantation, and challenge the widely held assumption among patients and clinicians that CIs lead to improved environmental sound perception. Additional research is needed to provide a more comprehensive assessment of environmental sound perception and determine patient characteristics associated with greater benefit. These results also suggest the need for specific rehabilitation in this overlooked and understudied area of auditory function.

M26: OPTIMIZED STIMULI FOR MEASURING AUDITORY STEADY-STATE RESPONSES ACROSS THE ELECTRODE ARRAY IN CI USERS

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Cochlear implant (CI) users rely primarily on the temporal envelope modulations (TEMs) of speech to perceive it intelligibly. However, clinical CI fitting procedures do not take into account how well the auditory system of the CI user is able to process TEM information. Several studies have demonstrated that behavioral TEM processing measures can help improve speech perception in CI users. Assessing the TEM encoding ability using speech-like stimuli and auditory steady-state responses (ASSRs) as objective measures will be beneficial to future novel CI fitting strategies. Recently, 40-Hz ASSRs measured for each electrode in the array has been shown to relate to speech perception in noise. However, measuring TEM encoding at each available electrode can take long measurement times. Furthermore, stimuli with prominent speech envelope modulations are more relevant to use for these purposes. In this study, we use new speech-like stimuli that contain the most relevant modulation frequencies for speech, i.e. 2-5 Hz (syllabic rate) and 18-25 Hz (phonemic rate), as well as a combination of both. Using these modulation frequency bands can provide more insight in how well the brain of the CI user can process the TEMs of speech.

We measured ASSRs in 3 adult unilateral CI users with a Cochlear™ Nucleus implant using a conventional EEG-recording system. The carrier wave pulse trains were set to 500 pulses per second and stimulation in monopolar mode, which allow for stimulation artifact removal by linear interpolation. The new speech-like stimuli are created by modulating the electrical pulse train using distributions of modulation frequencies around 4, 20 and 40 Hz. Subjects received these stimuli at a basal, middle and apical electrode at a time. This set-up allows us to probe the neural transmission of temporal information at the periphery and processing at the subcortical (40 Hz) and cortical (4 and 20 Hz) level at the same time.

The goal of this study is to evaluate the utility of speech-like stimuli to quickly measure neural TEM encoding capability. If successful, we will be able to efficiently measure TEM processing for speech-relevant TEMs across the electrode array. Quick and reliable measurements are desirable for efficient clinical practice of CI fitting and rehabilitation. We will present preliminary results and discuss the potential applications at the conference.

M28: INVESTIGATION OF AUDITORY NERVE FIBERS FACILITATION EFFECT IN COCHLEAR IMPLANT RECIPIENTS

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Electrical stimulation of auditory nerve fibers (ANFs) in animals with pairs of pulses has shown facilitation which is defined as an increase in nerve excitability caused by subthreshold stimulation in short intervals (Dynes, 1996; Cartee et al., 2000; Heffer et al., 2010). Apart from animal studies, the facilitation effect has also been observed in human cochlear implant (CI) recipients (Cohen, 2009; Hey et al., 2017). Facilitation may occur when the neuron does not respond to the first pulse, but if the membrane potential remains near the threshold long enough, the second pulse can produce a response (Boulet et al., 2016). Although facilitation has been observed in animals and human CI recipients, no study has modeled this in human CI users until now. Thus, the aim of this study is to model the facilitation effect measured via electrically evoked compound action potential (ECAP) at short masker probe intervals (MPIs) and small probe current levels (CLs) and explore the effect of masker and probe levels on this phenomenon.

11 CI recipients implanted with the Nucleus® implants participated in the study and individual amplitude growth functions (AGFs) were recorded for three test electrodes (E6, E12 and E18) with a masker offset of +10 CL. The ECAPs were measured with the modified forward masking method by Miller et al. (2000) and the probe level was set to a visually detected threshold of the ECAP (vT-ECAP) and a current level that yielded 100 µV ECAP response amplitude. 10 masker offsets from +10 CL to the masker level equal to zero as a baseline were measured and the MPIs varied from 13 µs (the shortest MPI possible with the clinical Custom Sound EP software) to CI recipient's individual absolute refractory period.

A decaying exponential function was fitted to facilitation data by finding the minimum residual sum of squares and the same function used for +10 CL masker offset condition could be applied to all other masker offsets measurements. Facilitation time constant and amplitude showed no dependency on the probe level. However, facilitation effect was stronger for the masker level at or around vT-ECAP. There was a positive correlation between facilitation amplitude and AGF slope, which indicates that CI subjects with better peripheral neural survival have stronger facilitation effect.

Although facilitation time constant for most of the CI recipients in this study was in the range, which was reported by Cartee et al. (2000), one CI subject had larger facilitation time constant. We further examined ECAP data recorded from this subject and found an enhancement of recovery function at the MPI around 1000 µs. The larger facilitation time constant might lead to this elevation while the facilitation effect did not disappear completely when the recovery function started to rise and these two phenomena had a larger overlap in comparison to the other CI subjects participated in the study. Further investigations should be conducted to explore the range of facilitation time constant and possible correlation with other parameters.

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M29: INVESTIGATING THE REDUCTION OF THE FACIAL NERVE STIMULATION IN COCHLEAR IMPLANTS BY TRIPHASIC PULSES

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Co-stimulation of the facial nerve (FNS) is a well-known side effect of the electrical stimulation in cochlear implant (CI) users. Symptoms range from simple awareness to painful spasm of the facial muscles (Berretini et al. 2011). Conventional methods, such as the deactivation of affected electrodes, can lead to a reduced hearing performance of the user (Crew et al., 2012; Dorman & Loizou, 1997). Recent studies have shown that applying triphasic instead of biphasic stimulation pulses can significantly reduce the FNS (Bahmer & Baumann, 2016; Bahmer et al., 2017).

Electrically evoked compound action potentials (ECAP) were recorded to clarify whether there is a intracochlear difference between biphasic (BP) and triphasic pulse (TP) stimulation in terms of spread of excitation (SOE, Cohen et al., 2003). Additionally, computational models of implanted cochleae and facial nerves (Frijns et al., 2009; Kalkman et al., 2015) were created to investigate the effect of different pulse shapes outside the cochlea, i.e. at the level of the facial nerve.

By using the SOE and the artifact reduction method introduced by Miller et al. (2000) it is possible to estimate the overlap of neuron populations stimulated by single electrode contacts. For this purpose, probe pulses were applied at apical, medial and basal probe positions in thirteen CI users. At the same time, the masking pulse varied over all activated electrodes. The ECAPs were recorded at an electrode neighboring the probe. The resulting SOE profiles were normalized and the profile widths of BP and TP were compared at 25%, 50% and 75% of the maximum amplitude.

A computational model of the implanted human cochlea with facial nerve was used to determine thresholds of both auditory and facial nerve fibres. The model simulates three-dimensional current spread in the cochlea and facial nerve, and predicts neural activity by modelling the neurons as active electrical double cables, using the human-based Schwarz-Reid-Bostock neural kinetics scheme (Schwarz et al., 1995). In order to gain a comprehensive insight into the pulse shape dependent effects, model simulations were run using monophasic pulses (MP), BP and TP of both polarities.

Preliminary results show a slightly narrower SOE for TP in the apical and medial cochlea region. In addition, results of the simulations suggest that a difference in polarity sensitivity of auditory and facial nerve fibers may be the cause of the TP's FNS reducing effect. Considering both results, it is likely that the origin of FNS suppression by TP may be located outside rather than inside the cochlea.

M30: EFFECTS OF ELECTRICAL PULSE POLARITY SHAPE ON INTRA COCHLEAR NEURAL RESPONSES IN HUMANS: TRIPHASIC PULSES WITH ANODIC SECOND PHASE

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Charge balanced pulses are used in modern cochlear implants to avoid direct current (DC) stimulation that may damage neural tissues. In this context the effect of electrical pulse shape and polarity is still a matter of debate and the most effective pulse shape needs to be determined (Bahmer et al., 2010; Undurraga et al., 2010; Wieringen et al., 2008; Macherey et al., 2008). A study published in 2013 by A. Bahmer and U. Baumann investigated the effectiveness in neural stimulation of a precision-triphasic pulse (pTP) with cathodic second phase. This study showed that neuronal responses to pTP are less effective than to biphasic pulses. Our study aims to support the results gained in the previous study and to investigate the effectiveness of a pTP with anodic second phase.

The pTP consists of three phases with alternating polarity and same phase duration. To provide balanced charge the sum of the amplitude of the first and third phase equals the second phase. The ratio between the amplitudes of the first and third phase is called phase amplitude ratio (PAR). A psychophysical and an electrophysiological measurement are conducted for cathodic and anodic second phase pulses. Electrical compound action potentials (ECAP) were recorded on an apical, medial and basal electrode position for an increasing PAR from 0 to 0.9 with a step width of 0.1. Additionally, the threshold in the psychophysical measurement is determined on an apical and medial electrode position by the weighted up-down method.

So far, the results gained in the previous study could be replicated for the pTP with cathodic second phase. The ECAP measurement for the pTP with anodic second phase and increasing PAR shows a less deflected course of amplitude than for cathodic second phase. Surprisingly, the increase of psychoacoustic threshold with PAR is similar to cathodic second phase.

Triphasic pulses with various pulse shapes elicit different response strength. As these pulses can be activated in MEDEL implants, it is important to know their effectives in neuronal tissue stimulation.

M31: ULTRAFAST RED-SHIFTED OPTOGENETIC STIMULATION OF THE AUDITORY NERVE

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Rationale: The electrical cochlear implant (eCI) provides open speech comprehension making it first important treatment restoring a human sense. Yet, a disadvantage of the eCI is the broad spread of the electric stimulus along the tonotopic organization which results in channel crosstalk and limits frequency resolution. For eCI users, this cognitively translates into hampering of listening to speech in noise, receptive prosody, and music appreciation. Here, optogenetics brings possibility to optically control SGN populations with improved frequency selectivity since light can be conveniently confined. However, the original channelrhodopsins have slow closing kinetics, which could trade off improved spectral coding for poorer temporal fidelity.

Aim: This work concentrates on engineered very fast Chrimson (vf-Chrimson), a red-shifted (λpeak = 590 nm) channelrhodopsin with fast closing kinetics (τoff = 1.6 ± 0.1ms) enabling fast spiking interneurons to reliably follow stimulus rates up to 400 Hz. Hence, the aim is to characterize response properties of mouse spiral ganglion neurons transduced with vf-Chrimson upon light stimulation.

Methods: As a first step, we virally delivered either vf-Chrimson or its enhanced membrane-targeted version (vf-Chrimson – ES/TS) to the SGNs of mouse pups by cochlear injections. Light responsiveness of AN was examined in adult mice via optically-evoked auditory brainstem response (oABR) measurements using subdermal needle electrodes where light stimulus was presented by an optical laser fiber placed at the round window.

Results: Both variants of vf-Chrimson enabled activation of AN upon light stimulation indicated by the first wave of ABR trace. By visual inspection, the threshold radiant flux values for activation were determined to be 9.9 ± 8.5 mW and 6.2 ± 5.1 mW for vf-Chrimson and vf-Chrimson–ES/TS for 1 ms long pulses, respectively. The shortest stimulus duration eliciting highest wave I amplitude is 0.4 – 0.6 ms for membrane-targeted vf-Chrimson – ES/TS compared to 0.8 – 1.0 ms for vf-Chrimson. Lastly, both variants were constantly able to follow stimulation rate up to 200 Hz and with decreasing amplitude up to 500 Hz.

Conclusion/Outlook: Using vf-Chrimson, we transduced and drove the auditory nerve by light. Yet, to better understand the functional capabilities of this optogene at AN, we are currently investigating the light-triggered spiking pattern of single SGN fibers.

M32: COMPARISON OF ELECTRICAL AND OPTICAL STIMULATION OF THE COCHLEAR NUCLEUS: IMPLICATIONS FOR FUTURE AUDITORY BRAINSTEM IMPLANTS

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Introduction. The auditory brainstem implant (ABI) is indicated for human subjects with absent or damaged cochlear nerves and electrically stimulates the cochlear nucleus (CN) using a multichannel surface electrode array. Currently, the performance of most ABI patients, as measured by speech comprehension, is poor. Optical stimulation may offer improved selectivity in an ABI prosthesis because light may not spread as much as electric current within the brain. Furthermore, opsin expression, light sensitive proteins, could be targeted to specific cell types in the CN, which might eventually be important if certain cell types are important for speech processing. We will compare electrical stimulation vs. optical stimulation using two transgenic mouse lines. Comparisons were made in terms of the latency and strength of response, tonotopic selectivity, and the results of lesions of the output pathways of the CN.

Methods. Using anesthetized CBA/CaJ mice or two transgenic mouse lines (Bhlhb5-ChR2, VGlut2-ChR2), surgical exposure of dorsal CN (DCN) and IC were performed using a posterior craniotomy. Stimulation was provided either by a 3- or 4- channel conformable stimulating electrode array or a 500 μm diameter optical fiber coupled to a 488 nm laser. Electrically (eABR) or optically (oABR) evoked auditory brainstem responses were recorded with needle electrodes in the skin, and multi-unit neural activity was recorded with a 16-channel recording probe (NeuroNexus) placed in the central nucleus of the contralateral inferior colliculus (IC). Surgical cuts were made with a scalpel and confirmed in Nissl-stained transverse sections by comparing sections to our previous database of labeled axons.

Results/Conclusion. There were similarities and important differences in the two types of responses. Overall latencies were similar, although electrical responses could be observed immediately following stimulation while optical responses occurred about 1 ms later. Both stimulations exhibited a robust response that lasted approximately 10 ms. Electrical stimulation could exhibit a clear multipeak response while optical stimulation generally did not. However, both electrical and optical responses could be divided into an early and late response component. A cut of the dorsal acoustic stria alone or combined with the intermediate acoustic stria attenuated only early electrical components and did not affect late components, suggesting that the early responses to electric stimulation originate in the DCN. The tonotopic selectivity of electrical stimulation was broad while optical stimulation was narrower, suggesting that an optically based ABI would provide better tonotopy and improved pitch sensations. Lastly, the eABR and oABR both exhibit multipeak waveforms.

M33: EXPLORING RAMPED PULSE SHAPES FOR COCHLEAR IMPLANTS IN AN ANIMAL MODEL

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A limiting factor in cochlear implants (CI's) is the broad excitation patterns of spiral ganglion cells caused by current spread. In current CI devices, the electrical pulse has a biphasic rectangular shape. However, recent evidence from in vitro studies and our modeling work suggest that an alternative, non-rectangular pulse shape with a ramped slope might be more beneficial because it better matches ion channel dynamics of spiral ganglion cells. Here, we explore biophysically-inspired electrical pulse shapes in vivo. Our hypothesis is that non-rectangular pulses can reduce unwanted excitation patterns.
Mice were deafened with neomycin and acutely implanted with a 4-channel array (Bionics Institute, Melbourne). Electrical pulses were generated by a dedicated Animal Stimulation Platform (Oticon Medical, Nice) using biphasic pulses with 40 µs/phase, 10 µs interphase gap, monopolar configuration.

In experiment 1, electrically-evoked Auditory Brainstem Responses (eABR) were recorded in response to four pulse shapes: rectangular (constant phase amplitude), rampUP (1st phase amplitude ramped from 0 uA to x uA, 2nd phase of opposite polarity ramped from 0 uA to x uA), rampDOWN (1st phase amplitude ramped from x uA 0uA to, 2nd phase of opposite polarity ramped from x uA to 0 uA), rampLONG (1st phase amplitude ramped from x uA to 0 uA, 2nd phase of opposite polarity ramped from 0 uA to x uA), presented either as anodic or cathodic-first. A non-rectangular pulse shape produced a significant lower threshold of wave II compared to a rectangular pulse shape in terms of charge injected (Tukey HSD, $p < 0.05$, n=6), while a rampUP pulse shape a significant steeper growth function of wave II compared to a rectangular pulse shape (Tukey HSD, $p < 0.05$, $n = 5$). No effect of polarity of significant.
In experiment 2, electrically-evoked Compound Action Potential (eCAP) were recorded in response to rectangular and rampUP pulse shapes. To our knowledge, this is the first eCAP recordings demonstrated in mice. Preliminary data showed a lower threshold and steeper P1 growth function with rampUP pulse shapes compared to rectangular pulse shapes in terms of charge injected ($n = 3$), in accordance with the eABR data. rampUP pulse shapes also tended to have a shorter latency. Future eCAP experiments will look into spread of excitation curves and temporal jitter with ramped and rectangular pulse shapes.

In summary, the study presents first evidence of neural responses to non-rectangular CI pulse shapes in vivo. The data supports the hypothesis that non-rectangular pulse shapes can have beneficial properties. A lower threshold implies lower power consumption, while the consequences of a steeper growth function are less clear.

M34: CONGENITAL SINGLE-SIDED DEAFNESS: TO TREAT OR NOT TO TREAT

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Potential treatment options for subjects with single sided deafness (SSD) are a conventional hearing aid with contralateral routing of sound (CROS), a CROS bone-conduction device (C-BCD), or a cochlear implant (CI).

In some countries, cochlear implantation is becoming the standard treatment. The CI enables bilateral input and may ultimately provide binaural hearing. In contrast, CROS-devices cannot restore any bilateral hearing as only the contralateral hearing ear is stimulated.

We present an overview of localization performance of subjects with SSD listening with a C-BCD or a CI and we compare these results with those of SSD subjects who never asked for any treatment. We focus on sound localization ability because it is a sensitive measure of binaural hearing.

We found moderate to good unilateral sound-localization abilities in the horizontal plane, at the side of their hearing ear in (unaided) SSD listeners. This performance proved to be related to processing of monaural spectral cues, which are only perceivable for SSD listeners with thresholds better than 40 dB HL at 4 and 8 kHz. Localization remains unchanged when listening with a C-BCD. In contrast, sound localization improved significantly when SSD subjects were listening with a CI. However, our data suggest that there is no true processing of binaural cues as the SSD subjects mainly lateralized sounds. A general observation is that the input from the CI is not always appreciated. It can be speculated that in daily live, when most sounds are not only audible but also visible, lateralization of sounds can already be really helpful.

We present our results with SSD in the context of treating unilateral conductive hearing loss with a BCD. In these patients, similar to treating SSD with a CI, binaural hearing is expected. However, we found that the improvement in sound localization abilities is somewhat disappointing and device non-use was unexpectedly high (>40% within 3-4 years of follow-up).

We conclude that the non-invasive CROS device is to be preferred over a C-BCD in case of SSD; both offer reduction of the head shadow with no access to binaural cues (i.e., no bilateral input).

Although treatment of congenital SSD with a CI seems promising, we suggest a conservative approach in advocating a CI, as it enables users a left-right discrimination but not true binaural hearing required for the optimal understanding of speech in noise. There is a considerable risk of non-use which might be related to a remaining hearing asymmetry after implantation, and unique dynamics of the normal hearing ear contralateral to the CI.

M35: MEASURING LOCAL FIELD POTENTIALS IN PATIENTS WITH AUDITORY BRAINSTEM IMPLANTS

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Introduction. The measurement of the electrically evoked action potential (ECAP) in cochlear implant (CI) patients is used to provide evidence of a functioning electrode-nerve interface, to confirm proper location of the electrode array and to program the sound processor especially in patients who cannot give sufficient feedback about the perceived volume of the channel-specific stimulation. In patients with an auditory brainstem implant (ABI), the ECAP measurement paradigm can also be utilized to record responses via the electrode array. Since the array is not located inside the cochlea we call these responses local field potentials (LFP). So far, studies (e.g., Otto et al. 2005, J Am Acad Audiol 16:219-227) didn't find a correlation of LFP responses and programming parameters. Forward masking was used as artifact reduction paradigm in these studies. Since Azadpour et al. (Poster W19, CIAP2017) suspected that masking effects at the level of the nucleus cochlearis are very different from those found in CI, and could evoke facilitation, we assume that alternating polarity might be the better way to record LFP.

Materials and Methods. In 15 patients implanted with a MED-EL ABI we have measured LFP routinely during the behavioral fittings on 179 different electrode contacts in total. The used artifact reduction method was alternating polarity. Like in CI patients we delivered stimuli with increasing current to one electrode contact of the ABI array and recorded the response from an adjacent electrode contact. The responses were characterized by a negative and a positive peak. From their difference the LFP amplitude was calculated.

Results. On 65% of all measured contacts we found responses. The LFP amplitude, as well as the slope of the amplitude growth function (AFG), is highly variable and about 10 times higher compared to values typically found in CI patients. On channels where LFP responses were detected, an auditive sensation was evoked in 77%. In cases where no LFP was recorded, no hearing sensation was elicited at least up to the stimulation level used in the LFP measurement. In 9 patients we had both the behavioral threshold and the objective threshold measured by LFP available on 80 channels. Here a highly significant ($p < 0.01$) correlation between the two thresholds was found (Pearson correlation coefficient $r = 0.72$). Additionally, we were able to detect an electrode migration in 2 cases by comparing LFP measurements at different times.

Conclusion. LFP measurements have the potential to support the fitting in ABI patients. With LFP it is possible to verify the electrode position without radiation.

M36: THE EFFECT OF CURRENT SHAPING ON SPECTRAL RESOLUTION WITH LATERAL WALL AND MID-SCALAR ELECTRODE ARRAYS

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Spectral representation is considered one of the primary bottlenecks for cochlear implants (CIs). Reshaping of current field in the cochlea using multipolar stimulation (e.g. current steering and current focusing) have been proposed as tools for improving spectral representation. Current steering typically involves simultaneous stimulation on two adjacent physical electrodes creating an electric field such that the peak of stimulation is between the two physical electrodes (i.e., a "virtual channel"). This technique is often used to increase the number of stimulation sites beyond the number of physical electrodes. Current focusing is a technique in which simultaneous stimulation is provided out-of-phase on multiple electrodes to reduce the spread of the electrical field to reduce interactions between adjacent electrodes. In this study, we investigate the contributions of current steering and focusing independently and in combination on spectral abilities. Furthermore, as the shape of an electric field is likely to depend on the position of the corresponding electrode, results with users of lateral wall (HiFocus 1J) or Mid-Scala (HiFocus MS) electrodes are compared.

For each subject, spectral ripple performance was measured with 5 maps (4 experimental and their clinical map.) The experimental maps consisted of variants of the CIS strategy with and without focus, or virtual channel current steering. The stimulation modes in the experimental maps consisted of monopolar (MP; No Steering and No Focusing), monopolar virtual channels (MPVC; Steering and No Focusing), partial tripolar stimulation (TP+1; No Steering and Focusing) and virtual tripolar (VTP; Steering and Focusing) stimulation. All experimental maps were created using BEPS+ research software on BTE research processors. Maps were loudness balanced to the subjects' clinical maps.

Preliminary data with 10 subjects (5 HiFocus 1J users and 5 HiFocus MS users) was collected using the 4 repetitions of the SMRT task (Aronoff and Landsberger, 2013) for each strategy. Baseline spectral ripple performance was better for the HiFocus MS users than the HiFocus 1J users. However, the HiFocus 1J users consistently benefited from both focusing and steering. The effects of focusing and steering with the HiFocus MS were less consistent across subjects. More data will be collected to increase the sample size of both HiFocus 1J and HiFocus MS users. Additionally, spectral testing will also be conducted using an alternative spectral ripple task (EasyQSMD; Gifford et al., 2014; Landsberger et al., in press) as a replication.

Support provided by the NIH/NIDCD (R01 DC012152), as well as Advanced Bionics for subject testing.

M37: ASSESSMENT OF ADJUSTMENT TO ELECTRICAL THRESHOLD (T) LEVEL AND ELECTRICAL STIMULATION RATE ON IDL AND AM DETECTION AT SOFT PRESENTATION LEVEL IN ADULT CI USERS

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Cochlear Implant (CI) users often show poorer speech perception at low intensity levels. Very little is understood about the influence of sound processor fitting parameters on the discrimination of low intensity acoustic cues.

A pilot study was conducted to evaluate the influence of electrical stimulation rate and the setting of electrical threshold (T) Level on intensity difference limens (IDLs) and amplitude modulation (AM) discrimination.

Participants were thirteen adult experienced Advanced Bionics CI users. The frequency of the acoustic sinusoidal stimuli was set to 1076Hz with the intention of stimulating electrode seven. Nine experimental maps were created with T levels set at: the perceptual threshold of audibility; perceptually equivalent to ‘very soft’ and 10% of the perceptual equivalent to ‘most comfortable loudness’. Rates of electrical stimulation used were 900, 1800 and 2700 pulses-per-second. Adaptive 2I-2AFC IDL and AM discrimination tasks were presented via headphones at soft presentation levels (48 and 54dBSPL for IDL and AM tasks respectively).

The influence of T Level and stimulation rate adjustments on IDL and AM detection have been explored with the intention of understanding the impact of altering individual parameter settings to optimise detection of acoustic cues at low presentation levels.

M38: AUTOMATED ADJUSTMENT AND EVALUATION OF ELECTRICAL HEARING THRESHOLDS IN COCHLEAR IMPLANT PATIENTS

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When fitting cochlear implants, the most accurate determination of the electrical hearing threshold (threshold, T-value) is required. In many cases, a precise determination of the T-value is difficult due to uncertain information from the patient. The study by Rader et. al. (2018) shows that by using the adaptive precT method for T-value adjustment, the speech intelligibility threshold in noise at noise levels (OLSA: speech 50 dB, noise adaptive) significantly improves by -1.8 dB SNR.

Here, the precT procedure is implemented in MATLAB and can be performed by the CI user without the interaction of any audiologist. The stimuli are generated as audio signals and transmitted via a sound card and audio cable to a defined programmed Cochlear audio processor and the answers are queried via a touch screen. The audio signals are calibrated with the Cochlear CIC4 Decoder Implant Emulator so that the measured values can be transferred directly in CL to the fitting software. In 15 CI users, the T-values are automatically determined on all electrodes using the new automated precT method- patient's feedback to the number of the perceived sounds takes account into increasing or decreasing stimuli level. Speech perception in noise at soft presentation level (Oldenburg sentence test; speech presentation level: 50 dB, noise adaptive) is tested with three different program settings: (P1) used by the CI user, (P2) newly determined T-values with automated precT and (P3) same as (P2), but T-values decreased by 10 CL to emulate insufficient (too low) T-value settings.

The speech perception threshold in noise improves significantly from (P1) 2.5 dB to (P2) 1.6 dB SNR for soft sound levels by using the automated precT method. In (P3) the worst SNR of 2.9 dB is shown as expected. Precise adjustment of the electrical hearing threshold with CI allows for significantly better speech understanding in noise at low speech levels.

Rader, T., Doms, P., Adel, Y. et. al (2018): A method for determining precise electrical hearing thresholds in cochlear implant users. In: International journal of audiology 57 (7), S. 1–8. DOI: 10.1080/14992027.2017.1412519.

M39: SPECTRAL ALIASING IN A SPECTRAL RIPPLE DISCRIMINATION TASK

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Tests of spectral ripple discrimination SRD are widely used to test spectral resolution in cochlear-implanted individuals and have been shown to correlate well with measures of speech identification and discrimination. Additionally, SRD tests have been used to examine development of spectral resolution in normal hearing listeners. Previous work has found that adults with intact acoustic hearing have SRD upper limits around 8-11 ripples per octave (RPO) across various methodologies including phase inversion detection, ripple detection, and density discrimination. These tasks generally use a multiple sine-wave carrier rippled in intensity across frequency. The carrier density used has varied from approximately 30/octave to about 400/octave. Recently, we encountered a non-monotonicity when adapting an SRD task with a 30/octave carrier, the spectrotemporal modulation ripple test, for use with infants. Some subjects were able to distinguish 16 RPO from 20 RPO but failed to do so at lower ripple densities. It was hypothesized that an interaction between the carrier and ripple densities produced “spectral aliasing” when the ripple density was within a few Hz of the carrier density, akin to the Nyquist frequency limit. The present study was designed to test this hypothesis by examining the effect of carrier rate and stimulus duration on SRD.

Participants were 5 normal hearing adults (mean age 31 years old) naïve to the task who participated in a single 2-hour test visit. Stimuli were generated as described by Aronoff and Landsberger with alterations to enable modification of carrier density and stimulus length (Aronoff and Landsberger, 2013). Phase-randomized sinusoidal carriers were spectro-temporally amplitude modulated with a time-variant full wave rectified sinusoid with ripple depth of 20dB, 100ms on/offset ramps, and 5Hz sweep rate. Spectral ripple density varied from 1 to 20 RPO in ¼ log2 steps. A single-interval yes/no procedure was used with feedback in which the listener raised their hand when a trial contained a ripple density < 20 RPO. In between trials, the listener heard repeating 20 RPO stimuli at 0.5s ISI. Stimuli were presented at 70dB SPL in sound field. Ripple density and starting phase was varied randomly across trials. Each subject was tested in 4 conditions in random order with two within-subject variables: carrier density (33/octave or 100/octave) and stimulus duration (1s or 0.5s).

The effects of ripple density, carrier rate, and stimulus duration on mean proportion correct were examined with a full-factorial linear mixed effects model. Significant main effects of density (negative effect), carrier rate (positive effect), and stimulus duration (positive effect) were found. The only significant interaction was between carrier rate and ripple density. Post-hoc comparisons revealed a non-monotonicity at 16 RPO for the 33/octave carrier but not the 100/octave carrier. If this monotonicity was ignored, the threshold at the 70% point of the psychometric function was approximately 11-12 RPO for the 33/octave carrier but 16-17 RPO for the 100/octave carrier.

This experiment confirms that spectral aliasing limits spectral peak repesentation of the stimulus and creates a non-spectral beating cue at an RPO ½ of the carrier rate. This will create a ceiling effect when the low carrier rate is used to probe spectral resolution in NH listeners or in CI users who have relatively good spectral resolution (such as bimodal or hybrid listeners). Although using a higher carrier rate can overcome this problem, it should be noted that the task becomes one of probing ripple discrimination rather than ripple detection. It is likely that the upper limit for spectral peak resolution, in normal hearing listeners, is higher than the 20 RPO referent used in the present study.

M40: CHANNEL INTERACTIONS IN COCHLEAR IMPLANTS: DO THEY REALLY INCREASE AT HIGH CURRENT LEVELS?

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Because of the conductive properties of the cochlea, the neural populations recruited by adjacent electrodes overlap. These channel interactions are thought to alter the transmission of sound information to cochlear implant (CI) listeners. Here we aim to better understand the relationship between these interactions and the stimulation level.

When considering a single electrode, an increase in level enables the recruitment of more distant neurons. It is, therefore, often concluded that channel interactions should increase with current level. However, if we assume that channel interactions relate to the proportion of fibers stimulated by both electrodes relative to the total number of fibers excited, the effect of current level on these interactions appears more difficult to predict.

This question was investigated in a pitch discrimination task with nine users of the Cochlear CI24 device. On each trial, the subjects heard a reference and a test stimulus, presented in random order and had to indicate which one was higher in pitch. The reference stimulus consisted of two 300-ms duration, 80-pps interleaved pulse trains presented on two electrodes. The delay between the two pulse trains was equal to half a period, yielding an “aggregate” temporal pattern with a pulse rate of 160-pps. This reference stimulus was compared to seven different test stimuli with rates ranging from 80 to 210 pps. For all test stimuli, the two electrodes were activated with a very short delay so that the aggregate temporal pattern was identical to the temporal pattern on each electrode.

For this task we defined two level-conditions, corresponding to 60% (soft) and 100% (loud) of the dynamic range, and two electrode-conditions by using two pairs of electrodes (11-12 and 11-13). In this paradigm, the temporal pitch of the reference stimulus being judged close to 160Hz would suggest that the percept is dominated by neurons responding to the aggregate stimulus. In the opposite, a reference pitch judged close to 80Hz would indicate that the recruited neural populations were more independent.

Results showed that for all but one condition in one subject, increasing the spacing between electrodes yielded a decrease in pitch consistent with a predictable decrease in electrode interactions. However, the effect of the stimulation level was much more difficult to anticipate. Out of eleven conditions completed so far, four showed an increase in pitch suggesting that a higher level produced larger interactions; two were not affected by the stimulation level; and four yielded a decrease suggesting that the neural population conveying the aggregate temporal pattern was relatively smaller at the loud than at the soft level.

To conclude, we found that the pitch percept resulting from a dual-electrode stimulus depends on the amount of interactions between the two channels. However, these channel interactions do not necessarily increase with stimulation level and the opposite is sometimes observed. This phenomenon may arise from different patterns of neural survival and may add to the inter subject variability in performance observed in the CI population.

M41: INDIVIDUAL DIFFERENCES IN RECALIBRATING TO UPWARD SPECTRAL SHIFTS

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Cochlear implant (CI) patients have difficulty encoding spectral (frequency) aspects of a speech signal. They are therefore at a severe disadvantage compared to normal hearing listeners in distinguishing consonants that differ by place of articulation (PoA), which are cued by spectral differences. Apart from the well-known reasons for this that include poor place specificity and electrode interaction, another reason for this difficulty could be due to the upward shifting of spectral energy that occurs with incomplete insertion depth of the electrode array. The present study measured the effects of spectral shifting on phoneme categorization, with specific focus on consonants where differences in spectral energy are vital for categorization. Normal hearing listeners heard sinewave-vocoded speech with simulated shifts of 0, 2, 4, and 6 mm of cochlear space to model shallow insertion depth. Stimuli included monosyllabic words and /b-d/ and /ʃ-s/ continua that varied by formant transitions or frication noise spectra, respectively. Results show phoneme categorization became biased towards /d/ and /s/, consistent with the acoustics of these segments. While group data suggested a partial trend in recalibration to the spectral shift, individual data suggest a different conclusion: half of the listeners were able to recalibrate and maintain two distinct phonetic categories, while half of the listeners were completely biased in their categorization. These results were followed up in a series of experiments that looked to further examine whether incremental exposure to shifting would promote better recalibration. This study shows that consequences of shallow CI insertion depth are systematic with respect to speech acoustics, but also subject to individual differences in the ability to adjust acoustic-phonetic mapping.

M42: SPECTRAL CONTRAST EFFECTS REVEAL DIFFERENT ACOUSTIC CUES FOR VOWEL RECOGNITION IN COCHLEAR-IMPLANT USERS

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The identity of a speech sound can be affected by the spectrum of a preceding stimulus in a contrastive manner. Such contrastive aftereffects are often reduced in people with hearing loss and cochlear implants (CIs), presumably due to degraded spectral resolution. Here we explore a contrastive aftereffect that is greater than normal in CI users (Feng & Oxenham, 2018). We hypothesized that CI users rely on different acoustic cues to not only identify vowels but also to adapt to the acoustic context.

We enrolled three groups of listeners: normal hearing (NH; n=17), normal hearing with vocoded stimuli (NH-VC; n=16; 16-channel vocoder with simulated current spread of 12 dB/octave), and cochlear-implant users (CI; n =13, 16 ears). The target word was taken from a 10-step continuum between the test words “bit” and “bet” and was always preceded by a context sentence consisting of “The last word you hear is…”. Spectral envelope difference (SED) filters were created and applied to the context sentence to perceptually enhance either the /I/ in “bit” or the /ɛ/ in “bet”. The SED filters were manipulated to retain either only the coarse spectral shape (lowpass spectral envelope filter), only the fine spectral details (highpass spectral envelope filter) or all the properties of the spectral shape (original SED filter).

Results confirmed that the CI group showed a significantly larger contrast effect than the NH and NH-VC groups with the original SED filter. Interestingly, when the preceding sentence was filtered with the smoothed (lowpass) SED, where the fine spectral details were removed, spectral contrast effects were eliminated for the NH group, but remained unchanged for the CI group. In contrast, the highpass SED filter, which retained the fine spectral details, had the opposite effect, retaining the contrast effect for the the NH group, but eliminating it for the NH-VC and CI groups. The results show that the spectral contrast aftereffect is determined in NH listeners solely by the fine-grained local spectral cues that are also used to discriminate the target speech sounds, resulting in a surprising insensitivity to the larger, global spectral cues utilized by CI users. Restricting the spectral resolution available to NH listeners via vocoding results in patterns of responses more similar to those found in CI users. However, the size of the contrast aftereffect remains smaller, suggesting a longer time course is needed to acclimate to the cues used for perceptual adaptation than to those needed for discrimination.

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Feng, L., & Oxenham, A. J. (2018). Effects of spectral resolution on spectral contrast effects in cochlear-implant users. J Acoust Soc Am, 143(6), EL468.

M43: EVALUATING THE EFFECT OF INCREASED SPREAD OF EXCITATION ON SPEECH-IN-NOISE PERCEPTION BY COCHLEAR IMPLANT LISTENERS

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Cochlear implant (CI) listeners struggle to understand speech in background noise. Interactions between electrode channels due to current spread increase the masking of speech by noise and reduce the effective number of channels. Therefore, strategies to reduce channel interaction have the potential to improve speech-in-noise perception by CI listeners. We investigated the effects of channel interaction on speech-in-noise perception and its association with spectro-temporal acuity by imposing spectral blurring as a simulation of increased spread of excitation, in a study with 12 CI users. Research questions were: (1) does spectral blurring affect CI users' speech-in-noise perception when either all or only a subset of channels are blurred? (2) are listeners with better spectro-temporal acuity more affected by spectral blurring? (3) do the effects of spectral blurring depend on whether it is applied at the input (analysis filter bank) or at the output (electrode level) stage of the CI?

Experiment 1 adjusted the spectral overlap of the analysis (input) filters thereby producing spectral blurring at the input stage. The resulting channel interaction effects were studied by measuring speech reception thresholds in a competing talker as a function of the amount of blurring applied to either all, or 5 out of 15, electrode channels. Large amounts of blurring applied to all channels significantly degraded speech-in-noise perception. Performance for each listener remained roughly constant as the amount of blurring applied to all channels increased up to some knee point, above which it deteriorated. Higher knee points corresponded to better performance on a non-speech spectro-temporal task ("STRIPES", Archer-Boyd et al, 2018). We argue that the knee-point may provide a method for evaluating the effects of spectro-temporal acuity on speech perception that is largely independent of cognitive influences. Surprisingly, even extreme amounts of spectral blurring applied to 5 out of 15 channels did not affect performance overall. These findings show the resilience of CI listeners against spectral blurring at the input stage.

We will further compare the results of spectral blurring at the input stage with results from Experiment 2, in which we apply spectral blurring at the output stage (the electrode level). In this case, 5 out of 15 channels of the analysis filter bank are used to stimulate a set of adjacent electrodes simultaneously. This will allow us to evaluate the effects of a channel of information spreading widely across the cochlea, as would occur for example with an electrode far from the responding neurons.

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M44: EFFECT OF PHASE DURATION ON JITTER DETECTION: PSYCHOPHYSICS AND COMPUTATIONAL MODELING

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Previous studies in the field of functional electrical stimulation have shown that increasing the phase duration of an electrical pulse has the effect of (1) reducing spike initiation threshold more for small-diameter than for large-diameter fibers and (2) reducing threshold more for fibers remote from the electrode than for those nearby. These two observations imply that for a given current increment, the number of additionally recruited fibers is larger for long than for short phase duration pulses. By extension, the slope of the input-output growth function for the fiber population is also steeper for long than for short phase duration pulses (Grill and Mortimer, 1996). The problem of cochlear implant stimulation is similar as the targeted neural population encompasses fibers with different diameters and located at different distances from the electrode. Assuming that loudness relates to the total number of action potentials elicited by each electrical pulse, we would therefore expect long phase-duration pulses to show a steeper recruitment as a function of current level and therefore a smaller dynamic range than short phase duration pulses. However, several studies have shown that the opposite is true and that the electrical dynamic range of cochlear implant listeners (expressed in dB) increases with increases in phase duration (Zeng et al., 1998). One possible explanation is that loudness does not only relate to the total number of discharges but also to the firing synchrony and that this synchrony is weaker for long than for short phase durations.

To test this hypothesis, five users of the Cochlear CI24M or CI24RE device took part in a jitter detection experiment. In each trial, they heard a regular 200-pps pulse train presented on a single electrode of their implant and the same pulse train with the pulse-to-pulse intervals jittered by a certain amount. They were asked to detect in which interval was the more irregular/noisy sound. This experiment was repeated for different amounts of jitter and for two phase durations (25 and 400 µs). The rationale was that if there is already more spike jitter for the 400-µs condition in response to a regular pulse train, then the detection of an additional jitter imposed on the stimulus should be more difficult to detect than for the 25-µs condition. At most comfortable loudness, this did not turn out to be the case and, despite some between-subject variability, there were no consistent differences between the two conditions. We also performed simulations using a computational model derived from cat's single fiber data (Resnick et al., 2018) which predicted that, while spike jitter should indeed be greater for a 400-µs than for a 25-µs pulse, this jitter difference is larger at low than at high stimulus level. We are, therefore, currently collecting additional data at lower levels in the dynamic range. Implications concerning computational model validation, signal coding in CIs and theoretical models of loudness perception will be discussed.

Grill WM Jr, Mortimer JT (1996) "The effect of stimulus pulse duration on selectivity of neural stimulation." IEEE Trans Biomed Eng 43:161-166.
Zeng FG, Galvin JJ 3rd, Zhang C (1998) "Encoding loudness by electric stimulation of the auditory nerve." Neuroreport 9:1845-1848.
Resnick JM, O'Brien GE, Rubinstein JT (2018) "Simulated auditory nerve axon demyelination alters sensitivity and response timing to extracellular stimulation." Hear Res 361:121-137.
Work funded by the Bloedel Traveling Scientist Program

M45: RECOVERY FROM PRIOR STIMULATION IN ABI AND CI USERS: AN INSIGHT INTO TEMPORAL PROCESSING PERFORMANCE

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Auditory brainstem implants (ABIs) are clinically used in patients for whom cochlear implants (CIs) are not a viable treatment option, due to damaged or abnormal auditory nerve or cochlea. ABIs bypass both the ear and the auditory nerve, and directly stimulate the brainstem via electrodes placed on the cochlear nucleus. Current ABI devices use the same coding strategies as CIs and encode acoustic envelopes by modulating the amplitude of electrical pulses delivered by implant electrodes. However, despite identical external hardware, signal processing, and stimulation patterns being delivered by ABI and CI electrodes, the two devices have very different outcomes. Although outcomes are quite variable within each group of patients, most ABI patients cannot understand speech with their device whereas most CI users understand speech well enough to communicate effectively.

We hypothesized that differences in speech perception between ABI and CI users (as well as within each group) can be attributed, at least in part, to perception of temporal cues. Temporal cues provided by amplitude modulation of electrical pulse trains may not always be accurately transmitted by the neural system, particularly when stimulation is delivered to the brainstem with an ABI. The brainstem is complex and consists of different neuron types with differing roles in the normal auditory system. Amplitude modulations of stimulation pulses might not be accurately represented at the neural level if neural responses to individual pulses are strongly suppressed or enhanced due to the sustained effects of prior stimulus pulses.

The aim of this study was to assess the effects of prior stimulation pulses in ABI and CI users, and evaluate whether those effects can explain hearing outcomes. The effects of prior stimulation pulses were measured behaviorally as well as physiologically. The physiological measure was ECAP (electrically-evoked action potential), which was obtained using the recording capabilities of the implant device. ECAP was recorded in response to a target pulse preceded by a masker pulse. The time course of ECAP recovery from suppression or enhancement effects of the masker pulse was assessed by varying the time interval between target and masker. The behavioral measure used the same masker-target stimuli as the physiological experiment and evaluated the contribution of the target pulse to the overall stimulus loudness at different masker-target intervals. The loudness contribution of the target was expected to depend on the resulting neural excitation, which would in turn depend on neural suppression or enhancement effects of the masker pulse.

Our preliminary results support the hypothesis that recovery from prior stimulation may be related to ABI users' hearing performance. ABI subjects with longer recovery from a prior stimulation pulse tended to have poorer hearing performance with their device. These experiments illuminate differences in neural response properties among ABI and CI users and may provide better understanding of the reasons for generally poor speech perception of ABI users as well as the variability in outcomes within ABI and CI user groups.

M46: APPLYING ACROSS-CHANNEL MODULATION MASKING TO THE IDENTIFICATION OF POORER COCHLEAR IMPLANT CHANNELS

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Across cochlear implant (CI) users there is a large variability in the ability to understand speech, particualry in noisy situations. This may be partly explained by variability in the number and distribution of surviving auditory neurons, in combination with how electrical stimulation from each electrode contact recruits neurones. Hence, it would be very useful to identify “bad” channels, i.e. those which produce neural excitation only via the spread of electric current to remote places. Deactivating such channels can lead to improved outcome. We describe the use of a new method for identifying bad channels with the following desirable characteristics: no “direct” electrical stimulation is required; based on the ability to discriminate the amplitude modulation (AM) pattern applied to one electrode when there is a different pattern of AM on adjacent electrodes; (3) reasonably quick.

The stimuli are amplitude modulated sinusoidal carriers delivered via the auxiliary input of the sound processor. The “target” sound has a carrier frequency centered on channel N. AM is applied to this carrier with an adaptively varying depth: initially 80%. A two-interval forced-choice task is used with an AM rate of 4 Hz in one interval and 8 Hz in the other. The task is to indicate the interval with the “faster” AM. The target sound is presented together with interfering sounds with carriers centered on channel N-1, N+1, or both N-1 and N+1. The mean level of each carrier is selected to match the level of the speech falling within the given channel for speech at 65 dB SPL. The signal envelope is scaled by a factor S, the modulation envelopes by M. An adaptive procedure varies both S and M to determine the ratio of S/M giving 71% correct discrimination of the target. A “bad” target channel is indicated by a high value for S/M: greater, for example, than the starting ratio of 8. Three groups were tested: group 1) eight normal hearing (NH) participants tested under headphones, group 2) six CI users where typically 6 adjacent pairs of channels were assessed twice to study test-retest and group 3) eight CI users where all of their active channels were assessed and programs created with the 4 channels having the highest S/M ratios deactivated.

For group 1 there was substantial learning over the first five runs made. After this, the mean S/M ratio across participants was 3.5. No significant learning effect was found for the CI groups, with group 2 showing no significant difference ($p>0.05$) for two runs of test-retest repeatibility. For group 3 the mean S/M ratio across all active channels and participants was 29.4. Removing one outlier channel from each participant dropped the ratio to 3.5. The outlier was often a basal channel. Dropping a total of the 4 poorest channels per participant dropped the mean S/M ratio across participants further to 2.0. The evaluation of programs based on these deleted channels is currently underway.

A lack of learning for CI users indicates that the task relates well to the everyday use of the CI, so suggests relevance. When tested with comparible sounds, the CI groups performed as well as the NH particpants, once a single outlier CI channel was neglected. When deleting the 4 chanels having the hightst S/M ratio, the CI users actually outperformed the NH users ($p<0.03$). Testing all channels took between 45 and 75 minutes. Self-driven testing, either at home or in the clinic, or a shorter test would be needed prior to clinical deployment.

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M47: SPREAD OF EXCITATION WITH INCREASING PULSE AMPLITUDE OR PHASE DURATION

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Introduction: In cochlear implants (CIs), electric charge for a pulse is coded by pulse amplitude (PA) and pulse duration (PD). In this study, we compared how changes in PA or PD affected spread of neural excitation (SOE) for equally loud stimuli using a forward masking paradigm. Increasing PA with a fixed PD increases the current spread, thereby recruiting a larger number of neurons from distant locations resulting a wide spread of neural excitation (SOE). Increasing PD with a fixed PA does not increase current spread, but increases the probability of neural firing within the extent of the current field. We hypothesized that for equally loud stimuli, SOE may be greater with relatively high PA/short PD than for low PA/long PD. SOE was also compared to speech reception thresholds (SRTs) in noise to test the hypothesis that greater SOE is associated with poorer SRTs.

Methods: Subjects included 10 adult users of Cochlear Nucleus CIs. All masker stimuli were biphasic pulse trains presented at 1000 pulses per second (pps) to a middle electrode (11) for 300 ms. First, the dynamic range (DR) was estimated for the PA and PD maskers. Loudness growth functions were estimated for increasing PD or PA on a linear scale. PA maskers were loudness-balanced to PD reference maskers presented at 30, 50, or 70% DR using a method of adjustment. Thus, at low, medium, and high masker presentation levels, the PA and PD maskers were equally loud. Next, unmasked thresholds were measured for probe stimuli presented on electrodes 8-14 using an adaptive, three-alternative forced-choice (3AFC) procedure. Probe stimuli were 20 ms in duration, 1000 pps, with a fixed PD of 100 us/ph. The PA of the probe stimulus was adapted according to subject response. Next, masked thresholds for each probe were measured for the equally loud PA and PD maskers presented at low, medium, or high presentation level. The amount of masking was quantified as the threshold shift in dB. For each condition, threshold shifts were normalized to the peak masking (usually at electrode 11). The slopes of linear fits to the apical and basal sides of the masking functions were estimated and averaged. SRTs for CUNY sentences presented in amplitude-modulated noise were measured using an adaptive procedure. A sentence in noise was presented at the target signal-to-noise ratio (SNR), the subject repeated the sentence as accurately as possible, and the level of the noise was adapted from trial to trial in 2 dB steps according to subject response (initial SNR=20 dB).

Results: Loudness growth was steeper with increasing PD than PA as a function of % DR, but shallower as function of charge. A two-way repeated-measures analysis of variance (RM ANOVA) showed no significant effect for presentation level ($F_{2,18} = 2.10$, $p = 0.15$), but a significant effect of masker type ($F_{1,9} = 12.17$, $p = 0.007$), with narrower SOE for the PD than the PA masker at equal loudness. Post-hoc pairwise comparisons showed a significant difference between the PA and PD masker only at the low presentation level ($t_9 = 3.85$, $p<0.05$). The slope of the PA masker at the low presentation was significantly correlated with SRTs ($r = 0.63$, $p = 0.025$), with wider SOE associated with poorer speech recognition in noise ($r = -0.73$, $p = 0.014$). The difference in SOE slope between the PD and PA maskers at the low presentation level was also correlated with SRTs. This suggests that subjects with poorer SRTs may benefit from longer PDs at low levels.

Discussion: Our data suggest that SOE with electric hearing does not change with increasing loudness, consistent with previous studies (e.g., Chatterjee et al., 2006). At equal loudness, low PA/long PD produced less SOE than high PA/short PD at the low presentation level. It is possible that the longer PD was effective at increasing the firing probability of local, less sensitive neurons that were less responsive with the shorter PD. The data also suggest that subjects with poor speech recognition in noise, if due to increased channel interaction, may benefit from using longer phase durations to reduce SOE.

M48: PITCH MATCHING: ELECTRODE LOCATION OR PROCEDURAL ARTIFACT?

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Sequential pitch matching is one of the most common methods used in cochlear-implant (CI) research to identify the relative places of stimulation in two ears. Pitch perception inevitably depends on the neural population stimulated, but may be influenced by plasticity and non-sensory biases. This study examined the extent to which pitch matching provides information about cochlear place of stimulation in bilateral (BI) and single-sided deafness (SSD) CI users via comparison to composition-tomography (CT) scans.

BI-CI listeners made pairwise sequential comparisons to pitch-rank a subset of electrodes in both ears. SSD-CI listeners ranked a subset of the electrodes in the CI ear and a range of pure tones in the acoustic ear. The insertion angle for each electrode was estimated using an anatomical model based on high-resolution micro-CT scans of cadaver temporal bones, and converted to an equivalent frequency based the spiral-ganglion place map of Stakhovskaya et al. (2007).

The results generally showed a weak relationship between the CT-scan predictions and individual pitch-ranking results for individual listeners. However, the group-average data were well-defined and showed a different pattern of results for the BI-CI and SSD-CI listener groups. For the 20 BI-CI listeners, the average pitch matches coincided closely with the average CT-scan predictions across the electrode array. For the 15 SSD-CI listeners, average pitch matches were much lower than the average CT-scan predictions in the middle and at the basal end of the array, and slightly higher at the apex.

Four possible explanations for this pattern of results are discussed, with the first two explanations representing methodological biases and the last two representing an actual shift in the perceived pitch relative to the electrode location. (1) SSD-CI listeners might place less weight on the pitch of the electrical stimulus and more weight on the pitch of each acoustic stimulus relative to the fixed range of acoustic pitches. (2) The average pitch-matching responses are shifted away from the edges of the acoustic comparison range because of a truncation effect. (3) The pitch percept might have adapted over time to the clinical map for SSD-CI listeners, but not for the BI-CI listeners who have much less interaural place mismatch. (4) The neural place of stimulation is shifted due to asymmetric neural excitation, which would be less likely to affect the BI-CI listeners who would have similar shifts in both ears.
In summary, pitch ranking does a poor job at identifying electrode locations for an individual listener. For the group-average data, methodological biases in the pitch-ranking procedure need to be ruled out before it can be concluded that the electric-acoustic pitch-ranking results truly reflect a shift in the perceived pitch relative to the CT-scan predictions.

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M49: EFFECT OF NUMBER OF ACTIVE ELECTRODES AND CHANNEL STIMULATION RATE ON SPEECH RECOGNITION AND SOUND QUALITY

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Cochlear implant signal processing is confined by poor spectral resolution, whether due to a limited number of electrodes, channel interaction, unknown survival pattern of spiral ganglion cells, as well as potentially inadequate access to temporal cues. To address these limitations, high stimulation rates are often used in CI devices because they offer better temporal sampling, increase the electrical dynamic range by reducing threshold stimulation levels (Hong and Rubinstein, 2003), and induce pseudo-stochastic firing of auditory neurons (Litvak et al, 2003). However, previous studies examining the effects of high stimulation rates have yielded inconsistent results on improving speech outcomes (Loizou et al., 2000; Friesen et al., 2005; Shannon et al., 2011), potentially due to differences in experimental methods, speech materials, CI technology, as well as unknown electrode placement across participants. The latter point is relevant given that research has shown that temporal modulation detection is correlated with spatial tuning curves for adult CI users (Zhou et al., 2018).

The objective of the current study was to determine the relationship between number of active electrodes, stimulation rate, and the interaction between these two parameters on speech recognition and sound quality measures, while controlling for electrode placement. Listeners with electrodes completely in scala tympani and closer to the modiolus using current CI devices, were hypothesized to be able to utilize higher stimulation rates to achieve better speech recognition performance and sound quality ratings than listeners using older technology.

Electrode scalar location was determined by CT imaging using validated CI position analysis software (Noble et al, 2014) in 6 (with anticipated 8) participants with Advanced Bionics devices and Mid-Scala electrodes. Participants were acutely assessed using a variety of auditory and speech measures, as well as measures of sound quality. Sound processors using 4-, 8-,12- or 16-electrodes, were each mapped with target stimulation rates of 600, 1200, 2400 or 4800 pps, to replicate the experimental conditions of Shannon et al., 2011.

Preliminary results suggest no significant differences in speech recognition performance or sound quality ratings as stimulation rates increased from 600 to 4800 pps. This finding is largely consistent with previous studies (Loizou et al., 2000; Shannon et al., 2011), indicating no significant improvements on speech recognition performance or sound quality ratings with high stimulation rates, even for listeners with precurved electrodes. Collapsing across stimulation rates, we observed no significant differences beyond 8 active channels for all speech and sound quality measures, with the exception of AzBio sentences in +5 dB SNR scores and sound quality ratings, which trended towards continuous improvements up to 12 active channels. These results are largely consistent with previous literature (Friesen et al., 2001), but also support more recent studies that have suggested more than 8 channels are needed for asymptotic speech recognition in noise and sound quality for pre-curved electrode recipients (Croghan et al., 2017; Berg et al., in press). Additional analyses are planned to investigate the relationship between mean electrode-to-modiolus distance and channel independence as well as the impact on temporal processing in this sample.

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M50: HOW MANY CHANNELS DO PEDIATRIC COCHLEAR IMPLANT USERS NEED FOR MAXIMUM PERFORMANCE?

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Rationale: Current cochlear implant (CI) stimulation relies on electrical pulses propagated through highly conductive fluid, which result in imprecise excitation patterns and poor spectral resolution (e.g., Hughes et al., 2013; Jeon et al., 2015; Padilla & Landsberger, 2016). As a result of this phenomenon, seminal CI channel studies have shown that CI users only have access to 5-8 independent channels despite having access to up to 22 intracochlear electrodes (Fishman et al., 1997; Loizou et al., 2000; Friesen et al., 2001). Very recently, our lab replicated the Friesen et al. (2011) study with adults using current generation technology implanted using modern surgical approaches. Berg et al. (2019) found that adult CI users with precurved electrode arrays achieved significantly greater performance with 16- versus 8-channel CIS for speech in quiet and that 16 channels in a 16-of-m strategy yielded significantly higher outcomes than 8- and 10-channel CIS for a number of speech and auditory perceptual tasks as well as subjective sound quality. This relationship between number of active channels and speech recognition performance has yet to be studied in pediatric CI recipients. Previous simulation studies have shown that children do not employ spectral cues in the same way that adults do, so further investigation in the pediatric population is warranted (e.g., Eisenberg et al., 2000; Warner-Czyz et al., 2014). The current study was undertaken to investigate channel independence for speech recognition for children implanted with precurved electrode arrays. We hypothesized that speech recognition performance would increase beyond 8 channels based on our lab's recent findings for adults.

Methods: We investigated the number of channels needed for maximum speech recognition in six pediatric CI users with precurved electrode arrays. Spatially selective CI programs were created using methods described by Friesen et al. (2001) using 4, 8, 12, 16, and 22 active electrodes. For the 22-electrode condition, children were tested with 8 and 16 maxima using an n-of-m strategy; all other channel conditions employed continuous interleaved sampling (CIS). Speech recognition was assessed using monosyllabic words and sentences in noise for each condition.

Results: Maximum average performance for AzBio/BabyBio +5 dB SNR (86%) and CNC monosyllabic word recognition (82%) was measured with 22 electrodes and 16 maxima. When comparing CIS strategies, the 12-channel condition was not statistically different from the 16 or 22-channel conditions. When comparing n-of-m strategies (8 vs. 16 maxima), the 16 maxima condition yielded higher CNC and AzBio/BabyBio scores, but the difference was not statistically significant.

Conclusions: These preliminary data demonstrate greater channel independence for pediatric CI recipients with precurved electrode arrays as compared to previous studies with straight electrodes. Specifically, children demonstrate performance gains with up to 12 channels in a CIS strategy. We speculate that greater channel independence results in better spectral resolution and ultimately better temporal resolution (Zhou et al., 2018). Further investigation is needed to parse out the contributions of spectral and temporal processing as increasing the number of channels in a CIS strategy without manipulation of interpulse interval results in greater overall stimulation rate. Nonetheless, consistent with our adult data, children may benefit from more channels than previously thought. These findings have clinical implications for electrode design, channel selection, and device selection for[JG32]

M51: FREQUENCY WARPING AND SPEECH INTELLIGIBILITY IN COCHLEAR IMPLANT LISTENERS

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When the electrode array is inserted into the cochlea during cochlear implant surgery, the most apical electrode is often about a full turn to a turn and a half in from the cochlear base. It is well-known that low-frequency speech information is important for good speech reception, so the current clinical practice is to extend analysis filters downward to about 100 Hz, despite the fact that there are no electrodes to stimulate the corresponding regions of the auditory nerve. Instead, low-frequency envelope information is delivered to the most apical electrodes, which means delivering it to regions of auditory nerve that typically encode higher frequency information. This upward frequency shift of envelope information is referred to as frequency warping, and is known to be detrimental to speech reception. We examined several approaches to address warping. In a no-warping condition, all analysis bands were centered on their respective electrode frequencies, and low-frequency information was discarded. In other conditions, all but one or two bands were centered, and the lowest one or two frequency bands were extended downward to cover the entire usable spectrum. Speech intelligibility of normal-hearing participants listening to vocoded sentence materials was measured in acute presentations of these conditions, and results showed that no-warping and 1-channel of warping produced significantly improved speech intelligibility over the standard clinical map. These results suggest that best practice may be to deliver envelope information to the correct frequency place, even if it means discarding information to do so.

M52: MODULATION FREQUENCY DISCRIMINATION INTERFERENCE IN COCHLEAR IMPLANT USERS

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Most stimulation strategies used with cochlear implants (CIs) convey acoustic information by envelope modulations across multiple stimulating electrodes. A sense of musical pitch can be transmitted by modulation frequency of constant-rate pulsatile stimulation, but studies have found that this sense of pitch is weak compared to the sense of pitch observed in normal-hearing listeners provided by harmonic complexes, even when harmonic complexes are solely comprised of unresolved harmonics. One promising study was conducted by Kreft et al., 2013, in which they examined modulation frequency discrimination in the presence of interfering modulations with normal-hearing listeners and CI users. While their interpretation of the results focused on the impoverished nature of the modulation cue and its susceptibility to distortion, they also uncovered that modulation frequency discrimination appears to be robust to interference from higher frequency distortions. The present study examines the robustness of modulation frequency discrimination in the presence of interfering stimulation. Modulation frequency discrimination is measured using a 2-interval, 2-alternative, pitch ranking procedure. In the acoustic version (NHL and CI users), modulation frequency discrimination is measured for sinusoidally amplitude modulated (SAM) tones in the presence of interfering SAM tones. In the electrode psychophysics version, modulation frequency discrimination is measured for SAM pulse trains in the presence of interfering SAM pulse trains. For the acoustic paradigm, both normal-hearing listeners and CI users show a clear frequency-tuning in their results with poorer performance observed when the interfering tone carrier frequency is closer to the target tone carrier frequency. However, for the electric paradigm, a wider range of results have been observed with many CI users able to discriminate change of a target modulation frequency of a SAM pulse train even when the interfering SAM pulse train (with independently roved modulation frequency) is presented simultaneously on the same electrode. Preliminary results confirm the positive trends uncovered by Kreft et al., 2013, that modulation frequency discrimination is relatively robust to interference from a relatively high-frequency modulator and, further, that measures of such discrimination using controlled electrode psychophysics is less affected by spatial proximity of the interference. While pitch perception based on modulation frequency is poorer than that observed in normal-hearing listeners attending to harmonic complexes, it is robust in the presence of interfering stimulation and may serve as an important cue for high-level auditory stream segregation.

M53: AMPLITUDE MODULATION DEPTH DISCRIMINATION BY COCHLEAR IMPLANT USERS

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Cochlear implants (CIs) convey the envelopes of speech sounds by modulating high-rate pulse trains. However, not all of the dynamic range (DR) may be perceived by users. We studied the effective portion of the DR contributing to the perception of AM depth (AMD) by CI users, and its dependence on AM rate.

10 users of the Cochlear device took part in three experiments. For each experiment, standard stimuli were 1000-pps 448-ms pulse trains modulated at 100% of DR, presented on electrode 16 in monopolar mode. Modulation rates of 15.625, 31.25, 62.5, 125 and 250 Hz were tested. AMD thresholds were obtained using adaptive tracks to find the value giving 79% correct discrimination. Exp. 1 used 3-Interval 2AFC adaptive trials with feedback. The signal differed from the standard only in its AMD. Peak amplitude for all stimuli was fixed at C level, and signal AMD was adjusted to determine the threshold (AMDT). Participants could use any cue, including loudness, to identify which stimulus was different. Stimuli in Exp. 2 were identical to those in Exp. 1, but 2-Interval 2AFC trials were used, in which participants were instructed to ignore loudness cues. Participants were asked 'which is less wobbly?' or 'which is the higher pitch?' depending on modulation rate. To determine whether loudness was being ignored 'catch trials' were inserted, in which the less-modulated signal was softer than the standard. Feedback was provided except for catch trials and 14% of regular trials. Exp. 3 employed 3-Interval 2AFC trials with feedback. Here the signal was identical to the standard above a 'deviation point'. Below this point the stimulus trough was duplicated and time-compressed by a factor of two. The position of this deviation point was adaptively varied to obtain a threshold. The standard and signal had identical peak and RMS level and hence were presumed to have equal loudness. Participants had to identify the 'different' stimulus in each trial. A control condition was included, in which the stimulus was truncated above the deviation point, to determine potential contributions of forward masking or cue level to the task.

In Exp. 1 modulation rate significantly affected AMDTs, which were best at the 31.25-Hz rate. AMDTs worsened at higher rates, consistent with the expected influence of forward masking by the modulation peaks, and at 15.625 Hz, where there were only seven modulation cycles. For Exp. 2, in 80% of subject/AM rate combinations, catch-trial accuracy was greater than 50%, indicating that participants were not using loudness cues. The effect of modulation rate was not significant but was broadly similar to that in Exp. 1. Overall, AMDTs were about 35% DR and worse than in Exp. 1. In Exp. 3, thresholds for the deviation points were surprisingly very poor at all rates, and were typically less than 10% DR; hence participants were sensitive only to changes near stimulus peaks. No dependence of thresholds on modulation rate was observed, suggesting that forward masking was not limiting performance. Performance was improved in the control conditions, but was still poor, perhaps reflecting that stimulus peaks were still predominately uninformative, or that discriminating changes in the lower part of the DR is difficult per se. Overall the results show that listeners are largely insensitive to the modulation pattern of a large lower portion of the dynamic range. Implications for processing strategies and for theories of modulation perception will be discussed.

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M54: COMPARING ANALOG AND PULSATILE STRATEGIES USING PRIMARILY TEMPORAL INFORMATION

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Early cochlear implants (CI) used analog stimulation which was eventually replaced with interleaved pulsatile stimulation to reduce both power consumption and electric field interactions. However, a sizable proportion of CI users who have had the opportunity to use both analog and pulsatile strategies prefer the analog strategies. Stupak et al. (2018) demonstrated that analog stimulation provides different perceptual qualities than pulsatile stimulation, but what those qualities are is still undetermined. It is possible that analog stimulation, which might better represent a waveform than pulsatile stimulation, may have an advantage for encoding temporal information.

In the present study, we implement single-channel analog and pulsatile strategies. This allows evaluation of performance without useful spectral information or channel interactions. Both maps were programmed into a body-worn Advanced Bionics Platinum Series Processor (PSP) using SCLIN software; Analog stimulation was implemented with the SAS strategy, pulsatile stimulation was implemented with the CIS strategy. In both maps, only electrode 1 was active and represented a frequency range of about 250-700 Hz. Stimulation for both strategies was in monopolar mode. Subjects were given a short time to adapt to each strategy by listening and simultaneously reading along to an audio book for 20 minutes. Afterwards, performance was evaluated on vowel and consonant identification as well as a pitch direction task (Melodic Contour Interval; Galvin et al., 2007).

Pilot data has been collected with 2 subjects. Despite the 20 minutes of adaptation, performance on the vowel task was near chance for both subjects using the pulsatile strategy. However, using the single-channel analog strategy, one subject remained at chance for vowel identification while the other was able to identify 32% of vowels (d' = 1). Performance was near chance for both subjects with both strategies for consonant identification. For the MCI task, one subject performed similarly with both strategies while the other improved noticeably with the analog strategy. Data with more subjects will be presented.

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M55: USING AUTOMATIC SPEECH RECOGNITION AND SPEECH SYNTHESIS TO IMPROVE SPEECH INTELLIGIBILITY FOR COCHLEAR IMPLANT USERS IN REVERBERANT AND NOISY LISTENING ENVIRONMENTS

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Cochlear implant (CI) recipients have difficulty understanding speech in listening environments with reverberation and noise. One speech enhancement strategy, proposed by Hazrati et al. (2015), used automatic speech recognition (ASR) to convert a reverberant speech signal into a hypothesized word sequence. The decoded sequence was then used as the input to a speech synthesizer to regenerate an anechoic speech signal. Hazrati et al. (2015) trained the Kaldi ASR toolkit (Povey et al., 2011) to recognize speech in both anechoic and reverberant conditions using various recorded room impulse responses (RIRs) and reverberation times. Compared to the unmitigated reverberant condition, the approach improved the intelligibility for CI users in reverberant listening environments. However, this strategy cannot be implemented in real-time because it uses a non-causal ASR model, which requires knowledge of the future signal as well as the identity of the speaker.

If a causal ASR model is used instead, the strategy proposed by Hazrati et al. (2015) has the potential for real-time implementation. In this study, we implemented the recognition-synthesis approach using a causal ASR model that does not depend on future acoustic information. Because the accuracy of the recognized word sequence greatly influences the listener's intelligibility, this research focused primarily on developing an ASR model that is robust to both reverberation and noise. A speech recognition model was trained on multi-condition sentences with different reverberation times and noise types. To evaluate the performance, the trained model was used to decode sentences from a separate testing database, and the hypothesized word sequences were compared with the known text transcriptions. Results will be presented for ASR experiments, as well as the performance of normal hearing subjects on listening tasks using vocoded speech.

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M56: EVALUATING INDIVIDUALIZED COCHLEAR IMPLANT PROCESSORS WHOSE SITES OF STIMULATION WERE SELECTED USING THE INTERPHASE GAP EFFECT AND A COMBINATION OF PHYSICAL AND VIRTUAL ELECTRODES

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One hypothesized source of variability in outcomes with cochlear implants (CIs) is the health of the auditory periphery. Evoked compound actional potentials (ECAPs) can be used to make direct measurements of peripheral neural responses, and animal model studies have shown that the ECAP-based interphase gap (IPG) effect, which is the difference between the slopes of two ECAP amplitude growth functions (AGFs) measured in response to waveforms with two different IPGs, is highly correlated with spiral ganglion cell packing density (e.g., Ramekers et al., 2014, J Assoc Res Otolaryngol, 15, 187-202). It has also been shown that, for bilateral users, the between-ear difference in the across-site mean IPG effect is correlated with the between-ear difference in speech recognition measures (Schvartz-Leyzac et al., 2018, Ear Hear, 39, 344-358). Thus, we sought to test the hypothesis that increasing the mean IPG effect within single ears would improve speech recognition abilities. Additionally, rather than limit site selection to physical electrodes, the IPG effect was measured for both physical and virtual electrodes, where virtual electrodes corresponded to parallel stimulation by two adjacent physical electrodes.

In the first part of this study, virtual electrodes were compared to physical electrodes using ECAP waveforms and compound discharge latency distributions, AGF slopes, and the IPG effect. Although several investigators have previously compared virtual electrodes to physical electrodes using ECAP-based measures, such as spread of excitation, to our knowledge, this study is the first to do so in patients implanted with CIs manufactured by MED-EL, and to assess AGF slopes and IPG effect for virtual sites. The difference in device manufacturer is noteworthy because electrode arrays made by MED-EL typically (1) extend to more apical regions of the cochlea, and (2) have a wider electrode spacing compared to previously studied devices.

In the second part of this study, the IPG effect was measured at every electrode. Processors were then created with the aim of using the IPG effect for controlling stimulation. For all processors, the most apical and basal electrodes were always fixed to preserve the total stimulated cochlear region.

Two different versions of each processor were created, one in which the frequency allocation of the filter bank was fixed across processing conditions and equivalent to MED-EL's clinical, modified logarithmic distribution of center frequencies (Logarithmic FS), and a second in which the filter bank center frequencies were adjusted based on the selected sites of stimulation. The latter set of processors was implemented to mitigate the potential confound of changes to the place-frequency map (due to changes in electrode assignments for each frequency band) during the acute behavioral evaluation of the processors.

Subjects performed monosyllabic words tests and sentence tests in quiet and in noise, with stimuli delivered via the MAX clinical interface controlled by software developed for the Research Interface Box, version 2 (RIB2) and custom research software. ECAP measures and speech recognition data obtained with the individually-optimized processors will be presented.

M57: INDIVIDUALIZING ELECTRIC FREQUENCY FILTER ASSIGNMENTS FOR COCHLEAR IMPLANT AND ELECTRIC-ACOUSTIC STIMULATION DEVICES: NORMAL-HEARING SIMULATIONS

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Cochlear implant (CI) and electric-acoustic stimulation (EAS) device users demonstrate variable rates of speech perception acclimatization within the initial months of device use. Performance variability may be due in large part to a frequency-to-place mismatch created by the default mapping procedures of the electric frequency filter assignments. For patients listening with the CI-alone, the default mapping procedure distributes the speech spectrum logarithmically across the active electrodes. For patients listening with EAS, the default mapping procedure identifies the frequency at which unaided acoustic hearing exceeds a criterion level (e.g., 65 dB HL) and presents that low-frequency information on the most apical electrode; the remaining mid- to high-frequency information is distributed logarithmically across the remaining active electrodes. While default mapping procedures ensure full representation of the speech signal, they do not consider the natural tonotopic place of stimulation. Electrode array angular insertion depth (AID) varies across patients, and is dependent upon the cochlear anatomy, electrode array design, and surgical approach. Therefore, the default procedures can create a discrepancy between the place of stimulation and the natural tonotopic organization of the cochlea, known as a frequency-to-place mismatch. The magnitude of the frequency-to-place mismatch may influence speech perception variability during the initial months of device use.

We investigated the effectiveness of a place-based mapping procedure that incorporates the AID of individual electrodes into the device's filter assignments. Imaging algorithms use the postoperative CT scan to calculate the AID, which is used to estimate the cochlear place frequency based on the spiral ganglion function. With the place-based procedure, the frequency filter assignments of individual electrodes are adjusted to match the cochlear place frequency. As a first step to evaluating the efficacy if this approach we tested normal-hearing subjects who were randomized to listen to a simulation of a CI-alone or EAS device that was mapped with either the default or place-based procedure. Subjects were asked to recognize AzBio sentences presented in multi-talker babble at increasing signal-to-noise ratios. A noise vocoder simulated the electric component of a CI-alone and EAS device, and low-pass filtered speech simulated the acoustic component of an EAS device. The simulation parameters were based on the AID of individual electrodes for an actual Flex24 electrode array recipient. There were two conditions for this simulation: 1) low-frequency hearing preservation and use of an EAS device, or 2) low-frequency hearing loss and use of a CI-alone device.

Subjects demonstrated better speech perception and less performance variability when listening with a place-based map as opposed to the default map in both conditions (with and without simulated hearing preservation). This indicates that matching the electric frequency filters to the cochlear place frequency may improve the initial speech perception with CI and EAS devices and reduce the acclimatization required for asymptotic performance. Critical evaluation of the variables that may contribute to early speech perception performance is needed to support optimal outcomes in CI and EAS device users.

M58: INDIVIDUALIZING ELECTRIC FREQUENCY FILTERS FOR COCHLEAR IMPLANT AND ELECTRIC-ACOUSTIC STIMULATION DEVICES: PATIENT DATA

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Cochlear implant (CI) and electric-acoustic stimulation (EAS) device users experience variable rates of speech recognition acclimatization within the initial months of device use. This variability is impacted by a combination of patient variables (e.g., hearing detection, duration of deafness) and device variables (e.g., electrode array location, mapping procedures). Optimizing the device variables therefore offers tremendous potential for improving speech recognition of CI-alone and EAS device users. The angular insertion depth (AID) varies widely across patients, determined primarily by the length of the electrode array and the cochlear duct length. The default mapping procedures for CI-alone and EAS devices do not incorporate the variability in AID into the electric frequency filter assignments, which can result in marked frequency-to-place mismatches. Deviations between place of electric stimulation and the natural cochlear tonotopicity may degrade initial speech recognition of CI-alone and EAS device users, an idea that is supported by CI-alone and EAS device simulation data in listeners with normal hearing. In this experiment we test the hypothesis that a place-based mapping procedure, which adjusts the frequency filter assignments of individual electrodes to match the cochlear place frequency, reduces the frequency-to-place mismatch and improves the initial speech recognition of CI-alone and EAS device users.

We are conducting an ongoing investigation of the effectiveness of a place-based mapping procedure as compared to the default mapping procedure in CI-alone and EAS device users. Subjects are recruited at initial activation of their device or within two months of activation, to limit the influence of listening experience on speech recognition performance. Speech recognition is assessed using CNC words in quiet for three maps: the default map, a place-based map using the spiral ganglion function (Stakhovskaya et al., 2007), and a place-based map using the Greenwood function (Greenwood, 1961). The subjects and the tester are blinded to the mapping procedure for each condition.

Preliminary results indicate that CI-alone and EAS device users have better speech recognition and report improved sound quality with a place-based map as compared to the default map. Performance differences between the place-based maps using the spiral ganglion function versus the Greenwood function will be discussed. These findings indicate that matching electric frequency filter assignments to the cochlear place frequency may reduce the acclimatization period for CI-alone and EAS device users. Individualizing the mapping of CI-alone and EAS devices by incorporating patient and device variables may reduce the variability in initial speech recognition.

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M59: MASK ESTIMATION MODELS FOR REVERBERANT ARTIFACT REMOVAL IN COCHLEAR IMPLANT PULSE TRAINS

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Cochlear implant (CI) users experience far larger degradations in speech intelligibility in reverberant environments than their normal-hearing counterparts (Kokkinakis, Hazrati, and Loizou, 2011). Reverberation occurs when sound reflects off of surfaces in an enclosure, after the enclosure has been excited by an impulsive sound source. Reverberation can be characterized as the convolution of a sound with an acoustic room impulse response (RIR). Late reverberant reflections which arrive at a listener after the termination of a phoneme obscure the gaps between phonemes. Removing the reverberant artifacts between phonemes can significantly recover speech intelligibility for CI users in reverberation (Desmond et al. 2014; Kressner et al. 2018).

To remove reverberant artifacts between phonemes, the technique of time-frequency masking can be used to determine which time-frequency units of a signal to retain or discard based on a measure of the local signal and interference energies. In the CI framework, knowledge of the clean signal energy is unavailable, and so mask values can be estimated from the reverberant signal using machine learning algorithms. Current approaches for estimating mask values have not considered the constraints of a cochlear implant system. CIs require enhanced speech to be obtained in real-time with minimal computational delays and current approaches have used non-causal information (i.e., information from the future signal), inhibiting real-time processing. Also, to benefit CI users in reverberation, mask estimation algorithms must be able to generalize to novel scenarios, such as new speakers and new reverberant conditions. Even though reverberation is well-characterized as a linear process, slight shifts in source or receiver position may lead to large changes in the RIR (Kokkinakis and Loizou, 2009). A nonlinear algorithm may model the effects of a changing RIR on mask estimation better than a linear model and therefore may generalize better to unseen reverberant conditions. While previous approaches used nonlinear models, the application of these models to the cochlear implant framework was limited by their parametric complexity.

The literature is lacking a comparison of algorithms for mask estimation in reverberation within the CI processing framework. This work will explore a range of models for estimating time-frequency masks to mitigate reverberation in cochlear implant pulse trains, by comparing their generalization to new speakers and new reverberant conditions. Specifically, we will test a range of causal linear and nonlinear models, with the hypothesis that nonlinear models will generalize better to previously unseen realizations of reverberation. This work will investigate model robustness in varying reverberant environments and the tradeoff between model generalization capabilities and parametric complexity. The algorithm performance, measured as the mean-squared error of the estimated mask or the area under the receiver operating characteristic curve for the detection of reverberant-dominant mask values, will be reported. Additionally, we will report the resulting speech intelligibility of normal hearing subjects when tested with reverberant speech vocoded to simulate CI processing and mitigated by the investigated algorithms.

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M60: A REAL-TIME NOISE REDUCTION ALGORITHM BY ESTIMATING SPEECH GAP FOR COCHLEAR IMPLANT

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Background noise can strongly affect the speech intelligibility of cochlear implant (CI) recipients, and it is generally detrimental to their speech perception even at moderate signal-to-noise levels. To reduce noise, a cochlear implant should have the capability of distinguishing background noise segments from the microphone's input audio signals. In this study, a specific single-channel noise reduction algorithm utilizing adaptive noise estimation and spectral subtraction was developed for cochlear implants.

Firstly, the input signals were converted into 128 frequency bands by WOLA (Weighted Overlap Add) spectral analysis. Then, a signal gap detection algorithm was used to track the energy troughs of the input audio signal. The trough detection algorithm utilized a mechanism similar to the charging and discharging of a capacitor in an envelope detector, which offered the ability to estimate the noise floor. Once a local energy trough was detected, the WOLA spectral templates of background noise were updated accordingly. An estimated noise spectrum was derived by averaging all the stored spectral templates of the estimated noise. Finally, channel gains used to attenuate frequency bands dominated by noise were calculated based on the spectral subtraction algorithm. To evaluate the effects of noise reduction, an audio signal was re-synthesized from the spectrally attenuated WOLA signals.

The proposed noise reduction algorithm was simulated through offline processing in Matlab, and it was also implemented in real time on the Ezairo 7150SL (On Semiconductor Corporation) DSP platform with a WOLA co-processor. Initial evaluation results showed that the algorithm can reduce the background noise in different environments successfully. The signal-to-noise (SNR) ratio can be improved by up to 20 dB after noise removal.

M61: LONG-TERM EVALUATION OF SINGLE-SIDED DEAF AND ASYMMETRIC HEARING-IMPAIRED CI RECIPIENTS

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Introduction. The aim of the present study was to investigate the long-term benefits of cochlea implants (CI) in single-sided deaf (SSD) and asymmetric hearing impaired (AHL) patients. Long-term was defined as more than 3 years after initial fitting of the CI. The wearing behavior, subjective benefits of the CI and auditory hearing rehabilitation were investigated.

Methods. Validated questionnaires were used to determine the daily wearing behavior (IIEH), the subjective benefit of the CI (SSQ) as well as the subjective quality of life (HUI Mark 2/3) and subjective evaluation of the tinnitus (visual scale). In addition, speech recognition in noise and localization ability were determined. The results of the above-mentioned examinations and questionnaires were collected, evaluated and compared at different points in time (preliminary examination, 12 months and >3 years).

Results. More than 85% of the included 78 CI recipients with SSD and AHL wear their CI for a daily average of 6 to 10 hours. Four CI recipients were non-users and one was dead at the time of evaluation. The wearing behavior of 9 % of the patients is unknown. Daily wearing behavior of the users was stable throughout the period surveyed. In addition, there was a significant positive correlation between the results in the subsections speech intelligibility and quality of speech in the SSQ and the wearing behavior in the IIEH. In the course of CI use, there was a significant improvement in subjective speech intelligibility and spatial resolution in the SSQ. Furthermore, speech recognition in noise (SssdNnh) and localization improved at 12 months and long term compared to the preliminary examination, respectively.

Conclusions, For the first time, we were able to examine a large number of CI recipients with AHL and SSD (n=78) in a long-term setting. The majority of participants wear their CI regularly over three years after implantation. In addition, the presented long-term study proves that SSD and AHL patient benefit from their CI in subjective speech intelligibility and spatial resolution as well as speech recognition in noise and localization stable for more than three years.

M62: SOCIAL FACTORS AND INDIVIDUAL OUTCOMES IN COCHLEAR IMPLANT USERS

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Background: Cochlear implants (CIs) can improve the quality of life for people with profound sensorineural hearing loss, but individual users struggle to varying degrees with different listening environments, which can negatively impact social well-being. In this study, our aim was to assess the social engagement of CI users in daily life and relate it to objective hearing outcomes.

Methods: Ecological Momentary Assessments (EMAs) collected using a Smartphone app were used to probe patterns of listening behavior in CI users in natural environments. These results were compared with those of normal hearing (NH) adults to detect differences in social engagement and overall quality of life. Speech perception measurements and difficulty ratings were also completed by CI users to uncover possible correlations between listening or social behaviors and overall success with the device.

Results: Preliminary data suggest that CI users consistently report more difficulty listening in everyday environments than NH peers, but also tend to be in environments with overall lower levels of background noise. Perception of listening difficulty is also very different for CI users and NH listeners, with CI users reporting little difficulty while speech perception performance is poor.

Conclusions: Overall, the data suggest that systematic differences exist between how CI users and NH adults navigate and manipulate listening and social environments in everyday life.

M63: QUALITY OF LIFE FOR ADULT COCHLEAR IMPLANT RECIPIENTS WITH ASYMMETRIC HEARING LOSS AS REPORTED BY PARTICIPANTS AND THEIR SIGNIFICANT OTHERS – INITIAL RESULTS OF A CLINICAL TRIAL

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Objective: Asymmetric hearing (severe to profound hearing loss in one ear and better hearing in the other ear) results in a lack of bilateral input and is detrimental to communication. Individuals with asymmetric hearing loss report difficulty with sound localization, speech understanding in noise, reduced sound quality and increased listening effort. Our initial work with this population has focused primarily on behavioral outcomes with limited data collection of participant reports. This study objective was to evaluate a broader range of quality of life measures, including reports of spouses and significant others in adults with asymmetric hearing who receive a cochlear implant (CI) in the poor ear and have mild to moderate hearing loss in the better ear. This is part of an ongoing longitudinal FDA-approved multi-center clinical trial.

Design: Post-lingual adults with at least six months of device use (n=16). To better characterize the impact of asymmetric hearing loss and CI as a treatment, Quality of Life assessments regarding health, communication, social/emotional consequences, perceived benefit and satisfaction were administered to the participant and spouse/significant other. Data collection occurred pre-implant and at 6 months post-implant. Results on Quality of Life measures are compared to results on behavioral measures.

Results: Group mean results on the Health Utility Index (HUI3), a measure of ability/disability in eight health dimensions indicated no decline in overall health as the result of CI. The Speech, Spatial and Sound Qualities (SSQ) probes speech recognition in various sound environments. The Hearing Handicap Inventory (HHIE/A) assesses the emotional and social consequences of hearing loss. Results on both measures indicated significant and substantial improvement pre- to post-implant. The Glasgow Benefit Inventory (GBI) was specifically developed for otorhinological conditions and interventions. On this measure at six months post-implant, participants reported receiving positive benefit from CI use, with the greatest benefit in areas related to communication and no decrement in areas related to physical health. Satisfaction with hearing devices was evaluated with The Satisfaction with Amplification in Daily Life (SADL), a measure that includes questions related to dependability and appearance of the devices as well as every day benefit. Group mean post-implant SADL scores indicate participants believed obtaining the CI was in their best interest and that the CI frequently aids with speech understanding. Most participants report that using the CI and hearing aid together was no more trouble than using hearing aid(s) alone. Reports from the spouse/significant other were obtained using The Communication Profile for the Hearing Impaired (CPHI), an assessment of adjustment to hearing loss and The Hearing Impaired Impact – Significant Other Profile (HII-SOP), which addresses the impact of hearing loss on the spouse/significant other (rather than on the participant) as reported by the spouse/significant other. Comparison of pre- to post-implant results on these two measures indicated an observed significant improvement in the participant's communication ability as well as a significant reduction in the negative impact of the participant's hearing loss on the quality of life for the spouse/significant other. Speech recognition and sound localization results also indicated improved performance at six months post-implant in the CI + hearing aid condition compared to the pre-implant bilateral hearing aid condition.

Conclusion: These study participants with asymmetric hearing attributed improvements in communication and quality of life to obtaining a CI for the poor ear and using it in conjunction with a better ear hearing aid. The surgical placement of the CI and management of the device did not negatively impact overall health or add undue burden. Communication improvements were identified by both the participants and their spouses/significant others. Areas of benefit encompassed understanding speech in quiet and in noise, sound localization, participating in social activities, emotional response to hearing loss, and quality of sound. In addition, quality of life improved for the spouses/significant others. Inclusion of participant report measures for individuals with asymmetric hearing is critical for capturing the deficits of hearing loss and benefits of treatment reported by this patient population. Funding Source NIH/NIDCD U01DC 014938

M64: ENVELOPE COMPRESSION AS A QUALIFYING FACTOR IN THE "EIGHT-CHANNEL LIMIT"

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It is common to use vocoders to approximate the performance of real cochlear implant (CI) patients with systematic control in listeners with normal hearing. In general, the literature suggests that spectral resolution in CI listeners is limited to eight channels, on the basis of both electrode-activation studies and also largely on the basis of vocoder studies where 8 spectral channels approximate CI performance rather well. In those studies however, envelope properties – especially envelope modulation depth – are preserved in a way that is not reflective of real electric hearing, where the dynamic range is severely compressed. We hypothesize, therefore, that the eight-channel estimate of spectral resolution would change if the temporal envelope of a vocoded stimulus is compressed in a way that better mimics CI dynamic range. Consistent with prior experiments where intelligibility changed as a function of the interaction of both spectral channels and also temporal resolution, we hypothesized that envelope compression would limit temporal resolution and thereby demand a higher number of spectral channels to approximate CI performance. When the temporal envelopes of vocoded speech channels were compressed in the current study, listeners require a greater number of spectral channels to reach the same level of intelligibility as eight-channel simulations with fully-modulated temporal envelopes. The commonly accepted eight-channel limit is therefore potentially an accidental consequence of overestimating temporal resolution and underestimating spectral resolution. Envelope compression should be incorporated into simulations of CIs so that spectral resolution can be estimated in the context of limiting factors known to be relevant to electric hearing.

M65: PURE TONE AUDIOMETRY VS. SPEECH AUDIOMETRY AS INCLUSION CRITERIA FOR COCHLEAR IMPLANTATION IN ADULTS

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Depending on the country, pure tone audiometry, unaided speech audiometry and/or best aided speech understanding are used as inclusion criteria for cochlear implantation (CI). Aim of this study is to examine the sensitivity of these preoperative measures for the improvement in speech understanding after CI. The effect will be illustrated by evaluating the old and newly introduced British and Flemish inclusion criteria. In addition, other factors, such as patient characteristics and implant/electrode types, were added into a prediction model to define other significant predictors for improvement in speech understanding after CI.

552 post-lingually deaf adults with CI, of which 9 were implanted bilaterally, were included. Pure tone audiometry (at 0.5, 1, 2 and 4 kHz), unaided speech audiometry and speech audiometry with best-fitted hearing aids were used as preoperative measures. Postoperatively, speech audiometry in the free field with only the CI was used to determine the benefit in speech understanding. All speech audiometry was conducted with the standard Dutch speech perception test of the Dutch society of audiology, consisting of phonetically balanced monosyllabic consonant-vowel-consonant words. The standard testing procedure consisted of 44 words per condition presented at 65dB. The various measures were compared by receiver operating characteristic (ROC) curves and a linear mixed model was used for prediction modelling.

The different preoperative measures were strongly correlated with each other (pure tone audiometry with unaided speech audiometry $R=-0.71$, $p<0.001$ and with best-aided speech audiometry $R=-0.575$, $p<0.001$, aided and unaided speech audiometry $R=0.74$, $p<0.001$). The ROC analysis showed that the best aided speech audiometry was statistically the best method for patient selection ($d'=1.36$) and the best predictor for improvement in speech understanding (explained variance 82%, $p<0.001$). Interestingly, almost no difference was found when including more pure tone audiometry points (old British criteria: 2 and 4 kHz $d'=0.78$; new British criteria: 0,5, 1, 2 and 4 kHz $d'=0.80$). Based on the Flemish, old and new British criteria, respectively 61%, 35% and 10% of the patients in our series would not be implanted, although all of them experienced an improvement in speech understanding after implantation. Better preoperative speech understanding ($p<0.001$), shorter duration of deafness ($p<0.05$) and a precurved electrode ($p<0.05$) appeared to be significant predictors for an improved speech understanding after CI.

It is concluded that - despite their strong correlation - the predictive value of pure tone audiometry, unaided and optimally aided speech audiometry for improvement in speech understanding with CI differs considerably. The best-aided speech audiometry appears to have the highest predictive value for improvement in speech understanding, making it the most appropriate measure to be used as an inclusion criterion for CI.

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M66: CONTEXT AND USER REQUIREMENTS FOR DIGITAL SPEECH THERAPY FOR THE SEVERELY HEARING IMPAIRED – FIRST RESULTS (THERESIAH)

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Goals: The aim of THERESIAH is to develop a digital therapy and documentation system for pronunciation and hearing training in at least severely hearing-impaired patients who suffer from speech and voice disorders due to insufficient auditory input (audiogenic speech disorders).

Motivation and approach: The THERESIAH project is developing a digital system consisting of the following modules: software modules for automated pronunciation evaluation using an automated speech recognition system (ASR), elements of adaptive training programs with listening and pronunciation exercises (PC or Tablet PC/Smartphone with headset), and the connection of electromyographic methods (EMG) for explorative investigation of articulatory muscle functions. Overall, tools are to be developed that continuously objectify articulation and pronunciation quality. Patients will have the opportunity to do exercises at home, self-determined and with a high training frequency. In addition, it is planned to support phoniatrists and speech therapists in the clinical environment and in postoperative outpatient therapy with new documentation functions.

Methods: N=12 medical experts (speech therapists, audiologists, and phoniatrists) were interviewed for the context and user analyses. N=50 patients with severe hearing loss (PTA > 60 dB at frequencies 0.5, 1.0, 2.0 + 4 kHZ better ear) and possible speech disorders were selected from a database of 1,700 hearing impaired patients. A total of N=23 patients were interviewed. Qualitative in-depth interviews and interviews with (partially) standardized questionnaires were conducted.

Context analyses: Data from disease-specific HrQoL questionnaires such as the Nijmegen Cochlear Implant Questionnaire (NCIQ, scale 'Speech production'; Hinderink et al., 2000) and the German version of the Articulation Handicap Index (AHI-12; Keilmann et al., 2017) showed that postlingually severe hearing impaired patients with a progressive or acute pattern reported a comparatively low severity of symptoms in terms of speech production and articulation. This was also supported by a study by Grundmann et al. (2019) with bimodal patients. Prelingually deaf / hearing impaired cochlear implant (CI) patients who were fitted with CI's at a late stage were identified as the primary target group. It was found that the THERESIAH system should be primarily used in outpatient speech therapy and that clinical CI rehabilitation can initiate outpatient care. The trustworthy speech therapist-patient dyad was assessed as essential and is to be supported by a digital therapy system, but not substituted.

According to expert interviews and literature reviews, the most common abnormalities are replacements or omissions of phonemes, as well as backshifting of phonemes, an increased voice pitch, a disturbance of nasality, an increased speaking speed, low sentence melody and other disturbances of prosody. Extensive diagnostic measurements will be carried out with the planned patient group in order to quantify the suspected abnormalities and, if necessary, to qualify further speech disorders.

User requirements analyses: Initial analyses of user requirements towards THERESIAH showed that a serious gamification approach with a high-resolution display of learning progress was desired by the respondents and that the incorrect or correct pronunciation of the patient should primarily be reported visually due to the model-oriented intervention approach, based on the Speech Motor Control Model from Perkell et al. (2000). In addition, EMG measurements were accepted as an additional diagnostic and training option in the clinical environment. Measurements are currently being carried out with a THERESIAH prototype in order to iteratively further develop the system. First results of this second iteration involving further prelingually deafened patients will be reported and discussed with regard to further development.

This work will be supported by the Federal Ministry of Education and Research – BMBF, THERESIAH (13GW0209A)

M67: COMPREHENSIVE ONLINE ASSESSMENT OF AUDITORY ABILITIES IN COCHLEAR IMPLANT USERS

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Benefits of cochlear implants (CI) vary considerably across individuals and across domains of auditory function including speech-in-quiet, speech-in- noise, music and environmental sound perception. However, testing is rarely performed across multiple domains in one CI user, which may result to a misleading interpretation of CI users' auditory abilities. Thus, the first goal of the present study was to develop a comprehensive battery of tests that examine different domains of auditory function. The second goal was to evaluate the online use of this test battery by CI users independently or with an audiologist's guidance.

The battery included 16 brief tests that varied in difficulty and focused on three broad domains of auditory function: basic spectro-temporal processing, nonlinguistic meaningful sounds (environmental sounds and music), and speech perception in quiet and in noise (gender identification, vowel and consonant identification, word recognition and sentence comprehension). The battery was administered online to three groups of adult listeners: two groups of postlingual CI users and one group of normal-hearing (NH) listeners of similar age. The first CI group and the NH group were instructed in person by an audiologist in the clinic, while a third group of CI users took the tests independently at home following online instructions.

Results indicate comparable overall performance between CI groups tested independently at home and in the clinic. CI scores for both home and clinic tests highly correlated with speech recognition scores obtained earlier in the clinic. Both CI groups scored significantly lower than the NH listeners on 14 tests. The greatest differences between averaged CI listener scores and those of NH listeners were observed on two speech-in-noise tests: identification of three-digit sequences and sentence comprehension. Similarly, NH and CI listeners differed considerably in signal-to-noise ratio (SNR) needed for discrimination of tone patterns in noise. Notable differences between CI and NH listeners were also observed in environmental sounds, musical instruments and musical style identification scores. These results support the use of the online test battery for a comprehensive online assessment of auditory abilities in adult CI users.

M68: RELIABILITY OF VISUAL SPEECH PREDICTS NEURAL SUPPRESSION OF DEGRADED AUDITORY SPEECH

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Face-to-face communication typically involves use of both auditory and visual speech information. The Dynamic Reweighting Model (DRM; Bhat et al., 2015) posits that when the auditory signal is degraded, a more reliable visual speech signal will suppress and overwrite early auditory cortex information, weighting speech processing more strongly toward the visual signal. Cochlear implant users, who experience an impoverished auditory signal, would therefore weight the more reliable visual signal more heavily and suppress early auditory cortex activity more than individuals with normal hearing. The current study sought to test these predictions for both cochlear implant (CI) users and normal-hearing (NH) listeners.

Postlingually deafened CI users and age-matched NH controls completed an audiovisual phoneme identification task with electroencephalography (EEG) recording. Auditory tokens (/aba/, /aga/, /awa/) were presented above or below a participant's predetermined signal-to-noise ratio (SNR) threshold and paired with clear or blurred videos of mouth movements that were either congruent or incongruent with the auditory token. Participants identified the consonant they heard on the computer keyboard.

Behavioral results showed generally greater visual influence in CI users than in NH controls: CI participants were more likely to report the visually-resented consonant in all conditions, particularly when the visual stimulus was clear and more reliable than the auditory stimulus. Event-related potentials (ERP) time-locked to the acoustic onset show P1 suppression for NH participants in the clear relative to blurred conditions, with a similar trend for CI participants. The magnitude of P1 suppression in CI participants was predicted by AV gain, a measure of auditory speech perception benefit with the addition of visual cues versus auditory speech alone. CI users with high AV gain showed greater P1 suppression for clear versus blurred stimuli relative to those with low AV gain.

Behavioral and ERP results suggest that clear visual information influences early auditory cortex as predicted by the DRM, though NH perceivers demonstrate this effect more strongly. CI users who benefit more from visual cues for speech perception show stronger influence of reliable visual cues on early auditory activity. These findings support a neural suppression mechanism wherein visual speech reliability modulates auditory processing.

M69: ANALYSIS OF FRICATIVES IN SPEECH PRODUCED BY HEARING IMPAIRED INDIVIDUALS AIDED WITH DIFFERENT ASSISTIVE HEARING DEVICES

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The speech produced by deaf people is different from that of the normal hearing peers in the manner/place of articulation for consonants. They also tend to substitute/omit phonemes due to the absence of auditory feedback. In our work, we have studied the production of four American English unvoiced fricatives /s/, /sh/, /f/ and /th/ by the hearing-impaired individuals. The choice of focus on the fricatives is based on the outcome of previous studies, which shows that aging hearing-impaired people (aided or unaided) are experiencing increasing difficulty in producing high-frequency consonants in their daily communication. Feature analysis of these fricatives at the phonemic level may help us in knowing the amount of feedback that they are receiving with their assistive hearing devices. In this study, we used the deaf speech corpus from Mendel (2017) and studied these fricatives (/s/, /sh/, /f/ and /th/) of both medium and high intelligibility reproduced by 17 hearing-impaired talkers (2 CI; 7 HA; 5 CI+HA; 3 unaided). We measured features like duration, intensity and first and second spectral moments (Center of Gravity (CG) and Standard Deviation (SD)) of each of the four fricatives across all the talkers. We also investigated the contribution of these features to the intelligibility of the speech produced by each hearing-impaired talker. Our findings are summarized as follow:

• Duration and intensity were statistically not attributing to the intelligibility of the speech produced by the participating talkers.
• Significantly higher first spectral moment (CG) for high speech intelligibility group than medium intelligibility group for /s/ are noted.
• Between the two intelligibility groups, medium intelligibility group showed higher second spectral moment (SD) for /sh/.
• For fricative /f/, both first (CG) and second spectral moments (SD) were statistically higher with high-intelligible talkers as compared to mid-intelligible talkers.
• For fricative /th/, second spectral moment (SD) were statistically higher with high-intelligible talkers as compared to mid-intelligible talkers.

Our acoustic analysis found that each fricative in deaf speech is attributing to the overall intelligibility of speech in its own unique manner. Further analysis and consolidation of results are still in progress.

M70: DISCRIMINATION THRESHOLDS IN SELF-PRODUCED SPEECH IN COCHLEAR IMPLANT LISTENERS AND NORMAL LISTENERS

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Introduction. We listen to ourselves while talking to ensure that our speech matches what we intended to say and how we intended to say it. Normal hearing speakers maintain acoustic consistency by accessing their auditory feedback, which the auditory system uses to detect errors and update motor plans while talking. This experiment investigates error detection in cochlear implant (CI) users. In people with CIs, fine-grained spectral distinctions in the speech input are degraded because the CI processor only uses a finite number of spectral channels. This signal degradation may result in sub-optimal comparison between the speech output and speech target, possibly diminishing the ability to correct nascent errors. Automatic error-detection is important for producing intelligible speech and successful communication. This experiment investigates whether CI listeners can detect variability in their own productions, an important first step in understanding the extent to which CI users rely on their auditory feedback while speaking, and the extent to which the CI is important for learning and maintaining intelligible speech.

Hypothesis. This experiment seeks the auditory threshold in variation in the first and second formants (F1/F2), spectral peaks which are important for distinguishing vowel height (e.g. "he" vs. "hey") and backness ("he" vs. "who"). Adjacent vowels may be separated by less than 100 Hz in F1 and 1000 Hz in F2, but large electrode frequency bandwidths may not preserve subphonemic differences in pronunciation. For example, the default Cochlear TM frequency allocation table sets bandwidths at 125 Hz in F1 frequency space and 125-500 Hz in F2 space. We hypothesize that CI users may not be able to detect subphonemic differences in their speech, especially if those differences do not cross electrode boundaries.

Stimuli. Participants were recorded speaking the words "Ed" and "oh" ten times each. A single token of each word was selected as a base for stimuli generation. F1 was decreased in "Ed" and F2 was increased in "oh" in increments of 1 Hz using Audapter (Cai et al. 2008, Tourville et al. 2013). For NH listeners, the resulting stimuli were passed through a 16-channel vocoder to approximate the spectral degradation of a CI.

Perception Task. Speakers heard their own altered speech in a four-interval, two-alternative-forced choice design, where one stimulus was different from the others. Listeners determined whether the odd stimulus occurred in the first or second pair of sounds (i.e. AABA or ABAA presentation), where A was always the unaltered stimulus. The initial interval size was 500 Hz. The interval between the base and altered stimulus increased by three steps after an incorrect response and decreased by a single step after a correct one. The experiment ended after 20 reversals (change from correct to incorrect or vice versa). The intervals from the final six reversals were averaged to approximate the threshold.

Results. Pilot data (CI n=1, NH n=3) show thresholds that vary both by individual and formant. For the CI listener, the threshold of F1 was 47 Hz and in F2 it was 30 Hz. Given how frequencies are distributed across electrodes, such low thresholds were not expected. The NH listeners were variable: for F1, thresholds were 165, 188 Hz, and 120 Hz; for F2, thresholds were 115 and 135 Hz (first two subjects only); thus listeners varied in how well they accessed various acoustic cues to perceive fine distinctions in speech. These preliminary results suggest the possibility that CIs may in fact preserve some accessible information about subphonemic speech variation. The results of this study will be used to guide further research to determine how this acoustic information may be used by CI users to maintain speech intelligibility while speaking.

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M71: VALIDITY AND RELIABILITY OF THE COCHLEAR IMPLANT QUALITY OF LIFE (CIQOL) PROFILE AND GLOBAL INSTRUMENTS IN COMPARISON TO LEGACY INSTRUMENTS

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Background: Patient-reported outcomes (PROs) are not routinely measured in adult cochlear implant (CI) users. Validated and efficient instruments that measure PROs are valuable as they may complement information from speech recognition outcomes and reveal the varied communication and other experiences of CI users and how they contribute to quality of life (QOL). To meet this need, the CIQOL item bank was developed according to the Patient-Reported Outcomes Information System (PROMIS) and COnsensus-based Standards for the Selection of health status Measurement INstruments (COSMIN) guidelines. Rigorous psychometric analyses were applied to responses to the CIQOL item bank from a nationwide sample (n=371) of adult CI recipients recruited through the CIQOL Development Consortium. Two additional instruments were developed from the CIQOL item bank: (1) the CIQOL-35 Profile, which consists of 35 items in 6 domain constructs (communication, emotional, entertainment, environment, listening effort, and social) and (2) the CIQOL-10 Global, which contains 10 items that provide an overall CIQOL score.

Methods: In the present study, a new sample of 334 adult CI users provided responses to: (1) the CIQOL instruments; (2) a CI-specific PRO (Nijmegen Cochlear Implant Questionnaire, NCIQ); and (3) a general-health PRO (Health Utilities Index-3, HUI-3). Responses were obtained again after 1 month. Here, we report the reliability and validity properties of the CIQOL-35 Profile and CIQOL-10 Global instruments and compare these to the same properties for the NCIQ and the HUI-3. Psychometric properties and construct validity of each instrument were analyzed using confirmatory factor analysis (CFA), item response theory (IRT), and test-retest reliability (using Pearson's correlations).

Results: The NCIQ had poor construct validity, as a majority of the subdomains and the total score had substantial CFA model misfit. In contrast, all six domains of the CIQOL-35 Profile and the CIQOL-10 Global instrument had adequate to strong construct validity. Based on the CFA results, IRT analysis could only be applied to the basic sound performance and activity limitation subdomains of the NCIQ. IRT results showed strong psychometric properties for these two NCIQ subdomains, all CIQOL-35 Profile domains, and the CIQOL-10 Global instrument. Test-retest reliability was strong for the CIQOL-35 Profile, CIQOL-10 Global, and NCIQ but moderate to weak for the HUI-3.

Conclusion: Overall, the CIQOL-35 Profile and CIQOL-10 Global were more psychometrically sound than the NCIQ and the HUI-3. The CIQOL-35 Profile and CIQOL-10 Global demonstrate validity, reliability, and efficiency as PRO instruments that can be used in clinical and research settings to measure QOL-related communication, health, emotional, and social outcomes in adult CI recipients.

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TUESDAY POSTER ABSTRACTS

T1: CLINICAL RESULTS WITH A FULLY IMPLANTABLE ACOUSTIC PROSTHESIS; THE BENEFIT OF LISTENING WITH TWO DEVICES

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The Carina system is a fully implantable middle ear implant system that can be used with a button (i.e. an external microphone) and with a fully implantable internal microphone. One-year follow-up (6 weeks, 6 months and 1 year) of clinical (surgery, post-operative pain) and audiological data (pre- and post-operative audiometric thresholds, word recognition in quiet, aided thresholds) of the first subjects implanted with the Carina are presented.

In the Netherlands reimbursement for this implant system is limited and therefore only unilateral treatment of patient with bilateral hearing loss and a contra-indication for a conventional hearing aid, is considered.

Unilaterally implanted patients benefit more from a second device compared to patients receiving an implant while having a contralateral normal hearing ear. We demonstrate this by comparing sound localization and speech understanding in patients fitted bilaterally with the Codacs (n=1), Bonebridge (n=2), VSB (n=3), percutaneous bone-conduction device (n=11), and Bonebridge/VSB (n=1).

The aim of our study is to improve the counselling of patients and to better understand the limitations in the different listening conditions as well as the limitation of listening with just one hearing implant.

Preliminary data indicates that bilateral implanted patients lateralize, instead of localize, sounds. True binaural fusion seems not possible. Still, the benefit of bilateral treatment as compared to unilateral treatment is significant.

Patient implanted with the Carina system demonstrate promising hearing thresholds and speech understanding with both the button (i.e. external microphone) and the fully implanted microphone. Patients indicate a preference for the button because of better speech understanding and less noise. The Carina system is an effective treatment for patients with moderate to severe sensorineural or mixed hearing loss.

T2: THE QUEST FOR BINAURAL CUE PROCESSING IN COCHLEAR IMPLANT USERS' SPEECH PERCEPTION

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An increasing number of cochlear implant users hears with two ears: either by having residual hearing in the non-implanted ear, or by having two implants. It is beyond dispute that listening with two ears provides them with benefits in speech understanding in complex listening environments. However, the conclusion is often (too) easily drawn this is the result of binaural cue processing and spatial attentional mechanisms, as a direct translation from the effects experienced by normal-hearing listeners. Here, we show that speech understanding for cochlear implant users can be characterized as a simple function of monaural signal-to-noise ratios, or monaural sound qualities in general.

In our quest for evidence of binaural cue processing, we analyzed an extensive selection of the literature with a theoretical framework on binaural speech understanding [1]. Within this framework, an explicit distinction is made between the benefit of redundant (or complementary) monaural information, and the benefit induced by binaural information (interaural time and level differences). As the former is often ignored in the literature, binaural cue processing is often asserted in situations where it is probably absent.

Using our framework, we found no evidence in the literature that binaural cues are processed in speech intelligibility tasks by cochlear implant users. Considering future signal processing strategies, this suggests two pathways that can be followed to optimize speech perception. The easiest pathway is to focus on the maximization of monaural signal-to-noise ratios, with little to no concern for binaural cues. The other pathway is to enhance the perception of binaural cues – in particular interaural time differences – such that they might (!) be used for improved speech understanding.

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T3: THE ABILITY TO UNDERSTAND INTERAURAL ALTERNATING SPEECH IS INTACT IN BILATERAL COCHLEAR-IMPLANT LISTENERS

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Speech perception for cochlear-implant (CI) users is often compromised by degraded auditory input from CIs. Declines in executive function such as attention and working memory as CI listeners age also add to the challenge, where central processing may be generally slower for understanding degraded speech. In this study, we explore factors that include peripheral degradation, aging, and executive function in bilateral CI (BiCI) listeners and normal-hearing (NH) listeners, using a paradigm of interaural alternating speech. When a single speech stream is constantly switching between two ears at varying rates, intelligibility from NH listeners demonstrate a U-shape function as the interaural switch rate is increased. One working hypothesis suggests that interaural switch rate at the poorest performance marks the boundary where listeners no longer selectively attend to one ear at a time, and beyond which they began to fuse between two ears to form the percept of a single stream.

Seventeen BiCI listeners (ages between 20-78 years, median of 68 years) were presented sentences at switching rates of 1, 2, 4, 6, 8, 12, 16, and 32 Hz, as well as a control condition with continuous speech stream (no switching). Younger and older NH adults (ages <35 and >60 years, respectively) were tested as control subjects using both unprocessed and eight-channel vocoded speech to investigate possible aging effects. Listeners were also tested on four measures of executive function: inhibitory control, processing speed, working memory, and attention shifting.

In Experiment 1, sounds were presented to both ears (dichotic) with the single speech stream constantly switching between ears. Intelligibility from BiCI listeners showed a U-shape curve as a function of interaural switching rate with the poorest performance at 4 Hz. Both NH groups performed at ceiling in the unprocessed speech conditions. When tested with vocoded speech, intelligibility from NH listeners was a similar U-shape function of interaural switching rate as BiCI listeners, with the poorest performance also at 4 Hz. Interestingly, performance was overall similar between BiCI listeners and younger NH adults when tested with vocoded speech.

In Experiment 2, sounds were presented only in one ear (monotic), with the single speech stream being interrupted depending on the switching rate. A binaural intelligibility benefit from monotic to dichotic listening was calculated for each switching rate by comparing performances between the two experiments. Preliminary results suggested that binaural intelligibility benefit was negatively correlated with switching rate for both BiCI and NH listeners, where a larger benefit was seen in the lower switching rates. However, some BiCI listeners received little to no binaural benefit. The role of individual factors such as age and executive function in affecting the overall intelligibility and the U-shape function will be discussed. These preliminary findings provided insights into BiCI listeners' central processing such that they may have intact abilities in understanding interaural alternating speech.

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T4: CHRONIC BILATERAL STIMULATION THROUGH COCHLEAR IMPLANTS DURING DEVELOPMENT CAN REVERSE THE EFFECT OF EARLY-ONSET DEAFNESS ON NEURAL ITD SENSITIVITY

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Bilateral cochlear implant (CI) users with a pre-lingual onset of hearing loss show poor sensitivity to interaural time differences (ITD) compared to those with post-lingual hearing loss. Similarly, neural ITD sensitivity in the inferior colliculus (IC) of rabbits that are deafened as neonates is degraded compared to animals deafened as adults. Here we investigated whether chronic bilateral CI stimulation during development can reverse the effect of early-onset deafness on ITD sensitivity.

Four Dutch-belted rabbits were deafened as neonates with daily injection of neomycin and then bilaterally implanted at 2 months of age. Starting just after implantation, they received daily stimulation (5 hrs/day) by environmental sounds using wearable sound processors programmed with the “Fundamental Asynchronous Stimulus Timing” (FAST) strategy designed to deliver ITD information effectively with bilateral CIs. Single-unit recording from the IC using an unanesthetized preparation commenced at 5 months of age. Stimuli were periodic trains of biphasic electric pulses with varying pulse rates (20 – 640 pps) and ITDs (-2000 to +2000 μs). The results are compared to measurements from adult-deafened rabbits (Chung et al., J Neurosci. 36:5520) and early-deafened rabbits that did not receive daily stimulation (Chung et al. JARO. 20:37).

More IC neurons in the stimulated rabbits showed significant ITD sensitivity in their overall firing rate (75%) compared to unstimulated animals (62%). The difference in prevalence of ITD sensitivity was most prominent at high pulse rates (>200 pps). ITD sensitivity based on analysis of variance and neural ITD discrimination thresholds also showed improvements in the stimulated animals compared to unstimulated animals, with the largest effect found at high pulse rates. The fraction of ITD sensitive neurons, and ITD STVRs and thresholds in the stimulated animals were comparable to those from adult-deafened animals at high pulse rates.

In summary, chronic bilateral cochlear implant stimulation during development can partly reverse the degradation in neural ITD sensitivity resulting from early-onset deafness. The effect is most pronounced in response to high-rate stimulation.

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T5: MODELLING EXPERIENCE-DEPENDENT SOUND LOCALIZATION FOR DIFFERENT HEARING-IMPAIRMENTS

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It is assumed that interaural level and time differences and monaural spectral pinna cues for sound localization are learned throughout life, so that normal-hearing listeners acquire and maintain accurate and precise spatial hearing. However, those cues are heavily perturbed or absent in the hearing impaired, and altered by restorative hearing devices. In this study, we show that even with perturbed localization cues the brain learns to (re-)weigh the available information into a spatial percept. We aimed to identify the underlying mechanisms by comparing sound-localization performance of normal-hearing listeners, single-sided deaf with and without a cochlear implant, and unilateral and bilateral cochlear implant users with each other, and with the performance of artificial neural networks, trained to map acoustic measurements from each of the listener groups onto speaker locations. The different localization patterns of the normal-hearing and hearing-impaired listeners can be mimicked by the neural networks, from which we conclude that spatial information is present even when binaural cues have been removed.

Although this information might be ambiguous (sound level) or have poor signal-to-noise ratio (spectral pinna cues), it allows for some spatial hearing when trained to do so. The different localization behaviors of each listener group suggest that humans can learn to map the impoverished acoustic information to spatial locations, even at an adult age. Our experiments also indicate that, besides the long-term experience-dependent effects, listeners (and networks) immediately re-weigh the available cues when an acute monaural hearing impairment is introduced. We discuss the implications of our results for rehabilitation strategies of the hearing impaired.

T6: IMPROVING BINAURAL UNMASKING BY ADJUSTING FREQUENCY MAPS IN SSD-CI SIMULATIONS

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Binaural listening is important for speech perception in masking noise. Bernstein et al. (2016) found that users of cochlear implants (CIs) with single-sided-deafness (SSD) could achieve binaural unmasking. That is, when presented with target and masker sentences in their normal hearing ear, subjects showed improved target recognition when the masker was simultaneously presented to their contralateral CI. Using acoustic simulations of SSD listening with normal hearing (NH) subjects, Wess et al. (2017) showed that binaural unmasking benefit is highly sensitive to interaural frequency mismatch in the masker presented to each ear (that is, mismatch between the cochlear places stimulated in each ear). In particular, frequency mismatch in the CI can occur because the locations in the cochlea of neural elements receiving stimulation are shifted relative to the acoustic frequency information delivered (i.e. frequency map) by the CI. When this shift reaches about 2mm, binaural unmasking benefit is greatly reduced in SSD simulations. The present study builds upon these findings to evaluate whether the detrimental effects of interaural frequency mismatch on binaural unmasking can be mitigated when the frequency map is adjusted for varying degrees of simulated insertion depths.

In this study we tested 16 normal hearing subjects (< 25dB HL thresholds 250Hz-8000Hz) who were native English speakers, ages 18-34. Stimuli were sentences selected from the Coordinate Response Measure (CRM) test. Target sentences were always the same male voice. Masker sentences were two talker babble comprised of different male voices non-overlapping in content with the target. Unprocessed target and masker sentences were delivered to one ear with a fixed SNR of -3 dB. To assess binaural unmasking in SSD-CI listening, masker sentences were presented to the contralateral ear via an 8-channel noise vocoder. In this ear, different amounts of insertion depth were simulated by varying the frequency range of the synthesis filters, and different amounts of frequency mismatch were simulated by adjusting the frequency range of the analysis filters relative to the synthesis filters. Adjusting the analysis filters is analogous to adjusting the frequency-to-electrode map in the CI.

Results show that binaural unmasking is reduced significantly for frequency shifts larger than 1.5 mm. However, adjusting analysis filter frequencies to reduce the mismatch between analysis and synthesis filters recovered much of the binaural unmasking that was lost due to frequency shift. This result supports the contention that a tonotopically matched frequency-to-electrode map in the speech processor has the potential to benefit binaural performance for SSD-CI users.

T7: TOWARDS A CLINICAL APPROACH FOR CREATING BILATERAL COCHLEAR IMPLANT MAPS

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Despite the prevalence of bilateral cochlear implant (CI) users, only limited progress has been made towards developing programming techniques specifically targeted at this population. This often results in sub-optimal pairing of electrodes across ears, which can greatly reduce binaural benefits. There are obstacles for developing bilateral CI programming techniques to deal with this. One such obstacle is that there are multiple methods that can be used to pair electrodes across ears and it is unclear which method is best. A second obstacle is that these techniques for pairing electrodes currently utilize research interfaces not available in clinics.

To address the first obstacle, electrode parings were determined based on either interaural time difference (ITD) sensitivity, interaural level difference (ILD) sensitivity, or pitch matching. Bilateral programs were created based on each measure, by assigning the same frequency allocation in each ear to electrodes that were optimally paired by a given measure. Participants were assessed on two tasks. One task, melodic contour identification, was predicted to most benefit from using pitch-matched electrode pairs. The other task, sound source localization, was predicted to most benefit from using electrode pairs that yielded the best ITD or ILD sensitivity. The results indicated that programs based on pitch matching maximally improved melodic contour identification and those based on ITD sensitivity maximally improved localization abilities

To address the second obstacle, a method to assess pitch matching using off-the-shelf hardware was developed. Acoustic stimuli were designed based on the frequency allocation for a 15-channel current steered strategy, reflecting the strategy used in the processors for this experiment. Stimulus amplitude was adjusted based on frequency to counteract the effects of pre-emphasis. Four bilateral CI users completed two pitch-matching tasks, one using a research interface and one using pure tones. In both tasks, pitch matches were made for 31 reference stimulation locations. The results indicated that the pitch matches obtained with the two methods were similar. This suggests that it is possible to design a pitch matching paradigm using off-the-shelf hardware that accurately measures the relationship between pitches in the two ears.

Taken together, these are promising first steps for developing clinical programming techniques specifically designed for bilateral CI users.

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T8: EFFECTS OF SPECTRAL RESOLUTION AND FREQUENCY MISMATCH ON SPATIAL RELEASE MASKING IN SIMULATED BILATERAL COCHLEAR IMPLANTS

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For cochlear implant (CI) patients, monaural factors such as competing talkers and/or their differing vocal characteristics may be difficult to discriminate due to limited electrical dynamic range, poor auditory spectral resolution, and interactions among the implanted electrodes. In addition to issues with monaural factors, bilateral CI patients may also be less able to take advantage of binaural cues that normal-hearing (NH) listeners use for spatial hearing, such as inter-aural time differences (ITDs) and inter-aural level differences (ILDs). Because of these factors, patients with unilateral or bilateral CI are less able to segregate spatial and temporal properties of speech from target speakers from other competing talkers. In CI patients, the sensitivity of ITDs and ILDs is highly dependent on the inter-aural mismatch between the two electrodes placed in each respective ear. The goal of this research project is to evaluate the effects of spectral resolution and inter-aural mismatch on speech recognition in the presence of competing talkers in normal-hearing subjects listening to bilateral cochlear implants.

During testing, both target and masker speech are presented in matrix-like five-word sentences that have the same syntax but are not necessarily meaningful. There are five categories in fixed order (Name, Verb, Number, Color, and Fruit), each of which has 10 items, such that multiple sentences can be generated by randomly selecting a word from each category. Speech reception threshold (SRT) for the target sentence presented in competing speech maskers was measured. The target speech was delivered to both ears and the two speech maskers were delivered to: 1) both ears (diotic maskers), or 2) separate ears (dichotic maskers: one delivered to left ear and the other delivered to right ear). Speech contains one original speech presentation and three 16-channel CI simulations with different inter-aural mismatch (0, 1, and 2mm). Spatial release from masking (SRM) was calculated by the performance difference between diotic and dichotic listening conditions.

Preliminary results showed significantly poorer speech recognition performance and less spatial release from masking (SRM) in spectrally degraded speech. While similar performance was observed with inter-aural mismatch for diotic condition, SRM was significantly reduced with increased inter-aural mismatch. The results from the present study suggested that binaural speech recognition in spatially separated maskers is highly sensitive to inter-aural mismatch. It is critical to minimize the inter-aural mismatch to restore the binaural benefits in terms of spatial speech recognition in the competing talkers for bilateral CI patients, a realistic listening environment in the daily life.

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T9: INTERAURAL MISMATCHES IN INSERTION DEPTH AND SCALA LOCATION FOR BILATERAL COCHLEAR-IMPLANT USERS

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The binaural-hearing centers of the brainstem are exquisitely sensitive to interaural differences, and asymmetries introduced by bilateral cochlear-implant (BICI) processors or internal devices may substantially impair binaural functioning. Specifically, binaural neurons are frequency tuned, relying on place-matched inputs from the periphery. Although differences in interaural place of stimulation have been shown to impair binaural sensitivity, this observation is based on the artificial introduction of interaural mismatch. The prevalence and magnitude of differences in array placement for BICIs as a consequence of surgical or morphological differences across the ears remains unknown. Therefore, this study used computed-tomography (CT) scans to characterize the asymmetry of electrode placement for BICI users in terms of insertion angle and scalar location.

Temporal-bone CT scans for 88 individuals with BICIs were extracted from an existing IRB-approved database of over 600 adult CI recipients maintained at Vanderbilt University. These BICI users represented a variety of manufacturers (27 Advanced Bionics, 43 Cochlear Ltd., and 18 MED-EL) and electrode types (e.g., pre-curved perimodiolar versus lateral wall). The precise intra-cochlear position of each electrode was determined using published automatic image processing methods that have been validated in µCT studies. In addition, interaural time difference (ITD) sensitivity was measured on 20 BICI listeners.

Results showed that 8.8% of electrodes had >90 degrees of interaural mismatch in insertion angle. These asymmetries, however, were concentrated toward the apex, with 18.1% (16/88) of the BICI users showing >90 degrees of mismatch in insertion angle for the most apical electrode pair. The percentage of electrodes located in scala tympani was 71%. There were 27% translocated electrodes and 2% were extra-cochlear; however, 43% of the translocations were in the apical end of the array. Furthermore, 34% of the electrode pairs had interaural differences in scala location. Comparisons between CT and ITD data showed that ITD sensitivity decreased by a factor of 2-4 when the electrode pairs were in different scala.

In summary, there are larger interaural insertion depth differences and a higher prevalence of scala translocations (including interaural scala location differences) at the apical end of the array. While it was previously known that large interaural insertion depth differences caused reduced binaural sensitivity, it appears that scala location also plays an important role in binaural sensitivity, which helps to explain the large variability within and across-subjects to ITD processing. Ultimately, CT scans provide precise location information of electrodes, which could be used for individualized programming of devices, thereby providing the types of inputs that the precise binaural system requires.

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T10: IMPROVING SPEECH INTELLIGIBILITY OF BILATERAL COCHLEAR IMPLANT USERS WITH A BINAURAL N-OF-M SOUND CODING STRATEGY

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Introduction: Bilateral cochlear implantation has the potential to further improve speech intelligibility of the user in many adverse listening environments in comparison to unilateral implantation. However, bilateral cochlear implant users (BiCIs) make use of two independent hearing devices, which can be one of the reasons for the gap in performance between normal hearing people and BiCIs. A healthy auditory system is specialized in processing sound perceived by two ears and makes use of binaural cues. The brain takes advantage of these cues in order to create an auditory scene and isolate target speech sound from spatially separated noise to achieve better intelligibility. In order to take BiCIs closer to a normal binaural listening scenario, binaural sound coding strategies are desirable. In this work, we investigate the potential benefit on speech-in-noise understanding of a binaural N-of-M sound coding strategy.

Methods: In this work, we propose a binaural N-of-M strategy to improve speech intelligibility in noise. N-of-M sound coding strategies stimulate, out of the M available bands, the N most energetic ones. Ideally, the selected bands contain the targeting signal, in noisy conditions, however; the band selection could be corrupted, degrading the perception of the desired signal. The proposed sound coding strategy takes advantage of a “better ear” which will send information about which bands to select to the masked ear, providing it with an improvement in signal-to-noise ratio.
The benefit of speech perception in noise with a binaural N-of-M sound coding strategy was assessed by means of the HSM (Hochmair-Schulz-Moser) sentence test in 10 BiCIs for a “better ear” listening condition. The presence of squelch effect is reported by also performing monaural listening tests with each hearing sides. Additionally, the importance of correct band selection has been investigated by assessing speech-in-noise intelligibility scores with ideal binaural processing, where the bands are selected as if no noise was present.

Results: Results indicate that the proposed coding strategy improves speech perception scores in BiCIs, furthermore, an ideal band selection can restore speech intelligibility to the level attained in quiet. The monaural tests revealed that the binaural benefit achieved by the sound coding strategy was directly proportional to the listening symmetry of the subjects.

Conclusions: The outcomes of this work show that, in a “better ear” binaural listening scenario, a binaural N-of-M sound coding strategy yields an improvement in speech intelligibility in noise of BiCI users, especially in subjects with high hearing symmetry.

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T11: ASSESSING SOUND SOURCE LOCALIZATION IN LISTENERS WITH BILATERAL COCHLEAR IMPLANTS

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Bilateral cochlear implants (BICIs) are provided to improve localization of sound sources and speech understanding in noise. However, while some listeners show localization abilities within the range observed in normal hearing listeners, others struggle to identify whether a sound is from left or right side. The standard statistic used to describe performance across individuals, root-mean square (RMS) error, does not provide a clear indication as to the pattern of performance. That is, similar RMS error values can emerge from error patterns that are vastly different, as was shown in a longitudinal study of children with BICIs [Zheng et al., 2015, PLoS One, 10(8), e0135790].

A novel way of assessing localization patterns and identifying response profiles has the potential to provide insight into the patient-specific factors that affect spatial hearing. Ultimately these procedures will help researchers interpret results, and can help guide clinicians in counseling patients about expectations of performance and improve evaluation of performance.

The goals of the present experiment were two-fold: (1) compare analysis techniques to determine which are indicative of different aspects of patient performance; (2) identify factors that contribute to localization outcomes in listeners with bilateral CIs. We predicted that the longer periods of exposure to acoustic hearing prior to onset of deafness and shorter delays between implantation in the two ears would be associated with better localization performance.

Forty-eight adults with BICIs participated in this experiment. Listeners ranged from 20-85 years of age and had at least 0.5 years of listening experience with their BICIs. Stimuli were presented from one loudspeaker from an array of 19 loudspeakers ranging from ±90 degrees azimuth. Fifteen repetitions were collected for each target location. Stimuli were trains of four, 170 ms pink noise bursts separated by inter-stimulus intervals of 50 ms. All stimuli were presented at 50 dB SPL(A) with ±4 dB level rove and ±10 dB spectrum rove.

Localization data were first analyzed to determine root-mean-square (RMS) error. Second, we computed the localization sensitivity index (Zheng et al., 2015) as a suggested alternative to RMS error and potentially a better indicator of localization response profiles. Third, the data were fit with a logistic function, extracting the parameter values of the function to indicate left/right bias, curvature, and systematic errors at larger lateral angles. Fourth, a traditional machine learning technique (k-means clustering) was used to sort data from each listener into the different categories described in Zheng et al. (2015).

Our findings show that analysis of localization data should use more targeted techniques and evaluate performance beyond RMS error. While RMS error is related to age at onset of deafness and inter-implant delay, fitting data with a logistic function and performing clustering analyses provided unique identifying information about patient biases toward left/right, whether patients struggled identifying far laterally compared to more medially presented sounds, and variance at each location. Together, these results show that a combined approach could provide investigators with important information about localization outcomes in listeners with BICIs.

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T12: ASSESSMENT OF BINAURAL STREAMING IN CI PATIENTS

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This study investigates if bilateral and bimodal cochlear implant (CI) patients can stream binaurally by pitch-proximity like normal-hearing (NH) listeners. This ability might be affected by perceptual differences across ears arising from the CIs. To assess this, a detection-task based on Diana Deutsch's (1975) scale illusion was used. Listeners had to detect one deviation within a repeating melody-stream, while simultaneously presented with a randomized distractor-stream. Every second note in each stream was presented to the opposite ear, requiring the combination of binaural input into a common stream to reliably detect the deviant. Results indicate that bilateral CI patients streamed binaurally like NH listeners, but introducing pitch-mismatches across ears prevented grouping by pitch-proximity. Bimodal CI patients did not stream binaurally like NH listeners even with matched stimulation.

T13: SOLVING THE COCKTAIL PARTY PROBLEM WITH THE INTERAURAL LEVEL DIFFERENCE CUE

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There are two main sources of benefit when targets and maskers are spatially separated. The first, called the better-ear effect, is derived from the interaural level difference (ILD) cue, and occurs because of the improved signal-to-noise ratio at the ear nearer the target. The better ear effect is a release from energetic masking. The second refers to the improved perceptual performance that comes when one is better able to attend to one or another sound source due to spatial separation. This effect is colloquially referred to as solving the cocktail party problem, and is a release from informational masking driven by the interaural time difference (ITD) cue. The ILD cue is not thought to contribute to informational masking release. Recent work (Brown, 2018) has examined modifying the ILD cue in real-time across both frequency and azimuth in a corrective way, to significantly improve localization by bilateral cochlear implant (CI) users, who do not have robust access to ITDs. It is hypothesized that while naturally-occurring ILDs do not provide a release from informational masking, magnified ILDs can. Behavioral and electrophysiological data are presented to support this hypothesis.

T14: A VR-BASED ENVIRONMENT ENABLING BICI SPATIAL SOUND RESEARCH - DEVELOPMENT AND EXPERIMENTAL VERIFICATION

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This project investigated the feasibility of using Virtual Reality (VR) to improve the auditory localization performance of bilateral cochlear implant (BiCi) users. The real-time VR setup we developed allowed us to introduce novel auditory spatial cues in a dynamic environment, and to use a subject's visual system to train his or her auditory system about those cues. We hypothesized that spatially-oriented coding strategies can enhance the scarce spatial auditory cues normally available to BiCi users and that immersive audio-visual training can help them learn new those new cues efficiently.

The project had three tasks: (1) develop of a VR-based dynamic BiCI simulation system, (2) design and implement a few example spatial enhancement coding strategies, and (3) evaluate the auditory localization performance of simulated BiCI (vocoder) users using the example strategies.

We first developed a Virtual Reality-based dynamic auralization framework for BiCI users. The system allows for simulating listening environments by chaining software-based virtual acoustics (using BTE-HRTFs) within the Oticon Medical Research Platform (OMRP) and can include custom binaural processing strategies implemented in software using the Master Hearing Aid (MHA) [1].

Next, three coding strategies involving different types and amounts of spatial information were implemented: (1) BTE-HRTF-based ILD-only mode (ITDs fixed to 0), (2) a mode with physiologically relevant ITDs added (in addition to ILDs) and, (3) a mode where an additional 'artificial coloration cue' was added. This cue was a simple low-pass filter used for sources behind the listener.

Finally, the system was used to assess auditory localization performance of 9 NH individuals (3 per coding strategy) exposed to simulated (wavelet vocoder) BiCI signals in a pilot experiment involving audio-visual localization training (4 sessions of 30 minutes in a span of 2 weeks). The data showed that audio-visual training improved both vertical and horizontal localization precision of most of the subjects. The results between strategies suggested that for continuous broadband stimuli restoring ITD cues may not add much for horizontal localization precision in cases where ILDs are maintained.

The developed dynamic VR system has proven promising for investigating spatial-information-centric algorithmic innovation, as well as improving auditory localization abilities through training in simulated BiCI users. Future developments will involve experiments with real bilateral cochlear implantees.

[1] Giso Grimm, Tobias Herzke, Daniel Berg, and Volker Hohmann, The master hearing aid: a PC based platform for algorithm development and evaluation, Acta acustica united with Acustica, vol. 92, pp. 618-628, 2006

T15: LATERALIZATION OF VIRTUAL SOUND SOURCES WITH A BINAURAL COCHLEAR-IMPLANT SOUND CODING STRATEGY INSPIRED BY THE MEDIAL OLIVOCOCHLEAR REFLEX

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Many users of bilateral cochlear implants (BiCIs) localize sound sources less accurately than do people with normal hearing. This may be partly due to using two independently functioning CIs with fixed compression, which distorts and/or reduces interaural level differences (ILDs). Here, we investigate the potential benefits of using binaurally coupled, dynamic compression inspired by the medial olivocochlear reflex, an approach termed “the MOC strategy” (Lopez-Poveda et al., 2016, Ear Hear 37:e138-e148). Twelve BiCI users were asked to localize wideband (125-6000 Hz) noise tokens in a virtual horizontal plane. Stimuli were processed through a standard (STD) sound processing strategy (i.e., involving two independently functioning sound processors) and three different implementations of the MOC strategy: one with fast contralateral control of compression (MOC1), one with slow contralateral control of compression but effectively greater contralateral inhibition in the higher than in the lower frequency channels (MOC2), and one with slower control of contralateral inhibition and slightly greater inhibition in the lower than in the high frequency channels (MOC3). Localization was most accurate with the MOC1 strategy, presumably because it provided ILDs that were closer to the natural head-shadow ILDs. The angle error improved slightly from 25.3 degrees with the STD strategy to 22.7 degrees with this MOC1 strategy. The improvement in localization ability over the STD strategy disappeared when the contralateral control of compression was made slower and/or greater in the lower frequency channels. Results suggest that some MOC implementations hold promise for improving not only speech-in-noise intelligibility, as shown elsewhere, but also sound source lateralization.

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T16: THE IMPORTANCE OF SOUND LEVEL IN SOUND LOCALIZATION ASSESSMENT

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Sound localization is a key outcome measure in the evaluation and management of individuals with hearing impairment. In monaural listeners, spatial hearing is poor. Still, it has been well documented that monaural spectral and head-shadow cues provide information for sound localization in monaural listening situations, especially in familiar environments. A common tool in determining rehabilitative benefit, an increasing number of studies provide evidence that sound localization performance can be enhanced through training. The aim of the present study is to demonstrate how information and feedback about the participant's localization ability, rather than training per se, can bias localization outcomes in acute monaural listeners.

Normal hearing participants (n=39) were tested. Instant adaptation to stimulus level cues is demonstrated by a short duration (<25 min) experiment consisting of four listening conditions investigating effects of sound level and prior knowledge on monaural sound localization in azimuth.

Results demonstrate that monaural sound localization improved when stimuli were presented at one level and deteriorated immediately after roving the stimulus level.

The present study demonstrated that the monaural sound level cue can be used to improve the sound localization accuracy, especially in common laboratory settings were sounds are presented at one single level. Our findings, demonstrating an instant improvement in monaural localization abilities, corroborate previous research showing that monaural listeners rely heavily on level information for sound localization. This has important implications for assessment of bilateral versus unilateral hearing benefit in clinical settings. Our data showed that information about the monaural listening situation, in combination with minimal exposure to broadband noise bursts (presentation of 18 broadband stimuli at a single level from known speaker locations), improved monaural localization performance in real time.

T17: THE EFFECT OF SOUND LEVEL ON THE SPATIAL SPEECH PERCEPTION IN COMPLEX AUDITORY ENVIRONMENT FOR COCHLEAR IMPLANT USERS

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Spatial hearing is the capacity of the auditory and cognitive system in interpreting or exploiting different sound paths and sound sources to tell about the nature of the listening space. With spatial hearing, the auditory system can 'unmask' the sound source otherwise obscured by noise, and direct attention towards or away from the source. With spatial hearing loss, hearing impaired listeners will face a great difficulty in communication in their daily settings. In this study, we would like to highlight the importance of speech level on the spatial speech perception in complex auditory environment for cochlear implant users. One target sentence was presented with two masker sentences at fixed 10 dB target to masker ratio (TMR) at each trial. The stimuli were presented randomly from three of five loud-speakers set at 45-degree azimuth separated. Three sound levels were considered: levels of the targets were at 75, 65 and 55 dB while the maskers were at 65, 55, and 45 dB. Three CI patients in different hearing conditions (Bilateral CI, Unilateral CI with no residual hearing in unaided ear, and Unilateral CI with residual hearing in unaided ear) were tested with- and without their CI turned on. Our results showed that, in aided condition, the performance was better when target speech was presented from the speaker at the azimuths nearer to the CI aided ear. For the bilateral CI and unilateral CI user with no residual hearing in the contralateral ear, spatial speech perception scores increase as the speech level decreases in the presence of maskers at a fixed TMR. Interestingly, the average speech perception scores were higher at higher presentation levels that was observed with the unilateral CI patient who has residual hearing in the contralateral ear. The patient may rely mostly on this acoustic hearing. Continuous data collection is being undertaken in this study. The findings from the present study will contribute to understanding spatial speech perception in CI users and its reliance on the level of speech in noisy environment. This study will also provide useful information in developing signal processing strategies in CIs that improves spatial hearing.

T18: EFFECT OF LINKED AND "SPATIALLY AWARE" COCHLEAR-IMPLANT COMPRESSION ON SPATIAL PERCEPTION IN A REVERBERANT ROOM

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This study investigated the effects of broadband cochlear-implant compression on spatial perception in a reverberant room using a vocoder simulation with normal-hearing listeners. Four different schemes were tested: independent compression in each ear; a linked compression between the two ears; "spatially aware" compression, where the compression was applied to anechoic signals before they were spatialized for presentation; and as a reference condition, linear processing without compression. Furthermore, each of the compression schemes was tested using two different release times and two different compression thresholds. Virtually spatialized speech was then presented to listeners, and thereafter, listeners were asked to indicate the location and extent of the sound images they perceived. The root-mean-squares of the error between the presented and reported angles were calculated. The errors correlated with the measured interaural level differences (ILDs), which indicate that the ILDs were the main, if not only, spatial cue available for the listeners. Results showed that the errors were significantly larger for the independent compression schemes than for each of the other schemes (i.e., linked, "spatially aware" and linear compression). However, there was no significant difference between the linked and "spatially aware" compression schemes, which may be explained by the fact that the ILDs between the two compression schemes were identical and that the interaural coherence differences were reduced due to the vocoding. Lastly, compression threshold had a larger influence on spatial perception than release time.

T19: SYNCHRONIZED AUTOMATIC GAIN CONTROL (AGC) IN BILATERAL COCHLEAR IMPLANT RECIPIENTS YIELD SIGNIFICANT LOCALIZATION BENEFIT

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Background: Individuals with bilateral cochlear implants rely mostly on interaural level difference (ILDs) cues to localize sounds in the horizontal plane. However, because the automatic gain control (AGC) circuits in modern-day cochlear implant sound processors work independently, this cue can be distorted. Previous work has shown significant improvement in localization abilities with the use of synchronized processors (Chen, 2017). The purpose of this investigation was to determine if synchronizing the AGCs in bilateral cochlear implant recipients could improve spatial hearing abilities in the horizontal plane for dynamic listening conditions.

Materials and Methods: Minimum audible angle (MAA) and minimum audible movement angle (MAMA) thresholds were collected from 2 bilateral cochlear implant recipients using both synchronized and non-synchronized AGCs. MAA thresholds were obtained by presenting two 500 ms stationary stimuli from different positions in the horizontal plane. Spatial separation between the two stimuli were varied adaptively from trial to trial to track 70.7% performance. Minimum audible movement angle (MAMA) threshold determination was assessed by varying the duration of the stimulus that was moving at a constant angular velocity of 20 degrees per second. The duration of the stimulus was varied adaptively from trial to trial to track 70.7% performance. Both tasks used a presentation level of 70 dB SPL with across-trial level roving for a Gaussian noise band-pass filtered from 100 to 8000 Hz.

For the synchronized AGC conditions, the AGCs on each processor receive input from both ipsilateral and contralateral signals, the larger of the two signal envelopes at any given time is used for AGC gain estimation, and the same compression gain was applied to both processors. The single-channel, dual-loop AGCs had fast and slow attack time constants were 0.33 and 140 ms, respectively; fast and slow release time constants were 46 and 383 ms, respectively.

Additional data collection is on-going with planned data from at least 5 bilateral CI participants to be presented.

Results: Average MAMA thresholds improved from 61.9 to 22.2 degrees with AGC synchronization. Average MAA thresholds improved from 42.4 to 17.3 degrees with AGC synchronization.

Conclusion: Use of unsynchronized implant processors with independent AGCs is known to disrupt ILD cues—an important consideration for bilateral CI users who lack access to fine structure ITDs. Synchronization of AGCs in bilateral cochlear implant recipients significantly improved spatial hearing abilities in the horizontal plane for dynamic conditions. These data hold significant clinical application for improving spatial hearing abilities for bilateral CI users.

Reference: Chen, C. (2017, July). Effects of synchronizing automatic gain controls for bilateral cochlear implant users. Presentation at the 18th biennial Conference on Implantable Auditory Prostheses, Lake Tahoe, CA.

T20: EFFECT OF (MIS)MATCHED COMPRESSION SPEED ON SPEECH INTELLIGIBILITY IN BIMODAL LISTENERS

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Automatic gain control (AGC) compresses the wide dynamic range of sounds to the narrow dynamic range of hearing-impaired listeners. AGC parameter settings are an important part of the fitting of hearing devices. These parameters also change the loudness elicited by the cochlear implant (CI) and hearing aid stimulation. Furthermore, they can influence speech intelligibility in some noise conditions noise as reported by Veugen et al. (2016) [1]. Our aim was first, to investigate whether the very specific effect found by Veugen et al. (2016) can be replicated in bimodal listeners using Nucleus 6 processor of Cochlear Ltd. plus an Enzo 3D HA of GN Hearing; second, to disentangle the effect of matching the knee points and the time constants, by systematically evaluating speech in noise performance in a CI-only condition (fast or slow time constants) and bimodal use (matched slow or unmatched fast AGCs).

We compared the matched condition with the mismatched default AGCs of Cochlear and GN Hearing in 18 subjects. As a baseline, we also included a condition with the mismatched AGCs of the participants' own devices. We tested speech intelligibility in quiet and in noise from different directions. For speech in noise, we tested the bimodal configuration and the CI only, in order to disentangle the influence of time constants from the matched knee points. We tested the participants' short-term memory skills to assess whether they can predict the benefit of the speech intelligibility in noise that comes with the time constants.

No significant differences between the standard and the matched AGC configurations for speech intelligibility in quiet or in noise were found, i.e., we would not replicate the results of Veugen et al [1]. With respect to the bimodal benefit, we found that when the noise comes from the CI-side, the standard AGC provided more benefit than the matched slow AGC. Furthermore, standard AGCs yielded larger spatial release from masking when noise is moved to the CI-side. In contrast, for the CI-only condition and noise coming from the HA-side, the slow matched AGCs yielded larger spatial release from masking. Finally, we did not find any evidence that the bimodal AGC-preferences or speech reception threshold differences (in terms of better performance with one of the AGC configurations) can be predicted from short-term memory tests.

[1] Veugen, L. C. E., Chalupper, J., Snik, A. F. M., Opstal, A. J. Van, & Mens, L. H. M. (2016). Matching Automatic Gain Control Across Devices in Bimodal Cochlear Implant Users, 260–270.

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T21: MASKING EFFECTS IN THE PERCEPTION OF MULTIPLE SIMULTANEOUS TALKERS IN NORMAL-HEARING AND COCHLEAR IMPLANT USERS

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For normal-hearing (NH) listeners, monaural factors may play an important role in the segregation of speech signals in multi-talker environments. However, cochlear implant (CI) patients may have some difficulty in segregating speech signals in multi-talker environment due to the coarse spectral resolution. The present study is to examine how the vocal characteristics and the number of the competing talkers influence listeners' ability to extract information from a target phrase in a multi-talker environment.

Sentence recognition was measured in the presence of speech signals from one or multiple competing talkers. Both target and competing speech were using the matrix-like five-word sentences that have the same syntax, but are not necessarily meaningful. There are five categories in fixed order (name, verb, number, color, and fruit), each of which has 10 items, such that multiple sentences can be generated by randomly selecting a word from each category. Speech reception thresholds (SRTs), defined as the signal-to-noise ratio (SNR) that produced 50% correct word recognition were adaptively measured using a modified coordinate response measure (CRM) procedure. Two target keywords (randomly selected from the number and color categories) were embedded in a five-word carrier sentence. The first word in the target sentence was always the name "Xiaowang" followed by randomly selected words in the four remaining categories. SRTs of a target male talker were measured in the presence of one, two, or four competing talkers with a combination of vocal characteristics in NH listeners and CI patients.

The results showed that CI patients performed significantly poorer than did NH listeners regardless of the number and/or the vocal characteristics of the competing talkers. The mean SRTs significantly worsened from -22.0 dB to -5.2 dB for NH listeners but significantly improved 5.9 dB to 2.8 dB for CI patients when the number of competing talkers was increased from one to four. While both NH listeners and CI patients seem able to take advantage of the difference in vocal characteristics between the target and competing speech (i.e., talker advantage), the amount of talker advantage was significantly less for CI patients (2 dB) than NH listeners (12 dB). The data from the present study suggest that CI patients are highly susceptible to the competing talker due to its difficulty in segregating the target from the competing talkers, especially one competing talker with the similar vocal characteristics as the target, using monaural factors.

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T22: THE SEGREGATION OF SEQUENTIALLY INTERLEAVED SENTENCES BY NORMAL-HEARING AND COCHLEAR-IMPLANT LISTENERS USING MONAURAL LEVEL CUES.

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Many cues such as pitch and spectral differences that are used for sound segregation by normal-hearing (NH) listeners are severely degraded in cochlear implants (CIs). However, CI listeners are good at detecting level differences, and there is evidence that NH listeners can use level differences to segregate pairs of vocoded sentences (Ihlefeld and Shinn-Cunningham, 2008) when those sentences are interleaved on different sets of frequency channels. The present study investigated whether unilateral cochlear implant (CI) users could use level differences to segregate two sentences, in the absence of additional cues. Due to the greatly reduced frequency resolution and increased target-masker ratio thresholds of CI users, the sentences were interleaved in time and presented sequentially. The Boston University (Kidd et al., 2008) corpus was used to construct interleaved, five-word sentences, consisting of name, verb, number, adjective, and object. The presentation order of the words alternated randomly for each word type. Each sentence began with the same two words and listeners were required to select the last three words in the target sentence.

Experiment 1 tested young NH (YNH) and older NH (ONH) listeners in two sessions. Sentences were presented at three levels: 55 dB SPL, 62.5 dB SPL with a ±7.5 dB trial-to-trial rove, and 70 dB SPL. The level differences between the words ranged from -12 to 12 dB. To prevent training effects that would not be available to CI listeners, the NH listeners were presented with 8-channel vocoded speech in the first session, and clean speech in the second session. Results showed that the task was possible for both with younger and older NH listeners, with performance increasing as absolute level difference increased. No effect of presentation level or level rove was found in either NH group.

Experiment 2 tested unilateral CI listeners at a presentation level of 58 dB SPL, without a rove, and with automatic gain control. In one condition, level differences between the words were randomly varied from trial to trial, similar to the NH listener conditions. In another, CI listeners were tested at a single level difference within a test block, and given prior knowledge of whether the target sentence would be higher or lower in level than the distracter sentence. Results showed that they achieved similar performance to NH listeners at positive level differences. At negative level differences, their performance was more variable. Prior knowledge of the level difference to be presented improved performance in comparison to randomly interleaved level differences.

The CI listener results will be discussed in relation to the effect of fast and slow time-constant dynamic range compression on the unilateral level cues available to CI listeners.

References: Ihlefeld and Shinn-Cunningham (2008). J. Acoust. Soc. Am., 123(6), 4380. Kidd at al. (2008). J. Acoust. Soc. Am., 124(6), 3793

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T23: MODULATION INTERFERENCE BETWEEN BILATERALLY PRESENTED STIMULI IN COCHLEAR-IMPLANT USERS

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Bilaterally-implanted cochlear-implant (CI) users often hear similar temporal envelopes presented to the same approximate electrode location in the two ears. Temporal envelope cues are important for both speech recognition and for complex harmonic pitch perception by CI users. The perception of harmonic pitch (voice pitch) within temporal envelope cues has been linked to the perception of speaker sex, lexical tones, speech intonation and vocal emotions by CI users. The temporal envelope is susceptible to interference through modulation interference, but little is known about such interference mechanisms across ears in bilateral electrical stimulation. In this presentation, we report on contralateral interference in temporal envelope modulation detection by nine adult, bilaterally-implanted CI users. Carrier stimuli were 600ms-long trains of 900-Hz, biphasic current pulses presented in monopolar mode. The target signal was a 50-Hz sinusoidal amplitude modulation presented on one electrode (typically El. 18) on the earlier-implanted side. The interferer was a fixed temporal modulation presented on the carrier stimulating the other ear. The two carrier stimuli were synchronized. Psychometric functions were obtained in a 3-alternative forced-choice procedure in the method of constant stimuli. For each modulated interferer [Mod], a corresponding steady-state interferer was constructed with an amplitude at the peak of the modulation [SSpeak]. Modulation interference was quantified as the difference in accuracy in detecting the target modulation between the Mod and SSpeak interferer conditions. Interferer modulations were at the same rate as the target, or at different rates, or noise. Interferer modulation depths were fixed (typically at 30% above modulation detection threshold for the interferer electrode). Results showed significant modulation interference (higher thresholds with modulated vs. SSpeak interferers) when the interferer and target modulations were similar, and reduced interference when they were different. These results indicate that CI users likely experience substantial contralateral interference between temporal modulations in the two ears. Ongoing analyses of findings with a different interferer electrode location and lower modulation rates for target/interferer will be presented. Implications for speech recognition and voice pitch perception will be discussed.

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T24: ANODIC VERSUS CATHODIC QUADRAPHASIC PULSES: EFFECTS ON THE PERCEPTION OF INTERAURAL TIME DIFFERENCES IN COCHLEAR IMPLANT LISTENERS

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Animal physiological recordings suggest that for a fixed firing efficiency, the neural response to cathodic stimulation has a longer first spike latency than with anodic stimulation (Miller et al., 1999, Hear. Res. 130, pp 197-218). Since the differences in latency they reported (approx. 200 µs) is in the range of perceivable interaural time difference (ITDs), we investigated whether changing the polarity of the stimulation in one ear was enough to affect the perceived localization when presenting pulses simultaneously to both ears.

Six subjects balanced in their right ear the loudness of 20-pps quadraphasic pulse trains that had either a cathodic or an anodic central phase. These pulses have been previously used in the literature to investigate polarity effects in humans. The binaural stimuli were then constructed with the loudness-balanced anodic or cathodic quadraphasic pulse at the right ear, and a quadraphasic anodic pulse at the left ear, with ITDs varying from -1200 to +1200 µs in 400 µs steps. The subjects were asked to rank all stimuli on a left-right axis using a mid-point comparison procedure.

Results showed only individual effects of polarity on the perception of ITD, and no effect at a group level. Furthermore, for some subjects, changing the loudness balancing method had a significant effect on the lateralization results. This suggests that small loudness cues might shadow effects of the stimulus polarity on the latency of the neural response, at least for ITD-based localization in electric hearing.

T25: NORMAL HEARING LOUDNESS GROWTH IN BILATERAL COCHLEAR IMPLANT USERS

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The objective of this study is to provide bilateral cochlear implant (CI) users with normal hearing loudness growth, and to assess whether benefits are obtained in terms of speech perception, localisation and hearing-in-noise capabilities, compared to their conventional map.

Loudness is crucial for functional hearing and can be restored in the deaf by CI stimulation. For CI recipients utilising bilateral devices, the importance of meaningful loudness presentation includes binaural hearing aspects, not present in unilateral CI fitting, such as: loudness summation, localisation and hearing in spatially-dispersed noise.

Conventional CI sound processing and fitting from Cochlear is not designed to convey normal hearing loudness perception, particularly at high input levels, and the parameter configuration to modify loudness growth is limited to broad-band adjustments. Thus, achieving normal-hearing loudness perception simultaneously across a range of frequencies and input levels is challenging.

In order to provide more flexibility in matching normal-hearing loudness targets, an experimental setup was provided that allowed full configuration of loudness mapping. To achieve this, multiple independent hearing-aid style automatic gain controls were used to map input level (in dB SPL) to stimulation level (in Current Level units) for each electrode. Categorical measures of loudness were obtained for one-third octave noise bands at presentation levels from 20 to 90 dB SPL at 6 different frequencies. These were subsequently used to create individualised loudness growth functions for both ears in each subject. Using this data and a model of loudness for electrical hearing, adjustments were applied to the experimental setup in order to match normal-hearing loudness targets.

For each subject, the experimental setup was compared against the conventional fitting under a number of test conditions. Basic speech performance was assessed with monosyllabic words-in-quiet and sentences in babble noise, while hypothesised improvements in binaural hearing abilities were assessed by localisation and speech reception in spatially-separated noise tests.

The results of the study will be presented.

T26: SPECTRAL AND BINAURAL LOUDNESS SUMMATION IN SINGLE-SIDED-DEAFNESS AND BILATERAL COCHLEAR IMPLANT USERS

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In a study of Oetting et al. [(2016) Hearing Research, 335:179-192] large individual differences in loudness perception of binaural broadband signals for hearing impaired listeners compared to normal-hearing listeners were found, suggesting that binaural, broadband signals should be included in hearing aid fitting. Clinical cochlear implant (CI) fitting typically not considers broadband signals, which might cause suboptimal loudness perception in bilateral CI and especially in bimodal CI listeners. This study investigates the spectral and binaural loudness summation of three listener groups: Normal hearing listeners (reference group), bilateral CI users, and single-sided-deafness (SSD) CI users with normal hearing in the contralateral ear. To compare the three groups, categorical loudness scaling of an equal categorical loudness noise [ECLN; Ewert and Oetting (2018), International Journal of Audiology, 57:71-80] is used. The ECLN consists of the sum of six spectrally separated third-octave noises at equal loudness levels. The acoustical ECLN stimulus was adapted to an equivalent stimulus in the electrical domain using direct stimulation. The employed test setup allows acoustical stimulation, electrical stimulation, as well as combined acoustical and electrical stimulation. To ensure the same broadband loudness in binaural measurements with simultaneous electrical and acoustical stimulation, a binaural equal loudness broadband noise is introduced and the binaural perception is validated with a binaural fusion and loudness matching experiment. Results show a higher (spectral) loudness summation of equally loud narrowband signals in CI users compared to normal hearing listeners, indicating unbalanced loudness perception of equally loud narrowband signals in both ears. The suggested binaural equal loudness noise appears to improve binaural fusion at least for the SSD CI users.

T27: USING PARTICIPATORY DESIGN TO DEVELOP AND EVALUATE A TOOL FOR DETECTING LOUDNESS IMBALANCE ACROSS EARS IN BILATERAL COCHLEAR-IMPLANT USERS

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Introduction: Appropriate loudness balance across ears is crucial to optimise the localisation of sound sources and the understanding of speech in noisy environments. Teenagers with bilateral cochlear implants often report problems when listening in everyday environments. Since teenagers spend a significant part of their time in noisy environments (such as schools and social events' venues), these difficulties can impact on their speech and language development, education, and social wellbeing. Through work with patient and public involvement (PPI) representatives, a localisation training software application originally created within the 3D Tune-In EU-funded project has now been customised specifically for teenagers with bilateral cochlear implants (see https://www.youtube.com/watch?v=E-Rn7ipiJAg&t=10s). Before evaluating the localisation app within a future project, it was necessary to make sure that any imbalances between right and left implants are minimised. This can be done using a simple application that can inform the audiologist when fitting bilateral cochlear implants.

Methods: A participatory design experiment will be performed to evaluate a procedure and application that can be used to detect loudness imbalance for different frequency bands across ears. The first stage will involve twenty normal-hearing participants randomly allocated to one of two groups. Group NH1 will be presented with sound stimuli delivered via headphones. The sound level balance across ears will be controlled using a knob and several frequency bands will be investigated. Participants will set the knob so that the sound is perceived in a central position. This will be done to determine: 1) The feasibility of the task; 2) The occurrence of learning or fatigue effects; 3) The reproducibility of the results; 4) The outcomes expected for normal-hearing listeners. Group NH2 will perform a similar task, but asymmetric hearing will be simulated by selectively attenuating specific frequency bands on the stimuli presented to one of their ears. This will be done to determine the reliability of the developed application to detect loudness imbalance across ears. Two overall levels will be used: 50 and 70 dB SPL. The second stage will involve twenty bilaterally implanted teenagers and young adults (11-25 years old) randomly allocated to one of two groups (CI1, CI2), similarly than normal-hearing participants. The tasks will be the same than for groups NH1 and NH2, respectively, but each task will be carried out with and without the automatic gain control (AGC) of their cochlear-implant processors switched on in order to determine whether any lateralisation biases are influenced by amplitude compression. Loudness ratings for sounds delivered via each cochlear implant separately will be obtained for comparison with the biases detected by the tool.

Results: Findings on the reliability of the tool (procedure and application) and how it can be used to guide implant mapping will be presented.

Conclusions: A tool that allows implant users (and audiologists) to give feedback about the parameters of their implant map could lead to better bilateral mapping and in turn improved speech-in-noise and sound localisation outcomes.

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T28: ONSET WEIGHTING OF INTERAURAL TIME DIFFERENCES IN NEONATALLY DEAFENED CI RATS IS COMPARABLE TO NORMAL HEARING RATS

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Cochlear implants (CIs) are undeniably useful, but the auditory perception gained from current devices still fails for complex, real life, environments. One particular shortcoming is the inability to provide CI users with adequate temporal spatial cues, or interaural time differences (ITDs). We have previously shown that neonatally deafened rats are, perhaps surprisingly, capable of discriminating ITDs as small as 50 µs, apparently no worse than their normally hearing litter mates. Here we assessed whether both neonatally deaf (ND) CI and normally hearing (NH) rats show a similar strong emphasis on the onset in their ITD based location judgment of rapid sequences of pulses, as has been described in normal hearing humans.

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Neonatal rats were deafened using an established kanamycin protocol and, as young adults, bilaterally implanted with CIs. Normally hearing rats served as controls. A 2-alternative forced choice task was used to determine the temporal weighting functions (TWFs) of ITD cues. The animals lateralised pulse trains consisting of eight binaural pulses (either biphasic electric stimuli delivered via CI for the ND rats or acoustic clicks delivered over tube phones for the NH animals). Correct responses were reinforced with drinking water. ITD values of individual pulses were jittered, pseudorandomely, within the physiological range. Presented trials were divided into honesty trials, where all pulses were either left or right leading, and probe trials with ITDs shifting between left and right for each of the eight pulses. TWFs were subsequently calculated using multiple regression analysis to determine the perceptual weight of each pulse in the train of the probe trials.

Both NH and ND rats had temporal weighting functions comparable with human subjects from previous studies in that they tended to put more weight on the first pulse in the train than on subsequent pulses. However, while the onset cues dominate ITD perception with CI stimulation, this up-weighting does not seem to be as pronounced as in normal hearing listeners.
These findings are relevant to the design of future CI processing strategies aiming to provide better sound source localization and spatial unmasking with CIs.

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These findings suggest that, while the onset cues dominate ITD perception with CI stimulation, this up-weighting does not seem to be as pronounced as in normal hearing listeners. These findings are relevant to the design of future CI processing strategies aiming to provide better sound source localization and spatial unmasking with CIs.

T29: SENSITIVITY OF COCHLEAR IMPLANT USERS TO ITDS OF PURE TONES USING CLINICAL CODING STRATEGIES

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Cochlear Implants (CI) are remarkable in restoring speech intelligibility in quiet in profoundly deaf individuals. However, speech intelligibility in noise and spatial release from masking are still challenging. The spatial separation of target and interfering sound sources relies primarily on binaural cues, i.e. ILDs (interaural level difference) and ITDs (interaural time difference). While normal-hearing listeners rely on both ILD and ITD cues, ILDs are the dominant cues available to CI listeners [1]. The continuous interleaved sampling (CIS) strategy relies on envelope coding. It conveys coarse envelope ITDs, but discards ITDs in the fine structure (FS). The FS4 coding strategy was developed to convey FS of sound. Laback et al [2] reported that CI subjects are sensitive to ITD fine structure cues up to 400 - 800 pps on single pitch matched electrode stimulation.

This study assessed just noticeable differences (JNDs) for ITDs of low-frequency pure tones at various frequencies in 30 CI listeners. Pure tones were presented bilaterally over direct-input cable to clinicalOPUS2 audio processors. ITD sensitivity was tested with HDCIS and FS4 sound coding strategies, and with the FSP sound coding strategy in some subjects. ITD sensitivities were measured using a 2-cue 2-interval alternative forced choice (AFC) paradigm, and JNDs defined as 50% correct points on the psychometric function were determined via generalized-linear model fit to the data.

Results showed that FS4 can convey ITD cues at 100 Hz in most of the subjects with the clinical fitting, whereas HDCIS and FSP could not. This was also true for subjects that used HDCIS or FSP in their daily fitting, indicating a physiological rather than a learning effect. ITD sensitivity at 100 Hz with FS4 corresponded to JNDs reported by Laback et al. for pitch-matched bilateral electrode pairs [2]. For higher frequencies, JNDs increased rapidly and ITD sensitivity was lost around 200 Hz in most subjects. Nevertheless, the best performing subjects were sensitive to ITDs at pure-tone frequencies of up to 400 Hz. This is below the maximum rates of 400-800 pps (1000 at best) at which ITD JNDs were still measurable on pitch-matched electrode pairs in carefully selected subjects in [2].

Almost all subjects showed ITD sensitivity at low frequencies, when stimuli were delivered by the clinical speech processor running an FS4 coding strategy with the subjects' everyday maps. The variability of ITD sensitivity across subjects was higher than in comparable studies, which may be explained by the fact that subjects were not pre-selected and that stimuli were presented via the standard audio processors (which are not synchronized) programmed with clinical everyday maps, instead of selected pitch-matched electrode pairs.

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T30: WITHIN-EAR BALANCING OF RESPONSE STRENGTH BETWEEN ACOUSTIC AND ELECTRIC STIMULATION IMPROVES NEURAL SENSITIVITY TO INTERAURAL TIME DIFFERENCES IN BIMODAL STIMULATION

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Unilateral cochlear implants (CIs) have emerged as a treatment option for subjects with single-sided deafness (SSD), allowing combined electric stimulation of one ear and acoustic stimulation of the other ear. Although such bimodal stimulation enables binaural hearing in these subjects ('SSD-CI users'), their speech perception in noise and directional hearing is typically poorer than in normal-hearing listeners. Moreover, improvements in directional hearing in SSD-CI users are mainly based on interaural level differences, not on interaural time differences (ITDs). Possible explanations for these deficits in SSD-CI users include deafness-induced degradations in neural ITD sensitivity or between-ear mismatches in the sites of activation or in the relative stimulation level of either mode.

Here, we characterized the responses of single neurons in the inferior colliculus to ITDs in normal-hearing gerbils that had been unilaterally implanted with a round window electrode to enable electric stimulation of auditory-nerve fibers while maintaining acoustic sensitivity of the implanted ear. This approach excluded the possibility of deafness-induced degradations as a contributing factor in ITD processing, and allowed us to directly compare ITD coding to both bimodal and unimodal-acoustic stimulation (low-rate biphasic electric pulses and acoustic clicks) in the same neuron.

The incidence of ITD-sensitive neurons was similar for bimodal and unimodal-acoustic stimulation. Generally, shape categories of ITD tuning functions were similar to those described for unimodal acoustic click or electric pulse stimulation (Vollmer, J Neurosci 38, 2018). Also, ITD-dependent modulations in spike rate occurred within similar ITD ranges after adjusting for peripheral delay differences between acoustic and electric stimulation in the implanted ear. However, within given neurons, the shapes of ITD response functions for bimodal stimulation often differed from those for unimodal-acoustic stimulation and were highly level dependent. To balance the response strength between stimulus modes, we adjusted the electric stimulus level in the implanted ear to match the spike rate of the same ear in response to acoustic stimulation. This in turn balanced the binaural cues between the two ears and increased the shape similarity of ITD response functions to bimodal and unimodal-acoustic stimulation obtained from the same neuron. Moreover, matched-pair comparisons in the same sample of neurons revealed no differences in degree of ITD sensitivity or in neural discrimination thresholds (relative to best ITD) between bimodal and unimodal-acoustic stimulation.

Our results in the normal hearing system reveal widespread similarities of neural ITD coding to bimodal and unimodal-acoustic stimulation. However, the results also reveal that balancing relative delay and binaural level cues between the two modes of stimulation is important to improve the binaural benefit from bimodal hearing in SSD-CI users.

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T31: IMPROVING ITD-BASED LOCALIZATION OF BILATERAL CI USERS BY SELECTED TEMPORAL MANIPULATION OF THE SOUND'S ENVELOPE

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Interaural time differences (ITDs) help normal hearing (NH) listeners perceive, locate and understand sounds in noisy and reverberant conditions. However, users of bilateral cochlear implants (BiCI) show only limited sensitivity to ITDs in the timing of electrical pulses at the high rates used in most CIs, but they can utilize ITDs in the amplitude envelope applied to the pulse train, particularly if that envelope is characterized by deep modulations and sharp onsets. In natural listening situations with background noise and reverberation, however, both characteristics are disrupted (Monaghan et al., 2013). Monaghan & Seeber (2016) therefore developed an onset enhancement (OE) algorithm that selectively sharpens and deepens modulations at onsets of selected peaks in the signal envelope. The algorithm was shown to improve envelope ITD sensitivity for NH individuals listening through a tone vocoder, and for BiCI users (Wijetillake & Seeber, 2015). It uses knowledge of the short-term direct-to-reverberant ratio (DRR) to select peaks that are dominated by the direct sound rather than reflections and applies enhancements at the times of envelope peaks. However, analysis revealed that envelope peak timings do not optimally convey the source's ITD in reverberation.

Wijetillake et al. (2017) presented an updated version of the OE algorithm that additionally estimates the short-term ITD from the signal's temporal fine structure and encodes that ITD in the timing of enhancements. Furthermore, the new algorithm enhances envelope peaks selected by the short-term interaural coherence (IC), which, unlike the DRR, requires no a-priori knowledge. Evaluations with a vocoder version revealed that the algorithm significantly improved ITD sensitivity, for all DRRs examined, relative to the old algorithm and unenhanced case, without degrading speech understanding.

For the present study, the algorithm was implemented on the RIB II research interface for testing users of Med-El CIs with a comprehensive binaural test suite in virtual acoustic reality. The new algorithm is evaluated against the old algorithm and unenhanced processing with regard to the sensitivity to the ITDs of the direct sound in (simulated) reverberation and to speech understanding. The former is assessed with an intracranial lateralization test, the latter with an Oldenburg sentence test. Both tests employ speech stimuli convolved with binaural room impulse responses (BRIR) that simulate conditions in a reverberant rectangular gypsum-walled room. The simulated source-receiver distances of the BRIRs are varied to generate different DRRs. The ITD of the direct signal is adjusted, and the interaural level difference (ILD) set to 0 dB, without altering the reflected signals. This ensures that outcomes are not confounded by ILD cues in the direct signal or by shifts in the position of reflections. Results from the ongoing evaluation will be presented.

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T32: ARE BALANCE DEFICITS IN CHILDREN WITH BILATERAL AND UNILATERAL DEAFNESS DUE TO VESTIBULAR IMPAIRMENT ALONE?

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Objective: We aim: 1) to assess balance deficits in children with bilateral and unilateral deafness and 2) to identify the sensory abnormalities which underlie balance problems in these children. Rational: Children with hearing loss are at risk of balance problems. These deficits are expected as many etiologies of hearing loss affect the vestibular system. Balance challenges may extend beyond vestibular function alone as poor binaural/spatial hearing in and of itself may also be an important contributor. Clinical tests of vestibular end organ function (Vestibular evoked myogenic potential (VEMP), video head impulse testing (vHIT), calorics) rely on muscular reflexes to detect deficits in the vestibular system but may not be sensitive to the balance challenges experienced by children with hearing loss.

Hypotheses: 1) Balance is poorer in children with bilateral deafness compared to unilateral deafness; 2) Balance problems in children with hearing loss may be worse than indicated by tests of vestibular end-organ function.

Method: Balance (Bruininks Oseretsky Test of Motor Proficiency (BOT-2) balance subtest), otolith function (subjective visual vertical (SVV)) and vestibular-ocular reflexes (dynamic visual acuity (DVA)) were assessed in 32 children who received early bilateral cochlear implants (BCIs) simultaneously (mean age(SD)=8.94(2.88) years), and 20 children with untreated single-sided deafness (SSD) (mean age(SD)=10.73(4.17) years). In addition, the vestibulo-ocular reflex (VOR) was assessed using video Head Impulse Testing (vHIT) in eight of the children with BCIs (mean age(SD)=9.79(3.38) years). Results were compared to 36 normal hearing peers (mean age(SD)=10.03(3.25) years).

Results: Children with BCIs and SSD had significantly poorer balance as measured by lower BOT-2 balance scaled scores compared to children with normal hearing; 41%(BCI) and 50%(SSD) fell below the normal range. There were no significant differences in utricular function, as measured by SVV absolute mean scores or VOR function, as measured by DVA scores, between groups. Lateral canal function, as measured by vHIT gain, was poorer than clinical norms in 2/8 children with BCIs. None of the vestibular measures were correlated with one another and none significantly predicted balance performance as measured by BOT-2 scores.

Conclusions: Balance problems exist and are more prevalent in children with BCIs and SSD than normal hearing peers but are not significantly explained by differences in the prevalence of otolith and/or VOR dysfunction. The findings suggest that: 1) children with hearing loss have balance dysfunction that is likely multifactorial and extends beyond vestibular impairment alone and 2) the present measures of vestibular function may not be adequately sensitive to vestibular impairments in children who are deaf and have poor balance.

T33: DISRUPTED INTERHEMISPHERIC COHERENCE IN CHILDREN RECEIVING BILATERAL IMPLANTS SIMULTANEOUSLY

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Objective: To investigate the integrity of functional cortical auditory networks in children who received bilateral cochlear implants in the same surgery.

Rationale: Children receiving bilateral cochlear implants simultaneously develop expected strengths of cortical peak source activity from each ear, thus avoiding an aural preference. Despite this advantage over peers implanted sequentially, the simultaneous group has impaired binaural hearing as measured both cortically and in behavioral measures. We thus hypothesize that the inputs from each ear are not integrated sufficiently in children receiving bilateral cochlear implants.

Methods: Cortical responses were evoked using cochlear implant pulse trains in 16 children, aged 6.0 ± 0.7 years, who received bilateral cochlear implants in the same surgery at 2.0 ± 0.9 years of age and had 4.0 ± 1 years of bilateral implant experience. These data were compared with cortical responses evoked by acoustic click trains in 13 children with normal hearing who were matched to the implant group by “hearing age” (5.1 ± 1 years). Responses were elicited under both unilateral and bilateral stimulation conditions. Connectivity analyses were performed by calculating the coherence between source time series estimated by the Time Restricted Artifact and Coherent source Suppression (TRACS) beamformer. The imaginary part of coherence was also calculated to account for volume conduction.

Results: Interhemispheric coherence between the auditory areas was reduced in response to bilateral stimulation in bilateral implant users relative to the normal hearing group. There was no significant difference between groups in the unilateral conditions.

Discussion: These findings reflect either disrupted interhemispheric communication between the auditory areas or differing processing strategies within each auditory cortex which creates more independent functioning. In either case, disrupted cortical connectivity to bilateral input is consistent with impaired binaural processing observed in children with cochlear implants.

T34: HEAD SHADOW ENHANCEMENT TO IMPROVE SOUND LOCALIZATION AND SPEECH INTELLIGIBILITY IN NOISE FOR BIMODAL LISTENERS

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Due to the head shadow, the human ear naturally focuses on sounds that arrive from its ipsilateral side. This can attenuate noise sources such that it improves speech understanding, and it introduces interaural level differences (ILDs) which can be used to localize sounds in the horizontal plane. Aiming to amplify these advantages – in particular for listeners with poor speech understanding and localization performance – we recently developed a method to enhance the head shadow effect. Head shadow enhancement was achieved by supplying each ear with a fixed beamformer that attenuates sounds coming from the contralateral side – in contrast to standard beamformers that attenuate sounds coming from the back.

In a previous experiment with simulated bimodal listeners (cochlear implant listeners with a contralateral hearing aid) and pre-processed stimuli, we found that this method significantly improved localization performance and speech intelligibility in spatial conditions where head shadow is expected to be present [1]. Here, we validate head shadow enhancement on actual bimodal listeners in a real-time implementation. Results of the localization and speech-in-noise intelligibility experiments will be presented at the conference.

Apart from bimodal listeners, the method is also promising for bilateral cochlear implant and hearing aid users. Its computationally cheap processing makes the method suitable for application in current clinical devices.

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T35: SPATIAL HEARING OF BIMODAL EAS USERS

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Aim: Monaural listeners (single-sided deaf and unilateral cochlear implant [CI] users) use sound level to localize sounds, even though this cue is ambiguous and confounds head shadow with sound-source level. Bimodal electro-acoustic stimulation users with a contralateral hearing aid can potentially use binaural cues - specifically interaural time differences (ITDs) - to localize sounds due to bilateral residual hearing of lower frequencies. However, for higher frequencies, these individuals are essentially monaural, only having aided hearing in their CI. The goal of this study is to determine how ITD and level cues play a role in low- and high-frequency sound localization, respectively, of bimodal EAS users.

Design: Seven bimodal EAS users had to localize low-pass (100-500Hz) and broadband (500-10000Hz) and sounds, presented over a 30-dB level range (50, 60, 70 and 80 dBA), from -75 to +75 deg in the horizontal plane. Testing was done both with all the devices turned on (aided) and with all the devices removed (unaided).

Results: Bimodal EAS users localized broadband sounds poorly, both aided (rms error = 45 ±7deg) and unaided (rms error = 33 ± 10 deg for 2 listeners, the other listeners reported hearing no sounds). Responses were systematically biased as a function of sound level in the aided condition alone: louder sounds were perceived more towards the hearing aid ear. Low-pass sounds were localized more accurately in both conditions (rms error = 32 ±3 deg for aided and 35±10 deg for unaided). Two listeners had a systematic, linear stimulus-response relationship for low-pass sounds (r2= 0.89, rms error = 16 deg). No systematic bias was observed, neither in the aided nor in the unaided condition.

Discussion: ITD cues seem to be used by 2 out of 7 listeners, both when aided and when unaided, but only for low-pass sounds, however it is striking that only two participants had access to ITDs despite substantial residual hearing. For sounds with higher-frequency content, the bias per sound level in the aided condition was opposite to that expected for monaural listeners. The monaurally deaf generally localize softer sounds towards the deaf ear, and louder sounds towards the hearing ear. The bimodal EAS users localized the louder broadband sounds towards the hearing aid side, even though this side is practically deaf for those sounds.

T36: SPATIAL SPEECH INTELLIGIBILITY IN BIMODAL AND SINGLE-SIDED DEAF COCHLEAR IMPLANT USERS – A MODEL, SIMULATION AND PATIENT MEASUREMENT COMPARISON

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Contralateral audiometric thresholds and speech intelligibility vary greatly across cochlear implant (CI) users with acoustic hearing in the non-implanted ear. This study systematically compares spatial speech-in-noise performance in these (bimodal or single-sided deaf, SSD) CI users using three different paradigms, in order to reveal the influence of spatial scenario and contralateral audibility on speech intelligibility. The three paradigms include (1) measurements of 16 actual CI users with a mobile measurement platform, (2) vocoder simulations of electric and acoustic listening with normal hearing (NH) listeners, and (3) an "effective" model of electric, acoustic and bimodal electroacoustic speech-in-noise performance. All three paradigms controlled for secondary factors, e.g., head movements, room acoustics, and hearing aid signal processing (using the Master Hearing Aid). Eleven NH participants listening to unprocessed speech and noise were used as a reference group.

The results show a clear dependence of speech reception thresholds (SRTs) on spatial scenario, and a dependence of both SRTs and spatial release from masking (SRM) on contralateral audibility in all three paradigms. Task-specific "better-ear listening" dominates the results in all three paradigms. This is true even for the effective model, where the possibility of processing the signal's fine time structure across ears was enabled, but was not effective. Instead, the model utilized the best signal-to-noise ratio of either acoustic or electric listening, which could change, depending on contralateral audibility and spatial scenario.
Both, model and simulations were capable of predicting patient data with high accuracy (rank correlation of 0.99 for SSD, and 0.88 for bimodal CI users). Thus, model and simulations create "virtual" SSD and bimodal CI listeners that can be used to evaluate signal enhancement algorithms in a systematic way, before testing them on actual CI users.

T37: EFFECTS OF ELECTRO-ACOUSTIC STIMULATION ON HEARING IN GUINEA PIGS WITH HYBRID COCHLEAR IMPLANTS

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The Electro-Acoustic Stimulation (EAS) or "hybrid" cochlear implant (CI), combines high-frequency electric stimulation with residual low frequency acoustic hearing, and can be used with a hearing aid in the same ear. Hybrid CI users have shown to benefit from this combination, for example demonstrating greater speech comprehension in background noise in comparison to traditional CI users. However, 30-55% of hybrid CI users lose residual acoustic hearing days to months after implantation and activation of the CI, indicating both surgical trauma and electric stimulation may play a role in this residual hearing loss. Through this study, we aim to identify the mechanisms of residual acoustic hearing loss related to implantation and activation of hybrid CIs in an animal model. Additionally, we aim to assess age as a risk factor for increased residual hearing loss with hybrid CIs.

Two groups of guinea pigs, aged 12-21 months, were implanted with a CI in the left ear. After four weeks of recovery, the stimulated group (n=3) received 40 hours a week of electro-acoustic stimulation for a period of 20 weeks. The non-stimulated group (n=5) received no acoustic or electric stimulation over the same time frame. Auditory brainstem responses (ABRs), electrically-evoked auditory brainstem responses (EABRs), and cochlear microphonics (CMs) and compound action potentials (CAPs) were recorded monthly over the course of the experiment to assess changes in acoustic thresholds, electric hearing, and neural responses. Following the completion of the experiment, all animals were perfused and cochlear tissue was harvested for histological evaluation to assess physiological differences between implanted and control ears, and between stimulated and non-stimulated groups.

Cochlear implantation led to an immediate increase in ABR thresholds in both young and old animals with thresholds peaking between 3-5 weeks after surgery and then recovering and stabilizing. The older animals exhibited larger post-operative threshold shifts than younger animals tested in previous studies, suggesting that older age may increase the amount of hearing loss caused by surgical trauma. Preliminary findings also suggest that the stimulated animals had greater delayed low frequency ABR threshold shifts compared to the non-stimulated group. For all animals pooled together, higher EABR thresholds were positively correlated with greater high-frequency ABR threshold shifts after surgery. Additionally, EABR amplitude growth function slopes were negatively correlated with high frequency ABR threshold shifts. The correlations between acoustic threshold shifts and electric stimulation measures suggest that surgical trauma may disrupt both acoustic hearing and electric stimulation via the neural pathway.

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T38: EFFECT OF THE DEVICE DELAY MISMATCH ON SOUND LOCALIZATION ACCURACY IN BIMODAL LISTENERS

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Differences in processing latencies of a cochlear implant (CI) provided ear contralateral to a hearing aid (HA) provided ear constantly superimpose interaural time differences (ITD) in bimodal CI/HA listeners. In case of MED-EL CI systems the device delay mismatch is as large as 5 to 10 ms depending on the type of HA worn contralaterally, with the CI stimulation reaching the auditory pathway first. In the current study, we investigated the effect of the device delay mismatch on sound localization accuracy in actual and simulated bimodal listeners. To deal with the device delay mismatch in actual bimodal listeners we designed a battery-powered, portable and programmable delay line. This device was used to delay the CI stimulation according to the measured HA processing delay in 9 bimodal listeners. The aim was to minimize the device delay mismatch in order to personalize the CI for use with the individually worn contralateral HA. Localization tests were conducted without and with the delay line. In between the tests a one-hour-acclimatization-period to the delay line was accomplished. With the minimized device delay mismatch, localization accuracy was highly significantly improved compared to the situation without (mean improvement: 11%; $p<.01$, Wilcoxon Signed Rank Test). In simulated bimodal listeners in virtual acoustic space the simulated device delay mismatch was varied, resulting in decreasing localization accuracy with increasing device delay mismatch. We conclude that the implementation of a programmable delay line in CI processors is a promising way to improve localization accuracy in bimodal listeners.

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T39: THE BENEFIT OF CONTRALATERAL ROUTING OF SIGNALS IN CI USERS WITH RESIDUAL HEARING

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In the Netherlands and other countries, bilateral cochlear implantation is not the standard of care. Unilateral cochlear implant users can benefit from a technology referred to as contralateral routing of signals (CROS). A CROS device consists of a microphone worn on the contralateral ear that redirects the sound to the speech processor via a wireless link (Taal et al., 2016). CROS can improve contralaterally presented speech understanding by eliminating the head-shadow effect. Because of the current trend towards more lenient implantation criteria, a larger proportion of unilateral CI wearers have substantial residual hearing in the implanted ear. In this study, we analyze the benefits of wearing a CROS device in relation to the amount of residual hearing.

17 unilaterally implanted subjects were recruited. 6 subjects normally wore a hearing aid in the contralateral ear. One subject had near-normal hearing in the contralateral ear. While the hearing aid was taken out during testing, no ear plugs were used in any of the subjects. Speech understanding was tested by determining the speech reception threshold (SRT) in fluctuating noise using the Dutch/Flemish Matrix sentence material. Speech and noise were presented on opposite sides at angles of 90°.

When the speech was presented contralaterally (i.e., on the CROS side), and the noise ipsilaterally (i.e., on the CI side) there was a significant improvement of the SRT by 6.4 dB ($P < 0.0001$). In the reverse situation, there was a significant disadvantage of 8.4 dB wearing the CROS device ($P < 0.0001$). The difference between the advantage and disadvantage (2 dB) was significant ($P < 0.05$). Both the advantage and disadvantage of the CROS were negatively correlated with the amount of residual hearing ($P < 0.01$ for both). A regression analysis showed that the advantage and disadvantage of the CROS was nil at a Fletcher's index of +23 dB (near normal-hearing) and -34 dB (far beyond normal hearing), respectively.

In conclusion, when speech is presented contralaterally, CROS significantly and substantially improves speech understanding. Residual hearing negatively impacts the maximal benefit and CROS becomes beneficial only at a Fletcher's index of approximately 23 dB. This corresponds to the notion that speech understanding is only affected at hearing losses larger than 20 to 30 dB (Smoorenburg, 1992; Killion and Mueller, 2010). Conversely, more residual hearing correlates to a lesser disadvantage of CROS use when the speech is presented on the CI side. This disadvantage never becomes nil, as the CROS always adds noise to the CI. The benefit and disadvantage become equal only when there is no functional residual hearing left. Otherwise, the disadvantage when speech is presented ipsilaterally is always bigger than the advantage in the opposite speech direction. Our results support the notion that a CROS device will have maximal benefit and minimal disadvantage when the contralateral ear has no residual hearing left (Taal et al., 2016).

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T40: CONTRALATERAL SUPPRESSION OF HUMAN HEARING SENSITIVITY IN SINGLE-SIDED DEAF COCHLEAR IMPLANT USERS

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Cochlear implants (CIs) are being implanted in people with unilateral hearing loss because they can improve speech intelligibility and sound source localization. Though designed to restore the afferent auditory stimulation, the CI possibly restores some efferent effects. The present study aimed at investigating this possibility through otoacoustic emissions and psychoacoustic measurements. Five single-sided deaf CI users with less than 30 dB hearing loss up to 4 kHz in their acoustic ear participated in a study consisting of two experiments. The first experiment consisted on detecting absolute thresholds for their acoustic ears. Pure tones of 500 and 4000 Hz with durations of 10 and 200 ms in the presence and in the absence of contralateral broadband electrical stimulation (CBES) delivered with the CI were measured for this purpose. The electrical stimulus consisted of pulse trains (symmetric biphasic pulses with phase duration 36 μs) on all 16 electrodes sequentially stimulated at a rate of 843 Hz. Its intensity was set to sound as loud as broadband noise at 50 or 60 dB SPL in the acoustic ear. Thresholds were measured using a three-interval, three-alternative, forced-choice procedure with a two-down, one-up adaptive rule to estimate the level for 71% correct in the psychometric function. Thresholds measured without the CBES were lower for the longer than for the shorter tones, and the difference was larger at 500 than at 4000 Hz. CBES equivalent to 50 or 60 dB SPL caused significant threshold elevation only for short (10 ms) and low frequency (500 Hz) acoustic tones of 1.2 and 2.2 dB. These increases appear smaller than previously reported for normal hearing listeners in related experiments. These results support the notion that for single-sided deaf CI users, the CI modulates hearing in the acoustic ear. The second experiment consisted on assessing the effect of contralateral electric stimulus on transient evoked otoacoustic emissions (TDOAEs) and differential product otoacoustic emissions (DPOAEs) on the normal hearing side. The contralateral electric stimulus consisted of noise presented through the direct in cable of the CI speech processor. Before starting the experiment, a tympanometry was conducted to make sure that the electric noise masker did not activate the stapedius reflex. The 4 subjects that participated in experiment 2 presented a reduction of TDOAEs with an average of 0.68 dB. Both otoacoustic and psychoacoustic experiments support the notion that for single-sided deaf CI users, the CI modulates hearing in the acoustic ear. The OAEs probably indicate that this modulation is caused by the medio olivocochlear reflex.

T41: PITCH MATCHING IN COCHLEAR IMPLANTEES WITH SINGLE-SIDED DEAFNESS: EFFECTS OF ELECTRODE POSITION AND ACOUSTIC STIMULUS TYPE

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Background: Studies in patients with single-sided deafness (SSD) have reported results of direct pitch comparisons between electric stimulation of their cochlear implant (CI) and acoustic stimulation presented to the normal-hearing contralateral ear. The acoustic stimuli were generally pure tones of different frequencies, while it has been shown that the percept elicited by single-electrode electric stimulation is different than that produced by a pure tone and may be closer to a wideband stimulus. For example, Lazard et al. (2012, PLoS ONE 7(6):e38687) tested subjects with residual hearing at the apex and showed that an inharmonic complex tone provided a better match to the sound sensation of the most apical electrode. Similarly, comparisons between speech presented via CI and vocoder simulations have shown that a sine vocoder sounds substantially different (Dorman et al. 2017, Otol Neurotol 38(8):e268). Given that pitch comparisons between sounds with different timbres is a difficult task and subjected to various types of range biases (Carlyon et al. 2010, J Assoc Res Otolaryngol 11(4):625), the present study aims to investigate the effect of using different comparison sounds on the frequency and variability of the electric-acoustic pitch matches.

Methods: Pitch matches were collected from 13 unilateral CI users with SSD using a method based on the binary search algorithm to limit range biases. Electric stimulation was presented at either an apical or medial electrode position and at a constant stimulation rate of 800 pps. Acoustic comparison sounds were either pure tones (SINE), 1/3-octave wide narrow bands of Gaussian noises (NOISE), or 1/3-octave wide pulse spreading harmonic complexes (PSHC, Hilkhuysen and Macherey, 2014, J Acoust Soc Am 136(3):1281). On the one hand, NOISE and PSHC are presumed to better mimic the spread of excitation produced by a single-electrode stimulation than SINE. On the other hand, SINE and PSHC contain less inherent fluctuations than NOISE and may therefore provide a temporal pattern more similar to that produced by a constant-amplitude electric pulse train than NOISE. We hypothesized that (1) the medial electrode will be matched to a higher frequency than the apical electrode and that (2) pitch matches obtained with PSHC will be less variable than those obtained with SINE or NOISE.

Results: Mean pitch matches using a two-way repeated-measures ANOVA (electrode position and comparison sound) showed an effect of electrode position ($F(1,8) = 41.9$, $p < .001$) and an effect of comparison sound ($F(2,16) = 3.8$, $p = .044$), but no interaction effect. Post-hoc analysis confirmed that for a given comparison sound, the medial electrode was matched to a higher frequency than the apical one ($p < .001$), with significantly higher across-subject pitch matches for PSHC compared with SINE ($p = .029$). Analysis of mean pitch match variance showed that NOISE and PSHC were generally higher than SINE, but a one-way repeated-measures ANOVA showed no significant effect of comparison sound. Frequency estimations based on x-rays (using the angle of insertion, Stakhovskaya et al., 2007, J Assoc Res Otolaryngol 8(2):220) only correlated with mean pitch matches of PSHC for the apical electrode (Pearson's $r = .58$, $p = .037$, two-tailed) but not for the medial electrode or for other comparison sounds.

Conclusion: Preliminary analysis showed that the electrode position had an effect on pitch matching independent of comparison sound, which is in accordance with the place pitch theory. There was a general effect of comparison sound but without significant differences in post-hoc analysis. Still, an effect of comparison sound was found in the apical region when the variation in angles of insertion was considered.

T42: BINAURAL PITCH FUSION: COMPARISON OF ISOLATED AND TEMPORALLY FLANKED DICHOTIC STIMULI

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A recent study shows that binaural pitch fusion, the fusion of dichotically presented stimuli that evoke different pitches, can be affected by temporal envelope modulation (Oh and Reiss, 2018, Trends in Hearing, 22, 1-12). The current study investigated how another type of cue, temporal flanking stimuli in a stream segregation task, can affect binaural pitch fusion, and whether effects differ between normal-hearing (NH) listeners and hearing-impaired (HI) listeners who use hearing aid (HA) and/or cochlear-implant (CI). We hypothesized that adding stimuli either prior or posterior to the binaurally fused tone combination will lead to competition for streaming and reduce binaural pitch fusion.

24 adult subjects including 6 NH listeners, 6 bilateral HA users, 6 bimodal CI (CI worn with HA in contralateral ear), and 6 bilateral CI users were recruited in this study. Fusion ranges, the frequency or electrode ranges over which binaural pitch fusion occurs, were measured with two different types of stimuli: isolated dichotic stimuli with various stimulus durations (1500, 1000, 500, 250, and 120 msec), and temporally flanked dichotic stimuli in a sequence with two stimulus/interstimulus interval durations (250/120 and 120/60 msec). Stimuli were pure tones or electric pulse trains depending on the hearing device.

The averaged results for each listener group show that fusion ranges for isolated stimuli increased by 1.5 to 2.5 times as stimulus duration decreased from 1500 to 120 msec. At fixed stimulus durations of 250 ms or 120 ms, fusion ranges with flanked stimuli in a stream segregation task decreased by up to 3 times compared to those observed for isolated stimuli. Hearing-impaired listeners showed greater reductions in fusion with temporally flanked stimuli than normal-hearing listeners. The findings suggest that binaural pitch fusion can be mediated at least in part by central processes involved in auditory grouping or segregation.

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T43: IMPACT OF FLAT PANEL CT-BASED COCHLEAR IMPLANT FITTINGS ON SPEECH, TIMBRE, AND PITCH PERCEPTION

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Music perception remains the most difficult listening endeavor for many cochlear implant (CI) recipients, due in part to the frequency mismatch that occurs between the cochlear neural interface and the frequencies allocated by the programming. Due to individual differences in CI users' ear anatomy, electrode array length, and surgical insertion, great variability exists in CI users' implants, but these differences are not typically accounted for by current CI programming techniques. Flat panel computed tomography (FPCT) technology has been used in recent years to visualize the location of the electrodes within the cochlea to improve pitch perception accuracy.

In order to assess the impact of FPCT-based CI fittings using custom frequency allocations, we scanned 10 CI recipients (4 bilateral, 6 unilateral) and administered a test battery of speech and music perception tests. Speech metrics included words (CNC), vowels (hVd), and consonants (aCa); music assessments, developed by our lab, examined instrument timbre discrimination and puretone pitch scaling.

Subjects used 3 different FPCT-based fittings for a chronic period of 1 month each, and the test battery was administered at the beginning and end of each chronic trial. Our first fitting methodology involved assigning the center frequency of channels to that of the characteristic frequency (CF) of the corresponding electrodes. During this iteration of the multiphase study, we chose to deactivate electrodes located at CFs >16 kHz, and logarithmically distribute the channels for electrodes with CFs from 2 to 16 kHz. The second and third fitting methodologies preserved the CT-based activation/deactivation status for electrodes and employed a logarithmic frequency allocation across all channels, but varied the total bandwidth.

Preliminary results show no significant change with acute use of experimental fittings; however, both speech and music test score averages improved for the group in almost every category following chronic use of the first and second FPCT-based fitting methodologies. Further data collection and enrollment is ongoing.

Image-guided fitting is a promising tool, although additional research is necessary to identify optimum use of its findings. While the current sample size is small, and the results preliminary, this study may have significant implications for all CI recipients, and be especially relevant for very young children and special populations. This project and previous work suggest that an image-based approach to CI mapping may improve pitch perception outcomes by reducing pitch-place mismatch. Future studies in pediatric and newly-implanted CI recipients are needed to assess the full potential of personalized image-guided CI fitting strategies.

T44: ELECTRODE PITCH RANK ORDER IN FULL-TIME AUDITORY BRAINSTEM IMPLANT (ABI) USERS

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Auditory brainstem implants (ABI) can provide limited sound perception by electrically stimulating the cochlear nucleus (CN). The positioning of the ABI electrode array and the neural substrate stimulated is vastly different from that for the cochlear implant. Even though the cochlear nucleus exhibits tonotopic organization, its structure and neural firing patterns are more complex than that of the auditory nerve. CN cell firing patterns reflect what might be considered a first level of auditory processing with respect to the onset or offset of sound, noisy versus sonorous quality, duration of sound, and sometimes low and high pitch. In addition, the electrode array is placed using anatomical landmarks and adjusted using electrical far-field potentials because direct visualization of the CN is not possible. As a result, the physical orientation of the ABI array varies across patients (Barber et. al, 2017)

ABI electrode stimulation can elicit auditory percepts as well as side effects like facial tingling, pressure, gagging, and dizziness. Although reported as auditory, a patient's percept of sound quality and pitch often changes from being similar for every electrode to being distinct on a variety of sound characteristics. Not surprisingly, the organization of what is interpreted as pitch across the ABI paddle is highly variable across patients and is frequently affected by other sound attributes or physical qualities.

Electrode pitch ranking is performed because the speech processing strategies used to program the ABI implant processor are the same as those used for cochlear implant and assume a pitch order. During pitch ranking, patients are instructed to identify the higher pitch tone or quality for two sequentially stimulated electrodes. The process is repeated in various combinations of electrodes across the array until all electrodes have been tested and a final sweep across the array results in a logical progression of tonal development from low pitch to high pitch.

This poster will present the electrode pitch rank ordering from 9 full-time adult ABI users with NFII and no residual hearing. Results will be evaluated with respect to the physical orientation of the electrodes in the ABI array and patient performance. In addition, rank ordering will be evaluated with respect to the physical position and orientation of the array anatomically measured on imaging.

An improved understanding of electrode position and pitch organization may allow us to provide a more organized signal from the day of activation for both adult and pediatric patients.

Barber, SR, et al. (2017) Auditory brainstem implant array position varies widely among adult and pediatric patients and is associated with perception. Ear and Hear. 38 (6) e343-e351.

T45: EXPLORING POLYPHONIC PITCH PERCEPTION IN COCHLEAR IMPLANT USERS

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A cochlear implant (CI) restores partial hearing to individuals with profound sensorineural loss through electrical stimulation of the auditory nerve. These devices take advantage of the tonotopic organization of the auditory nerve to provide reasonable speech recognition, provided the background is quiet. However, for the auditory system to robustly perceive speech and music, multi-sourced stimulation may be required. While commercial place-pitch strategies are sufficient for speech comprehension in quiet conditions, CI users struggle to detect multiple, simultaneous sources of pitch. Previous studies have used pitch-ranking procedures in the presence of a masker to explore polyphony in CI users. In these tasks, however, non-random beating or a shift in pitch of a perceptually fused stimulus could serve as a cue for success without the need for polyphonic pitch perception. This study uses a demanding polyphonic-pitch-trajectory task in which neither the beat frequency nor a shifting of a perceptually fused stimulus correlate with success. This study more carefully examines whether CI users perceive multiple pitches when stimulated by multiple streams. Participants with Cochlear Americas CI devices and normal hearing listeners (NHL) perform a hierarchy of tasks that separately probe pitch ranking ability and polyphonic pitch detection. These tasks serve both as a measure of comparison between NHL and CI users, and as a source of training for the more demanding psychoacoustic task which combines pitch ranking and polyphonic detection. In this polyphonic-pitch-trajectory task, two streams (low and high pitch) are presented simultaneously. Participants perform a 1-interval-4-alternative forced-choice procedure to identify which stream changed in pitch and whether it went higher or lower in pitch (low-pitch-lower / low-pitch-higher / high-pitch-lower / high-pitch-higher). In the acoustic version of this test (CI and NHL participants), the low stream is a sinusoidally-amplitude-modulated (SAM) tone with a carrier roved around 1000 Hz and a modulation frequency roved around 110 Hz. The high-stream is a SAM tone with a carrier roved around 4000 Hz and modulation frequency roved around 220 Hz. The stimulus is 2 s in duration and the target stream (low or high) contains an ascending or descending modulation-frequency sweep over the last 200 ms of the stimulus. For the electrode psychophysical version, the low stream is a SAM pulse train presented to the most apical electrode and the high stream is a SAM pulse train presented to varying electrodes with electrode separations of 0, 2, 4, and 8 examined. The low and high stream will have a carrier roved around 4000 pps and have a modulation frequency roved around 110 and 220 Hz, respectively. Like the acoustic version, the last 200 ms of the SAM pulse train contains a frequency sweep, the endpoint of which is adaptively controlled based on correct answers. Preliminary results from the hierarchy of tests used to provide training indicate that CI users can perform as well as NHL in detecting polyphony and perform polyphonic-pitch-ranking when the tonal streams are limited to envelope manipulations contained in SAM tones. Preliminary results also indicate that CI users perform better on the electrode psychophysical tasks than on the acoustic variations of the task, suggesting a loss of envelope information when transmitted through the clinical processor. These preliminary results suggest that CI users are able to perceive polyphonic pitch, but that resolution is limited by how temporal information is conveyed by clinical devices.

T46: THE EFFECT OF STIMULUS CARRIER RATE ON PITCH PERCEPTION AND LOUDNESS IN COCHLEAR IMPLANT USERS

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Stimulation rate in cochlear implant (CI) sound coding; or the “carrier” rate in pulses per second (pps), is known to influence pitch perception, as well as loudness perception and sound quality. We describe three experiments investigating voice perception by 15 Nucleus® CI users, where we controlled the modulation characteristics and carrier rate using STEP, a novel experimental multi-channel sound coder. STEP employs an FFT-based approach with dual filter-bank, the first one with narrow, good quality filters and the other one with a bank of parallel wide filters allowing enhanced spectral and temporal processing, respectively. We used a fixed set of threshold and comfortable stimulation levels for each subject, obtained from clinical MAPs. In the first experiment, we determined equivalence for voice pitch ranking and gender identification between the clinical ACE strategy and STEP for fundamental frequencies (F0) 120–250 Hz. In the second experiment, loudness as a function of the input amplitude of speech samples was determined for carrier rates of 1000, 500 and 250 pps per channel. Using equally loud sound coder programs, we then evaluated the effect of carrier rate on voice pitch perception. Pitch ranking scores were heterogeneous across subjects, although nearly all subjects could identify voice gender at a level significantly above chance. Overall, carrier rate did not have a substantial effect on voice pitch ranking or gender identification as long as the carrier rate was at least twice the fundamental frequency, or when stimulation pulses for the lowest, 250 pps carrier were aligned to F0 peaks. These results indicate that carrier rates as low as 250 pps per channel are sufficient to support functional voice pitch perception for those CI users sensitive to temporal pitch cues; at least when novel strategies such as STEP well control temporal modulations in the coder output.

T47: RATE PITCH DISCRIMINATION WITH DOUBLE PULSE INTERVALS OPTIMIZED USING ECAP RESPONSES

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The rate pitch discrimination ability of cochlear implant (CI) users is poor compared to normal-hearing (NH) listeners. Already at low pulse rates, the just noticeable difference (JND) is on average about 20% of the base rate, while NH listeners can still discriminate small frequency differences of about 0.2% at 1 kHz.

A recent study investigated the application of double pulses with short interpulse intervals (IPIs) to improve temporal coding and therefore improve rate pitch discrimination. It was shown that double pulses with equal amplitudes have no significant effect on rate pitch discrimination. Short IPIs, smaller than the absolute refractory period, result in a facilitation effect (first pulse reduces threshold for second pulse). The effect has its maximum if the amplitude of the first pulse is at or slightly below the ECAP threshold. The hypothesis is that double pulses with maximum facilitation improve temporal processing and therefore influences rate pitch discrimination.

Consequently, in our study, the amplitude of the first pulse was set at ECAP threshold, which was determined for each subject individually at one single apical electrode. The amplitude of the second pulse was increased until the pulse train was at most comfortable level. The rate pitch JND of this pulse train was determined for loudness balanced single and double pulses with 15 µs IPI. We will present first results but data collection is still ongoing.

T48: BENEFITS OF VARIABLE-RATE STIMULATION FOR COCHLEAR IMPLANT PITCH PERCEPTION

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Cochlear implants restore a remarkable degree of hearing to people who would otherwise be profoundly deaf. Most conventional devices stimulate the auditory nerve using constant-rate pulsatile stimulation that is amplitude modulated by acoustically-derived envelopes. Strategies have been developed that instead use variable-rate stimulation to encode the temporal fine structure of sound. The present study considers two aspects of the comparison between constant and variable-rate stimulation. The first experiment examines how fast constant-rate stimulation must be to avoid beat-frequency distortion between the modulation frequency and the underlying pulse rate. Detection of beat-frequency distortion is measured using a 3 interval, 3-alternative, forced-choice procedure in which the standard stimuli are modulated pulse trains with pulse rates that are integer multiples of the modulation frequency; target stimuli are similarly defined but with pulse rates having a 10-Hz offset above perfect integer multiples. For stimulation rates less than 2000 pulses per second, such an offset produces a clearly audible 10-Hz distortion. Sensitivity to beat frequencies is assessed for modulation frequencies near 110, 220, and 440 Hz. Preliminary results indicate that cochlear implant users are more sensitive to beat-frequency distortion with increasing modulation frequency, and many implant users can hear distortions for a 440-Hz modulator unless the pulse rate is increased above 6000 pulses per second. The second experiment examines the salience of pitch conveyed by amplitude-modulated constant-rate stimulation compared to variable-rate stimulation. Pitch discrimination thresholds are measured using a 2-interval, 2 alternative, forced-choice procedure in which the target interval is adaptively higher in either modulation frequency or pulse rate. Pitch discrimination is measured for base modulation frequencies or pulse rates near 110, 220, and 440 Hz. Consistent with previously studies, discrimination thresholds are similar when comparing modulation-frequency and pulse-rate discrimination near 110 Hz. However, preliminary results indicate that cochlear implant users are more sensitive to pitch changes near 220 and 440 Hz when conveyed by variable-rate stimulation. Thus, preliminary results indicate two primary advantages of variable-rate stimulation over amplitude-modulated constant-rate stimulation. First, variable-rate stimulation avoids the artifactual beating between modulation frequency and pulse rate that occurs with constant-rate stimulation. Second, variable-rate stimulation provides better pitch discrimination, specifically when attempting to encode pitch above 200 Hz. These results motivate further research and development of variable-rate sound processing strategies for cochlear implants. These results indicate a latent temporal pitch mechanism that can be tapped into by new variable-rate coding strategies.

T49: PITCH CONVEYED THROUGH ELECTRODE LOCATION AND STIMULATION RATE IN COCHLEAR IMPLANT USERS

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This study examines the overall contribution of stimulation place and rate to cochlear implant pitch perception. In the normally-functioning auditory system, frequency is represented through the spatial and temporal response properties of the auditory nerve. The spatial pitch cue is driven by the tonotopic organization of the cochlea and ascending neural structures, and the temporal cue is driven by the synchronous firing of auditory neurons to the rate of the stimulus. Cochlear implant users instead hear pitch primarily driven by temporal envelopes and place of stimulation, while temporal fine structure is generally discarded. Many implant users express dissatisfaction when listening to music, indicating that it may be essential to utilize both stimulation location and temporal fine structure to precisely encode pitch. Cochlear implants provide the means to functionally separate these two cues and determine their individual contributions to pitch. Understanding the tradeoff between these two cues may help in programming frequency allocation to optimize spectral resolution. The goal of the present study is to identify the specific contribution of electrode location and stimulation rate to pitch perception at various frequencies. Adult cochlear implant users with devices from Cochlear Corporation serve as subjects in a 2-session psychophysical protocol. During the first session, the subject's threshold and comfort levels are measured for each electrode in monopolar stimulation mode and one hour of frequency discrimination testing is administered. For the second session, subjects complete two hours of frequency discrimination testing. The frequency discrimination test consists of single- and multi-electrode stimuli for 100, 200, 400, 800, and 1600 Hz. Single-electrode stimuli are comprised of pulse trains whose stimulation rate corresponds to the testing frequency and whose place of stimulation is held constant. The multi-electrode stimuli are generated as 5-electrode pulse trains and the electrode location and stimulation rate are manipulated. There are 15 conditions for multi-electrode stimuli with varied place of stimulation, varied rate of stimulation, and covaried place and rate of stimulation across 5 frequencies. The overall results evaluate performance with separate and combined stimulation and compare performance between single- and multi-electrode rate discrimination. Results indicate that the subjects receive a significant benefit from the combined stimulation at lower frequencies, where stimulation rate pitch is the stronger cue. At higher frequencies, stimulation rate does not provide salient enough information to yield a significant difference between electrode location and combined performance at frequency discrimination. The results demonstrate that pitch evoked through stimulation rate is stronger at rates below 400 Hz transitioning to place of stimulation being the stronger cue at higher frequencies. This point of transition could inform a change in frequency allocation where a single electrode encodes frequencies below the transition point providing a higher density of electrodes encoding place of stimulation in the frequencies above the transition point. Emerging evidence also shows that, as a group, single-electrode performance at rate discrimination is better than multi-electrode performance. We interpret that even minor perturbations across electrodes can have major implications for rate sensitivity, which needs to be kept in mind for cochlear implant strategies using variable stimulation rate, such as Med-El's FSP. We will report on the effect of combined stimulation on pitch perception in cochlear implant users both at the individual and group level in this ongoing study.

T50: EFFICIENT EXTRACTION OF SPECTRAL AND TEMPORAL INFORMATION FOR PITCH CODING IN CI

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The role of a sound coding strategy within a CI system is to extract perceptually relevant features from sound and encode those features via electrical current pulses. Advances in coding strategies have yielded tremendous improvements in listening outcomes for CI recipients such that users of conventional strategies these days can achieve good speech understanding in quiet. However, CI users frequently report disappointment when listening to music, as well as difficulty in understanding tonal languages. Both can be attributed, at least in part, to degraded pitch perception. Most clinical strategies have been designed to optimize speech comprehension (for non-tonal languages in quiet conditions) and thus attempt only to encode the slow temporal fluctuations in acoustic signal amplitude (i.e. the 'temporal envelope') but not the fast oscillations in the signal waveform (i.e. 'temporal fine structure'; TFS). To provide access to pitch, one could argue (based on knowledge with normal hearing listeners) that it is also important to encode fundamental frequency (F0) and harmonic cues with spectrally resolved TFS at lower frequencies, and to include F0 cues in the temporal envelopes at higher frequencies. This requires algorithms that can accurately identify and extract F0 and harmonic cues, and code those cues in a spectrally resolved manner across electrode-channels. To be implementable in a clinical CI sound processor, such algorithms must consist of low computational complexity, introduce minimal signal processing delay in real-time, be robust to noise, and ideally make minimal assumptions about the nature of the acoustic signal.

Presented here is an algorithm ('Synthetic Feature eXtraction'; SFX) designed for real-time implementation in a CI sound processor that identifies and extracts temporal (TFS + envelope) and spectral cues from the main spectral features in acoustic signals. These spectral features can include F0 and harmonic cues. Essentially SFX computes a sliding Fast Fourier Transform (FFT) from the acoustic signal and identifies key features as maxima in the resulting spectra. A number of parameters is then estimated for each maxima (e.g. frequency, amplitude and phase) with higher accuracy than that offered from the sliding FFT directly. It does so by utilizing knowledge about the temporal windowing function employed during the FFT calculations. Finally, the algorithm estimates both the TFS and envelope of each feature using those estimated parameters. SFX additionally estimates the spectral kurtosis of each feature, which could be used by signal classification or noise reduction algorithms.

Evaluations thus far suggest that SFX is able to estimate frequency, energy and phase with negligible error for pure tones presented both in isolation and within tone-complexes. For simple melodies and voiced/tonal speech samples SFX has been found to estimate the frequency of F0 and harmonics with errors of just a few Hz. These errors are lower than those offered by the FFT alone. The frequency estimation errors, as well as the resolution of harmonics, are also improved with SFX relative to time-domain filter-bank methods, when the latter is implemented with a comparable level of computational complexity to the former Furthermore, when the output of SFX for those signals is resynthesized, subjective sound quality tests thus far indicate high fidelity relative to the original unprocessed acoustic signal. This highlights the accuracy and robustness with which SFX is able to extract TFS and envelope cues.

T51: TEMPORAL PITCH WITH SHORT INTER-PULSE INTERVALS: AMPLITUDE MODULATION, RATE LIMITATIONS, AND PITCH-CUE DOMINANCE

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Current cochlear-implant (CI) stimulation paradigms typically use amplitude-modulated (AM) pulse trains presented at a constant high rate and thus not transmitting acoustic fine-structure information. CI listeners hence rely on the less salient AM-based temporal-pitch cues and generally show degraded pitch sensitivity. In addition, a rate limitation manifests as deteriorated pitch sensitivity for rates exceeding a few hundred pulses per second. Earlier studies have shown that sensitivity to interaural time differences (ITDs) improves when inserting extra pulses with short inter-pulse intervals (SIPI pulses) at certain rates in these high-rate pulse trains. In this contribution, we investigated the effect of SIPI pulses with respect to monaural pitch sensitivity.

In the first study, the effect of inserted SIPI pulses on pitch-discrimination sensitivity was examined. Single-electrode AM stimuli encoding the fundamental frequency (F0) via the AM rate were tested in six CI listeners. Five modulation depths (from 0.1 to 0.9), two nominal F0s (125 Hz representing male and 250 Hz representing female talkers), and two SIPI-insertion approaches were tested: SIPI pulses were inserted either in every AM period (full-rate-SIPI condition) to support the F0 cue or in every other AM period (half-rate-SIPI condition) to circumvent a potential rate limitation. Results show that, compared to stimuli with AM only (i.e., no-SIPI condition), full-rate SIPI pulses improved temporal-pitch sensitivity, across F0s and in particular at low modulation depths where AM-based pitch cues are weak. In general, sensitivity in both the no-SIPI and the full-rate-SIPI condition degraded for higher F0s, indicating the presence of a rate limitation. This limitation was not circumvented by the half-rate-SIPI condition which resulted in individually-variable performance, possibly arising from a dominance of the SIPI-based over the AM-based pitch cue.

In the second study, we examined the dominance of the SIPI-based pitch cue. Single-electrode AM stimuli with two modulation depths (0.1 and 0.5) and inserted SIPI pulses were presented in three CI listeners. Temporal-pitch sensitivity was examined in a two-interval discrimination task whose difficulty was varied by means of rate differences between intervals: AM-rate difference (ΔAM) and SIPI-rate difference (ΔSIPI) were either congruent, incongruent, or one was zero. Results show that only ΔSIPI reliably predicted the discrimination performance, indicating the dominance of the SIPI-based pitch. This conclusion is supported by the lack of an effect of the modulation depth on discrimination performance.

In summary, temporal-pitch sensitivity can be improved by a future stimulation paradigm incorporating SIPI pulses, particularly at low modulation depths. The SIPI rate provides the dominant pitch cue and its choice is crucial for preserving the absolute pitch. Such a multi-electrode stimulation paradigm would also improve ITD sensitivity. Concepts on how to implement such a paradigm will be discussed.

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T52: MANDARIN TONE PERCEPTION WITH COCHLEAR IMPLANTS USING PRIMARY PITCH WITHOUT RELIABLE SECONDARY CUES

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Mandarin tone perception with cochlear implants (CIs) is poorer and more variable than normal hearing (NH) listeners because of imperfect CI pitch coding. Secondary cues such as loudness contour and duration, inherently conveyed by naturally pronounced Mandarin monosyllables, may facilitate CI tone perception when the primary pitch cues are degraded.

In this study, we develop a new database consisting of disyllabic words having independent pitch and loudness contours and constant duration. Five disyllabic words, i.e., /Lǎo Shī/, /Róng Huā/, /Shè Jī/, /Píng Fāng /, and /Huā Xiāng/, were recorded from one female and one male speaker. We then created words where the primary (pitch) and a secondary (loudness) cue to lexical tone could be changed independently. The syllables /Shī/, /Huā/, /Jī/, /Fāng/ and /Xiāng/ were resynthesized to have either high-flat, rising, or falling pitch contours. The pitch-manipulated monosyllables were then multiplied by three loudness gain functions, i.e., 0 dB flat, –10 to 10 dB rising, or 10 to –10 dB falling. Substituting the pitch and loudness contour manipulated variant syllables back into the original recordings yielded a new speech database of 270 disyllabic words ("Di"), whose meaning depended on whether the listener relied on the primary pitch or the secondary loudness contour to judge the lexical tone. An existing database containing naturally produced monosyllables ("Mono") was also adopted as stimuli in this study. 17 CI and 8 NH subjects were asked to judge the meaning of each word. Pitch being considered the primary cue for lexical tone, we scored the number of times listeners picked the meaning indicated by pitch.

The median scores were 98.3 (Di-NH), 94.2 (Mono-NH), 75.9 (Di-CI), and 87.6 (Mono-CI) %. All differences between these median scores were statistically significant. For CI users, pitch-contour-based tone recognition with the new database is more challenging than the multi-cue-based recognition with the naturally pronounced database. Furthermore, the Di-CI results have strong correlations with the subjects' CI listening experience and implantation age, but no similar correlation can be found from Mono results. Thus, earlier implantation or longer CI listening experience may provide better pitch-contour-based tone perception, but different subjects have different strategies and learning speeds to utilize the multiple cues for lexical tone in natural speech. Another potential application of the new database is in the evaluation of pitch-enhancement based Mandarin tone enhancement strategies.

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T53: CAN LISTENERS COMBINE PURELY TEMPORAL INFORMATION FROM DIFFERENT FREQUENCY REGIONS TO HEAR THE "MISSING FUNDAMENTAL" PITCH?

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Normal-hearing (NH) listeners can accurately derive the fundamental frequency (F0) of a sound by combining information from individual low-numbered harmonics, which are resolved by the peripheral auditory system. This code is not available to users of most CIs, which do not convey information on individual harmonics. However, some new CI processing schemes convey timing information about the temporal fine structure in individual frequency bands, raising the question of whether the auditory system can derive the F0 of a sound by combining purely temporal cues across different frequency regions. Previous attempts to address this question with NH listeners showed that they are unable to extract the F0 from the envelopes of three transposed tones (Oxenham et al, 2004), or from the repetition rates of three bandpass-filtered pulse trains with different rates (Deeks et al, 2009). However, the stimuli used in those experiments occupied very high frequency regions and had quite weak "component" pitches.

We revisited this issue using NH listeners and stimuli where most components had low-to-moderate frequencies, and with a simple task that probed whether participants listened analytically or synthetically to a given sound. In condition 1, each of the two intervals of a trial consisted of two simultaneous groups of unresolved harmonics. The Low group had harmonics between 640-1280 Hz and an F0 of either 40 or 53.3 Hz. The harmonics were summed in alternating phase leading to a pulse rate (and expected pitch) of 80 or 106.7 Hz. The High group contained harmonics of a 160-Hz F0, ranging from 1760-3520 Hz, or 1760 to 2560, summed in sine phase. If the auditory system combines the periodicities present in each group (synthetic listening), the 106.7+160-Hz stimulus should have a pitch of 53.3 Hz and be judged as lower than the 80+160 Hz stimulus. Conversely, analytic listening to the Low group should result in the 106.7+160-Hz stimulus being judged as higher. Condition 2 checked whether listeners listen synthetically to low-numbered harmonics. It used two pure-tone dyads with frequencies 80+160 Hz and 106.7+160 Hz. All stimuli were presented in a noise background. F0 was roved by +/- 10% on a trial-by-trial basis. Results showed that all 9 participants listened synthetically to the pure-tone dyads, demonstrating that they combined information across frequencies to extract the F0. In contrast, results for the pulse-train conditions were mixed. Most participants could reliably identify an increase in the F0 of the Low region as an increase in pitch. However, when combined with the High-region complex, they did not extract the composite F0 – rather, they either listened analytically or responded inconsistently. Hence, we found no evidence that even NH listeners can extract a pitch by combining purely temporal information from different regions. This makes it unlikely that CI listeners could combine temporal information from different electrodes to extract a complex pitch.

References: Oxenham et al., (2004). PNAS, 101, 5; Deeks et al., (2013). JASA, 133, 377

T54: SPECTRAL SLOPE DISCRIMINATION WITH COCHLEAR IMPLANT SIMULATIONS

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Timbre is the perceptual attribute used to differentiate sounds with the same pitch and loudness, and is important for musical instrument, environmental sound, and talker voice identification. Cochlear implant (CI) users do not perceive timbre as well as normal-hearing (NH) listeners, due to their poor spectral resolution. Among the spectral cues for timbre perception, the global spectral slope related to sharpness perception should not require a high spectral resolution for perception. However, our recent study (Luo et al., 2019) found that CI users had significantly worse performance in spectral slope discrimination than NH listeners. To find the limiting factors for CI users' perception of spectral slopes, this study used the noise vocoder for CI simulation in NH listeners to simulate how various spectral distortions experienced by CI users may affect spectral slope discrimination.

As in our previous study, a two-alternative, forced-choice task was used to test spectral slope discrimination. In each trial, subjects listened to two stimuli and were asked to decide which stimulus was sharper in timbre (i.e., with a shallower negative spectral slope). The difference in spectral slope between the two stimuli was adaptively adjusted to find the spectral slope difference limen (DL). The spectral slopes were centered on a standard value of -8 dB/octave. The root-mean-square level of each stimulus was roved around 65 dB SPL by +/- 10 dB. The original stimuli were harmonic complex tones with a fundamental frequency of 200 Hz and all harmonics up to 4000 Hz. In Experiment 1, the number of noise bands in the noise vocoder was 2, 4, 8, and 16 to simulate different spectral resolutions. In Experiment 2, the band-pass filters in the 8-channel noise vocoder had an order of 2, 4, and 8 to simulate more or less channel interactions. In Experiment 3, the synthesis filters of the 8-channel noise vocoder were shifted relative to the analysis filters by an equivalent distance of 0, 2, 4, and 6 mm along the basilar membrane to simulate different degrees of frequency mismatch.

In each experimental condition, the power spectra of two noise-vocoded stimuli (which originally had spectral slopes of -5 and -11 dB/octave) were normalized to the average power of the first noise band, and the difference in average power over the whole frequency range of noise vocoder between the two noise-vocoded stimuli was calculated. It was found that the average power difference increased with more noise bands and higher filter orders, but did not change with the degree of frequency mismatch.

The spectral slope DLs of NH listeners with the original stimuli were similar to those in Luo et al. (2019) and were significantly better than those of CI users in Luo et al. (2019). However, the number of noise bands, the filter order, and the degree of frequency mismatch all had no significant effect on the spectral slope DLs. As expected, spectral slope discrimination was robust to the various spectral distortions tested in this study. A more plausible explanation for the poorer spectral slope discrimination of CI users in Luo et al. (2019) is that CI users were much older than NH listeners in that study.

T55: DETERMINING UNDERLYING VOCAL PITCH DIMENSIONS IN COCHLEAR IMPLANT USERS

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Cochlear implant (CI) users have difficulty completing pitch tasks such as determining the gender of a speaker. The perception of vocal pitch is relatively well defined for normal hearing listeners, largely relying on F0 and harmonic structure. In contrast, for CI users these cues are distorted by the processor, making it unclear what cues they are using to perceive vocal pitch. The goal of this study is to determine the different perceptual dimensions underlying CI users' vocal pitch perception.

To determine the underlying perceptual dimensions CI users were relying on, five CI users were asked to compare pairs of voices based on vocal pitch, using a 7-step scale ranging from "very different" to "same pitch." The stimuli presented consisted of four male and four female adult speakers, producing a sustained /a/ vowel. The F0 for the different speakers ranged from 83-253 Hz. The resulting data were analyzed using a multidimensional scaling (MDS) approach. The results were also compared to the stimulation pattern in electrodograms to determine aspects of the stimulation pattern related to the perception of vocal pitch. The results suggested that one cue CI users were relying on was the temporal pitch carried in the amplitude modulation of the stimulation for each channel, which directly correlates with F0 in the acoustic signal. These results suggest that CI users are able to perceive a perceptual dimension that strongly relates to the F0 of the acoustic signal. It is unclear why they are not able to use this cue when doing tasks such as gender discrimination.

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T56: VOICE PITCH CONTROL IN COCHLEAR IMPLANT USERS

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Background: Speaking or singing relies on the quality of auditory feedback, which is degraded in cochlear implants (CIs). This is particularly true for voice pitch. Therefore, we hypothesize that the control of voice pitch must be hindered in CI users. On the other hand, some MED-EL devices aim to reproduce finer details in fundamental frequency (F0) and therefore have the potential to strengthen the reliance of vocal production on the voice pitch feedback.

Methods: Two groups of subjects, MED-EL CI users and age-matched controls with normal speech and normal hearing, participated in three phases of the study. The first phase was an altered feedback paradigm in which participants listened to their own voice – either intact or altered - while producing different vowels. When altered, the fundamental frequency (F0) of their voice was shifted up or down by 100 cents (with a fixed sign across trials). F0 points were extracted from all recordings using Praat and expressed in cents relative to F0 in intact trials. In the second phase, participants performed a F0 discrimination task of their own voice (using intact trials of the first phase), using an adaptive Bayesian procedure in a 3-interval 2-alternative forced-choice manner. Hits and False Alarms were converted into d' values and the just noticeable difference (JND) in F0 was extracted at d'=0.77. The third phase was a direct replication of the first but adjusting the size of the alteration to the F0 JND.

Results: In the first phase, control participants exhibited an adaptation phenomenon of 30-40 cents (opposing the direction of the pitch alteration). In the second phase, control participants obtained F0 discrimination thresholds ranging from 20 cents to as much as 2.7 semitones, with a mean around 70 cents. This sensitivity is relatively poor (compared to thresholds measured with synthetic complexes), presumably due to variability intrinsic to the recordings, e.g. non-stationary temporal envelope and fluctuations in spectral envelope. In the third phase, control participants exhibited a larger adaptation phenomenon, about 50 cents on average, which correlated with the size of the pitch alteration. Results among CI users will be presented during the meeting.

Conclusion: This project will shed light into the coupling between auditory feedback and the internal commands that regulate voice pitch. By implementing a personalized altered feedback paradigm in CI users, we hope to distinguish users that are capable of adjusting their production once an error in feedback is detectable from users that simply disregard feedback of their voice while speaking. This could in turn explain differences in vocal quality that are observed over years of CI use.

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T57: DO LISTENERS UTILIZE VOICE CUES IN NOISE AS IN QUIET FOR A SPEAKER DISCRIMINATION TASK?

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Cochlear implant (CI) users have difficulties in discriminating between talkers, which may partially explain why they experience poor speech perception in a multi-talker environment. For normal hearing (NH) listeners and early implanted pre-lingual CI users, the ability to track the voice of a specific talker in quiet was shown to relate to both spectral information (i.e., the formant frequencies that reflect the vocal-tract length, VTL) and temporal information (the fundamental frequency, F0). In contrast, late-implanted pre-lingual CI users had an advantage of F0 over VTL. The present study assessed the effect of background noise on the use of these voice cues in a talker discrimination task. Twenty-four NH young-adults (18-35y) listened to sentences of the same speaker, which differed by F0 only, VTL only, and VTL+F0 cues. Voice discrimination (VD) thresholds in a speech-shaped noise (signal-to-noise ratio=0) were obtained for each acoustic cue(s) using a two-down one-up adaptive procedure. Speech Reception Thresholds in noise (SRTn) were also assessed using the Hebrew Matrix sentence-in-noise test. Results showed that: (a) Best performance was achieved for the combined VTL+F0 cues, suggesting that both cues (spectral and temporal) contribute to listening in noise; (b) Listeners had an advantage of F0 (over VTL), suggesting that the noise degraded spectral information; (c) VD based on VTL cues was correlated with SRTn, supporting the importance of spectral information to listening in noise. The current results emphasize the need to address spectral degradation for improving speech perception in noise and contribute to our understanding of speech-in-noise in CI users. It was of interest to find that performance of NH in noise showed similar use of cues as late-implanted CI in quiet. VD data of CI users in background noise are currently being collected and will be compared to the present outcomes.

T58: HOW AGING AND LISTENING EXPERIENCE AFFECT VOICE-GENDER DISCRIMINATION AND SPEECH RECOGNITION IN NOISE IN ADULT COCHLEAR IMPLANT LISTENERS

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INTRODUCTION: There is evidence from studies with CI simulations that aging influences the ability to discriminate voice-gender (Schvartz & Chatterjee, 2012). It is unknown how this ability changes with CI listening experience and if these findings translate to more complex speech recognition tasks. This study examined how accurately adult CI recipients perceive voice-pitch cues in simple and complex tasks at various points in time (pre- to post-implantation). We also assessed cognitive function in the same listeners to determine the extent to which cognitive abilities contribute to performance on these measures.

METHODS: We recruited two groups of adult CI listeners (26 to 92 years of age). In the first group (Longitudinal; N=10), we assessed performance pre-operatively, and then at various points in time through six months post-activation. The second group of listeners (Long-term; N=14) were experienced CI users (>12 months post-activation). The voice-gender discrimination task consisted of vowel (H/vowel/D) stimuli which were manipulated to vary in fundamental frequency (f0) while holding all other voice-gender identification cues (e.g., vocal tract length) constant. We assessed conditions in which the average f0 between the male and female talkers were smaller (Difficult condition) or larger (Easier condition). Recognition of sentences in noise was measured using a target sentence (male talker) in the presence of steady-state noise, modulated noise, or a female voice. Measures of masker interference were calculated by comparing performance between different masker types. Cognitive assessments (NIH Toolbox-Cognitive) were also administered.

RESULTS: For the Difficult condition, voice-gender discrimination was worse soon after implantation (through 1 month post-activation), compared to pre-operative scores. Pre-operative performance was not related to the age of the listener; however, it was observed that voice-gender identification became increasingly dependent on age with more CI listening experience. For the Difficult condition, results showed that age was not significantly related to voice-gender identification at 1 week and 1 month post-activation, however the coefficient of determination was significant and became stronger (higher r2 value) from 3 to >12 months post-activation. Sentence-in-noise recognition for all masker types was also significantly correlated with age of the CI listener. Masker interference was not related to listener age. Cognitive abilities were not clearly related to any speech recognition task measured in the current study.

CONCLUSIONS AND IMPLICATIONS: These results suggest that older listeners have more difficulty using temporal envelope voice pitch cues compared to younger listeners, and even after significant listening experience (>12 months) this age-related deficit persists. These results argue for separate underlying mechanisms for perception of voice-pitch cues pre- and post-operatively and which are differentially affected by listener age. Results of the sentence recognition in noise task were not dependent on masker type, suggesting that older listeners' inability to use voice-pitch cues to identify talker gender did not seem to affect speech understanding in a more complex task. These results have significant implications for counseling and rehabilitative strategies in older CI recipients.

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T59: DISSOCIATED DEVELOPMENT OF VOICE PERCEPTION ACROSS GENDER CUES IN NORMAL-HEARING AND COCHLEAR IMPLANT CHILDREN

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Many acoustic features affect speakers' perceived voice gender, but it is primarily defined by two vocal cues: fundamental frequency (F0), related to glottal pulse rate, and vocal tract length (VTL), related to the speaker's size. Normal-hearing (NH) children's development of sensitivity to differences in speakers' voices takes many years to reach adult-like levels (Cleary, Pisoni, & Kirk, 2005; Mann, Diamond, & Carey, 1979). For cochlear implant (CI) children, sensitivity to voice differences depends both on cognitive development and the perceptual limitations related to electric hearing, e.g., reduced perception of F0 and VTL cues (Fuller et al., 2014). However, it remains unclear how NH and CI children's sensitivity to differences in voice cues develops over time. Therefore, we investigated if NH and CI children's sensitivity to voice gender cues, F0 and VTL (Exp.1: JNDs measured via an adaptive 3-AFC procedure, a low-order discrimination task), and their weighting of these voice cues for voice gender categorization (Exp.2: visual-auditory match-to-sample task, a high-order identification task) develop in parallel or if they are dissociated across gender cues.

Here we demonstrate that the development of sensitivity to voice gender cues, F0 and VTL, differs across the different tasks in NH children. Results from CI children are currently being collected and preliminary results for this group will be presented. NH children's sensitivity to VTL was adult-like around 8 years of age, but their sensitivity to F0 still differed from adults at 12 years. Their weighting of F0 and VTL for voice gender categorization continued to differ from adults' weighting at all ages for both cues. NH children's weighting of F0 and VTL cues was only moderately related to their F0 and VTL sensitivity. Hence, NH children's development of sensitivity and weighting of voice cues is dissociated across voice gender cues, i.e., both abilities develop at a different rate and show different developmental patterns for F0 and VTL. The dissociated developmental patterns for sensitivity and categorization across gender cues highlight the complexity of voice perception and the need for a better understanding of its underlying principles and mechanisms. These findings are particularly relevant for interpreting the results of CI children, as their sensitivity to voice differences likely derives from a combination of perceptual limitations and general cognitive development.

T60: SINGING PROFICIENCY IN CHILDREN WITH BIMODAL HEARING AND BILATERAL COCHLEAR IMPLANTS

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The purpose of the present study was to investigate the pitch accuracy of vocal singing in children with bimodal hearing or bilateral cochlear implantation in comparison to age-matched normal-hearing (NH) children. The participants included 34 children with NH, 13 children with bimodal hearing [cochlear implant (CI) in one ear and hearing aid (HA) in the other ear], 31 children with sequential bilateral CIs, and 10 with simultaneous bilateral CIs. All participants aged between 7 and 12 years old. Each participant was recorded singing self-chosen songs that were most familiar to him or her. The fundamental frequencies (F0s) of individual sung notes were extracted. Four pitch-based metrics including contour direction, pitch variance ratio of entire song, mean deviation of F0 across notes, and mean deviation of the pitch intervals were computed and used as measures of vocal singing proficiency. The results revealed significantly poorer performance on all four pitch-based metrics in the three groups of pediatric CI recipients in comparison to the NH controls. No significant difference was found between the children with bimodal devices and bilateral CIs. Principal component analysis and stepwise regression will be performed to examine the potential contributing factors such as age at CI, age at HA, duration of HA use, etc. for the highly variable performance in singing among the hearing-impaired children.

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T61: EFFECT OF ACOUSTIC BANDWIDTH ON BIMODAL BENEFIT FOR MUSIC PERCEPTION AND APPRECIATION

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Previous literature has examined the effect of acoustic bandwidth on bimodal benefit for speech recognition (e.g., Zhang et al., 2010; Sheffield & Gifford, 2014). The current study extends this earlier work to examine the effect of acoustic bandwidth for music perception and appreciation. The primary aims are three-fold: (1) to determine the acoustic bandwidth necessary to obtain bimodal benefit for music perception and appreciation, (2) to determine whether bimodal benefit increases with acoustic bandwidth, and (3) to determine whether optimal acoustic bandwidth can be predicted by neural representation of temporal fine structure. Acoustic stimuli will be filtered and presented to the non-implanted ear in accordance with Sheffield & Gifford (2014): <125, <250, <500, <750 Hz and wide-band (full, non-filtered bandwidth). Low-frequency temporal fine structure will be assessed via the Frequency Following Response (FFR) generated for musical notes with fundamental frequencies closest to the low-pass filter cutoffs: B2 (123 Hz), B3 (247 Hz), B4 (494 Hz), and F#5 (740 Hz). Music perception and appreciation for all filter conditions will be assessed via measures of pitch perception, chord discrimination, timbre perception, and subjective sound quality of real-world music samples including multiple genres. Preliminary data in 13 postlingually deafened adult cochlear implant recipients demonstrate that neural representation of temporal fine structure in the non-implanted ear is significantly correlated with bimodal benefit for CNC word recognition ($r = 0.78$, $p = 0.002$) and musical emotion perception ($n = 9$; $r = 0.67$, $p = 0.048$) and could thus help guide clinical decision making regarding retention of bimodal hearing or pursuit of a 2nd cochlear implant.

T62: MELODIC CONTOUR IDENTIFICATION COMPARABLE IN EARLY-DEAFENED, LATE-IMPLANTED AND POST-LINGUALLY DEAFENED COCHLEAR IMPLANT USERS

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Introduction. Music is an important auditory signal in daily life. Yet, post-lingually deafened and implanted cochlear implant (CI) users find music difficult to perceive, and also report to not enjoy listening to music. Another group of CI users, the early-deafened (during language acquisition) and late-implanted (EDLI) (after a long period of auditory deprivation), report a higher enjoyment, but do they show a better perception too?

Materials & Methods. Sixteen EDLI CI users, defined as: hearing loss onset before the age of six years, implantation >16 years of age were recruited. A group of fifteen gender matched post-lingually deafened control CI users were deafened and implanted after the age of 18 years of age served as controls. Using the Dutch Musical Background Questionnaire, the subjective music perception and enjoyment was evaluated. Psychophysically music perception was measured using the melodic contour identification (MCI). The piano and organ were used, together with and without a masking contour, and a semitone distance from 1 to 3 semitones between successive tones of the target.

Results. Subjectively, the EDLI reported to enjoy music more than post-lingually deafened CI users. Psychophysically, both groups performed evenly on melodic contour identification. However, an effect of instrument and masker within the groups was shown. Both groups recognized the piano best, and for both instruments, the masker with non-overlapping pitch was best recognized.

Discussion. The EDLI reported a higher enjoyment of music, even though psychophysically measured music perception did not differ significantly between the two groups. Both outcomes are surprising, since EDLI were expected to have lower implant outcomes based on the early deafness and the long period of auditory deprivation. Perhaps, the limitations of melody perception derive from electric hearing limitations in CI users in general. A lack of musical memory, and there with the inability to compare music heard via the CI to acoustic music, might cause the higher subjective enjoyment in EDLI. Our overall findings support a benefit from implantation for a positive, subjective music experience in EDLI.

T63: PERCEPTION OF SEQUENTIAL MUSICAL INTERVALS BY UNILATERALLY DEAF COCHLEAR IMPLANT USERS

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Background: Sequential musical intervals form the basis of melody. Due to the poor representation of temporal cues, limited number and spacing of implanted electrodes, the insertion depth of the electrode array, and the proximity of the electrodes to healthy neurons ("electrode-neural interface"), the representation of musical intervals is distorted for cochlear implant (CI) users, relative to normal-hearing (NH). It is unclear how this distortion varies across CI devices and/or individual CI patients. In CI patients with single-sided deafness (SSD), musical interval perception can be compared precisely between acoustic and electric hearing, potentially revealing differences in electric musical interval perception across devices and patients. In this study, magnitude estimation for sequential musical intervals was compared between acoustic and electric hearing in SSD CI patients. Given variations in of electrode position along the spiral ganglia, we hypothesized that there would be a mismatch in between interval sizes perceived between the acoustic ear and electric ear.

Methods: The magnitude of a probe electric interval (ranging from 2 to 36 semitones) was compared to the magnitude of a reference acoustic interval (4, 8, or 12 semitones). Acoustic reference stimuli were delivered to the acoustic ear via headphone; probe stimuli were delivered to the CI ear via direct audio input (DAI) to their clinical processor. The root notes for all intervals were either F3 (175 Hz) or C4 (262 Hz), and were randomized across ears and trials to avoid entrainment to a particular frequency. During testing, a reference and probe stimulus was played and subjects indicated which interval was larger by clicking a button (NH ear or CI ear). Each probe interval was compared to each reference interval 10 times; interval comparisons were randomized within and across subjects. Psychometric functions were fit to the data to determine the electric interval size that corresponded to each acoustic reference.

Results: Preliminary data suggest that SSD subjects required larger intervals in the CI ear to match the reference acoustic interval in the NH ear. There was great inter-subject variability; for example, for the 8-semitone acoustic reference, the matching electric interval ranged from 9 to 18 semitones. There was also great inter-subject variability in terms of electric interval ranges for the 4-. 8-, and 12-semitone acoustic references. For some subjects, the degree of interval distortion was similar across the references; for others, the degree of distortion was reduced for larger reference intervals.

Discussion: Consistent with our hypothesis, larger intervals with electric hearing were generally required to match the magnitude of a reference acoustic interval. This distortion effectively compresses the melodic pitch range for electric hearing. As such, the pitch changes within melodies would be perceived as smaller with electric hearing, especially for small intervals (e.g., minor 2nd, major 2nd, minor 3rd, major 3rd), resulting in a more monotonic quality. Because interval perception was measured with patients' clinical processors, it is unclear whether interval distortion is due to the frequency allocation, distortion of temporal cues, and/or to the electrode-neural interface.

T64: OBJECTIVE MEASUREMENTS OF MUSIC DISCRIMINATION IN INDIVIDUAL COCHLEAR IMPLANT USERS

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Introduction: The EEG is a non-invasive, silent and objective method which offers the recording of event-related brain potentials (ERPs). The Mismatch Negativity (MMN) response represents a potentially useful tool for an objective, clinical evaluation of auditory discrimination functions at the group level. In individuals, however, the reliability of the MMN still has to be improved. This is particularly true for MMN responses in CI users. With this study, we aimed to test the validity of MMN responses to musical stimuli in individual experienced and newly implanted CI users as well as in normal hearing controls. Furthermore, we aimed to examine the plastic changes involved in the CI adaptation process of recently implanted CI users at both the individual and the group level.

Methods: EEG recordings were carried out using a new musical multifeature MMN-paradigm (CI MuMuFe). The paradigm integrates only deviants and presents no standard stimuli. Deviants in pitch, timbre, intensity and rhythm are embedded in an Alberti bass pattern and presented randomly at four levels of magnitude. The duration of the paradigm is app. 30 minutes. EEG data were analyzed using a novel methodology based on Spike Component Analysis (SCA).

Participants. Eleven experienced (M age: 60.7 y) CI-users and 7 recently implanted CI users (M age: 59.9 y) and 14 normal hearing controls (M age: 63.4 y) underwent EEG-recording while listening to the CI MuMuFe paradigm. Recently implanted CI users were measured twice: shortly after switch-on and again after three months. CI users received sound through direct audio input while NH controls listened through in-ear headphones.

Results: We found significant MMN responses to all deviants at all four levels in all of the individual experienced CI users as well as in NH controls. In addition, MMN amplitudes corresponded well with levels of deviation magnitude for > 65 % of NH controls. Except for the intensity deviant, MMN amplitudes of individual experienced CI users were in general less consistent with level hierarchy. MMN amplitudes and latencies exhibited a high level of variance across participants. At the group level, the CI MuMuFe paradigm elicited significant MMN responses across levels in recently implanted CI users at both times of testing. After 3 months of CI experience, the MMN amplitudes were significantly stronger for the pitch and timbre deviants compared to baseline responses. For the rhythm and intensity deviants, MMN responses remained unchanged at the second measurement. Preliminary analyses indicate that MMN responses may also reliably be recorded in recently implanted CI users at the individual level.

Conclusion: The results indicate that the novel musical EEG-paradigm and the new SCA methodology can provide measures of musical discrimination abilities and thresholds in individuals at a rate of reliability which is higher than previously reported. Particularly, the results from experienced and recently implanted CI users are promising and suggest that the methods may be applied in clinical use as a supplementary objective tool for both prognostication and follow-up measurements. This is especially true for infants and small children with CI, as means for assessing the adequacy of the CI functioning, its improvement as a function of time of CI use, and the efficiency of different rehabilitation procedures.

T65: AN ON-LINE ALGORITHM FOR SPECTRAL COMPLEXITY REDUCTION OF MUSIC SIGNALS FOR COCHLEAR IMPLANT LISTENERS

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Cochlear implant (CI) listeners are known to prefer less complex music genres like country or pop music over more complex classical music. Also, they often appreciate an attenuation of the accompaniment and an emphasis on both rhythmic elements like drums and bass and on the leading voice. Recently, several approaches towards a complexity reduction of music signals for CI listeners have been proposed, which rely on filtering, source separation, or dimensionality reduction techniques [1].

In this contribution we present a novel pre-processing scheme to obtain the desired complexity reduction by means of a reduced-rank approximation using the sparse constrained projection approximation subspace tracking (SCPAST) algorithm [2]. The dominant spectral components which normally contain the leading voice of a music signal are identified blindly using subspace tracking methods (PAST, CPAST). Reconstructing the signal regarding only those dominant spectral components leads to a less complex spectral representation and thus to both an emphasis on the leading voice and an attenuation of the accompaniment. We enforce additional sparsity of the frequency spectrum which is controlled by a thresholding parameter. Due to the iterative structure of the subspace tracking algorithm our method is well suitable for low-latency on-line processing.

We evaluated the proposed pre-processing scheme on excerpts of classical chamber music processed with respect to several different degrees of complexity reduction and sparseness settings with instrumental signal quality measures as well as in listening experiments with CI users: In the practically usable parameter range we achieve an accompaniment attenuation of up to 9 dB measured by the signal-to-interference ratio (SIR). We also investigated auditory distortion using a spectral smearing technique which mimicks broadened auditory filters and found an improvement in auditory distortion resulting from the additionally enforced sparseness. In a paired comparison listening experiment spectrally reduced versions of eight excerpts of classical chamber music with three sparseness settings (CPAST, SCPAST-q90, SCPAST-q95) and two degrees of complexity reduction (5 and 8 retained components) were presented together with the unprocessed versions. Eight CI listeners were asked to rate their preferred versions regarding the individually perceived overall sound quality and the ease of listening. For all six parameter settings the processed versions were preferred to the unprocessed signals in at least 55% of all trials. For the SCPAST-q95 method with the highest degree of enforced sparseness and five retained spectral components we found a significant preference with a rate of 70% and $p < 0.001$. These results are comparable to the previously published block-based method bases on principal component analysis (PCA) [3].

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T66: THE OPAL STRATEGY IMPROVES COCHLEAR IMPLANT PITCH AND MELODY PERCEPTION

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Musical pitch and melody perception are often rated negatively by post-linguistic adult cochlear implant (CI) recipients. The Optimised Pitch and Language (OPAL) strategy is designed to enhance these aspects through improved coding of fundamental frequency (F0) in the temporal envelope of band-pass filtered channel signals. Previous studies with CI recipients have shown significant improvements in perception of pitch, lexical tones in noise, and speech intonation using OPAL as compared to the Advanced Combination Encoder (ACE) strategy, with no degradation to speech understanding in noise or in quiet.

In this study we compared perception of musical pitch and melody by CI recipients using the OPAL and ACE strategies implemented on the same CP900 speech processor.

Twelve adult CI recipients were evaluated both acutely and following four weeks of take-home experience on tests including: pitch ranking of synthetic band-pass filtered harmonic tones and naturally-produced sung vowels; identification of closed-set melodic contours played by a trombone (MCI test); and the Modified Melodies test with Backwards and Warp modifications.

Subjective preference for either strategy was recorded for speech discourse produced by a male and female talker, and for music with vocals produced by a male and a female singer.

Mean group results were significantly higher for OPAL as compared to ACE for pitch ranking synthetic tones and sung vowels; melodic contour identification; and Warp Modified Melodies. Subjective ratings showed no group differences between strategies after the take-home period of acclimatization with OPAL, however, individual subjects did indicate a preference for one strategy more than the other across the speech and music samples.

The OPAL strategy was shown to provide adult CI recipients with significant benefits as compared to their clinical ACE strategy in perception of musical pitch and simple (monophonic) melodies. Appreciation of more complex music was however not demonstrated, and may require longer periods of acclimatization with OPAL.

WEDNESDAY POSTER ABSTRACTS

W1: DESIGNING SHAPE MEMORY ALLOY ACTUATORS TAILORED TO THE HUMAN COCHLEA GEOMETRY

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Introduction: Nitinol is a shape memory alloy (SMA) widely used in medical devices and implants due to its biocompatibility and superelastic properties. The shape memory effect (SME) of this alloy can also be an advantage for cochlear implants (CIs) in implementing a specific curved geometry which is beneficial for the spiral shaped inner ear. Thus, thin wires made of Nitinol can be fabricated and serve as an actuator to make use of the SME for CIs. At low temperatures, the SMA displays a plastic state with reduced stiffness. This state can be used to straighten the electrode carrier (EC) for an insertion through the round window similar to that of a straight lateral wall EC. At high temperatures, the SMA returns to the trained shape which was imprinted during the fabrication process. By specifying a curved geometry, it is thus possible to achieve a perimodiolar final position after insertion through temperature-controlled actuation. This can be accomplished depending on the thermomechanical properties of the SMA, which can be varied and defined within the fabrication process.

Method: According to current literature, the largest diameter (A-value) of average-sized cochleae is 9.95 +/- 0.59 mm and the largest perpendicular distance (B-value) 6.54 +/- 0.48 mm. For this study, an average-sized cochlea was chosen from a large number of human temporal bone samples within the workgroup based on the evaluation of the A- and B-values. The A- and B-value of the selected cochlea is 9.3 mm and 6.7 mm respectively. The geometry of this cochlea derived from the image database that was acquired by means of serial cross-sectioning (microgrinding) technique. The cochlea was then segmented from the image data through mid-modiolar slice planes by rotating around the spiral axis in steps of 22.5°. The acquired data were then transferred to computer-aided software (CAD) for designing the SMA actuator geometry. The spiral shape of the SMA was designed according to the average-sized cochlea with a straight segment on the basal part followed by six circular arcs with decreasing radius covering an insertion depth of 16 mm. Nitinol wires with a diameter of 100 µm were used to fabricate the SMA actuators with the specified geometry as being the trained shape.

Results: Geometry deviations from the measurement results of the fabricated SMA actuators (n=10) compared to the designed geometry were evaluated along the length of the SMA. Based on the evaluation made, the fabricated geometry lies within a tolerable range.

Conclusion: To conclude, it is possible to design and fabricate SMA actuators that fit a specific cochlea geometry. The design of the curved geometry for the SMA actuator depends on good image segmentation of the cochlea from the image data provided. Further parameters besides the thermomechanical properties of the SMA need to be taken into consideration for future EC featuring a shape memory effect. One important parameter which requires further investigation is the influence of the EC stiffness on the thermomechanical properties of the fabricated SMA actuators

W2: DEVELOPMENT OF AN IMPLANTABLE MEMS SENSOR FOR HEARING DEVICES

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Background and goals: Traditional hearing devices pose important limitations to patients due to the presence of the external components, and totally implantable hearing devices come as an alternative solution to deliver more comfort and liberty to the user. One of the main challenges to totally implantable hearing devices is the development of a suitable sensor, and three main approaches can be found in the literature: (i) subcutaneous microphones, (ii) intra-cochlear acoustic receivers, and (iii) sensors coupled to the middle ear. Although different designs have been proposed, none of them have been able to successfully meet all requirements for an implantable sensor for hearing devices. In this sense, the most critical requirements are small size, low internal noise, low power consumption and large bandwidth. In this work, different designs of MEMS piezoelectric accelerometers coupled to the middle ear are numerically and experimentally evaluated as a possible solution to these problem.

Method: The Finite Element (FE) Method is used to model the different physics involved in a MEMS piezoelectric accelerometer coupled to the middle ear, and optimal configurations of the sensor in terms of sensitivity are probed. Some optimal designs were selected, manufacture and tested, allowing the validation of the FE models. The first optimization round was based on a 2x2 mm annular configuration for the MEMS accelerometer with a 500 nm Aluminum Nitride layer as the piezoelectric element, which were defined based on limitation of the fabrication process. In order to improve the sensor performance, mainly in terms of internal noise, a second generation of sensors was designed. The optimization process was redefined in order to ensure the lowest Equivalent Input Noise (EIN) of the sensor and some fabrication restrictions were removed, specially the possibility of considering lead zirconate titanate (PZT) as the piezoelectric material. In addition, preliminary fatigue and stress analyses were conducted with the most optimum designs, using mechanical property data available in the literature, in order to predict the viability of the design.

Results: A first generation of MEMS piezoelectric accelerometers as implantable sensors for hearing devices has been designed using FE models and validated. In order to improve the sensors performance, a second round of optimization was carried out, resulting in 1.5x1.5 mm and 2x2 mm sensor footprints with EINs when implanted similar to electret microphones traditionally used in hearing devices. In the frequency band from 200 Hz to 8kHz, both sensors displayed the best EIN values when compared with others implantable sensors previously described in the literature. Finally, although there is a need to validate the results obtained, the current designs seem to fulfill the requirements for an implantable sensor for hearing devices.

W3: COMPARISON OF MULTI-COMPARTMENT CABLE MODELS OF HUMAN AUDITORY NERVE FIBRES

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Background: Multi-compartment cable models of auditory nerve fibres have been developed to assist the improvement of cochlear implants. With the advancement of computational technology and the results obtained from in vivo and in vitro experiments, these models have evolved to incorporate a considerable degree of morphological and physiological details. They have also been combined with three-dimensional volume conduction models of the cochlea to simulate neural responses to electrical stimulation. However, no specific rules have been provided on choosing the appropriate cable model, and most models adopted in recent studies were chosen without a specific reason or by inheritance.

Methods: Three of the most cited multi-compartment cable models of the human auditory nerve, i.e. Rattay et al. [1], Briaire and Friijns [2], and Smit et al. [3], were implemented in this study. Several properties of single fibres were compared among the three models, including threshold, conduction velocity, action potential shape, latency, refractory properties, as well as stochastic and temporal behaviours. Experimental results regarding these properties were also included as a reference for comparison.

Results: For monophasic single-pulse stimulation, the ratio of anodic versus cathodic thresholds in all models was within the experimental range, despite a much larger ratio in the model by Briaire and Friijns. For biphasic pulse-train stimulation, thresholds as a function of both pulse rate and pulse duration differed between the models, and none matched the experimental observations even coarsely. Similarly, for all other properties including the conduction velocity, action potential shape, and latency, the models presented different outcomes and not all of them fell within the range observed in experiments.

Conclusions: While all three models presented similar values in certain single fibre properties to those obtained in experiments, none matched the experimental observations satisfactorily. In particular, the adaptation and temporal integration behaviours were completely missing in all models. Further extensions and analyses are required to explain and simulate realistic auditory nerve fibre responses to electrical stimulation.

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W4: DEVELOPMENT/ESTABLISHMENT OF IN VITRO MODEL TO UNDERSTAND THE EFFECT OF ELECTRICAL STIMULATION ON INNER EAR

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Introduction: While there is a trend to implant patients with residual hearing, cochlear implantation (CI) may cause some loss of this residual hearing. The direct effect of implantation of the electrode in affecting macroscopic structures of the inner ear is well described. Recently, a hybrid approach has been developed, where both residual hearing and electrical stimulation are used. However, the effect of the electrical field generated by the implant has not been investigated to date. There is a need to develop in vitro models of electrical stimulation of CI, which closely mimic human clinical conditions that will help in understanding the precise contribution of electrical stimulation in cochlear damage.

Materials and Methods: A custom stimulator circuit that allows to study several parameters, including stimulation amplitude, pulse width, and total stimulation duration was designed. The organ of Corti explant cultures from postnatal day three (P3) rats were used and placed in microchannel slide (Ibidi GmbH) in the incubator and exposed to stimulation or left unstimulated. We also determined the efficacy of an otoprotective compound in providing protection against adverse effects of electrical stimulation. Parameters (amplitude, pulse width and duration) were changed one at a time. The organ of Corti explants were subjected to FITC phalloidin staining to visualize hair cells using confocal microscopy. The number of surviving hair cells were counted. The organ of Corti was also subjected to CellROX and cleaved caspase 3 staining to determine the levels of oxidative stress and apoptosis, respectively.

Result: In vitro testing suggests that the electrical stimulation may cause some damage to hair cells, mainly with higher stimulation levels and longer times of stimulation. The identified otoprotective compound provides significant protection against loss of hair cells in response to electrical stimulation. The molecule mechanisms behind otoprotection involves abrogation of activation of oxidative stress and apoptosis pathways.

Conclusion: The stimulator circuit we designed and constructed very closely simulates the electrical field of a cochlear implant. It has enough task flexibility to be used as an in vitro model of electrical stimulation. The models developed in this study using electrical stimulation can be used to understand the effect of electrical field on inner ear sensory cells and to screen future otoprotective drugs for the preservation of residual hearing post CI using similar approach as used in this study.

W5: REPLICATION AND USE OF A LADDER NETWORK OF RESISTORS FOR MODELLING INTRA-COCHLEAR VOLTAGE MEASUREMENTS

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One the main limiting factors for speech understanding with Cochlear Implants (CIs) is the spread of current along the electrode array. This is because the cochlear scalae are filled with perilymph, a liquid much more conductive than the bony structure of the cochlea. Back-telemetry allows the measurement of the drop in stimulation voltage along the electrode array when stimulating with one electrode (e.g. Electrical Field Imaging, TransImpedance Matrix). However, the measured patterns can be difficult to interpret in terms of the distribution and amount of current flow within the cochlea. A proposed solution has been to model such intra-cochlear voltage measurements with a ladder network of resistors (Vanpoucke et al. 2004). This model has the advantage of having fewer parameters than 3D finite-element models. Yet, it might still allow the localization of the main current pathways in the cochlea. It might also allow the estimation of the actual voltage at the stimulated electrode, without the influence of the contact impedance.

In this study, we first attempt to replicate the findings of the original paper. We investigate in particular the stability of the obtained resistor values when changing the order of the model, the number of electrodes, the start values, minimum/maximum values, tolerance values and when adding noise to the recorded voltage measurements. Preliminary results indicate a strong influence of the start values and of the tolerance values. This was not discussed in the original paper, although it might substantially change the interpretation of the model output.

We therefore first validate the fitting procedure on known resistor values. We then investigate the influence of the model parameters when fitting the ladder network to measurements obtained with electrode arrays inserted inside a highly simplified bench model of the cochlea as well as human cadavers. Both setups allow one to create artificial current shunts at various locations along the electrode array, and are therefore a valuable intermediate stage before interpreting data from regular CI users.

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W6: THE ANATOMICAL NEURAL FRAMEWORK SUPPORTING AUDITION IS PRESERVED IN DEAF CATS

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Evidence from behavioural, electrophysiological, and functional imaging studies in humans and animal models demonstrate compelling evidence for crossmodal reorganization of auditory cortex in the deaf. This phenomenon was thought to reflect largescale differences in anatomical connectivity between sensory cortices, such that presumptive 'auditory' brain regions are more closely integrated into networks subserving the remaining modalities. Here, we summarize behavioural evidence for crossmodal function in deaf 'auditory' cortex of the cat, and describe a series of detailed anatomical studies of early-onset deafness that do not support this proposed link between changes in function and the underlying anatomy. Instead, across each of the cortical fields examined (ranging from core to higher-level cortex) we find that projections originating in visual and somatosensory brain regions are comparable between normal hearing and early-deaf animals. In light of these findings, we will discuss alternative hypotheses for the anatomical basis for crossmodal reorganization, and consider the implications for barriers to hearing restoration.

W7: SPATIAL DECONVOLUTION OF INTRACOCHLEAR POTENTIALS SUPPORTS ECTOPIC ELECTRICAL STIMULATION HYPOTHESIS

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Previously, we hypothesized the possible occurrence of an ectopic (out-of-place) site of electrical stimulation at the base of the cochlea that may produce competing neural activity which in turn may diminish cochlear implant (CI) performance. Physiological data leading to this hypothesis were unexpected latency shifts in intracochlear evoked potentials (IEPs, a.k.a. NRI, NRT, ART, ECAP responses). In particular, we measured the spatial spread of IEPs by holding the site and level of monopolar-coupled stimulation constant and recorded from different electrodes spaced longitudinally along the array. In this case, the latency of the N1 component of the IEP was frequently observed to vary depending on the location of the recording electrode, whereas normally no latency shift would be expected. When latency shifts were observed, the response latencies typically became progressively shorter as the recording site was moved basally away from an apical stimulation site. Conversely, basal stimulation frequently produced similar shifts toward shorter latencies as the recording electrode was moved apically.

To explain these paradoxical latency shifts, we hypothesized that the recorded responses in the scala are the net sum of response fields arising from two neural stimulation sites. One site is the spiral ganglion cell region near the stimulating electrode producing a long-latency response due to slow charging of the cell bodies. The other site is at the base of the modiolus where auditory axons exit the cochlea into the internal auditory meatus (IAM). This ectopic site is stimulated by monopolar-coupled, injected current exiting the bone-enshrouded cochlea at the base of the osseous spiral lamina into the IAM, thus producing a secondary, short-latency neural response. At individual recording electrodes within the scala, the relative, summed contributions of the long- and short-latency response fields differ and result in apparent latency shifts in the net neural response across recording locations.

Presently, we have extended the analysis by spatially deconvolving the neural responses by performing independent component analysis (ICA) across scalar recording locations to derive estimates of the morphology, latency, magnitude and distribution of response components within the scala due to each stimulated site. The results indicate that fields from multiple neural response sites of differing waveform morphology, latency, magnitude and scalar distribution can contribute to a measured IEP within the cochlea. The characteristics of these generators are consistent with the ectopic stimulation hypothesis.

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W8: ELECTRODE MISDIRECTION INTO THE SUPERIOR SEMICIRCULAR CANAL: COMPLICATION OF COCHLEAR IMPLANTATION BY ROUND WINDOW APPROACH

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OBJECTIVE: The purposes of this study were to investigate the misdirection of the electrode into the superior semicircular canal during cochlear implantation and to suggest surgical principles for correct electrode insertion through the round window membrane.

MATERIALS and METHODS: In this retrospective case review, operative records and postoperative images of cochlear implantations performed at a tertiary care facility from 1988 to 2010 were reviewed.

RESULTS: In 3 out of 629 cases, electrode insertion into the superior semicircular canal was found. All 3 cases occurred in cochlear implantations using the round window approach, and none was found when using the cochleostomy approach. Insufficient exposure of the round window membrane and intra-cochlear soft tissue were regarded as the cause of misdirection of the electrode. The electrodes were repositioned appropriately into the cochlea with revision surgery in all 3 cases.

CONCLUSION: In order to prevent electrode misdirection during cochlear implantation through the round window, the round window membrane needs to be clearly visualized by sufficiently drilling bony overhangs and removing soft tissues around the round window.

W9: SIMULATING THE EFFECTS OF "M-CURRENT" POTASSIUM CHANNELS IN COCHLEAR IMPLANT EXCITATION OF AUDITORY NERVE FIBERS

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Having an accurate description of the patterns of action potentials (APs) generated in auditory nerve fibers (ANFs) by cochlear implant (CI) stimulation is a crucial component to relating stimulation strategies to perceptual outcomes. Biophysical computational models are a powerful tool for capturing what is known about the electrochemical dynamics and ion-channel gating mechanisms underlying neural excitability.

Previous computational models of an ANF node of Ranvier suggest that low-threshold potassium (KLT) and hyperpolarization-activated cyclic nucleotide-gated cation (HCN) channels affect an ANF's absolute and relative refractory periods and produce adaptation/accommodation to high-rate pulse trains (Negm & Bruce, IEEE TBME 20014; Boulet & Bruce, JARO 2017). In this study we explore the effects of another type of potassium channel that has recently been identified in mammalian auditory nerve fibers, "M-current" potassium channels formed by Kv7.2 and Kv7.3 ion channel proteins (Kim & Rutherford, J Neurosci 2016). Like the KLT and HCN channels, the M current is active at the resting membrane potential of ANFs and has slower opening/closing dynamics than the AP-generating sodium and potassium channels. Thus, the M current is expected to also have an influence over the refractory, facilitation, accommodation and adaptation behavior of ANFs.

We have incorporated an M-current model used in other cell types (Lawrence et al, J Neurosci 2006) into the previous ANF model of Boulet & Bruce (JARO 2017). As a first step of evaluating this new model, we have compared simulation results to the room-temperature ANF patch-clamp data of Rutherford et al (J Neurosci 2012). This new model incorporating the M current is able to better predict these patch-clamp data in general. Further refinement of free parameters in the model is ongoing. The next step we are taking is to expand this model to describe extracellular CI stimulation of ANFs at mammalian body temperature.

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W10: MODELLING ELECTRICALLY EVOKED COMPOUND ACTION POTENTIALS AND SINGLE NEURON RESPONSES TO PREDICT POLARITY AND PULSE SHAPE EFFECTS ON SPIRAL GANGLION NEURONS UNDER ELECTRO-STIMULATION

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Single cell and population computational models of the Spiral Ganglion Neuron (SGN) are key in ameliorating the electrode-neuron interface in Cochlear Implants (CIs). Electrode-neuron distance, spread of excitation along the cochlea, neuron survival and the status of the auditory nerve fibres are known factors in the efficiency of the neural encoding of sound in CI users. Current research focuses on improving that interface; biologically through increased 'bio-mimicking' of electrical stimulation strategies, pharmacologically with neuro-trophic or –protective drug coatings applied to the electrode array, or through parallel advances in signal processing.

Successful models of the Spiral Ganglion Neuron (SGN) that use realistic morphology and physiologically derived ionic channels dynamics have been efficient in predicting Action Potential firing. Although these models help understand the behavior of SGNs when subjected to external electrical stimuli, they often fail to account for key characteristics of SGN firing such as adaptation or refractoriness. Recent work has shown that this could be caused by the use of an impoverished set of ionic channels and that said models could be improved by adding sub families of ionic channels such as Potassium Low Threshold (KLT) or Hyperpolarized cation channels (HCN).

Here, using cable-equation methods, we focus on the effects of polarity and the shape of electrical pulse on the electrically stimulated auditory nerve by means of a physiologically inspired model of a single SGN. This study investigates the effect of electrical stimulation in a realistic SGN model, as well as in a population of SGNs, in order to evaluate stimulation strategies and determine the efficacy of other proposed improvements in CI devices. The model compares predictions from ionic channel models with and without the KLT and HCN channels. The model incorporates relevant physiological characteristics that generate action potential and ECAPs. The model also allows for parameterization of ionic channels dynamics as well as geometry characterization. Specifically, we study the effects of polarity and pulse shape on the firing pattern on separate SGNs, and populations of SGNs, undergoing several degrees of degeneration – from partial (decrease of peripheral myelination) to total peripheral degeneration. Results are compared with published data from animal and computational models.

W11: EVALUATION OF A NEW ALGORITHM TO OPTIMIZE AUDIBILITY IN COCHLEAR IMPLANT RECIPIENTS

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Objective: Understanding varying levels of speech is necessary for effective communication in daily life; moreover, research has demonstrated a positive relation between audibility and speech understanding for cochlear implant (CI) recipients. Sound-field threshold levels of 20 dB HL across the frequency range provide CI users an opportunity to understand soft and very soft speech; however, programming the sound processor to attain good audibility can be time consuming for audiologists and difficult for some patients. To address these issues, Advanced Bionics (AB) designed a new algorithm, SoftVoice. The algorithm computes the energy within each frequency channel independently and suppresses sounds that fall below a pre-determined noise threshold, thereby removing system noise and improving the audibility of soft speech. The primary objective of the following studies was to evaluate the efficacy of SoftVoice in optimizing AB CI recipients' soft-speech perception.

Design: Two studies were conducted. Study 1 had two phases, 1A and 1B. Sixteen adult, AB CI recipients participated in Study 1A. Acute testing was performed in the unilateral CI condition using a Harmony sound processor programmed with participants' everyday-use program (Everyday) and that same program but with SoftVoice implemented. Speech perception measures were administered at several presentation levels in quiet (35-60 dB SPL) and at 60 dB SPL in noise. In Study 1B, ten of the participants compared Everyday and SoftVoice at home to obtain feedback regarding SoftVoice use in various listening environments. During Study 2, soft-speech perception was acutely measured with Everyday and SoftVoice for ten participants using the Naida CI processor. Results with the Harmony (Study 1A) and Naida processors were compared. In addition, Study 2 evaluated programming options for setting electrode threshold levels (T-levels or Ts) to improve the usability of SoftVoice in daily life.

Results: Study 1A revealed significantly improved sound-field threshold levels from 250-6000 Hz with SoftVoice compared to Everyday. Speech perception scores were significantly higher with SoftVoice than Everyday at soft presentation levels (35, 40, 45 and 50 dB SPL). No significant differences in scores were found between programs for tests presented at a conversational level (60 dB SPL) in quiet or in noise. After take-home experience with SoftVoice and Everyday (Study 1B), half of the participants reported a preference for SoftVoice over Everyday; however, six reported bothersome environmental sound when listening with SoftVoice at home. Results of Study 2 indicated similar soft-speech perception between the Harmony and Naida. Furthermore, implementing SoftVoice with Ts at the manufacturer's default setting of 10% of Ms reduced reports of bothersome sound during take-home experience; however, soft-speech perception was best with SoftVoice when Ts were behaviorally set above 10% of Ms.

Conclusions: Results indicate that SoftVoice has the potential to be an efficient tool for optimizing AB CI users' audibility and in turn, soft-speech perception. To achieve optimal performance at soft levels and comfortable use in daily environments, setting T-levels need to be considered with SoftVoice. Future work should examine program parameters that may benefit soft-speech perception when used in combination with SoftVoice (e.g., increased input dynamic range).
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W12: PRELIMINARY EVALUATION OF THE SOUNDBITE BONE-CONDUCTION DEVICE FOR CHINESE SSD ADULTS

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Objective: One option for patients with single sided deafness (SSD) is the SoundBite bone conduction device which had been commercially available in USA. The purpose of our study was to evaluate the efficacy, benefit and safety of the bone conduction system product in China now for Chinese patients with SSD.

Patients and Methods: Adults (ages ≥18 and ≤65 yr) with acquired, permanent SSD (N = 5) and no current use of any SSD device, was recruited. They were requested the continual daily wear of the new device over a 30-day trial period without payment.

The audiological tests included air conduction thresholds, word recognition score (WRS) in quiet and speech intelligibility in noise (MHINT & CMNmatrix). Efficacy was determined with the Abbreviated Profile of Hearing Aid Benefit (APHAB) and the single-sided deafness (SSD) Questionnaire. Safety was evaluated by comprehensive pretrial and posttrial dental examinations.

Results: The monosyllable WRS and the 50% threshold of signal-to-noise ratio (SNR50) was significantly better in all aided conditions. The (SNR50, either assessed by MHINT or CMNmatrix) improved an average of -2.5 dB after 30 days, compared with wearing no device ($p<0.001$). The Abbreviated Profile of Hearing Aid Benefit scores improved ($p<0.05$) for all subjects for the Global and Ease of Communication, Background Noise subscales. There were no medical, audiologic, or dental complications.

Conclusion: The SoundBite is a good alternative to the well-established implantable bone conducting devices in patients with single sided deafness. An improvement in hearing in noise and quiet as well as a decrease of the head shadow effect can be expected.

Key Words: Bone conduction instrument—SoundBite—Single sided deafness[JG35]

W13: BENCHMARK OF HEALTH-RELATED QUALITY OF LIFE QUESTIONNAIRES IN BIMODAL HEARING SYSTEM SUPPLY

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The benefit assessment of hearing systems is usually carried out by determining clinically relevant parameters, such as speech comprehension. In addition to such parameters addressing efficacy, the assessment of everyday benefits by means of questionnaires on health-related quality of life (HrQoL) is of increasing relevance. It is important to demonstrate the effectiveness over time, see the Medical Device Regulation (MDR) of April 5, 2017 (EU, 2017/745) and '522 Postmarket Surveillance Program' of the FDA as well as the cochlear implant (CI) rehabilitation phase. To assess the benefit of hearing systems over time, the questionnaires must be suitable to demonstrate sensitivity to changes. Sensitivity to change was tested across a range of functional, disease-specific, and generic questionnaires with N=40 bimodal patients (average age M = 64.7 years (SD = 11.0; 55% female), who switched from bilateral hearing aids (HA) provision to a bimodal supply (HA and CI). The participants stated that they suffer from hearing loss since M = 28.2 years (SD = 18.5). Since M = 20.5 years they were aided with HA's and in the last M = 8.5 years (SD = 11.4). The results of the speech test (Freiburg monosyllabic test at 65 dB) showed a significant improvement compared to the baseline before implantation (M = 12.2; SD = 14.2) and six months later (M = 64.1, SD = 25.3). The following questionnaires with selected sub-scales were examined: 'Speech, Spatial and Qualities of Hearing Scale' (SSQ-12; Noble et al. 2013), 'Nijmegen Cochlear Implant Questionnaire' (NCIQ; Hinderink et al. 2007), 'Oldenburg Inventory' (Excellence Centre for Hearing Research HörTech 2004), 'Hearing Handicap Inventory for adults' (HHIA; Newman et al. 1991), 'Nottingham Health Profile' (NHP; Hunt & McEwen 1980), 'Glasgow Health Status Inventory' Questionnaire (GHSI, Robinson et al. (1996), and 'Indicators of the Rehab-Status' (IRES-3; Frey et al. (2007). The subjects answered 166 items of a large questionnaire battery at four measuring time points (before implantation and three to nine months after implantation). Some of the questionnaire scales were change sensitive (Cohen's d) from baseline and nine months later. So, they and can be used for evidence-based evaluation in the field of CI and bimodal rehabilitation. According on this, we selected the functional questionnaire SSQ-12 (all items) with d=1.55, a disease-specific 'social subscale' from the HHIE with d=1.11, as well as the generic 'general sub-scale' from the GHSI with d=0.82. For rehabilitation purpose we suggest to add the 'coping with illness' sub-scale from the IRES-3 with d=0.53. Though, the here proposed reduced test battery consists of 38 items and seems to be suitable for an economic to handle test battery in prospective longitudinal studies to evaluate the patients' benefit in everyday life to meet different regulatory recommendations.

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W14: A CODING STRATEGY TO REMOVE TEMPORALLY MASKED PULSES AND ITS EFFECT ON SPEECH PERCEPTION IN COCHLEAR IMPLANT USERS

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Speech recognition in noisy environments remains a challenge for cochlear implant (CI) recipients. Unwanted current interactions both in the spectral and in the temporal domain have been suggested to be related to degraded performance. However, multiple approaches to alter the CI sound coding and/or to re-map the fitting to reduce these interactions have had varying success. Here we investigate the effect of reducing the number of overall current pulses on speech perception.

A psychoacoustic forward-masking model in the temporal domain (the temporal integrator) was used to identify and remove current pulses that were less likely to be perceived by the recipient. The decision criterion of the temporal integrator was set so that conditions could be generated with different percentages of pulses removed. In the first experiment, speech intelligibility in quiet was assessed with 7 CI users under 4 conditions. Speech was processed with the standard Continuous Interleaved Sampling (CIS) strategy and conditions were tested where 0 (baseline), 20, 50 and 75 % of pulses were removed. In the second experiment, performance for speech in noise was assessed by measuring the speech reception threshold (SRT) in an adaptive procedure that converged on 50 % correct, with conditions that had 0, 50 and 75 % of pulses removed.

Speech intelligibility in quiet revealed no significant difference between baseline and each of the conditions where pulses were removed, thereby suggesting that the number of current pulses can be reduced by up to 75% without harming speech perception compared to the standard CIS condition. A post-hoc analysis corrected for multiple comparisons indicated that conditions where 20 and 50 % of pulses were removed had significantly higher speech scores than when 75 % of pulses were removed. Preliminary results showed small improvements for speech in noise in the conditions where pulses were removed compared to the baseline but we are currently obtaining further measurements to test the significance of these findings.

W15: WORD LEARNING IN ADULTS WITH COCHLEAR IMPLANTS: EXAMINING THE INFLUENCE OF TALKER VARIABILITY AND AUDIOVISUAL SPEECH

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For many deaf people, cochlear implants (CIs) facilitate spoken language acquisition. However, CI listeners have poorer word-learning skills than their normal-hearing (NH) peers. Studies show that talker variability improves word-learning for NH listeners. In the presence of variation, listeners are able to tune into the acoustic dimension that is relatively invariant between talkers, allowing for robust representation of the word form. Additionally, viewing a talker's face, especially the mouth, provides CI listeners with direct access to audiovisual cues, which improves speech perception. This study used a word-learning task to determine whether talker variability improves learning for adult CI listeners and to examine gaze behavior of CI listeners while viewing a talking face.

Adults with NH and with CIs were taught novel-objects pairings spoken by a single talker or by multiple talkers. Participants were tested on their ability to learn the words using a novel talker in a two-alternative-forced choice task (2-AFC). Test phases consisted of easy and hard trials where word choices differ by several or a single phonetic feature, respectively. In both the learning and test phases, listeners received an audiovisual presentation of the talker to facilitate phonetic processing. Learning was assessed via listeners' eye movements to the target word over time. Preference for the mouth was assessed by calculating number of fixations to the mouth.

Preliminary results suggest that talker variability improves CI listeners' ability to distinguish similar-sounding words. During learning, CI listeners fixated on the talker's mouth more than NH listeners. These findings may provide novel approaches to improve word-learning in CI listeners.

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W16: THE EFFECT OF AGE ON COCHLEAR-IMPLANT USERS' RECOGNITION OF CONSONANT CONTRASTS THAT VARY IN DISCRETE TEMPORAL CUES AT DIFFERENT STIMULATION RATES AND ENVELOPE MODULATION RATES

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Perceptual cues to consonant identity are available within the temporal envelope of speech signals, which makes consonant identification possible even in the absence of spectral information. In cochlear-implant (CI) users, for whom access to spectral information is limited, the envelope modulation rate conveyed by their device is partly determined by the electrical stimulation rate. Faster stimulation rates sample the temporal envelope more frequently and thus, should facilitate more accurate neural representations of the rapid modulations that carry short-duration speech segments, such as stop consonant bursts. However, increasing the electrical stimulation rate does not uniformly result in improved consonant identification performance in CI users, and moreover, there is a large amount of individual variability in performance in response to increasing the stimulation rate. One factor that may contribute to this individual variability is the chronological age of the listener. Advancing age is associated with a decline in temporal envelope processing, particularly at faster envelope modulation rates. Spectrally degraded phoneme identification performance in normal-hearing listeners improves with increasing the envelope modulation rate of the signal, but older listeners do not obtain comparable benefits in performance to younger listeners with increasing modulation rate, likely due to underlying auditory temporal processing deficits. This experiment tested the hypothesis that older CI users would be less affected by reducing the envelope modulation rate compared to younger subjects because the higher rate modulations that are present in unfiltered stimuli would be less salient to older users due to underlying temporal envelope processing deficits. It was predicted that younger CI users would be able to take advantage of the higher sampling rate resulting from a faster electrical stimulation rate, but that older users would not achieve a similar benefit.

Phoneme recognition within monosyllabic words was measured in nine CI users ranging in age from 27-85 years (mean=57.7 years). Stimuli were selected to represent a range of consonants in which temporal contrasts are a cue to phoneme identity, including voice onset time, the relative onset of voicing following frication, silent interval duration between a release burst and onset of frication, and vowel duration as a cue to post-vocalic consonant voicing. Stimuli were presented via direct stimulation using eight-channel continuous interleaved sampling (CIS) maps with stimulation rates of 500, 900, and 1800 pps. To examine the effect of envelope modulation rate, stimuli were also presented with envelope smearing in which the rate of envelope fluctuations in the signal was reduced using a low-pass filter cut-off frequency of 50 Hz.

Preliminary results showed that envelope smearing produced an average decrease in phoneme recognition scores by 12 percentage points, and this result was consistent for both the younger and older subjects. Duration of severe to profound hearing loss before implantation was a stronger predictor of phoneme recognition performance than chronological age, on average. Subjects with durations of deafness greater than 10 years had poorer recognition scores overall. Although the effect of age was not significant in the preliminary data set, the older subjects (>60 years of age) had a higher percentage of temporally based errors (i.e., voicing errors) compared to the younger subjects, suggesting that deficits in temporal processing may impact CI users' phoneme recognition. On the group level, stimulation rate did not have an effect on performance; however, large amounts of individual variability were noted, with some subjects performing best with one rate, while others showed no effect of rate. The current results suggest that chronological age did not differentially impact performance when the envelope modulation rate was reduced to 50 Hz. However, the older CI users demonstrated more temporally based phoneme confusions compared to younger users, which suggests that age-related auditory temporal processing deficits may impact phoneme recognition performance. Increasing the electrical stimulation rate did not result in improved phoneme recognition. The effect of stimulation rate varied greatly across subjects, and it remains unclear as to why some subjects benefit from a particular rate while others do not. These results suggest that auditory temporal processing deficits may be impacting older CI users' performance, and that selecting the optimal stimulation rate for individual CI users may improve performance.

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W17: ACHIEVING EQUIVALENT COCHLEAR IMPLANT SPEECH RECOGNITION IN VIRTUAL AND REAL SOUND BOOTHS

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Objective: As the number of cochlear implant (CI) users increases, demand on clinic resources, including physical space and clinicians' time needed to perform the assessments, also increases. One way to alleviate demand for these resources is to provide a method of assessment that does not require using a sound booth or even visiting an audiology center, in order to perform speech recognition evaluations. In the first experiment, we evaluated whether it is feasible to achieve matched speech recognition scores when comparing testing with direct audio streaming to a CI sound processor testing in a sound booth. In a second experiment, we evaluated whether directly streaming speech tokens which were computer processed to closely emulate the sound booth acoustic environment would yield equivalent scores to those obtained in the sound booth.

Design: Two acute studies were conducted. Thirteen adult Advanced Bionics (AB) CI recipients participated in study 1. Recognition of speech tokens was measured in a unilateral CI listening configuration in quiet (AzBio sentences and CNC monosyllabic words) and in the presence of multi-talker noise (AzBio sentences only) in the sound booth and via direct audio streaming to the sound processor with calibrated loudness level (dBA) matched to the sound booth presentation level. Eleven adult AB CI recipients participated in study 2. Sentence recognition in multi-talker background noise was measured in a unilateral CI listening configuration for each participant. Sentence and noise tokens were processed based upon a measured acoustic impulse response with added noise floor and were used for speech recognition measures in the direct audio test modality; unprocessed tokens were used in sound booth assessments.

Results: Study 1 confirmed feasibility of conducting speech recognition measures through direct audio streaming of the speech and noise tokens to a recipient's sound processor. However, speech scores measured via the direct audio test modality were significantly better than scores measured in the sound booth. Results of study 2 showed equivalent speech recognition scores obtained using unprocessed tokens in the sound booth and processed tokens when conducting evaluations via direct audio streaming.

Conclusions: Results of these evaluations support the feasibility of assessing speech recognition in CI recipients outside the sound booth environment, through the use of direct audio streaming of recorded materials to the sound processor. However, to achieve sound booth-equivalent scores during direct audio testing, sound tokens may need to be adapted to more accurately emulate sound booth acoustic properties such as reflection/reverberation effects and noise floor. Further work may look at applicability of the virtual sound booth concepts across various test environments and incorporation of self-administration of test materials to enable remote patient assessments.

W18: SPEECH RECOGNITION IN NOISE IN SINGLE-SIDED DEAF COCHLEAR IMPLANT CHILDREN WITH APPLICATION OF DIGITAL WIRELESS ADAPTIVE MICROPHONE TECHNOLOGY

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Introduction. In children, congenital or early acquired single-sided deafness (SSD) affects the development of the central auditory nervous system during its sensitive phase and thus prevents the development of binaural hearing abilities. Even though timely cochlear implantation in SSD CI children has been proven to improve speech recognition in noise for near speakers and localization of sound sources, and thus to partially (re)habilitate binaural hearing, these children are limited, among other things, in speech recognition in noise for distant speakers. The objective of this study was to evaluate if the application of a digital remote wireless microphone system allows for an improvement of speech recognition in noise for distant speakers in SSD CI children.

Methods. Ten SSD CI children between five and twelve years of age at time of testing with a CI experience of at least 6 months were included in the study. Speech recognition in noise for a frontal and for each of two lateral speakers was measured with the Oldenburg children sentence test (OLKISA) at a speech level of 65 dB(A) and a noise level of 55 dB(A). Four different listening conditions were assessed for the frontal speaker: 1) normal-hearing (NH) ear and CI turned off; 2) NH ear and CI; 3) NH ear and CI with the remote digital remote wireless microphone system, Roger, attached; 4) NH ear with Roger and CI. For the lateral speakers, listening conditions 2) to 4) were investigated.

Results. For the frontal as well as both lateral speaker positions, speech recognition in noise significantly improved with the application of Roger at the CI or NH ear, respectively. Children with poorer speech recognition with their CI ear obtained a significantly larger benefit when using the Roger at the NH ear compared to the CI ear. Furthermore, there is a significant correlation between speech recognition in noise with Roger at the CI and duration of CI use.

Conclusions. In SSD CI children, the application of the digital remote wireless microphone system, Roger, is beneficial for speech recognition in noise for distant speakers. An individual adaptation of using Roger with the CI or NH ear depending on speech recognition obtained with the CI and subjective preference is necessary in order to achieve best possible care.

W19: DECODING THE AUDITORY NERVE. IMPLICATIONS FOR COCHLEAR IMPLANT TECHNOLOGY

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A vocoder based on the MAP-simulated (Model of the Auditory Periphery, e.g. Meddis, 2006) spiking of 30,000 auditory nerve fibers led to near-normal speech intelligibility of vocoded speech. The vocoder thereby reveals a very simple and computationally efficient way to predict how AN firing patterns and their encoding of speech waveform temporal fine structure (TFS) may be interpreted by the brain.

TFS transmission through cochlear-implants (CIs) is essential to improving CI users' pitch perception, music perception/appreciation and, of course, speech intelligibility. A breakthrough in CI TFS transmission is yet to be found. Part of the reason for this is that focus has mostly been placed on improving spectral resolution at the AN excitation level, which is inherently limited by spread of excitation. The proposed encoder predicts that, in response to a speech stimulus, the AN encodes signal periodicity (fundamental frequency and formants) and temporal modulations using spike timing. Physiological evidence (e.g. Shamma et al., 1985) suggests that such information is transmitted over as few as five, time-varying spectral bands. If so, the spectral smearing effect of CI spread of excitation would become a lot easier to mitigate. We demonstrate, here, how the vocoder can be used to evaluate the potential benefit of different fine-structure encoding strategies. Overall, the above approach may facilitate the development of real-time, population-level predictions of the effectiveness of AN-encoding, as well as help determine the likelihood of success in TFS transmission in CIs.

W20: THE MOST ACCURATE ACOUSTIC MODEL OF A COCHLEAR IMPLANT DIFFERS ACROSS INDIVIDUALS: THE INFLUENCE OF ELECTRODE INSERTION DEPTH AND AUDITORY PLASTICITY

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Acoustic models have been used in numerous studies over the past three decades to simulate the percepts elicited by auditory neural prostheses. In these acoustic models, incoming signals are processed in the same way as in a cochlear implant speech processor. The percepts that would be caused by electrical stimulation in a real cochlear implant are simulated by modulating the amplitude of either noise bands or tones. Despite their practical usefulness these acoustic models have never been convincingly validated. Validation has become feasible with the availability of "single-sided deaf" or SSD CI patients who can make a direct perceptual comparison between the output of the acoustic models and the stimulation provided by a cochlear implant.

Forty-two SSD CI subjects were tested over a total of 72 testing sessions. Each subject adjusted three parameters to find a self-selected model that sounded most similar to the CI. The first two adjustable parameters were the low- and high-frequency edge of the output noise bands or tones, and the third parameter was output bandwidth (ranging from tones to noise bands with different amounts of frequency overlap, as a way to model different amounts of channel interaction). These parameters altered the acoustic model synthesis filters (which simulate different cochlear locations), whereas the analysis filters of the acoustic models remained identical to those in each subject's speech processor. For each set of selected parameters, a sentence was played twice- first unprocessed in the CI via direct audio input connection to the processor (with the microphone deactivated), and then processed using the corresponding acoustic model –presented through a loudspeaker to the normal hearing ear. The selection was done by adjusting the parameters interactively. In addition to the self-selected model we also evaluated traditional frequency-matched models where the output noise bands (or tones) were exactly matched to the analysis filters. These included 6-channel models and full-channel models that had the same number of channels as the subject's clinical device.

All acoustic models were evaluated using two instruments: a similarity rating questionnaire and speech perception measures. Taking both measures into account, only the self-selected models were deemed a reasonable acoustic representation of a CI because speech perception scores were similar to those obtained with the CI alone, and the similarity rating was acceptable (6.1 on a scale of 1-9 where 7 represents "very similar"). The 6-channel models also had speech perception scores that were close to the CI scores but the similarity ratings were markedly inferior (2.8 on the same 1-9 scale, where 3 is "not very similar"). Full-channel models failed on both counts: they seriously overestimated speech perception and the similarity ratings were still poor.

In addition to validating acoustic models, the present data set is interesting because of its implications about electrode location, frequency-place function mismatch, and plastic changes as a function of experience with the CI. Along these lines, we present two important results. First, we found that subjects with shallower electrode insertions tended to select acoustic models whose noise bands had a higher low-frequency edge. This is consistent with the percepts presumably elicited by the most apical electrodes. Second, subjects who were followed longitudinally tended to select different acoustic models as they became more experienced with the implant. These changes were broadly consistent with changes in electroacoustic pitch matching reported in the literature.

In conclusion, one size may not fit all when it comes to acoustic models of cochlear implants. Different models may be necessary to target specific levels of frequency mismatch or electrode insertion depth. Observed longitudinal changes in self-selected acoustic models suggest that there are significant plastic changes over time, but some postlingually deafened patients, specifically those with shallower electrode insertions, may not always be able to completely overcome the frequency mismatch imposed by their devices.

W21: DETECTING EXTRACOCHLEAR ELECTRODES WITH TRANSIMPEDANCE MEASUREMENTS IN COCHLEAR IMPLANTS: A HUMAN CADAVER STUDY

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Extracochlear electrodes are not an uncommon phenomenon in cochlear implant (CI) patients, with an estimated prevalence of 13.4% on at least 1 electrode located extracochlearly. (Holder et al. 2018) Generally, extracochlear electrodes occur due to incomplete insertion or electrode migration. (Holder et al. 2018, Van der Marel et al. 2012) Around 40% of the extracochlear electrodes are not identified by objective measures such as contact impedances, evoked compound action potentials or hearing thresholds. (Holder et al. 2018) Although Computed Tomography (CT) can identify and quantify extracochlear electrodes, it is not part of standard care for CI patients and requires radiation. We investigated transimpedance measurements / Electric Field Imaging (TIMs, EFIs) as a detection tool for extracochlear electrodes.

Eight fresh-frozen human cadaveric heads were implanted with the Advanced Bionics (AB) HiFocus 1J lateral-wall electrode, while 7 fresh-frozen human cadaveric heads were implanted with Cochlear Corp. CI522 lateral-wall electrode. The cochleae of the specimens were flushed with 1.0% saline prior to implantation. EFIs and contact impedances were measured using AB Volta software (v1.1.1) with 1-5 extracochlear electrodes. TIMs and contact impedances were measured using Custom Sound EP 5.1 with 0, 2, 4, 6, 8 and 10 extracochlear electrodes. Three conditions were measured: air or 1.0% saline in the middle ear, or soft tissue covering the extracochlear electrodes.

Extracochlear electrodes in air were easily identified by high contact impedances for both AB and Cochlear. Saline in the middle ear, mimicking intra- and post-operative conditions, and soft tissue, mimicking fibrotic tissue on the extracochlear electrodes, showed no evident alteration in contact impedances for extracochlear electrodes. For both conditions, EFIs and TIMs lowered on the extracochlear electrodes and not only identified but also quantified the number of extracochlear electrodes.

Our results show that transimpedance measurements have great potential as a non-invasive detection tool for extracochlear electrodes in cochlear implants.

W22: IMPEDANCE DEVELOPMENT AFTER IMPLANTATION OF HYBRID-L24 ELECTRODES

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Introduction. In order to preserve residual hearing after cochlear implantation, shorter and thinner electrodes were developed. These shall be inserted through the round window membrane to minimize trauma. As trauma is regarded as one of the causes of fibrous tissue formation around the electrode carrier after implantation, and increase in impedance is considered to be connected to this fibrous tissue formation, the aim of the current study was to evaluate impedance development after implantation of Hybrid-L24 electrodes.

Material and Methods. Impedance values of 137 adult patients having received a Hybrid-L24 electrode were collected from our clinical database. At the time of evaluation patients had to be implanted for at least 1 year. Impedance development over time was retrospectively evaluated for all active contacts and basal, middle and apical contacts separately for up to 10 years and also in dependency of age at implantation.

Results. On average impedances increased to 13 kOhm before first fitting and dropped under electrical stimulation to 5 to 7 kOhm with lower values measured on apical contacts. Mean values remained relatively stable over years, but variability between patients increases. Values before first fitting were independent of age at implantation whereas lower values can be expected later in patients of higher age at implantation.

Conclusion. Indications for a really more atraumatic implantation and less tissue growth around the electrode array compared to conventional Contour electrodes were found. Furthermore, there are age-dependent differences in impedances after starting electrical stimulation which might be explained by less tissue formation in older patients.

W23: QUANTIFYING CHILDREN'S "REAL WORLD" SOUND ENVIRONMENTS: A COMPARISON BETWEEN SPEECH PROCESSOR DATALOGGING AND HUMAN CODER CLASSIFICATIONS

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Objectives: We sought to: 1) determine if scene classification algorithms in cochlear implant datalogging systems reflect human perception of sound environments and 2) describe the natural sound environments of young children who use cochlear implants.

Background and rationale: To learn oral language, children with cochlear implants need exposure to spoken communication. It may be possible to measure the quantity and quality of their "real world" language exposure through datalogging available in cochlear implant processors. Such devices include a scene classification algorithm that calculates how much time the cochlear implant user spent in 'Quiet,' 'Noise,' 'Speech-in-Noise,' 'Speech,' 'Music,' and 'Wind' categories. The accuracy of these labeled categories has been validated in a laboratory setting but requires testing in the 'real world.' In children, sound environments are likely to be more dynamic than laboratory simulations and may not always reflect how each category might be interpreted clinically. We, therefore, hypothesize that scene categories determined through processor datalogging do not always match the 'gold standard' of human coding. We further expect that children with cochlear implants will spend most of their time listening in environments with multiple sounds including speech.

Method: Ten children with cochlear implants wore a Language ENvironment Analysis (LENA) System digital language processor for one day. The audio recording was uploaded to LENA software and extracted as a .wav file. Each audio recording was then hand coded by the first author using a protocol based on Cochlear's definitions of auditory scenes with the addition of electronic sounds and a differentiation between 'Quiet' sounds and 'Silence.' A research assistant was also trained in the protocol to provide inter-rater reliability. Participants were loaned a Cochlear N6 processor to wear on the day of recording. This allowed for the collection of a single day of datalogging information, rather than an average over a longer period of time. Four participants wore bilateral loaner processors and three wore just one. Eleven datalogs were extracted from the cochlear implant processors using software provided by Cochlear and results were compared to those of the human coder using an interclass correlation. Individual differences in each auditory scene were also described.

Results: To date, data have been collected from seven children with an average age of 36.71 (SD=11.94) months. Initial interrater reliability testing indicates strong agreement between the two human coders (ICC=.98., CI=[.94,.99], $F(13,13)=51.1$, $p<.001$), supporting the accuracy of the human coding protocol. In total, 103 hours of audio recording and 102 datalogged hours were collected. Categories determined by the datalogs were strongly correlated with those determined through human coding (ICC=.82, CI=[-.51,.98], $F(5,5.15)=4.94$, $p=.05$) but some differences emerged. Datalogs identified significantly more time in 'Quiet' than human coders ($t(14.61)=5.62$, $p<.001$) and that children were spending most of their time in 'Quiet,' (M=2hr 52min, SD=46min; 30% of the day). By contrast, human coders found that children spent most of their time in 'Speech-in-Noise,' (M=3hr 52min, SD=55min; 31% of the day) and identified significantly more time in 'Speech' than the datalogging algorithm ($t(17.65)=-2.93$, $p=.05$).

Conclusions: Scene classification software available from cochlear implant datalogging algorithms provide a reasonable estimation of auditory environments in children's "real world". Major differences are in an overestimation of time spent in 'Quiet,' which likely reflects the algorithm's definition (<50 dB SPL) and could underestimate children's language exposure.

W24: SELECT AND CONVEY SOUNDS INFORMATION: THEIR EFFECTS IN VOCODED NORMAL HEARING LISTENERS

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Cochlear implants bypass most of the auditory chain, process external sound information and convey it directly to the auditory nerve fibers using electrical impulses into the cochlea. CIs has proven that simple imitations of the hearing system already ensure a close to perfect speech understanding in simple auditory environment. CI users however typically struggle in noisy conditions and routinely report poor music enjoyment.

Limitations in auditory performances given by the CI may be interpreted as a double layer issue, embedded signal processing may not always select the most relevant information which in addition is inaccurately spreaded into the cochlea. Improving in the control of CI output is largely focusing the scientific community (e.g. electrical spreading reduction, increase of channel number), but no breakthrough has been observed in the CI input side since decades.

It is still unclear what information is the most needed to aid electric hearing. CI systems now process sounds following two opposite philosophies, either by coding as many information as fast as possible or by reducing the information only to the most important and accurately convey it. Oticon medical has chosen the 2nd philosophy and developed the SFX, a new methodology of signal analysis able to accurately extract the most energetic components of the sounds and describe them in frequency, amplitude, phase and sparsity. Due to the limitation imposed by the CI number of electrical channels, it is however not possible to deliver all the information SFX can provide.

This study aims to use the SFX to better understand how the selection of relevant information affects hearing outcomes. Two ways of selecting SFX information will be used and coded following two strategies (fixed or time-varying rate) and investigated in normal hearing listeners using different vocoder types, a tone vocoder that generate sinusoidal waves which are phase-locked to the stimulation sequence (different levels of distortion will be used) and a noise vocoder aiming to replicate the spatial excitation made by the Neuro Zti CI electrical spreading.

W25: OBJECTIVE AND SUBJECTIVE ANALYSIS OF A FRONT-END AGC WITH A BACK-END MULTI-BAND DYNAMIC COMPENSATION SYSTEM

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Cochlear Implant (CI) sound coding strategy signal processing typically begins with a front-end automatic gain control (AGC), which significantly reduces the acoustic dynamic range to control the output level. However, the use of a front-end AGC also leads to distortions in the signal's envelope and prevents the energy of the acoustic input signal from being taken directly as that of the electrically stimulating stimulus, which can result in less speech intelligibility. Transients (e.g., b and p in logatomes such as "aBa" / "aPa") contain fine spectral properties that can lead to spectral distortions and a lower perceptual threshold with an AGC processing scheme. Therefore, it is desirable to embed an AGC-like mechanism in a CI system that maintains the full acoustic dynamic range during signal processing. Such an algorithm has the potential to better emphasize transients or speech in noise that are difficult to detect, and to improve speech understanding.

Objective measurement methods based on the short-time objective measure (STOI) and the analysis of generated electrodograms are intended to show differences between the two processes of front-end and back-end dynamic compression. Subjective tests were also performed on ten CI users to compare speech understanding between a single-channel dual-loop front-end AGC with no back-end compression and an adaptive multi-band back-end dynamic compensation (VG) system without front-end compression. The CI group consisted of Oticon Medical CI users and was stimulated directly via the Auxiliary Input of a research processor. A discriminatory test with logatomes and a speech intelligibility test with the HSM sentence test were performed in quiet and in noise at +10 dB SNR.

Significantly better speech understanding in quiet could be found in the VG condition. Seven patients were also able to complete the logatome test and achieved a significant better performance in the VG condition. The objective analysis using STOI also showed a significant improvement for VG, which was 0.013 better than the AGC condition. Overall, a multi-band back-end dynamic compensation system can outperform a simple front-end compression when no back-end compression is applied in terms of speech intelligibility and logatome comprehension.

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W26: THE IMPACT OF LOW RATE STIMULATION ON SPEECH UNDERSTANDING AND SOUND PERCEPTION USING THE ACE STRATEGY

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Introduction: Low rate stimulation in cochlear implant (CI) subjects has gained interest recently, as the development of smaller speech processors is increasingly challenging. Due to the transcutaneous wireless signal and power transmission, the power consumption of CI systems is inherently high. Subsequently, the relatively large battery occupies a significant amount of space inside the external speech processor. With lower stimulation rates, a significant reduction of the systems' power consumption could be achieved. However, former studies on performance at lower stimulation rates were not yet conclusive, so a new study investigating the effect of stimulation rate on speech understanding as well as frequency discrimination at lower rates was initiated. Frequency discrimination is an important aspect, as lower stimulation rates might hamper the perception of rate pitch, i.e. the perception of the fundamental frequency of different talkers in so called cocktail party scenarios.

Method: The study consisted of an acute and a chronic branch. Subjects with the latest generation of Cochlear devices using the ACE strategy were selected. In the acute part, rates of 1200 Hz and 500 Hz have been compared to the default clinical setting of 900 Hz with regard to frequency discrimination and modulation detection. In the chronic part, rates of 900 Hz and 500 Hz were compared to each other. Speech tests (Monosyllables and Oldenburg Sentence Test) as well as frequency discrimination have been examined at the clinical setting of 900 Hz first. Subsequently, subjects have been sent home with a 500 Hz stimulation rate for accommodation and the test battery was repeated at 500 Hz three weeks later.

Results: The results show non-inferior speech intelligibility of ACE strategy with 500 Hz compared to 900 Hz stimulation rate baseline. No significant difference in frequency discrimination or modulation detection thresholds were found.

Conclusion: Lower stimulation rates in the range of 500 Hz are applicable without limitations in the clinical routine.

W27: SOUND EVENT DETECTION AND CLASSIFICATION BASED ON WOLA SPECTRAL FEATURES FOR COCHLEAR IMPLANTS

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Audio signals from real-life hearing devices typically contain background noises. We aim to build a system model which can automatically separate background noise from noisy speech, and then classify background sound into predefined event categories.

In this study, we propose to use weighted overlap-add algorithm (WOLA) and deep neural network (DNN) for sound event detection. In our approach, an energy signal trough detection algorithm is used to separate out speech gaps which primarily contain background noise. To further analyze the noise signal's spectrum, we use the WOLA algorithm which extracts spectral features by transforming a tiny fraction of time domain signal into frequency domain data represented in 22 channels. Moreover, a feed-forward neural network with 2 hidden layers is used to recognize each event's diverse spectral feature pattern. And then it produces classification decisions based on confidence values.

Recordings of 11 realistic background noise scenes (cafe, station, hallway …), mixed with human speech at different SNR levels, are used for training. DNN will learn the mapping between spectral feature characteristics and sound events. After training, we evaluate the system by measuring the accuracy of event classification. The overall detection accuracy has achieved 95%, while the event 'hallway' has the lowest detection rate at 85%. This detection algorithm has the potential for improving noise reduction in hearing devices by applying distinct compensation gain, which will attenuate the noise dominated frequency bands for each particular predefined event.

W28: OTICON MEDICAL BRAINHEARING: TOWARDS PUPILLOMETRY AS CLINICAL TOOL FOR COCHLEAR IMPLANTS

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People with hearing impairment, including cochlear implant (CI) users, spend substantial cognitive effort to listen and understand speech, especially in noisy and reverberant situations. As the listening environment becomes more challenging, CI users must engage more cognitive resources to direct attention and understand speech. This leads to increased mental load and over time, fatigue, and can compromise other cognitive functions such as information storage and retrieval. Pupillometry, or the measure of pupil dilation, is increasingly being used to quantify listening effort in realistic listening situations. This poster presents two studies in adult Oticon Medical CI users that aim to transform pupillometry from a research tool to a clinical tool.

In the first study conducted at the Pitié-Salpêtrière University Hospital in Paris, France, pupillometry was measured in ten CI patients who completed a word identification task (Lafon cochlear lists) in quiet and in a fixed signal-to-noise ratio of +10 dB. Whilst sentences are typically used to measure listening effort with pupillometry, words would reduce test time. As expected, pupil dilation (mean pupil dilation and maximal pupil dilation) was greater for words presented in noise than in quiet. Interestingly, the pupil diameter after word presentation (during the relaxation phase) was significantly larger for words with incorrectly repeated phonemes than for words with correctly repeated phonemes. Mean pupil dilation during the relaxation phase was significantly correlated with Speech, Spatial and Qualities of Hearing Scale scores. The first study showed that pupillometry measured during word identification is significantly associated with both listening effort, speech intelligibility, and self-reported hearing ability. The association between pupil and speech intelligibility measures could be interesting for populations for whom behavioral speech tests are difficult to perform, e.g. in children and people with multiple disabilities.

In the second study conducted at the Lille University Hospital, France, pupillometry was performed in Oticon Medical CI users completing a French-language version of the QuickSIN, the adaptive Vocale Rapide dans le Bruit (VRB). Patients for whom the VRB test was too difficult completed another test of sentence comprehension, the HINT, in quiet and in noise at a fixed signal-to-noise ratio of +10 dB. Two settings of Oticon Medical's Free Focus adaptive directionality technology, Opti Omni (omnidirectional microphone mode) and Speech Omni (omnidirectional microphone mode in the low frequency and emphasis on speech cues above 1880 Hz), were compared. To our knowledge, this is the first time that pupillometry is used to quantify the effect of a CI feature / parameter. Objective measures such as pupillometry could supplement patient reports to inform CI mapping and fine-tuning.

Taken together, the results of these two studies show that pupillometry could be an interesting clinical tool for CI rehabilitation, both in terms of quicker tests, of alternative to behavioral speech identification measures, and in data-driven CI mapping and fine-tuning.

W29: SURGICAL SAFETY AND CLINICAL EFFICIENCY OF THE OTICON MEDICAL NEURO COCHLEAR IMPLANT SYSTEM

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The Neuro Cochlear Implant System (CIS), consisting of the Neuro Zti Implant and the Neuro sound processor, has been available since 2015. Over 3000 Neuro CIS have been implanted to date by more than 200 CI centers located in 30 countries. This is the first report from the evaluation of its surgical safety and clinical efficiency in adults with severe-to-profound sensorineural hearing loss. The registered clinical trial is a multicentric prospective follow-up evaluation, involving six Canadian and one Danish CI centers. Participants attend six sessions: a pre-operative assessment in best-aided condition to verify the inclusion criteria (<50% speech identification in quiet), monitoring of the CI surgery, and post-operative assessments at activation, and at 3, 6, and 12 months following CI surgery. Main outcome measures are surgical safety (monitoring of adverse events: surgical complications and device-related failures) and clinical efficiency (speech identification of HINT sentences in quiet and in noise with fixed +10 dB signal-to-noise ratio, measured in CI-only condition).

This report presents safety data from 50 surgeries and clinical efficiency data from the 30 patients included in English-speaking Canadian centers (same test, largest group).

In terms of safety, there was no report of device-related failure (0%) and only one major surgical complication (2%). The post-surgical complication was respiratory in nature and was not device related.

In terms of clinical efficiency, average pre-surgical scores on the HINT were 12.5% in quiet and 12.4% in noise. These scores rose steadily at 3, 6, and 12 months following CI surgery.

It can be concluded that implantation with the Neuro CIS is a safe surgical procedure that leads to significantly improved speech perception abilities in adults with severe-to-profound hearing loss.

This study was funded by Oticon Medical.

W30: ACCURACY OF DRILL DEPTH CONTROL OF AN IMAGE-GUIDED MICRO-STEREOTACTIC TARGETING SYSTEM DEDICATED TO COCHLEAR IMPLANTATION SURGERY

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Introduction: In the future, cochlear implantation surgery will require significant simplification in order to handle the strongly growing numbers of patients who could benefit from a cochlear implant (CI). The increasing demand is caused e.g. by a continuously extension of indication criteria due to improved implant design, an increasingly ageing population, as well as establishing cochlear implantation as a treatment modality for hearing loss in the developing world. In order to simplify the surgical procedure, reducing the duration of surgery, and thus decreasing the overall costs of the procedure while keeping the high safety standards, we have been developing a micro-stereotactic targeting system for minimally invasive cochlear implantation surgery. An intraoperatively customized drilling jig enables accurate drilling through the bony lateral skull base to gain access to the inner ear and perform insertion of a CI electrode array. In this study, accuracy of the system was evaluated with special focus on depth control of the drilling. Drill depth should be adjustable with an accuracy of ± 0.2 mm.

Methods: In total 30 drillings were evaluated with different depths varying between 25.1 mm and 29.6 mm, which is in the range of the typical distance from the skull surface to the inner ear. After fabrication of the corresponding jigs, drilling was performed in a homogenous block made of synthetic bone substitute (Sawbone Europe AB, Malmö, Sweden) using a custom-made twist step drill bit. Deviations from the planning were measured using a highly accurate portable coordinate measuring machine (CMM, Romer Absolute Arm Compact 7312, Hexagon Manufacturing Intelligence, Wetzlar, Germany). The mean deviation between actual and planned depth of the first 20 drillings was used to calculate a correction factor, which was expected to be necessary in order to compensate for manufacturing tolerances of the device used for customization of the jigs. This value was implemented in the planning procedure for the last 10 drillings to compensate for the measured systematic error.

Results: In the first 20 drillings the mean depth error was determined to be 0.34 mm ± 0.09 mm (range: 0.04 mm to 0.43 mm). Lateral deviation of the drilling in comparison to the planned trajectory was 0.19 mm ± 0.11 mm. After implementation of the correction value, the desired depth has been reached with an accuracy of 0.07 mm ± 0.04 mm (range: 0.00 mm to 0.13 mm).

Conclusion: In this study accurate control of the drilling depth using the developed system could be proven. The remaining inaccuracy can be easily compensated by a safety margin in the planning and seems to be non-critical for the desired application. By this, critical anatomical structures of the inner ear can be preserved. The accuracy measured, makes the method feasible for precise opening of the inner ear. Thus, highly accurate image-guided cochlear implantation surgery with residual hearing preservation seems to be feasible.

W31: A BINAURAL CI RESEARCH PLATFORM FOR OTICON MEDICAL IMPLANTS ENABLING ITD/ILD AND VARIABLE RATE PROCESSING – AN UPDATE

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We present an update to the The Oticon Medical Research Platform (OMRP) and invite researchers to see a working demo of the system. The OMRP is designed to be a safe, portable, binaural, real-time research platform for Oticon Medical cochlear implants. The platform is a software programmable behind the ear processor (BTE) capable of processing signals from 4 ear-worn microphones simultaneously and producing synchronized binaural outputs capable of driving two (bilateral) implants. Subject safety is achieved by loading the subject's CI fitting data directly into the hardware where a hardware limiter module automatically limits outputs in real-time. The platform consists of hardware and software parts. The hardware is responsible for: (1) digitizing the 4 microphone signals typically coming from ear-worn microphone systems and (2) generating the final electric outputs needed to drive two antenna coils. The Master Hearing Aid (MHA) software [1] is responsible for processing the four audio input signals and then generating two synchronized electrodograms as stimulation outputs. The platform can control electrode timing to better than 1 microsecond accuracy and supports simultaneous CI/vocoder output allowing investigators to compare CI user's performance to normal hearing listeners' performance or to preview stimulation strategies while working on them. Several PC-based control panels are now available to support various types of experiments and a full API that enables real-time binaural control will be made available to researchers working with the platform.

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W32: CCI-MOBILE: SAFETY AND PERFORMANCE EVALUATION

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Many individuals world-wide are at risk of hearing loss, arising from the use of personal audio device, noise exposure or illness. Hearing-aids (HAs) and cochlear implants (CIs), generally referred to as Assistive Hearing Devices (AHDs), are popular choices among many people who are experiencing severe hearing loss. CI/HA research is predominantly focused on enhancing the quality of sound perception and listening experiences. The CCi-MOBILE research platform is, a powerful speech & sound processor emulator developed by UTDallas CRSS-CILab [1], which is used to carry out psycho-physical studies involving human subjects. The CCi-MOBILE research platform facilitates customization of signal processing designs and stimulating strategies and hence allows researchers to develop and carry out investigational studies with CI users. However, several concerns can exist regarding safety while carrying out psycho-physical studies in all acoustical conditions. The FDA, the governing body responsible for establishing directive principles and regulatory guidelines for medical devices in the United States, has prescribed a safety upper limit on charge density of 216 mC/sq.cm for clinical applications and 100 mC/sq.cm for research platforms. Although, the hardware components and firmware design of the CCi-MOBILE research platform are implemented by applying the established regulatory guidelines of the FDA, the assessment of the safety compliance of such devices are not clearly addressed in the literature. Additionally, the customizability of signal processing and stimulating strategies further aggravates the potential to provide secure stimulation under all acoustical conditions and device configurations and hence compromises their deterministic behavior. In this study, the CCi-MOBILE research platform is evaluated for efficacy, performance, safety, and integrity. The CCi-MOBILE research platform is assessed across an extensively diverse audio data set to ensure that current levels transmitted across the intracochlear electrodes, and the effective loudness are maintained within safety limits, irrespective of the acoustical conditions [2]. Additionally, a set of user-defined settings are used to assess if the CCi-MOBILE research platform remains within safe operational limits. The behavior of the CCi-MOBILE research platform and safety is characterized by analyzing the impact of these three input parameters: (a) stimulation rate, (b) pulse width, and (c) number of electrodes. It was found that electric stimuli produced, using the software, hardware and firmware routines of CCi-MOBILE, did not exceed safety limits for the entire 380+ hours of audio data, ensuring safety under all acoustical conditions. Safety and Integrity of the CCi-MOBILE research platform was confirmed for all electrical stimuli produced from all the realizable set of user-defined configurations.

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W33: CCI-MOBILE: MOVING TOWARDS EXPLORING ADVANCED RESEARCH PARADIGMS FOR COCHLEAR IMPLANT AND HEARING AID USERS

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In spite of the tremendous growth in the number of cochlear implant (CI) and hearing-aid (HA) users over the last two decades, speech recognition performance of the devices being used has only seen modest gains relative to the pace of actual digital signal processing (DSP) and machine learning technologies. Hardware limitations to support sophisticated signal processing and stimulation strategies in real-time have limited most of these techniques to laboratory use. Thus, a portable processor capable of implementing and running take-home field trials with robust speech algorithms could help advance research ideas and test scientific hypotheses which in turn would improve the opportunity of migrating those research solutions to commercial applications. In our previous work, we developed a mobile research interface (CCi-MOBILE) for electric and acoustic stimulation to explore new research paradigms in studies involving CI and HA devices. In this present work, we elaborate on advanced capabilities of the CCi-MOBILE and its open-sourced nature t for research use.

The novelty and strength of CCi-MOBILE is that it allows the investigator to (i) control the signal at both ears with exquisite timing (bilateral), (ii) stimuli with precision to measure psycho-physical limits of performance and (iii) analyze real world listening situations in which complex signals are processed and the electrodes in the implant get stimulated in real-time. Since incoming signals can be analyzed together or separately, CCi-MOBILE allows for assessment of the capacity of subjects' inherent ability to use binaural cues and also, the potential limitations imposed by other CI processors. Furthermore, the platform provides the opportunity to introduce fine-tuning capabilities granting side-by-side comparisons to the CI-HA world by making adjustment controls available to researchers and clinicians, thus providing new opportunities for individualized parameter fittings. Additionally, the CCi-MOBILE platform is easily portable, allowing researchers to explore on-the-go parameter fittings in real world environments. This addresses a major outstanding problem in audiological practice, that is patients frequently complain that their CI or HA sounds fine when tested in controlled clinical space/booth, but changes completely in real world environments. Another important feature of the platform is that it can be configured to drive two hearing-aids and two cochlear implants simultaneously (bimodal) due to the availability of dual channels of synchronized acoustic stimulation in addition to the electric stimulation.

To effectively implement automated speech technology applications optimized for CI-HA sound encoding, the CCi-MOBILE offers high-performance computing capabilities for efficient data-transfer and quick evaluation in laboratory as well as take-home for use in every listening-environments. As of today, 25 CCi-MOBILE platforms have been produced and shared with various research-labs worldwide. All software including support module code as well as sample development module are made open-source, while the hardware is available for subscription. We propose to use this opportunity to develop a "streamlined" approach of lab-to-world strategy development to provide CI-HA users a better user- experience.

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W34: CCI-MOBILE: ENVIRONMENT-SPECIFIC SPEECH ENHANCEMENT WITH COCHLEAR IMPLANT LISTENERS USING CONVOLUTIONAL NEURAL NETWORK

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The presence of real-world distortion such as competing babble noise degrades speech intelligibility greatly for individuals with cochlear implants. However, suppressing real-world noise without introducing artifacts into the speech signal is challenging mainly in low signal to noise ratios. Traditional minimum mean square error (MMSE) based speech enhancement methods typically focus on statistical characteristics of the noise and mostly rely on assumptions of quasi-stationary noise. While these approaches achieve satisfactory performance in stationary noisy environments, their performance quickly degrades in non-stationary noise conditions. Recently, machine learning strategies have become successful in addressing such complex environments. This study proposes a novel speech enhancement technique using a fully convolutional neural network (CNN) for enhancement for cochlear implant users. The proposed algorithm contains a limited number of parameters compared to traditional fully connected networks. A large size of the training set is used to train the CNN network which ensures a powerful model capable of estimating the nonlinear mapping between noisy and clean speech via supervised learning. The proposed algorithm extracts envelope features from the output of a cochlear FFT filter bank, enhances the signal for each channel and feds this to the electrical stimulation generator for the CI user. Electrical stimulation can be visualized by generating electrodograms. Electrodograms are similar to spectrograms except that electric stimulation information (electrode and amplitude) are simulated and represented as a function of time. The algorithm decomposes the noisy speech signal into time-frequency units, extracts a set of auditory-inspired features and submits them to the convolutional neural network. In order to address a wide range of real-world noise scenarios, a large training set is designed to encompass many possible combinations of speech and noise. Global variance equalization is used in this study to alleviate the over-smoothing problem. The proposed CNN-based algorithm tends to achieve significant improvement against existing baseline systems such as log MMSE, Wiener filtering, and spectral subtraction in terms of various objective intelligibility measures. The results suggest that a substantial improvement in speech intelligibility performance can be gained for cochlear implant recipients in noisy environments. The proposed algorithm represents a viable option for implementation on the CCi-Mobile research platform as a preprocessor.

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W35: CCI-MOBILE: INDIVIDUAL CHANNEL BOOSTING OF CONSONANT AND VOWEL SEGMENTS IN N-OF-M STRATEGIES FOR COCHLEAR IMPLANTS

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Continuous Interleaved Strategy (CIS) for electrical stimulation of the acoustic input to the intracochlear electrode exists across the major cochlear implant manufacturer systems today. Trade-offs exist between temporal and envelope cues in individual signal processing of various commercial strategies. “n-of-m” strategies select a subset (“n”) of electrodes of the total electrodes (“m”) for stimulation within a single stimulation cycle. These strategies place emphasis on envelope cues to aid in speech recognition in daily listening conditions including diverse noisy settings. Prior studies have demonstrated the positive relationship between vowel information and sentence intelligibility in low-level noise conditions (<15 dB SNR), where consonants are generally important for individual word recognition. In this study, individual channel characteristics were used to classify segments of speech as either consonant- or vowel-dominant through multi-class labeling and transcription. The proposed signal processing approach stimulates consonant-dominant channels using a sigmoid compression scheme and vowel-dominant channels using a weighted exponential function. Sentences from the IEEE database were phonetically labeled and transcribed. Two different noisy conditions were developed for IEEE sentences: 10 and 5 dB SPL speech-shaped-noise. Additionally, CNC words and phonemes used to assess consonant and individual word recognition in quiet and equivalent noisy conditions. Sentence/word tokens were processed offline through MATLAB, streamed to CI users through the CCi-MOBILE Research Platform (CRSS-CILab, UT-Dallas) in a direct-connect setup, and scored for intelligibility. Results from 4 CI users will be discussed.

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W36: CCI-MOBILE: OPEN-SOURCE APP DEVELOPMENT FOR REAL-TIME COCHLEAR IMPLANT PARAMETER ADJUSTMENT USING THE CCI-MOBILE RESEARCH PLATFORM

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In this study, we present a versatile Android app capable of real-time cochlear implant (CI) processing and parameter customization for the CCi-MOBILE research platform. This research platform, created at CRSS-CILab, is a powerful and portable interface designed for conducting diverse listening experiments with CI, hearing aid (HA), and bimodal (CI/HA) subjects. The addition of an open-source Android app enables researchers to easily perform on-the-go field tests in real-life environments, requiring only an Android device (i.e., smartphone or tablet) and the CCi-MOBILE. The Android app enables its device to work as a portable sound processor which provides flexibility to researchers through a widely known, affordable, and commercially available interface. In addition, the familiarity of the general public with Android products makes this platform especially suitable for take-home testing with CI/HA users.

This app serves as a general foundation for which researchers can customize to suit any particular research/scenario need. The software is written in Java using Android Studio, with the user interface defined using XML, and the CI user MAPs are formatted using JSON. Basic app functionality includes real-time adjustment of CI parameters (e.g., stimulation rate, pulse width, volume), selecting and saving MAPs to and from the device, start and stop functions for streaming with the CCi-MOBILE, and a quick-select menu for accessing researcher-defined presets (e.g., environment settings such as in the car, at work, music). The open-source app is currently hosted on GitHub and will be available for free on the Google Play Store. In our presentation, we highlight features, user controls, and researcher programming/modification options.

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W37: CCI-MOBILE: A PORTABLE, FLEXIBLE, REAL-TIME SOUND PROCESSING PLATFORM FOR COCHLEAR IMPLANT RESEARCH

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One important obstacle to optimizing fitting and speech processing for cochlear implants is that clinical speech processors have limited computing power and flexibility. On the other hand, current implanted receiver electronics are orders of magnitude more flexible than external speech processors and this presents a key unexplored opportunity: the possibility of developing new external, portable speech processing platforms that are compatible with existing implanted electronics but are much more flexible than clinically available speech processors. The CCi-Mobile-1 platform, developed by our collaborators at UT-Dallas, is one example. It is open-source and available to the research community. It comprises two parts: a computing device (which can be an Android smartphone or a PC running Matlab, for lab-based research), and a custom-developed interface board that connects with Nucleus, FDA-approved RF transmitter coils. The interface board is programmed to make it impossible to deliver unbalanced stimulation, or to exceed the Shannon-McCreery charge density limits. CCi-Mobile-1 can deliver synchronized stimulation to two Nucleus cochlear implants as well as acoustic output to both ears. Here we will describe some features and capabilities of this platform, as well as possible workarounds for potential limitations.

W38: CCI-MOBILE: EVALUATING EFFECTS OF PULSE RATE ON TEMPORAL PROCESSING AND SPEECH PERCEPTION IN CI USERS

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In most cochlear implant (CI) processing strategies, the acoustic envelope information is encoded by modulating the amplitude of electrical stimulation pulses. The rate at which electric pulses are delivered can be viewed as the update rate for amplitude modulation. Higher pulse rates permit encoding of more rapid acoustic envelope modulations, which may be beneficial for transmission of brief or fast-changing phonetic cues. On the other hand, there is psychophysical evidence that higher pulse rates may actually impair perception of temporal cues in CI users. We recently showed that sensitivity to changes in loudness of a pulse train may deteriorate at higher pulse rates, indicating that high pulse rates can reduce the number of discriminable acoustic intensity steps (Azadpour et al., JARO 2018). One objective of this study is to find the extent to which this reduction in intensity resolution may influence speech perception.

This study systematically investigates the effects of pulse rate on temporal processing and speech perception performance in CI users. Temporal processing is evaluated by measuring detection thresholds for amplitude modulated noise-band stimuli. Speech perception is evaluated by measuring recognition of sentences, words and phonemes. Acoustic stimuli are processed with various ACE strategies that differ in the number of channels, as well as pulse rate (the number of pulses/second per channel). The range for pulse rate is between 250 and 2000 pulses/second per channel. The number of channels varies to activate single or multiple electrodes with amplitude modulations on each electrode. Phoneme recognition results with single-channel ACE strategies are used to evaluate transmission of overall envelope cues with a single electrode.

The CCI-Mobile-1 platform is used to process acoustic stimuli and stream electric pulse sequences to the implant. Stimuli are presented through the behind-the-ear microphone of the CCI-Mobile, and ACE processing is implemented in real-time using Matlab in a PC. These experiments provide an acute investigation of optimal individual-specific pulse rates for transmission of temporal and speech information presented to single and multiple implant electrodes. The results of the acute tests will be a baseline for future take-home studies with the CCI-Mobile platform to investigate optimal pulse rates in real-world environments where the subjects will have the opportunity to self-select their preferred stimulation rate, and adapt to it over time.

W39: CCI-MOBILE: DEVELOPMENT OF SOFTWARE BASED TOOLS FOR SPEECH PERCEPTION ASSESSMENT AND TRAINING WITH HEARING IMPAIRED BRAZILIAN POPULATION

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More access to hearing prosthesis, e.g. cochlear implants, requires not only more funding for the device but also more health care centers equipped with staff and structure to provide hearing evaluation, implantation, and rehabilitation. In 2014 new rules for the provision of cochlear implants by the Brazilian Public Health System (SUS) increased dramatically the number of patients that were eligible for cochlear implants. While the cochlear implant undoubtedly is the most sophisticated commercially available neural prosthesis actually clinical assessment in many regions in Brazil consists simply in using the audiologist's voice as sound source, due to limited technical resources, access to information or even lack of audiometric cabins at remote locations. This may be of impact in both lowering assertion at the selection of eligible candidates and may interfere on the rehabilitation efficiency as it is harder to find a subject his best configurations without further testing. To improve this situation, the work described herein aims the development and implementation of an open-source hearing test software suitable to be used for both research and clinical applications. Tests, such as speech perception, source localization and sound quality, are at its core, but the system is developed based on flexibility to attend academic research, auditory training activities for rehabilitation as well as evaluation with as little hardware as possible. The software is conceived based on the principles of modularity in order to enhance applicability and compatibility, divided into database management, acoustic scene synthesis, sound reproduction and hearing test management. Hardware interfaces are implemented using third-party frameworks such as CCi-MOBILE's software suite in MATLAB and Virtual Acoustics (VA) as a real-time auralization framework in C++ that extends communication with several languages. To add flexibility three methods for sound reproduction are adopted and can be compared in terms of usability, portability and limitations: using different sized arrays of speakers, an audio cable connected to the subject's clinical processor and also to the CCi-MOBILE platform, a research platform developed at CILAB-UTD.

Speech perception in noise test prototypes are developed in MATLAB and validated by means of subjective evaluations with normal hearing listeners and cochlear implant users. Unilateral Ci users were invited during their regular appointments at the University's Hospital clinic during the rehabilitation procedure after approval of the national ethical review committee. Implemented tests were adapted to compare noise reduction strategies developed at the Signal Processing Laboratory LPDS at Federal University of Santa Catarina - UFSC. Test sounds are composed of anechoic sentences mixed with 4-talker babble noise at different signal-to-noise-ratios (SNR). CCi-mobile, audio cable or headphones are used to reproduce the sound to the subjects in a single acoustic scene where both signals come from the same direction. Actually, two evaluation methods were implemented: a randomized presentation of several sentences over different SNR values and an iterative variation of SNR. Subject's are required to repeat what is understood. The audiologist or researcher will mark all words that were correctly understood in the interface and the software will register the rate of correct words and then select next signal. Insights from these pilot tests will help to improve the current version of the software. Future steps will include techniques to spatially separate signal and competing noise at the reproduction chain to be able to consider spatial release from masking and sound localization. For ease of deployment to the hearing centers standalone versions in Python and C# will be compiled for distribution.

W40: LATERALIZATION OF INTERAURAL TIME DIFFERENCES MEASURED WITH THE CCI-MOBILE RESEARCH PLATFORM

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Bilateral cochlear implants (biCIs) restore some spatial hearing abilities, but a gap remains when performance is compared to normal hearing (NH) listeners. One possible reason for this performance gap is the lack of synchrony between clinical processors. This lack of coordination disrupts the faithful encoding and delivery of interaural time differences (ITDs), caused by the delayed onset of sounds between ears, and interaural level differences (ILDs), caused by the head attenuating sound. While both ITDs and ILDs are important binaural cues, ITDs are particularly important for localizing low frequency sounds and spatially segregating speech from noise. However, low frequency cues and temporal fine structure are discarded by many CI signal processing strategies, which only provide envelope cues. BiCI users utilize ILD cues when completing spatial hearing tasks, but do not seem to use envelope ITD cues, even when they show sensitivity to ITDs in research settings. A previous study in our lab demonstrated that biCI listeners could use envelope ITD cues to partially lateralize sounds when transposed-tone acoustic stimuli were presented to clinical processors. However, listeners were only able to lateralize the stimulus to the full extent of the head when an ILD was also imposed on the stimulus. There are two possible reasons for this observation: (1) the envelope shape of the stimulus was not steep enough to promote good mapping of ITDs to intracranial location; or (2) the independent clocks in the two processors reduced fidelity of the envelope ITD cues.

In this work, we investigate these hypotheses using the CCi-Mobile, developed by UT-Dallas, which allows us to have greater control of the stimulus. Listeners completed a lateralization task where the stimuli were modulated pulse trains with a raised-cosine onset ramp and a modulation rate chosen to maximize ITD sensitivity from a previous study using the same stimulus in NH listeners. ITD values ranged from 0 to 1200 microseconds and ILD values ranged from 0 to 21 dB. In addition, lateralization responses were collected for combinations of ITD and ILD values from an 8 cm-radius spherical head model. The data were analyzed in terms of sensitivity (d') estimated from the lateralization data for each condition as well as lateralization range for the three conditions. The data will be compared to that collected through clinical processors. This data will help us understand the impact of envelope shape and synchronized processing on the use of ITDs/ILDs, and combinations thereof, for mapping sounds to locations in space by biCI users.

W41: A BINAURAL ADVANCED COMBINATION ENCODER STRATEGY FOR SOUND LOCALIZATION WITH THE CCI-MOBILE RESEARCH PLATFORM

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Bilateral cochlear implants (biCIs) restore speech understanding and some spatial hearing abilities. However, there is still a gap in performance between listening with biCIs and normal hearing, especially in real-life noisy environments. In particular, recent data from our lab showed that biCI listeners had difficulty distinguishing between stationary and moving sounds, and the direction of movement of non-stationary sounds. While some of the limitations in performance can be attributed to pathology and the surgical challenge of placing two implants at the same insertion depth, a part of the gap may instead be caused by a lack of synchrony between the two sound processors. For clinical CIs, each sound processor is controlled by an independent time clock, and there is no communication across processors. Furthermore, each CI processes sounds independently in each ear. For n of m sound processing strategies, such as the Advanced Combination Encoder (ACE) strategy, the processors in each ear could be selecting different electrodes to stimulate, thereby reducing the fidelity of binaural cues such as interaural time and level differences (ITD and ILD, respectively).

The CCi-Mobile research processor developed by UT-Dallas aims to solve these two problems; it has one system clock and both implants are controlled from a central processor. This allows for precise control of the interaural cues presented via electrical stimulation. The central processor allows for real-time binaural signal processing which enables the development of truly binaural processing strategies, and the testing of these strategies in real-time, realistic conditions. Hence, we developed a binaural ACE (bACE) strategy to test the hypothesis that synchronized processing and stimulation will improve sound localization performance. In traditional ACE, the n highest peaks in each time frame are chosen for stimulation. With independent processing in each ear, the n channels chosen may not always be the same. Hence, binaural cues, which are compared in the brain on a frequency-by-frequency basis, may not be transmitted on the same electrodes across the ears, resulting in disrupted binaural processing. In bACE, channel selection is conducted on inputs from both ears together. The n/2 highest peaks in each ear are selected and the corresponding electrode in the opposite ear is also chosen for stimulation.

We conducted a localization experiment with bilateral Cochlear users where the stimuli consisted of stationary and moving sounds that span trajectories of 10°, 20°, or 40°. Three conditions were compared: ACE and bACE implemented on the CCi-Mobile, and participant's listening with their own clinical processors. Our results will help determine whether synchronized processing improves discrimination of stationary and moving sounds, and the direction of moving sounds.

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THURSDAY POSTER ABSTRACTS

TH1: MONITORING OF THE INNER EAR FUNCTION DURING AND AFTER COCHLEAR IMPLANT INSERTION USING ELECTROCOCHLEOGRAPHY

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Introduction: To preserve residual hearing during cochlear implant (CI) surgery it is desirable to use intraoperative monitoring during the electrode insertion. A promising method is Electrocochleography (ECochG) and the recording of cochlear microphonics (CM). The aim of the monitoring is to identify critical steps as well as to modify the ongoing insertion procedure immediately if necessary.

Method: During the insertion of hearing preservation electrodes, intracochlear recordings were performed at different insertion steps using the CI electrode at the apical electrode contact 1 and the clinical CI software (Maestro, MedEl). After the insertion ECochG was measured on different CI electrode contacts. After six months the recordings using different electrode contacts were repeated. The stimulation was done acoustically using insert earphones and tone bursts at 500 Hz. The relations between ECochG findings and cone beam CT data were investigated. Up to now 9 patients were included.

Results: In most cases the CM amplitudes rose during the insertion. After insertion, the CM amplitudes were largest at contact 1 for most cases, however, in two cases receiving a Flex28 electrode the CM amplitude was largest at recording contact 2.

Conclusion: The intracochlear CM recording is very well possible during and after CI insertion as well as during the follow up. The behavior of the amplitudes seems to be in line with radiological findings.

TH2: CHARACTERIZATION OF EAS INTERACTION THROUGH ECOCHG AMPLITUDE GROWTH FUNCTIONS

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Introduction: Cochlear implantation is increasingly being used in hearing loss treatment for subjects with residual hearing to obtain combined electric acoustic stimulation (EAS). Previous psychoacoustic studies have shown that electric stimulation interacts with acoustic stimulation at threshold level (Krüger et al. 2017; Imsiecke et al. 2018). In EAS users, intracochlear electrocochleography (ECochG) can provide insights about the pathophysiology of the peripheral auditory. In response to acoustic stimuli the cochlear microphonics (CM/DIF) and the auditory nerve neurophonics (ANN/SUM) can be derived from ECochG recordings. CM/DIF and ANN/SUM recordings can be used to assess whether the EAS interaction origins in the peripheral auditory system.

Objective: This work characterizes electrophysiological EAS interaction from threshold to most comfortable level (MCL) by measuring ECochG amplitude growth functions (AGF) to assess the relation between electrophysiological and psychoacoustic EAS interaction and to give a more detailed insight about the origin of EAS interaction.

Methods: The backward telemetry capability of the CI was used to record ECochG AGFs in ten Advanced Bionics EAS users. CM/DIF and ANN/SUM responses were derived and compared to post-operative hearing thresholds and MCLs. In seven of Advanced Bionics EAS users, the AGFs were used to characterize the interaction between electric and acoustic stimulation for various acoustic stimulation levels. This interaction was compared with psychoacoustic masking measurements. Electrophysiologically, ECochG AGFs were recorded for an acoustic tone (A), an electric pulse train (E) and simultaneously presented acoustic and electric stimuli (A+E). The effect of electric stimulation on an acoustic tone was determined by subtracting the E from A+E response. Psychoacoustic threshold elevation of an acoustic probe caused by the presence of an electric masker was measured using a 3 interval-forced-choice task. An electric masker stimulus was presented at MCL at the most apical electrode while the level of an acoustic probe was adapted to the detection threshold.

Results: The results show significant amplitude responses for acoustic stimulation at MCL in 9 of 10 subjects for CM/DIF recordings and in 8 of 10 subjects for ANN/SUM recordings. The mean CM/DIF response was 8.76 µV and the mean ANN/SUM response was 0.98 µV. Significant CM/DIF amplitudes at the psychoacoustic detection threshold could be recorded for 8 of the 10 subjects. The CM/DIF threshold (defined as CM/DIF amplitude significant above noise floor) was in mean -17.5 dB below the psychoacoustic detection threshold. No significant ANN/SUM amplitude responses could be recorded at psychoacoustic detection thresholds.The results demonstrate EAS interaction using both, ECochG recordings and psychoacoustic measurements. A mean threshold elevation of 2.4 dB was observed from the psychoacoustic masking experiment. The CM/DIF measures show a mean interaction of 1.15 dB. The CM/DIF interaction at detection threshold was 1.5 dB and therefore lager than the interaction at MCL (1.0 dB). However, no significant effect of acoustic probe stimulation level could be observed. The results suggest a constant effect of the electric masker independent of the acoustic probe stimulus.

Conclusions: From these results we conclude that intracochlear ECochG can be used to estimate psychoacoustic detection threshold and that some aspects of EAS interaction can be measured electrophysiologically. However, the sensitivity of this measure underestimates the threshold elevations observed psychophysically and therefore EAS interaction may not only occur in the periphery but also more centrally along the auditory pathway.

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TH3: RELATIONSHIP BETWEEN INTRA-OPERATIVE ECOCHG MONITORING AND HEARING PRESERVATION

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Introduction. Many of today's Cochlear Implant (CI) candidates have significant residual hearing. During insertion the surgeon has no or very limited feedback about potential damage induced to the cochlear and has to rely only on his experience. It has been shown that electro-cochleography (ECochG), specifically the measurement of the cochlear microphonics (CM), could be a very suitable and fast tool to assess more or less instantaneously the cochlear health. The CM measurement can be performed continuously over the CI amplifier during the electrode insertion, resulting in an insertion monitoring. Objective of this study was to examine the relation between intra-operatively monitoring results and the post-operative hearing preservation.

Material and Methods. 30 CI candidates with substantial amount of low frequency hearing have been implanted with the HiRes Ultra implant and ECochG was monitored intraoperatively. All CI users underwent post-operative follow-up including hearing threshold as well as speech perception measures for at least 4 months post-op.

Results. The electrode (29 SlimJ, 1 MidScala) was successfully inserted in all cases through the round window. At one month post-op in 80% of the CI users hearing loss of less than 30dB was measured, in another 40% less than 15dB. Driven by the ECochG signal, the insertion of the electrode was halted or the electrode withdrawn until the CM recovered. Changes in CM amplitude during electrode array insertion were in line with surgical feedback and surgical video review. Intra- as well as post-operative ECochG measures were correlated to low-frequency hearing preservation. Subjects were grouped according to their intra-operative curve progression: 1) final amplitude at least 80% of maximal amplitude, 2) final amplitude between 20% and 80%, 3) complete loss (<20%). Hearing loss 4 weeks after surgery (expressed as LF PTA) in group 1 was 11.7 dB and significantly lower than in group 2 (20 dB). In group 3 the hearing loss was 28 dB, but with only 5 subjects assigned to this group, a statistical comparison was not possible. Further analysis of the ongoing data collection shall be performed.

Conclusion. Intra-cochlear ECochG measurement gives fast feedback about the CM response. The current data indicates, that a persistent intra-operative drop in CM amplitude (group 3) leads also to larger post-operative hearing loss while candidates with preserved intra-operative CM (group 1) will have likely better post-operative thresholds. Further analysis shall look into explanations for the large variations in group 2.

TH4: ACOUSTICALLY EVOKED COMPOUND ACTION POTENTIAL USING THE POSTOPERATIVE ELECTROCOCHLEOGRAPHY FROM EAS/HYBRID COCHLEAR IMPLANT USERS: A PRELIMINARY STUDY

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Objective: Shorter electrode arrays and soft surgical techniques allow for preservation of acoustic hearing in many cochlear implant (CI) users. For these electro-acoustic (EAS)/Hybrid CI users, it is possible to stimulate the ear acoustically and use the Neural Response Telemetry system to record peripherally generated responses from an intracochlear electrode (Abbas et al., 2017; Kim et al., 2018; Tejani et al., 2019). One of our research goals is to assess survival of functional cochlear elements in vivo. In recent work, we can record responses generated by the cochlear hair cells (cochlear microphonic (CM)) and the phase-locked responses of the auditory nerve (auditory nerve neurophonic (ANN)). Unfortunately, ANN responses are considerably smaller in amplitudes compared to the CM and complete segregation of the CM from the ANN has proven difficult (Forgues et al., 2014). Developing a better metric to assess the auditory nerve survival could provide a more complete picture of the status of auditory periphery, which might be clinically helpful to identify the site of lesion or monitor physiological responses at the nerve level when hearing changes in the EAS/Hybrid CI population. Compound action potentials (CAPs) can provide an alternative way to assess auditory nerve responses. In earlier work from our lab, we attempted to record click-evoked CAPs from EAS/Hybrid CI users (Abbas et al., 2017). However, response morphology was varied and we were only able to measure CAPs from 50% of subjects. In this study, we recorded chirp-evoked CAPs presuming that the improved neural synchrony offered by chirp stimuli would lead to better CAP responses compared to standard clicks or tone bursts (Fobel and Dau, 2004; Chertoff et al., 2010). This study describes results of within-subject comparison of CAPs recorded using low-frequency tone bursts, clicks, and broadband chirps.

Method: To date, we have results from four adult Nucleus L24 CI users with residual low-frequency acoustic hearing. CAP growth functions were recorded using low-frequency tone bursts (250, 500, 750, 1000Hz), clicks, and broadband chirps presented via an insert phone to the implanted ear in both positive and negative leading stimulus polarities. The most apical intracochlear electrode was used for recording. Measures of response morphology, threshold, as well as latency and amplitude vs. intensity functions were measured off line and compared to audiometric thresholds.

Results: Preliminary results reveal considerable variation across subjects and across three different stimulus types. Tone burst-evoked CAPs were recorded from only one subject while click- and chirp-evoked CAPs were recorded from all four subjects. Click-evoked CAP thresholds were slightly lower than chirp-evoked CAPs. N1-P2 amplitudes at 110dB peSPL were similar for click- and chirp-evoked CAPs. Subjects with more residual acoustic hearing at frequencies above 1000 Hz tended to have larger response amplitudes. Considerable cross-subject variations in response morphology and N1 latency were apparent. Earlier N1 latencies and sharper N1-P2 morphology were obtained in subjects with more hearing preserved at high frequencies. Other subjects with more high-frequency hearing loss had multi peak, longer latency responses.

Conclusion: Preliminary results suggest that CAPs can be measured more effectively using click and chirp stimuli in EAS/Hybrid CI users rather than low-frequency tone bursts. While data collection is ongoing, the advantages of using a chirp relative to standard click stimulus appear to be minimal at this point in time. Data from this initial subject group suggests correlations between response morphology and the configuration of the audiogram.

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TH5: POLARITY SENSITIVITY AND REFRACTORY RECOVERY OF THE ELECTRICALLY EVOKED COMPOUND ACTION POTENTIAL

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The purpose of this study is to examine the effects of stimulus polarity on the time course of refractory recovery as measured with the electrically evoked compound action potential (ECAP), and to relate those effects to polarity sensitivity as measured by the difference in growth-function amplitudes. Modeling data suggests that longer recovery times are indicative of a larger neural population. Theoretically, a larger neural population allows for individual fibers to operate closer to threshold, where refractory recovery times are known to be longer. Our current pilot data suggests significantly longer average recovery time for anodic- than for cathodic-leading pulses, suggesting that the anodic-first polarity possibly recruits a larger neural population than the cathodic-first polarity. If longer recovery times occur for larger populations (better neural survival), we hypothesize that electrodes with relatively long recovery times will show smaller differences in ECAP amplitude between polarities (reflecting better neural survival), and larger polarity effects will be observed for electrodes with shorter recovery times (reflecting poorer neural survival).

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TH6: POLARITY SENSITIVITY OF THE ELECTRICALLY EVOKED COMPOUND ACTION POTENTIAL: EFFECTS OF PULSE PHASE DURATION

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Stimulus polarity can have significant effects on both physiological and perceptual measures in cochlear implant recipients. Recent studies from our laboratory [1-2] have focused on evaluating polarity effects on the electrically evoked compound action potential (eCAP) using standard clinical pulse designs (i.e., symmetrical biphasic pulses) that are manufacturer-specific. Our results have found differences in polarity effects between manufacturers. Specifically, Cochlear recipients exhibited significantly larger eCAP amplitudes and steeper slopes of the amplitude growth function (AGF) for anodic-first than for cathodic-first biphasic pulses, whereas no significant polarity effects were observed for Advanced Bionics (AB) recipients. For these studies, two inherent differences in the stimuli used for each device type were interphase gap (IPG; 7 usec for Cochlear and 0 usec for AB) and pulse phase duration (PD; 25 usec/phase for Cochlear and 32 usec/phase for AB). When an IPG was added to the stimuli for AB devices, there remained no significant polarity effects [2]. The goal of the present study was to determine whether PD has a significant impact on eCAP polarity effects, to potentially explain the device differences observed previously.

ECAP AGFs were obtained for a single mid-array electrode in each of 16 Cochlear recipients and 15 AB recipients. Thresholds, average amplitudes, and AGF slopes were compared across polarity and PD conditions. The results showed that the previously observed device differences for amplitude and slope remained, even when PD and IPG were the same for both device types. Specifically, anodic-first pulses yielded larger amplitudes and steeper AGF slopes for Cochlear recipients, regardless of PD; whereas no significant polarity effects were found for AB recipients, regardless of PD. These results warrant further investigation into the underlying cause for polarity sensitivity differences between device types.

Research supported by grants from the NIH, NIDCD R01 DC009595 and NIGMS P20 GM109023.

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TH7: EFFECTS OF AGING AND DURATION OF DEAFNESS ON NEURAL FUNCTION OF THE ELECTRICALLY-STIMULATED COCHLEAR NERVE

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Background: Decline in the physiological status (i.e. number and responsiveness of neurons) of the cochlear nerve (CN) due to advanced age and/or deafness has been observed in animal studies (e.g. Hellstrom & Schmiedt 1996; McFadden et al. 1997; Makary et al., 2011). However, this has not been well established in human listeners. This project used electrophysiological measures of the electrically evoked compound action potential (eCAP) to study effects of aging and duration of deafness on CN responsiveness in adult cochlear implant (CI) users. Specifically, this study measured the eCAP Input/Output (I/O) function and CN sensitivity to amplitude modulation (AM), two functions depending on the physiological status of the CN. It tested the hypotheses that CN responsiveness declined with advanced age and longer duration of deafness.

Methods: To date, 16 adults have been recruited and tested for this study. All subjects were implanted with a Cochlear® Nucleus™ device (Cochlear Ltd., Macquarie, NSW, Australia) in the test ear. For each subject, the eCAP I/O function and CN sensitivity to AM were measured at multiple electrode locations across the electrode array. The eCAP I/O function was measured with a charge-balanced, cathodic leading, biphasic pulse. CN sensitivity to AM was assessed by measuring amplitudes of eCAPs evoked by individual pulses of an AM pulse train. The carrier stimulus was a 2000-pps pulse train presented at the maximum acceptable level (MAL). It was amplitude modulated with a sinusoidal function with 100% AM depth between 5 programming units above the eCAP threshold and the MAL. AM rates tested were 20, 40, 100 and 200 Hz. eCAPs to each of the 20 pulses selected over the last two AM cycles were measured. The stimulation levels for these pulses were the same across AM rates. In addition, eCAPs to single pulses were measured with the probe levels corresponding to the levels of the 20 selected pulses in the AM pulse train. The difference in the maximum and the minimum eCAP amplitudes measured for the AM pulse train (AMamp) and for the single pulse (NonAMamp) was calculated. The modulated response amplitude ratio was defined as the ratio of AMamp to NonAMamp, with a greater ratio indicating better sensitivity to AM. Dependent variables included maximum eCAP amplitude, eCAP threshold, slope of the eCAP I/O function and modulated response amplitude ratios measured for different AM frequencies. Spearman correlation tests were used to evaluate effects of aging and duration of deafness on these dependent variables.

Results: Aging showed a significantly negative effect on slope of the eCAP I/O function and modulated response amplitude ratios at all AM frequencies tested. It did not show any significant effect on maximum eCAP amplitude or eCAP threshold. Duration of deafness did not show any significant effect on dependent variables evaluated in this study.

Conclusions: Our preliminary results suggest that advanced age is a main factor for the physiological status of the CN.

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TH8: SHORT-TERM OVERSTIMULATION AFFECTS ECAP- AND EABR-THRESHOLDS IN GUINEA PIGS

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Changes in map T and C levels have been documented over time in both adults and children. These changes are possibly related to habituation to electrical stimulation and a training effect (Clark et al, 1988), which result in increased tolerance to loudness. However, a widening of eDRs and increasing C-levels are highly important for the postoperative outcome since both are associated with better speech perception scores in quiet and noise (Robinson et al., 2012). This knowledge is possibly responsible for the clinical observation that C-levels and thus, eDRs are sometimes extremely increased over time. However, it is questionable if the larger amount of electrical stimulation is tolerated by the remaining peripheral and central auditory pathway.

A short-term overstimulation could be helpful to investigate the generation of above-mentioned adaptive processes. As a first insight, the effect of a short-term overstimulation on the excitability of peripheral and central auditory structures was determined.

After mechanically deafening of 32 adult guinea pigs a special scala tympani electrode array with eight electrode contacts was inserted. Cochlear overstimulation was performed by adjusting the C-level on 0 CL, around 145 CL, 165 CL or 190 CL (n=8 for every group). All animals were stimulated with a CP810 sound processor in a standardized acoustic environment (radio play at 65 dB SPL) for eight hours under anesthesia. The eCAP and eABR measurements were performed before stimulation and after four and eight hours.

Both, the eCAP- and eABR-thresholds increased over time in the control group (insertion without stimulation) with stable electrode impedances but high inter-individual variations. High overstimulation increased eCAP-thresholds after 4 and 8 h at least in the basal part of the stimulated area. eABR-thresholds were only elevated after 8 h.

The results suggest that mechanically interventions (deafening, insertion of a cochlear implant electrode) induce fast physiological reactions which lead to an eCAP- and in turn to an eABR-threshold shift. Short time overstimulation in the applied range seems to influence the response behavior only in distinct cochlear regions.

This study was supported by Cochlear Research & Development Ltd., Addlestone, UK.

TH9: RESPONSE STRENGTH AND RESPONSE SPREAD IN PRIMARY AUDITORY CORTEX AS TOOLS TO FIND THE "BEST/OPTIMAL/EFFICIENT" STIMULATION STRATEGY.

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Many research efforts are still dedicated on improving the coding strategies of cochlear implants (CI). They all point out that the stimulation mode, the pulse shape and grounding schemes can exert either moderate, or drastic, consequences on the response strength, spread of excitation and nerve excitability. Several strategies are currently used to implement sound loudness such as increasing the pulse amplitude or the pulse duration. Here, we compared responses from auditory cortex neurons to stimulations delivered through a CI for which several parameters were modified such as the pulse amplitude, the pulse duration and the pulse shape.

Experiments were performed in urethane anesthetized guinea pigs. The tonotopic gradient of the primary auditory cortex (AI) was first established by inserting an array of 16 cortical electrodes (2 rows of 8 electrodes separated by 1mm and 350µm within a row). A dedicated stimulation array (300µm) was then inserted in the cochlea (4 electrodes inserted in the 1st basal turn) and its connector was secured on the skull. The cortical electrodes were placed back in auditory cortex at the exact same location as before the CI insertion. Twenty levels of charges were used to activate the auditory nerve through a dedicated stimulation platform. Stimulations were performed by increasing the pulse duration (PD) or pulse amplitude (PA) with either symmetric, asymmetric or ramped pulses. Asymmetric pulse shapes and ramped pulses were also tested for a given level of injected charge. For asymmetrical pulses, the ratio between the pulse phases increased from 1/1 to 1/10; for ramped pulses the angle was from 88 to 57°.

On average, the firing rate (FR) evoked by the pulse duration (PD) and pulse amplitude (PA) strategies was similar and it was often similar with the asymmetric and ramped pulses. However, in many animals FR was lower than with pure tones. The spatial recruitment was often similar with the PA and PD strategy and with asymmetric and ramped pulse, but it was often lower than the one obtained with pure tones played at 75dB SPL.

Group data suggest that equivalent cortical activation can be achieved with PA or PD strategy, with symmetric, asymmetic or ramped pulses. In individual cases, comparing the FR dynamic range and the spatial recruitment obtained with PA, PD, asymmetric pulses or ramped pulses, suggests that a particular strategy or pulse shape can be useful for limiting the spatial activation while still eliciting large FR changes.

TH10: EVALUATING AND COMPARING BEHAVIOURAL AND ELECTROPHYSIOLOGICAL ESTIMATES OF NEURAL SURVIVAL

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Variations in neural survival along the cochlea can potentially degrade the spectral representation of sounds conveyed by cochlear implants (CIs) and affect the fidelity with which temporal information is conveyed by different electrodes. Here we evaluate and compare several different methods that have been proposed as estimates of these neural survival patterns. All measures are obtained from the same 12 users of the Cochlear Corporation CI.

The two behavioural measures are multipulse integration (MPI) and the polarity effect (PE). We measure MPI as the difference between thresholds at 80 pps and 1000 pps, at a subset of electrodes across the array. The PE is measured as the difference in thresholds between cathodic- and anodic-centred quadraphasic (QP) pulses at the same subset of electrodes. These QP pulses, as with other asymmetric pulse shapes, have been shown to produce large and reliable PEs (Carlyon et al 2013; Macherey et al 2017). It has been proposed that good neural survival corresponds to a large MPI (Zhou and Pfingst, 2016; Zhou et al, 2018) and to a large negative PE (lower thresholds for cathodic than anodic pulses; Carlyon et al 2018).

Several methods of estimating neural survival using electrically-evoked compound action potentials (ECAPs) have been proposed. One of these is the effect of interphase gap (IPG) on ECAP amplitudes and on the slope of the ECAP amplitude growth functions (AGFs), both of which have been correlated with spiral ganglion nerve density in guinea pigs (Ramekers et al, 2014; Prado-Guitierrez et al, 2006). We will obtain both of these measures using the same subset of electrodes as for the behavioural measures. More recently, Goehring et al (this meeting) have proposed a method for estimating neural survival patterns and the current spread from each electrode using a measurement matrix, whereby ECAPs are obtained using the forward-masking technique (Brown et al 1990), for every possible combination of masker and probe. This matrix is then subjected to a nonlinear optimization algorithm termed Panoramic ECAP (PECAP). We will therefore also obtain the measurement matrix using all electrodes of the implant and use the PECAP algorithm to estimate neural survival.

The results will reveal the extent to which the different measures provide converging and consistent estimates of neural survival, and guide the future development of the PECAP algorithm. The long-term goal is to use these estimates of survival to explain and potentially remedy cases of poor speech perception by CI users.

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TH11: INTER-SCALAR SHIFT DETECTION FOR THE HIFOCUS MID-SCALA ELECTRODE ARRAY THROUGH INTRACOCHLEAR ELECTRICAL FIELD IMAGING

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Although speech perception outcomes with cochlear implant (CI) users have enhanced on average over time, these outcomes show still a huge variance. Electrode array placement is an important element as it comes into direct contact with the intra-cochlear tissues that line the neural elements. Previous studies have found that residual hearing is preserved and a better speech perception is achieved in CI users where the electrode array is inserted smoothly into the scala tympani, without for instance an inter-scalar shift into the scala vestibuli. The electrode position can be determined on post-operative (cone beam) CT-scans. However, such a scan is not conducted routinely after CI insertion in many hospitals. Electrical field imaging (EFI) measures the impedance matrix along all electrode contacts which can provide information about the distribution of electrical current within the cochlea. At the site of an inter-scalar shift the electrode array is in close contact with high resistance tissue and theoretically might change the impedance. Therefore, we investigated whether EFI could work as a detection method for inter-scalar shifts.

In 102 patients implanted with a HiFocus Mid-Scala electrode (Advanced Bionics, Sylmar, CA) intraoperative EFI recording and postoperative CT scanning were performed. A custom-made MATLAB software routine was developed to detect inter-scalar shift on the CT scans of all patients with an accuracy of 94% in our group (Siebrecht et al, CIAP 2019). 72 patients without and 21 patients with inter-scalar shift were identified. The 9 patients with an uncertain inter-scalar shift were excluded from further analysis. This outcome was used as ground truth data for the EFI detection method. We used the diagonal measurements of EFI matrix which are the measurements at stimulated contacts. In general, the diagonal follows a flat line and for some patients, there is a narrow peak. The median peak amplitude relative to baseline was 0.19 kOhm with an interquartile range from 0.08 to 0.88. These peak amplitudes were used to build a prediction model for the inter-scalar shift. We analysed the predictive ability of this model with a Receiver Operating Characteristic (ROC) curve and found the area under the curve of 0.95. Using a threshold of 0.75 kOhm, the prediction model achieved an accuracy of 95%. The access resistance derived from the diagonal measurements was investigated as an alternative measure to detect inter-scalar shift. This method turned out to be equally good to predict inter-scalar shift.

It is concluded that EFI measurements can be used to detect inter-scalar shift with high accuracy (at least in patients implanted with a HiFocus Mid-Scala electrode array). This finding would be clinically beneficial for surgeons to obtain a prompt feedback, which, in turn, may improve the intracochlear placement in future CI insertions and thus reduce insertion trauma.

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Siebrecht M, Briaire JJ, Frijns JH. Automated Inter-scalar Shift Detection for the HiFocus Mid-Scala from CT scans, Poster CIAP 2019.

TH12: BAND-LIMITED CHIRP-EVOKED COMPOUND ACTION POTENTIALS IN GUINEA PIGS: FEASIBILITY FOR COCHLEAR IMPLANTATION MONITORING

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Background: Patients with severely impaired high-frequency hearing and sufficient residual low-frequency hearing can be provided with cochlear implants (CIs), thereby facilitating ipsilateral electric and acoustic stimulation (EAS) with well-established advantages over electric stimulation alone. Still, residual hearing is often only partially preserved due to, inter alia, acute mechanical trauma during implantation. Possibilities of intraoperative monitoring using electrocochleography (ECochG) have been extensively studied in CI patients, primarily using the ongoing outer hair cell response to low-frequency tone bursts, i.e. cochlear microphonics. In contrast, neural phase-locking to the ongoing response as well as the neural transient response, i.e. compound action potential (CAP), were generally less prominent or sometimes absent, thus falling short of providing useful contribution to ECochG analysis. In this study, we investigate using band-limited chirps to better synchronize the neural response and provide more robust CAP in a guinea pig model of cochlear implantation.

Methods: In experiment 1, ECochG was measured in 9 normal-hearing guinea pigs (Dunkin Hartley) via gold-wire electrode placed at the round window niche. We compared input-output (IO) functions and derived-band responses using high-pass noise masking to infer neural contribution from the targeted frequency band to the CAP. Stimuli were constructed by adding a harmonic series either with zero phase delay (band-limited click) or by adjusting the phase delay according to a model of basilar membrane group delay (chirp) with 3 different parameters in order to examine level-specific changes in the delay model. The amplitude spectrum was thus identical between stimuli with differences only in phase. In experiment 2, guinea pigs were implanted with MED-EL custom-built CI electrode carrier using a motorized micromanipulator. ECochG was measured at each insertion step for the following stimuli: broadband click, band-limited click, chirp (3 parameters), and 10-ms tone bursts at frequencies 1, 2, 4, and 8 kHz. Insertion depths ranged between 4 and 5 mm.

Results: Chirps compared with equal-band click showed significantly lower thresholds and steeper slopes at inflection point of sigmoid-fitted IO functions. They also showed limited dynamic ranges and comparable or smaller CAP amplitudes at saturation. Derived-band analysis showed higher peak bandwidth of the Gaussian-fitted neural firing density with larger effective neural firing “mass”, interpreted as more synchronous activation in the targeted frequency band. Finally, intraoperative monitoring “sensitivity”, defined as relative amplitude change per unit distance, was comparable between chirp-evoked CAPs and tone burst-evoked ongoing responses, but it was smaller for other stimulus responses.

Conclusion: The chirp appears to be an effective stimulus to synchronize the neural response from a limited frequency band in guinea pigs. Therefore, it could be used to achieve a more holistic assessment of residual hearing in humans during cochlear implantation.

TH13: METHODS FOR MEASURING AUDITORY CORTICAL CHANGES IN FELINE MODEL OF COCHLEAR IMPLANTATION

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The congeniality deaf cat is a useful model for assessing the effects of hearing loss and cochlear implantation on auditory regions of the brain. The auditory cortex can be divided into six layers each with distinct functions and connections. It has been hypothesized that the cortex undergoes volume-preserving equivolumetric deformations during gyrification (Bok 1929). In gyri, outer layers become thinner and inner layers become thicker while the opposite occurs in sulci. Due to this topology, cortical columns are curved to maintain their normality with the outer (pial) and inner (gray-white) cortical surfaces. Thus, straight-line Euclidean distance is not a biologically accurate measure of cortical thickness. Instead metrics such as thickness and depth are best assessed on an Equivolumetric Normal Coordinate System (ENCS). Recently congenial deafness has been shown to alter the thickness of deeper cortical layers (IV, V and VI) in two-dimensional histological slices (Berger et al. 2017). Here we build an ENCS on three-dimensional reconstructions of SMI-32 and Nissl histology using diffeomorphic surface registration. Cortical layers can be isolated in histological images using segmentation algorithms such as the Alternating Kernel Method (AKM) (Priebe and Marchette 2000). We developed a Multimodality AKM (MAKM) which uses both ENCS depth and staining intensity to label layers in images. The depths of layers can then be accurately determined and measured within the ENCS. This method can be used for evaluation of plastic structural alterations of auditory cortical layers in deafness and whether these changes could be mitigated by cochlear implantation.

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TH14: CONGENITAL AUDITORY DEPRIVATION AFFECTS CORTICAL FIELDS DIFFERENTLY – COMPARISON OF THE PRIMARY AUDITORY FIELD AI AND THE POSTERIOR AUDITORY FIELD PAF

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Numerous studies in the cat auditory cortex have described the effects of congenitally deafness on neuronal response characteristics in the primary auditory field AI including lower firing rates, lower numbers of responding neurons, smaller dynamic range, lower cortical thresholds, and decreased sensitivity to binaural cues (Kral & Sharma 2012, Trends in Neurosci; Tillein et al., 2010, 2016, Cereb Cortex). In contrast to AI, PAF is a higher order auditory field. It is involved in visual cross-modal reorganization in congenitally deaf animals (Lomber et al., 2010, Nat Neurosci). One previous study described loss of induced local field potential activity both in AI and PAF (Yusuf et al., 2017, Brain). PAF was studied more often with respect to acoustic stimulation in hearing animals. Compared to AI PAF is characterized by longer latencies, increased jitter, phasic responses and increased spatial sensitivity (Stecker et al., 2003, J. Neurophysiol). An analysis of electrically evoked PAF unit responses in congenitally deaf cats has not been performed yet. Using simultaneous multi-electrode recording technique in the two auditory fields AI and PAF the present study focused on the question to which extend these two different fields are affected by congenital deafness.

Nine animals (6 congenitally deaf cats (CDC) and 5 hearing cats (HC), aged >6 month) were acutely stimulated with charge-balanced biphasic pulse trains (3 pulses, 200µs/phase, 500pps) in wide bipolar configuration with a custom-made cochlear implant inserted into the scala tympani of the cochlea on either side. Control animals were acutely deafened by intracochlear application of neomycin. In AI, 16 channel electrode arrays (Neuronexus probes) were inserted perpendicular to the cortical surface where local field potentials had the highest amplitudes. A second array was used to record the multi-unit activity in field PAF close to the posterior ectosylvian sulcus (PES). Here probes were inserted parallel to the PES up to a penetration depth of 5000µm. For histological track reconstruction at least one PAF penetration in each animal was marked by a fluorescent dye (DiI). Animals were stimulated mono- and binaurally with short pulse trains (500Hz, 3 pulses charge-balanced 200µs/phase) at intensities of 0-10 dB above brainstem response thresholds. Maximum spike rate, first spike latency (FSL) and response duration were analyzed.

In both groups (controls and deaf) responses to electrical stimulation of the cochlea could be measured in PAF, but they were less frequent in the deaf animals. While in controls in nearly half of the tracks in PAF one or more sites along the electrode array were auditory-responsive, this number decreased to less than a third in the deaf animals. In AI no such decrease was found. The response pattern in PAF, both in HCs and CDC, exhibited typical characteristics of PAF responses as previously described in hearing cats (peak latencies in the range of 15-30ms, phasic responses). In PAF the effect of deafness was similar to that found in AI but was more pronounced e.g. in reduction of the maximum firing rate and increased first spike latencies. In both fields, significantly shorter response durations were found in deaf animals.

These data demonstrate a significant reduction of auditory responsiveness of PAF in congenital deafness. However, PAF could still be activated through the auditory pathway despite the reported presence of visual cross-modal reorganization in this higher order auditory field.

TH15: EFFECTS OF PULSE PHASE DURATION ON THE ELECTRICALLY-EVOKED COMPOUND ACTION POTENTIAL IN CHILDREN WITH COCHLEAR NERVE DEFICIENCY AND CHILDREN WITH NORMAL-SIZED COCHLEAR NERVES

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Background: Prolonged pulse phase durations (PPDs) are often used as a mapping parameter for implanted children with cochlear nerve deficiency (CND) as a combined result of the lack of guidance for selecting this parameter, the absence of reliable behavioral responses, and the overall poor responsiveness of these patients to electrical stimulation of the cochlear implant (CI) (Buchman et al., 2011; Teagle et al., 2010). This clinical practice leads to reduced CI battery life due to high power consumption and increased risks of tissue and electrode damage (Loucks et al., 1939; MacIntyre et al., 1957). Therefore, it is clinically important to investigate whether prolonged PPDs actually provide the benefit of enhancing CN responsiveness for implanted children with CND. The electrically-evoked compound action potential (eCAP) is a near-field recorded neural response generated by CN fibers. Its presence depends on the existence of sufficient CN fibers responding synchronously to electrical stimulation. Therefore, the eCAP can be used to assess neural responsiveness of the CN. This study compared the effect of increasing the PPD on three eCAP parameters reflecting CN responsiveness: threshold, maximum amplitude and slope of the Input/Output (I/O) function between children with CND and children with normal-sized CNs. It tested the hypothesis that children with CND would show reduced effectiveness of increasing the PPD on changing CN responsiveness than children with normal-sized CNs due to their poor neural survival.

Methods: To date, 22 children with CND and 13 children with normal-sized CNs have been recruited and tested for this study. All subjects were implanted with a Cochlear® Nucleus™ device with an internal electrode array of 24RE[CA] in the test ear. The stimulus was a charge-balanced, cathodic leading, biphasic pulse with an interphase gap of 7 μs. The eCAP I/O function was measured at three electrode locations across the electrode array for each subject. PPDs tested in this study ranged from 25 to 88 μs. The amount of electrical charge for a biphasic pulse with a PPD of 88 μs perceived as loud but comfortable was used as the maximum charge level tested for all PPDs. Generalized Linear Mixed effect Models (GLMMs) with subject group, electrode location and PPD duration as the fixed effects and subject as the random effect were used to compare maximum eCAP amplitude, eCAP threshold and slope of the eCAP I/O function, as well as and the size of the PPD effect on these parameters.

Results: Children with CND had smaller maximum eCAP amplitudes, higher eCAP threshold and flatter slopes of eCAP I/O function than children with normal-sized CNs. Increasing the PPD resulted in increased eCAP threshold but had no significant effect on maximum eCAP amplitude or slope of the eCAP I/O function for both study groups. Children with CND showed smaller PPD effects on all three parameters than children with normal-sized CNs.

Conclusions: Our preliminary results suggested that for the same amount of electrical charge, increasing the PPD reduced CN responsiveness. This negative effect of the PPD on CN responsiveness was reduced in children with CND who have poor CN survival.

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TH16: SPECTROTEMPORAL RIPPLE DENSITY DISCRIMINATION IN INFANTS AND ADULTS WITH NORMAL HEARING: EFFECT OF CARRIER RATE

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Spectral ripple discrimination (SRD) tasks are known to correlate with speech identification and discrimination measures in cochlear implant (CI) users. Such measures could be used as non-linguistic tests of CI benefit and device efficacy in CI users too young for clinical speech perception testing. Studies of CI and normal hearing (NH) children have shown that development of SRD occurs through school-age and over time with CI experience in prelingually-implanted children. However, the carrier density used in some tests of SRD limits the fidelity of the rippled stimulus. Thus, SRD tests with relatively low carrier density will be prone to ceiling effects and underestimate the maximal spectral peak resolution and time-course for development. Over two experiments, we examined SRD in 6-month-old NH infants and adults tested using either low or high carrier densities. It was hypothesized that both age groups would show better SRD with the high carrier density but that adults would show a greater effect.

Subjects were NH 6-month-old infants and adults who each participated in one of two studies. Infants had no JCIH risk factors and all subjects passed a bilateral otoacoustic emissions screen. Stimuli were low-density (33/octave, Exp 1) or high-density (100/octave, Exp 2) pure tone carriers amplitude-modulated across frequency and time as described in Aronoff & Landsberger's "spectral-temporally modulated ripple test" (Aronoff and Landsberger, 2013). Stimuli were 1s in length with 5 Hz temporal sweep rate and spectral ripple density from 1 to 20 ripples per octave (RPO) in fractional log2 steps. An observer-based single-interval change/no-change procedure was used to determine the highest ripple density a participant could discriminate from a referent 20 RPO stimulus based on d' >= over five consecutive signal (RPO < 20) and no-signal (RPO = 20) trials. Thresholds in RPO were determined based on the 70% point on the psychometric function fit to individual data.

Each subject participated at two modulation depths (10 and 20dB). Thresholds at both depths were obtained from 80% of infants (n=33) and 93% of adults (n=13) in Experiment 1 and from 88% of infants (n=15) and 100% of adults (n=10) in Experiment 2. Psychometric functions for 4 infants and 3 adults were non-monotonic due to a temporal beating artifact noted at 16 RPO 33/octave stimuli. As such, their thresholds were assumed to be 11.312 RPO. In both age cohorts, mean SRD thresholds were significantly better for high-density than low-density carrier stimuli (by about 5-6 RPO). For both carrier rates, significant effects of age (better SRD for adults) were found as well as significant effect of ripple depth (better SRD at 20dB depth). No significant interaction between age and ripple depth was observed for either carrier rate.

These results show that both infants and adults have better SRD performance when carrier rate is high. With low carrier rates, the stimulus ripple resolution becomes limited in the stimulus itself before the perceptual ripple resolution is reached. While this is unlikely to affect previous results reported for CI users (given their limited spectral resolution), low carrier density could have masked the degree of immaturity in SRD for normal hearing children previously reported. Future studies using SRD tasks should use a carrier rate that is high enough to adequately represent the range of spectral resolution of the target listeners.

TH17: PERCEPTION AND PRODUCTION ACCURACY AND ERROR PATTERNS IN NORMAL HEARING AND CHILDREN USING COCHLEAR IMPLANTS

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Introduction: Speech production error patterns in children with hearing loss (HL) are driven by perceptual confusions. Cochlear implant (CI) studies suggest the relationships between perception and production are complex. Production and perception skills in children using CIs are associated with a wide variability of scores. Studies report production exceeds perception performance in many children using CIs while the opposite is observed in normal hearing (NH) children. In this study, we compare perception and production performance in NH children listening to unprocessed speech, NH children listening to 8-channel vocoded speech (CI simulations), and children using CIs. Limited information is available regarding the associations between perception/production accuracy and error patterns in these three groups. Data from this study allow a better understanding of variability related to speech perception and production performances and provide avenues for developing rehabilitation approaches for children using CIs.

Methods: 15 children who received CIs before 30 months of age are tested at 5-8 years of age. Two groups of NH children (each group N=15) are matched by hearing age with children using CIs and tested at 4-7 years of age. One NH group is tested with broadband speech; the other NH group is tested with 8-channel vocoded CI simulations. Speech perception and production performance are evaluated with a version of the California Consonant Test (CCT) (Owens & Schubert, 1977). Stimuli include 12 consonants (/f/, /v/, /θ/, /s/, /z/, /ʃ/, /p/, /b/, /t/, /d/, /k/, /g/) which occur in consonant-vowel-consonant (CVC) words in initial (4 times) and final (4 times) positions. Perception accuracy and error patterns are analyzed using MATLAB software. For the production experiment, children produce the same words used in perception experiment. Their productions are transcribed by four speech language pathologists and analyzed using Computer Aided Speech and Language Analyses (CASALA) software (Serry et al., 1997) to determine the accuracy scores and substitution errors for each consonant.

Results: Significant positive relationships between perception and production performance are evident across three groups. Performance of the CI simulation group is lower than the NH group for both perception and production. Different patterns of speech perception errors are observed for the NH group who heard the unprocessed speech compared to the NH group who heard 8-channel vocoded simulations. Performance patterns suggest production exceeds perception performance for children in the NH group listening to vocoded simulations, but the opposite effect occur for NH children listening to unprocessed speech. Initial consonants are perceived and produced more accurately than final consonants in children with CIs and in NH children listening to vocoder simulations.

Conclusions: Data provide information regarding processes involved in perception and production performance. Mapping relationships between speech perception and production can provide additional information regarding how degraded auditory inputs reflect perceptual confusions and production errors. Data will be useful for improving rehabilitation techniques in children using CIs.

TH18: CAN AURAL PREFERENCE DEVELOP IN AN OLDER CHILD AND THEN REVERSE AFTER HEARING RECOVERY IN ADULTHOOD? A RARE SINGLE CASE STUDY

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Objectives: We sought to determine whether aural preference occurred in rare case of sudden idiopathic hearing loss in childhood which recovered in adulthood and whether the aural preference would reverse with time after recovery.

Background and rationale: Previous work suggests that aural preference is established during a critical period in development and is difficult to reverse. Effects of later childhood onset of unilateral deafness are less understood. It is possible that aural preference does not develop or, if it does, that it may be reversible. We had the rare opportunity to study this in a young man who was diagnosed at 11 years old with deafness and tinnitus in his right ear. At 24 years of age, he presented with a sudden improvement of hearing thresholds in the right ear. Hearing improved from profound to a mild to moderate loss.

Hypothesis: We hypothesized that aural preference was established by this patient's long-term unilateral deafness in childhood but that it would be reversible after his hearing recovery.

Methods: Repeated testing included electrophysiological recordings and behavioral measures of speech perception and perception of binaural cues. Cortical responses were evoked by each ear separately and bilaterally using 64-cephalic electrodes, referenced to the right earlobe. Speech perception was tested using a monosyllabic word test in quiet and in noise. Binaural cue perception was tested using lateralization and fusion tasks. Both accuracy and reaction times were recorded.

Results: Cortical data at initial periods of hearing recovery reveal aural preference for the longer hearing left ear. These metrics after 2, 6 months post recovery were measured to asses potential reversal. Speech perception measures were consistent, with initially better scores in the left ear but increasing symmetry between the ears over time post-recovery. Perception of both ILDs and ITDs was normal when tested at 6 months post-recovery.

Conclusion: Aural preference can be established during late childhood as shown in this rare case of recovered single sided deafness. Reversibility was not seen over the first 6 months after recovery, perhaps reflecting continued asymmetry in hearing thresholds. Accurate perception of binaural cues was consistent with good binaural fusion. A hearing aid was provided in the poorer hearing ear. Follow-up testing to examine effects of hearing aid use will be conducted and presented.

TH19: EFFECT OF AURAL PREFERENCE ON CORTICAL BILATERAL ADVANTAGE IN CHILDREN WITH BIMODAL HEARING

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Objectives: We aimed (1) to evaluate whether bimodal hearing promotes a bilateral advantage in the auditory cortex of children, and (2) to determine the effects of aural preference on bilateral cortical responses.

Background: Asymmetric hearing during development abnormally strengthens pathways from the better hearing ear, resulting in over-representation of this ear in the auditory cortex (aural preference). For children with significant residual hearing in their better hearing ear, bimodal device use promotes cortical development and benefits speech perception and spatial hearing. However, both electrophysiological and behavioural measures indicate persistent aural preference with prolonged periods of early asymmetric input. We asked whether the auditory cortex responds differently to bimodal input compared to unilateral presentations of each stimulus, and how aural preference influences bilateral cortical processing in children.

Hypotheses: Bilateral cortical responses evoked by bimodal stimulation will resemble responses evoked by stimulation of the better hearing ear in children who experienced longer periods of asymmetric input. Consequently, changes in cortical processing between unilateral and bilateral input will be smaller than normal, limiting cortical bilateral advantage.

Methods: Cortical responses to unilateral and bilateral stimulation were measured using multi-channel electroencephalography in 56 bimodal users (mean(SD) age 9.4(4.8) years) and 58 age-matched peers with normal hearing (11.1(6.6) years, $t(104.1)=-1.7$, $p=0.1$). Bimodal users received their cochlear implant at age 6.7(4.8) years and used bimodal devices for 2.7(2.7) years. The left ear was implanted in 27 (48%) of the children. Responses were evoked by comfortably loud acoustic click trains presented via an insert earphone to non-implanted ears and biphasic electric pulse trains presented via an L34 research processor to an apical electrode (#20) of implanted ears. Bilateral stimuli were presented with no timing difference between the ears. The time-restricted artifact and coherent source suppression (TRACS) beamformer was used to locate cortical sources of activity underlying peak amplitudes measured at the surface of the head. Maximum dipole moment (nAm) and corresponding latency were extracted from the voxels in left and right auditory cortices with the largest signal-to-noise ratio (largest pseudo-Z). Cortical lateralization to all stimuli as well as aural preference of each cortex to the unilateral stimuli were calculated.

Results: Three groups of bimodal users were identified based on pre-implantation hearing thresholds averaged across frequency: 17 had severe/profound loss in both ears with an asymmetry of 16.0(14.0) dB; 17 had good low-frequency steeply sloping to high-frequency hearing loss with 6.5(5.4) dB asymmetry; and 22 had an asymmetric hearing loss of 55.0(31.2) dB. Evidence of aural preference was found in children with prolonged asymmetric input prior to implantation. Further analyses of responses will reveal whether typical bilateral cortical processing is promoted or remains impaired in bimodal users, as evidenced by patterns of cortical activation and cortical lateralization to bilateral versus unilateral stimulation. Effects of aural preference and contributions from predictive factors in the children's hearing histories will be explored.

Conclusion: This study will add to the understanding of bilateral cortical development, benefits of bimodal hearing for children with residual hearing, and consequences of asymmetric input during childhood.
This work was funded by Canadian Institutes of Health Research (CIHR).

TH20: LANGUAGE AND AUDITORY DATA OF CHILDREN WITH SINGLE-SIDED DEAFNESS AND A COCHLEAR IMPLANT

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Each year, approximately 20 children are born in Flanders (Belgium) with single-sided deafness (SSD), i.e. profound hearing loss in one ear (> 90 dB HL) and normal hearing in the other ear. As they have no access to binaural hearing, these children experience difficulties with localizing sounds and understanding speech in noisy environments. A growing body of research suggests that unilateral hearing loss is a risk factor for speech-language delays. Moreover, the single-sided auditory deprivation affects the brain development of these children, resulting in asymmetric auditory processing and the disruption of higher-order connections in the brain.

Despite these findings, there is currently no standard care for these children in Belgium (as is the case for many other countries worldwide). A cochlear implant (CI) in the deaf ear offers the potential to restore binaural hearing. Early implantation is likely of key importance, given the sensitive period for brain development early in life. In our current multicenter study (Leuven, Antwerp and Ghent), fifteen infants with congenital SSD received a CI at a very young age (range 8-26 months, mean 13.6 ± 4.8 months). At regular intervals we document the development of these children in terms of receptive and expressive language skills, cognitive abilities, and (from the age of four) localization and speech perception skills. Additional measures include assessments of the children's language environment with the LENA system, as well as parent questionnaires addressing their auditory, language, and socio-emotional development.

At the conference, we will present ongoing language and auditory data of the implanted children, starting 2 months pre-implantation and ranging to up to 4 years post-implantation. We will compare their data to those of both matched normal hearing peers and matched single-sided deaf children without a CI.

TH21: TOWARDS AN OBJECTIVE MEASURE OF PAEDIATRIC COCHLEAR IMPLANT OUTCOME: OUR SEARCH FOR AN AUDITORY BASELINE FOR SPEECH PROCESSING

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At present, paediatric cochlear implant (CI) recipients with poor speech understanding cannot be identified until they can reliably complete behavioural assessments. Our long-term aim is to develop an objective measurement of speech processing for clinical use based on cortical neuroimaging.

In this study, we sought to identify an appropriate auditory baseline stimulus for measuring speech-specific cortical activation using functional near-infrared spectroscopy (fNIRS), a CI-safe neuroimaging technique. It is challenging to functionally separate linguistic and lower-level auditory responses from one another as they are often expressed similarly. To overcome this, responses to speech can be contrasted against an auditory baseline to isolate speech-specific cortical activity. At present, it is unknown which baseline is best at retaining speech-specific responses in an experimental set-up involving fNIRS.

25 normally hearing children aged 6-12 years underwent fNIRS neuroimaging. Three auditory conditions were presented in an event-related format: normal speech, time-reversed (TR) speech and signal-correlated noise (SCN) with 25 sentences per condition. In order to measure brain activity, whilst participants passively listened to the experimental stimuli, 30 probes were arranged in two 5 x 3 arrays, targeting both cerebral hemispheres.

Significant activation was observed bilaterally in channels targeting auditory regions when stimuli were contrasted against silence. No significant activation was observed when normal speech was contrasted against TR speech or SCN. No lateralisation effects were observed under any contrast. Interestingly, a left-sided channel targeting posterior temporal regions showed significant activation only in response to normal speech so this was investigated further. Significantly greater activation was observed in this channel compared to the corresponding right-sided channel in response to the normal speech vs SCN contrast only.

Whilst TR speech is not a suitable baseline for isolating speech-specific responses when imaging using fNIRS, further studies are required to assess whether SCN may serve as a more suitable baseline in posterior temporal regions. This work represents an important step towards developing an fNIRS-based measure that can identify children struggling to hear with their CIs at an individual level.

This work is supported by an Action on Hearing loss and Cochlear Ltd. PhD studentship to the first author, and the NIHR.

TH22: A NEW METHOD FOR INVESTIGATING SOCIAL-COGNITION IN DEAF INFANTS WITH COCHLEAR IMPLANTS

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Infants with hearing loss who receive cochlear implants struggle to catch up to their hearing peers during the period of rapid language growth that occurs in early development. These children demonstrate huge variability in their language outcomes, even when accounting for known audiological or demographic factors. To better understand this variability, researchers have turned their attention towards the cognitive factors that are involved in processing new information and in social interaction. Here, we present a novel methodological approach to investigate social-cognitive development in infants with cochlear implants.

One important factor in social-cognitive development is action prediction—the basic ability to anticipate the actions of our social partners. This behavior facilitates smooth social interactions and may play an important role in the development of infants' early communicative skills. A large body of research has shown that young infants begin to anticipate observed actions in the first few months of life (e.g., Cannon & Woodward, 2012; Falck-Ytter, Gredebäck, & von Hofsten, 2006; Southgate & Vernetti, 2014). Recent evidence suggests that this ability is also predictive infants' language growth (Levine, 2017).

Despite its proposed role in typical cognitive development, no study to date has examined action prediction in infants with hearing loss. Therefore, the current project uses a novel, innovative methodology—head-mounted eye-tracking—to investigate action prediction skills in infants with hearing loss. Head-mounted eye-tracking affords a view of the world from the infant's perspective and allows researchers to quantify infant behaviors in a more naturalistic context than is possible with traditional laboratory measures. This study is one of the first to apply head-mounted eye-tracking to investigate cognitive processing during parent-child interactions in infants with cochlear implants. Here, we will describe our novel experimental approach and coding scheme. Data collection is ongoing, as this project is a longitudinal study that will follow infants up to one year post-implant. We will therefore present some preliminary findings from our initial analyses of the data collected thus far and discuss the potential of this novel approach to garner new insights into the early social and language development of infants with cochlear implants.

TH23: WHAT CAN SPEECH ACQUISITION DATA TELL US ABOUT COCHLEAR IMPLANT DEVICE LIMITATIONS? ANALYZING ACCURACY, ERROR PATTERNS, AND SPECTRAL FEATURES OF CHILDREN'S /T/ AND /K/ PRODUCTIONS

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Cochlear implants (CIs) are the standard of care for children with severe-to-profound hearing loss. However, even children who receive an implant at the youngest possible age (12 months in the United States) demonstrate persistent delays in speech and language development compared to their peers with normal hearing (NH). In combination with at least one year of auditory deprivation, processing limitations of the device likely contribute to differences in speech acquisition for children who use CIs. Critical spectral (frequency) information is lost or distorted when processed by a CI. Spectral cues are essential for differentiating speech sounds, especially place-of-articulation contrasts like /t/ vs. /k/. Because /t/ is formed towards the front of the mouth, energy in the spectrum for the release burst of /t/ is concentrated at relatively higher frequencies than that of the release burst of /k/, which is formed farther back in the mouth. Spectral information necessary to identify consonants is also affected by coarticulation. For example, spectral energy will be concentrated at higher frequencies for /k/ followed by a front vowel (e.g., “key”) compared to /k/ followed by a back vowel (e.g., “coop”). Spectral cues required to differentiate /t/ and /k/ in various vowel contexts may be particularly difficult for pediatric CI users to perceive, and thus learn to produce.

The present study analyzed /t/- and /k/-initial words produced during a word repetition task by 26 children with CIs and 26 children with NH (ages 31-66 months). Groups were matched in terms of age, sex, and maternal education. Productions were transcribed and coded as correct or incorrect. If the sound was produced correctly, spectral information was computed for the release burst. If the word was produced incorrectly, the type of error was described as a place, manner, voicing, or combined place/voicing error.

Statistical analyses were used to determine: 1) whether children with CIs produce /t/ and /k/ with similar accuracy as their peers with normal hearing; 2) whether children with CIs produce the same types of errors as their peers with NH; and 3) whether children with CIs produce /t/ and /k/ with similar spectral characteristics as their peers with NH.

Children with CIs produced /t/ and /k/ less accurately overall (68% accuracy) compared to their peers with NH (93% accuracy). This result suggests that children with CIs demonstrate delays in speech acquisition on the order of approximately one year.

Children with CIs also produced different types of errors than their peers with NH. At 36 months, the most common type of error for children with NH was a place error, whereas the most common type of error for children with CIs was a manner error. For the children with CIs, the rate of manner errors steadily decreased across the entire age range; however, place errors persisted from 36-48 months, and then slowly declined from 48-60 months. For the children with NH, almost all errors were resolved by 48 months. These results suggest that the timing AND trajectory of growth are different for children with CIs acquiring speech.

Children with CIs produced /t/ and /k/ with similar spectral characteristics as their peers with normal hearing in back vowel contexts. In front vowel contexts, children with CIs produced /t/ with similar spectral features, but they produced /k/ with energy concentrated at lower frequencies than their peers with NH, suggesting that children with CIs coarticulate less than their peers.

The results of these analyses indicate that processing limitations of the device—not just early auditory deprivation—contribute to differences in speech acquisition for children with CIs.

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TH24: THE EFFECTS OF EARLY ACOUSTIC HEARING ON SPEECH PERCEPTION AND LITERACY ABILITIES OF PEDIATRIC COCHLEAR IMPLANT RECIPIENTS

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The primary aim of our current project is to determine the degree to which a period of acoustic hearing (via hearing aid [HA] use) facilitates language and literacy in children with cochlear implants (CI). We tested 117 pediatric CI recipients ranging in age from 5-8 years on measures of speech perception, receptive vocabulary and language. Follow up testing (ages 7-10 years) included early literacy assessments on 104 participants. The literacy assessment includes subtests for decoding and reading comprehension from the Woodcock Reading Mastery Test. The speech perception test battery includes word recognition in quiet and noise (segmental perception), talker and stress discrimination, and emotion identification (suprasegmental perception). A continuum of residual hearing levels and length of HA use are represented: some children have bimodal devices, while others received their second CI either simultaneously or sequentially at varying time intervals since their first CI (mean age at 1st CIs = 2.1 years). Comprehensive auditory thresholds and device histories were collected on all CI recipients. Based on our analyses, we identified an optimal duration of HA use for each of three ranges of hearing loss severity (pure-tone-averages of 72, 92 &110 dB HL) that maximizes segmental and suprasegmental perception. Analyses of speech perception scores reveal that segmental and suprasegmental skills are separate constructs that are influenced differentially by duration of hearing aid experience. Analyses for literacy data reveal that suprasegmental perception operates independently from segmental perception to promote both decoding and reading comprehension. The clinical implications of these results will be discussed.
This work and presentation were supported by NIDCD R01 DC012778 (PI: LSD)

TH25: LONG-TERM EFFECTS OF EARLY COCHLEAR IMPLANTATION: A SUCCESS STORY?

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Introduction and aim: Few studies investigate the long-term outcomes of children who received their cochlear implants (CIs) at an early age. In Flanders (Belgium), a group of early implanted children has currently reached the age of adolescence. The aim of this study was to give an overview of some of their long-term outcomes, including their school results and their speech understanding in class.

Material and methods: 26 students with CI were included. All of them were implanted before the age of two and were enrolled in secondary mainstream education. Their school results were derived from two tests conducted in the last year of elementary school. Results were obtained for Dutch (Dictation, Reading, Grammar, Listening) and Mathematics (Knowledge of numbers, Arithmetics, Geometry, Measurement). Their speech perception was assessed with a class-like speech in noise audiometry (Sound-C). A questionnaire (LIFE-R) was used to document their experienced listening difficulties in class. Data of their normal hearing (NH) peers were collected as well.

Results: CI participants performed within the normal range of their NH peers for Dutch and Mathematics, except for one test, i.e. the Listening test ($p<0.030$). Correspondingly, CI participants also reported significantly more listening difficulties in class, when compared to their NH peers ($p<0.001$). The top three listening situations rated as most difficult were: listening during group work, listening to multimedia and listening in large-sized classrooms. This also corresponds with our finding that CI participants needed significantly higher SNRs (mean difference = 10.5 dB) to hear 50% of the sentences played in babble noise in a reverberant room.

Conclusions: Although early implanted children with CIs are doing remarkably well in mainstream education, they still encounter more listening difficulties than their NH peers. Children with CI seem to fail on listening tests, often performed by means of multimedia which was reported as a common listening difficulty in class. Noise and reverberation greatly diminish speech perception of children with CI, which explains why they experience difficulties during group work activities and large group assemblies. Further research is necessary to investigate how these difficulties can be dealt with and if these difficulties cause further psycho-educational problems.

TH26: AUDIO-VISUAL SENTENCE IDENTIFICATION IN EARLY-DEAFENED, LATE-IMPLANTED COCHLEAR IMPLANT USERS

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Introduction. Early-deafened, late-implanted (EDLI) cochlear-implant (CI) users are a special group of implantees, since they are deafened during language acquisition, and only implanted after a long period of auditory deprivation. Both factors that might negatively influence speech perception with the implant. Compared to the typical, post-lingually deafened CI users, many EDLI CI users might rely on visual only, or audiovisual communication, including sign language. We hypothesized that potentially low EDLI CI outcome performances for auditory speech perception may be compensated by visual cues.

Materials & Methods. Two groups of CI users were recruited: 1) EDLI CI users, defined as hearing loss onset <6 years and implantation >16 years of age, and 2) a control group of post-lingually deafened CI users. Identification of meaningful sentences was measured using three modalities: 1) audio only; 2) visual only; 3) audiovisual.

Results. Seventeen EDLI and fourteen control CI users were included. The results show that EDLI scored lower on auditory sentence identification than controls (64% versus 89%, on average). Using lipreading cues no significant difference between both groups was shown anymore (audiovisual sentence recognition 78% versus 92%). For visual sentence identification EDLI scored significantly higher (24% versus 5%).

Conclusions. As expected, EDLI CI users show a lower sentence identification for audio only, than post-lingually deafened CI users. EDLI, however, profit from the addition of visual cues for auditory sentence identification. Perhaps, the cross-modal effects of a language acquisition based largely on visual cues (lipreading or sign language) on the auditory cortex persist after implantation, and explain the better visual sentence identification and the benefit for audiovisual communication. The current outcomes could support implantation in EDLI, despite the auditory deprivation period.

TH27: VISUAL DISTRACTION DIMINISHES SPEECH UNDERSTANDING IN COCHLEAR-IMPLANT LISTENERS

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Both auditory and visual cues aid in speech understanding, especially for listeners using cochlear implants (CIs). Everyday listening environments contain many challenges to speech understanding in the auditory domain (including the degraded signal presented through a CI) as well as visual distractions that can divert cognitive resources from attention to speech. Normal-hearing (NH) listeners' speech understanding can be reduced by visual distractions or when performing a secondary task, particularly when the speech material is difficult (e.g., foreign accented) and particularly when the listener is older. While CI listeners have damaged peripheral hearing, their central auditory system and available cognitive resources are presumed to be similar to those of NH listeners of a similar age. Thus, a direct comparison of CI listeners and NH listeners presented with vocoded speech (CI-simulation) should reveal no differences unless distinct attention-switching central strategies have been adopted. This study tested the hypothesis that listeners with CIs will ignore visual distractions in the environment like their NH peers, but would be less affected by the demands of a secondary task than their peers listening to vocoded speech, perhaps due to cognitive strategies they have adopted through their experience with hearing loss.

Participants were 20 CI listeners (age 21-78) and age-matched peers (±2 years). Age-matched peers listened to vocoded speech with the unique configuration of channels that would equate their speech recognition in quiet to the same level as their matched CI listener. IEEE sentences were recorded in an audiovisual (AV) mode with two levels of auditory complexity (unaccented and accented talkers). Videos were presented with two levels of visual complexity (solid background or with the target talker embedded in a busy sidewalk scene). Listeners were asked to repeat the sentences spoken in background noise while either ignoring the sidewalk scene or engaging in a visual secondary task with the scene. Thus, each listener saw three audio-visual (A/V) conditions with each talker (solid-colored background, background scene, and background scene with secondary task), and one visual condition where only the secondary task was required. Results show highest speech understanding performance for unaccented speech with and without the background video. As expected, accented speech caused a significant reduction in performance in all conditions, possibly because of acoustic distortions in the accented speech coupled with age-related slowing of auditory temporal processing and diminishing of cognitive resources. The addition of a secondary task negatively affected all listeners in both the accented and unaccented conditions; however, the current data and analysis revealed only subtle differences between listener groups. In addition, while performance on the secondary task itself decreased when the listeners were asked to do both the primary and secondary task, that decrease in performance was not significantly different between the accented and unaccented conditions.

These results show that CI listeners can suppress irrelevant visual information as well as their NH peers, despite their reliance on visual cues for speech understanding. All listeners are negatively affected when given a secondary task, as well as when the speech is spoken with an accent even with the presence of visual cues. While CI listeners may have developed strategies for coping with visual distraction, these strategies are not functionally different from those utilized by their NH peers and the cognitive resources available to each group appear to be used similarly.

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TH28: RATE DISCRIMINATION AND SENTENCE RECOGNITION IN YOUNG AND ELDERLY NORMAL HEARING ADULTS USING VOCODED SPEECH

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In cochlear implant listeners, rate discrimination up to 300 Hz has been linked to good speech understanding. However, this has not been tested in elderly adults with cochlear implants. Temporal envelope processing, critical for speech perception under spectral degradation, may decline in many older patients. As a first step, we are studying the relationship between sentence recognition and rate discrimination in normal hearing young and elderly adults using stimuli that have been processed using CI-type processing (vocoded) in quiet and in different levels of noise. Listeners' psychophysical sensitivity to the temporal envelope cue will be measured using broadband noise amplitude-modulated by periodic signals. We hypothesize that older listeners will show poorer performance than younger listeners in the speech recognition task and that an interaction will be observed between age, vocoding and SNR. In addition, we expect that age-related declines in temporal-envelope sensitivity will be observed. We hypothesize that temporal-envelope sensitivity will predict listeners' performance in the speech recognition task under conditions of vocoding and background noise.

TH29: AGE-RELATED DEFICITS IN AUDITORY CORTICAL PROCESSING IN COCHLEAR-IMPLANT USERS

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Cochlear-implant (CI) usage is increasing among the aging population. Older CI users (OCI) perform worse on speech perception tasks compared to younger CI users (YCI), but mechanisms contributing to such age-related differences are less clear. Here, we examined one potential mechanism for the speech understanding deficits in older CI users, which postulates an age-related decline in auditory cortical processing, particularly at fast stimulus presentation rates. We compared such hypothesized aging effects on auditory cortical processing in CI users to age-matched normal-hearing (NH) listeners.

CI and NH participants passively listened to a 510-ms speech syllable /da/ and a 510-ms, 1000-Hz pure tone to elicit cortical evoked potentials. Each stimulus was presented in randomized blocks with interstimulus intervals (ISI) of 0.5, 1, 2, 3, or 4 s (i.e., fast to slow presentation rate). The stimuli were presented to the self-reported better ear via direct audio input to the sound processor at a comfortable listening level for CI users, and to the right ear via insert earphone at 75 dB SPL for NH listeners. The testing was repeated across two sessions to assess test-retest reliability.

Results from five younger and middle-aged CI (called simply younger CI users, YCI: < 65 years) and seven OCI (≥ 65 years) listeners revealed salient cortical P1-N1-P2 responses for both stimuli following removal of artifacts produced by the CI. Responses from the OCI group, compared to those from the YCI group, exhibited decreased amplitudes and prolonged latencies for N1 and P2 peaks. Such group differences unexpectedly persisted across ISIs. Further, the response test-retest reliability improved with slowing ISIs and plateaued for ISI at and above 2 s. Finally, responses from the OCI group, relative to those from three ONH (≥ 65 years) listeners, showed decreased amplitudes and prolonged latencies for N1 and P2 peaks across ISIs. Data collection will continue in younger NH and more ONH listeners to determine if the age by presentation rate effects on cortical responses found in previous studies can be reproduced.

Our findings suggest that age-related deficits in the cortical processing of speech signals occur in CI users. Unlike extant findings in acoustic-hearing individuals, however, the age-related cortical processing deficits found in CI users may be independent of stimulus presentation rate. Our findings also indicate that older CI listeners exhibited poorer auditory cortical processing than NH peers. Practically, in light of the test-retest reliability findings, we recommend an ISI of ~2 s for auditory event-related potential studies in adult CI users. Together, the present study points to auditory cortical processing deficits in older CI users, which may contribute to the age-related speech understanding deficits. Future studies will test the potential benefits of using auditory cortical responses to individualize CI programming for improving speech understanding and quality of life in older CI users. [Research was supported by the National Institute on Aging of the National Institutes of Health under Award Number R01AG051603.]

TH30: ENHANCED CORTICAL PLASTICITY IS RELATED TO BETTER COCHLEAR IMPLANT OUTCOMES

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Background: Previous work in human and animals have shown that deafness is associated with auditory cortex activation in response to visual stimuli. In CI users, greater degrees of auditory cortex activation to visual stimuli were associated with poor speech perception outcomes. The purpose of this study was to examine whether similar relationships exist in CI users and those waiting for a CI.

Methods: Normal hearing (NH), CI users, and those waiting for a CI ("pre-operative") were tested on a speech lip-reading paradigm using a silent movie as a stimulus. The movie consisted of a person uttering a single syllable animal lasting approximately 2.5 sec. The task was to watch the movie clip and indicate via keyboard the perceived word. A 64-channel EEG (electroencephalogram) recorded while subjects performed the task.

Results: Behavioral identification of the movie syllable object did not differ between all three groups. Evoked responses (P1/N170) were observed to the onset of the movie. P1 responses were generated in the visual cortex and did not differ between groups. The N170 (a face response) activated more auditory regions on CI and pre-op patients. The degree of auditory cortex activation of the N170 responses was significantly correlated to AzBio performance in CI users. Time-frequency analysis indicated a robust alpha desynchronization that localized to occipital cortex in all three subject groups and greater frontally in NH.

Conclusion: Cortical evoked potentials and brain oscillatory activity represent different aspects of neural processing. Evoked potentials appear to represent early sensory processing and show an abnormal generator in the pre-op population. Greater auditory activation to a visual stimulus (movie) in CI users would suggest that multimodal plasticity is beneficial for silent language task. Greater alpha brain oscillations in NH compared to CI and pre-op suggests that more cognitive neural networks are engaged perhaps related to increased effort to lip read in NH.

TH31: EVERYDAY LISTENING WITH COCHLEAR IMPLANTS: A WORKOUT FOR THE BRAIN?

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Cochlear-implant (CI) users report experiencing greater listening effort in everyday life than their normally-hearing peers. Chronically elevated listening effort may have negative consequences for communication, participation, and potentially even long-term cognitive health.

We have conducted a series of studies designed to shed light on the brain activity behind effortful listening. Taking advantage of the silence and flexibility of functional near-infrared spectroscopy (fNIRS), an optical brain-imaging technique compatible with CIs, we confirmed that effortful listening is associated with increased brain activity in the left inferior frontal cortex (IFC). Specifically, using noise vocoding as an approximation of CI listening, we confirmed that listening to spectrally degraded speech resulted in increased activation of left IFC when participants directed their attention towards the speech, but not a distractor. Subsequent results suggested a non-monotonic relationship between left IFC activation and listening task difficulty, with greatest activation occurring when speech recognition was possible, yet challenging.

In a pair of ongoing studies, we are combining fNIRS imaging with simultaneous pupillometry to study listening effort with hearing aids and cochlear implants. To improve ecological relevance, these studies are focusing on how hearing-device users perform at the sort of positive signal-to-noise ratios that predominate in real life. We will present the results of these studies, discussing how objective biomarkers of listening effort can be used to help optimize and evaluate novel interventions, with the goal of reducing the cognitive demands of listening.

TH32: DOES DEGREE OF SPEECH ASYMMETRY MODULATE BILATERAL SPEECH INTELLIGIBILITY AND LISTENING EFFORT IN ADULTS WITH BILATERAL COCHLEAR IMPLANTS AND ADULTS WITH NORMAL HEARING?

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Previous work has shown that patients who use bilateral cochlear implants (BiCIs) perform better on sound localization and speech understanding in noise when using two implants vs. a unilateral implant. It is fairly common for BiCI users to have asymmetrical speech intelligibility between the ears, consequently, listeners report having a “better” or preferred ear for listening. Previous work has suggested that causes of asymmetry include differences between the ears in surgical electrode placement, neural survival, and hearing loss etiology. The functional implications of asymmetry are not well understood.

This study aimed to investigate the effect of across-ear speech asymmetry in BiCI users on two outcomes: 1) bilateral speech intelligibility and 2) listening effort. The secondary aim was to explore potential causes of asymmetry by simulating factors that are thought to contribute to variable speech understanding abilities in CI users and presenting these degraded stimuli to normal hearing (NH) adults.

Both BiCI and NH adults listened to female-talker IEEE sentences. BiCI users listened to speech stimuli from a loudspeaker located at 0° azimuth in quiet, while NH adults were tested using spectrally degraded stimuli over headphones. The type of spectral degradation was either the same across the ears, or varied across the ears to create asymmetry. Participants were tested under three listening conditions: better-ear only, poorer-ear only, and bilateral. Listeners were instructed to attend to the talker and repeat the sentence that was heard. Speech intelligibility was measured as the percentage of correctly repeated words. Listening effort was quantified by measuring pupil dilation (reported as proportion change from baseline), where larger dilation is interpreted as greater task engagement or cognitive load.

Results from 11 BiCI users revealed that, in the poorer-ear only condition, speech intelligibility scores were lowest (average 66.4%) and pupil dilation was largest (proportional change: 0.370). Speech intelligibility was equivalent for the better-ear and bilateral conditions (average 86.2% and 86.3%, respectively). However, the bilateral condition elicited slightly greater change in pupil dilation (better-ear: 0.315; bilateral: 0.336). Speech asymmetry across ears ranged from 0-55% (average 20.3%). Degree of asymmetry was not related to pupil dilation in the bilateral condition. However, larger asymmetries were associated with lower speech intelligibility in the bilateral condition. Results from NH participants will help us better understand how specific types of signal degradation contribute to speech asymmetry, bilateral performance, and listening effort.

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TH33: THE IMPACT OF PITCH CUES ON LISTENING EFFORT IN A WORD RECALL TASK FOR NORMALLY HEARING AND COCHLEAR IMPLANTED LISTENERS

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Background: Although cochlear implant (CI) recipients derive some benefit regarding speech recognition in quiet, large individual differences exist in both speech performance and life quality which are not well understood. Specifically, CIs do not transmit salient voice pitch cues due in part to the envelope-based coding strategies. This limits CI users' performance on various tasks, such as music and speech-in-noise perception, prosody and speaker recognition, and competing speakers' segregation. Furthermore, impoverished pitch cues may require CI users to invest additional cognitive effort during the ongoing auditory stream to map the degraded inputs to the phonological representations stored in their memory. Therefore, we hypothesize that the poor pitch fidelity of current CIs can result in increased cognitive load when processing single words, relative to listeners with normal hearing (NH), as well as reductions in short-term storage.

Methods: Materials were either French or English words, whose F0 was manipulated in 4 conditions: 1) naturally intonated, 2) monotonized, 3) exaggerated, and 4) inverted. CI users and age-matched NH participants (always listening in their native language) wore eye-tracking glasses that recorded gaze and pupil size throughout the experiment. After auditory presentation of each word, participants were required to repeat the word verbally to the experimenter who typed it. At the end of a 10-word list, participants were required either to recall as many words as possible from the previous 10 words (regardless of order), or to move on to the next list (no-recall condition). Each of the eight experimental conditions was repeated three times, resulting in 24 blocks. Participants also gave a subjective score (1-10) regarding the effort spent at the end of each block.

Results: Among NH listeners, intelligibility of monotonized and inverted words was slightly impaired, but the recall was similar (6-7 words) across the four pitch manipulations, exhibiting a typical primacy/recency pattern. Subjective scores simply reflected the greater effort spent in recall blocks versus no-recall blocks, regardless of pitch manipulations. Pupil traces were overall higher for recall than no-recall blocks, a difference that emerged progressively over the first 4 words of a list, and depended on the number of words recalled. Pupil traces exhibited a first peak about 1.3 sec after word onset, which was more pronounced for monotonized and inverted conditions. At the onset of recall, pupil size increased by as much as 0.3 mm across all pitch manipulations. Results among CI users will be presented and discussed at the meeting.

Conclusion: Both the magnitude and the temporal dynamics of pupillary response differ greatly in sustained listening condition than in a single task, urging for more pupillometry studies in realistic listening situations. This project will present a comprehensive picture of the elevated listening effort experienced by CI users, its impact on their cognitive abilities, and highlights the need for improving pitch coding in CI devices.

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TH34: USING OBJECTIVE MEASURES TO REVEAL LISTENING EFFORT IN COCHLEAR IMPLANT LISTENERS

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Cochlear implants (CIs) help restore speech perception in people who have severe-to-profound hearing loss in one, or both, ears. However, the CI input is degraded and thus more challenging to understand than acoustic input in normal hearing. What is not well-understood is how effortful listening is with CIs. In this work, we investigate two objective measures that can hopefully shed light on this question. The first measure is of cortical activity using functional near-infrared spectroscopy (fNIRS). This is a non-invasive method, whereby near-infrared light is used to measure neural activity related changes in oxygen matablosim in the blood flow. fNIRS responses are examined in the a-priori determined brain region of interest (ROI). In this work, we focused on the bilateral inferior frontal gyrus (IFG), because other neuroimaging studies have identified that region as being involved in effortful listening. The second measure is task-evoked pupillometry. Previous work has shown that changes in pupil dilation correlate with task engagement and listening effort. The purpose of this study is to conduct measures from fNIRS and pupillometry in separate sessions, using similar tasks, to understand whether these measures reveal similar findings regarding listening effort across different hearing conditions.

The study design is to test CI users while listening to speech sentences in quiet. Normal-hearing (NH) participants are tested with vocoded speech. To increase task difficulty, two stimulus variables are manipulated in which the sentence structure and difficulty levels are varied.

This study aims to test the hypothesis that two measures of listening effort, fNIRS in IFGs, and Pupillometry, while listeners are engaged in similar tasks, would show consistent pattern of responses between different hearing conditions.

TH35: INVESTIGATION OF DYNAMIC METRICS AND PUPILLOMETRY DATA IN TARGET LOCALIZATION TRAINING WITH BICI SIMULATION IN A VR ENVIRONMENT

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While cochlear implantation has helped restoring auditory sensation in patients to reenable comminucation, some abilities such as source localization remain low, especially in the case of unilateral implantation as the implantee cannot benefit from binaural processing which can also affect speech understanding in noisy conditions.

In the case of bilateral implantation, it becomes possible to benefit from the binaural differences, however the outcomes remain poorer than those of normal hearing listener. Indeed numerous aspects of the surgery, coding strategies and hardware limitations, such as frequency mismatch between implants, reduced spatial range and precision, less precise processors' directionality and low synchronisation have an impact on localization performances.

To design and test new algorithms enhancing source localization, Oticon Medical platforms were used to create a testing environment with the use of virtual reality (VR) setup, consisting in an HTC Vive head-mounted display, and real time sound processing which could easily be reproduced in most contexts with very few constraints. The procedure involved 9 normal hearing test participants and cochlear implant hearing senstion was conveyed using a vocoder. A processor head-related transfer functions was applied to the signal as the VR headset provided the necessary information. Three different algorithms were tested: one with fixed and null interaural time differences (ITD), a second one with ITD and a third one with ITD and a coloration of sounds coming from behind (see "A VR-based Environment Enabling BiCI Spatial Sound Research - Development and experimental verification").

Source localization performance was first assessed, then followed 4 training sessions. Finally a post-training test was run in the same condition as the pre-training one: 100 trials were executed. One trial consisted in localizing, in maximum 14 seconds, a virtual source playing a broadband signal. While the trials were blind during the pre- and post-training, after each training trials, a visual feedback was provided.

The VR setup enabled to explore techniques to improve spatial tasks and evaluate the algorithms. As it provided position, dynamic metrics such as traveled angular distance and time to confidence were also computed. Pupil dilation was recorded during the pre- and post-training sessions in order to monitor cognitive load, this imposed an additional 4-second fixation time with the source playing to the trial.

While most participants improved their localization skills, pupillometry results show an increase of the peak pupil dilation (PPD) before and after training while it was expected for the peak pupil dilation to be lower after the training. This was the case for the first two conditions, implying that from the onset of the source, participants gathered and processed more information. However, for the third condition, the pupil dilation steadily decreased during the fixation period. After discussing with the concerned subjects, this suggests that they did not use the training to improve their spatial research skills from the onset of the source, but only once they could move in the virtual environment. The measured dynamic metrics were also investigated and links with the pupillometry were considered.

TH36: DECREASED WORKING MEMORY CAPACITY IN CI USERS TESTED IN A VISUAL TASK IN SILENCE AND NOISE

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Introduction: Verbal short-term memory is disturbed by certain background sounds (irrelevant sound effect, ISE). ISE is an empirically established phenomenon and occurs even when backgrounds sounds are irrelevant to a task and are ignored. A multitude of studies in normal hearing listeners have explored the sound characteristics for an ISE to be elicited. Up to now, this effect was not investigated in users of cochlear implants (CIs).

Method: 12 subjects with bilateral CIs (mean age: 26.3±7 yrs) and an age-matched control group of 19 normal hearing participants (NH, mean age: 28.2± 3.8 yrs) took part in the study. The standard task for measuring verbal short-term memory capacity, and thus for ISE exploration, is verbal serial recall. In the present study, unrelated verbal items (digits) were visually presented in succession and had to be recalled afterwards in the exact presentation order. The irrelevant background sound was presented at 65 dB SPL in free-field.
This task was completed 20 times per test condition. Test conditions were silence, continuous and amplitude-modulated noise, international speech transmission signal (ISTS) and a Japanese speaker (JS). Mean error rate (MER) was assessed for each stimulus. The ISE is defined as the individual performance decrement during a given background sound as compared with performance during silence.

Results: In the normal hearing group, MER in silence was 24.6±13%. This group showed no ISE in continuous and modulated noise. ISE in ISTS was 13.1% (p=0.001) and in JS 6.7% (p=0.028). In the CI group, MER in silence was 34.8±17%. CI users showed no ISE in continuous noise. In modulated noise, an ISE of 9.3% (p=0.035) was found. Highest ISEs were found in ISTS (15.6%, p=0.001) and in JS (8.7%, p=0.040). There was a significant effect of subject group in MER (p=0.008). Even in silence, CI users' MER was 10.2% higher compared with NH subjects. There was no significant effect of subject group in ISE.

Discussion: This is the first study that demonstrates the presence of an ISE in CI users. ISE of CI users was generally in the same range than in NH users. However, even in silence the performance in a visual serial recall task was severely degraded presumably due to a higher cognitive load and alertness to auditory stimuli.

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TH37: RELATION BETWEEN SUBJECTIVE LISTENING EFFORT AND SPEECH INTELLIGIBILITY IN CI USERS

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The usage of hearing devices can result in a relief of listening effort. This study evaluated whether the adaptive categorical listening effort scaling (ACALES, Krueger et al, 2017), a method to assess subjective listening effort (LE) in the laboratory, could be conducted with CI users to investigate the benefit of bilateral versus unilateral hearing device provision in bimodal or bilateral cochlear implant (CI) listeners and compare these results with speech intelligibility measures.

In the ACALES method, the signal-to-noise ratio (SNR) is varied adaptively to adjust the SNR range to the individual ratings using a 14-step scale from “effortless” to “extreme effort”, including the additional category “only noise”. The resulting listening effort rating functions for different conditions – e.g., one hearing device vs two - can be compared to assess possible release from LE for one of the conditions. The ACALES results were obtained for quiet and two different maskers (the stationary Olnoise and the fluctuating IFFM noise) with either 1) only the CI or one CI (better ear) active, in bimodal or bilateral CI-listeners, respectively, or with 2) both devices active. Additionally, free field audiograms with and without hearing devices were determined as well as speech intelligibility (SI) functions for quiet, Olnoise and IFFM noise with the Oldenburg sentence test in noise (OLSA). Further, questionnaires inquiring sound preferences and hearing habits (SP-HHQ, German translation) and subjective LE were used.

The results show that ACALES is able to measure and identify different benefits in LE for a bilateral and a bimodal provision compared to unilateral provision. The results show that SI increases with increasing SNR whereas LE is decreasing. LE ratings as well as SI scores depended on the masker. Results for the different provision conditions for the two maskers indicate a benefit of a provision with two devices (CI+HA or two CIs) in comparison to only the/one CI for SI. On the other hand, the listening effort results reveal two groups. Group A has a benefit in speech intelligibility but no reduction in listening effort. Group B, on the other hand, shows a benefit in both speech intelligibility and listening effort. Overall it can be concluded that listening effort and speech intelligibility are two different factors and both together might help to understand the problems and needs of CI users.

References:
Krueger, M., Schulte, M., Zokoll, M.A., Wagener, H.C., Meis, M., Brand, T., Holube, I. (2017). Relation between listening effort and speech intelligibility in noise. American Journal of Audiology, Vol. 26, 378-392.

TH38: THE EFFECT OF SPEAKING RATE ON CI USERS' LISTENING EFFORT AND ACCESS TO SENTENCE CONTEXT

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Slowing speaking rate is a well-known way to improve speech intelligibility in people with hearing loss, including those who use cochlear implants (CIs). In this study we explore whether reduced speech rate reduces listening effort, specifically via enabling better access to semantic context cues while an utterance is heard. Contextual cues play an important role in successful speech perception by CI listeners, by increasing intelligibility and reducing listening effort. For example, higher performance and less effort is expected for "The dog chewed on a bone" compared to "Alan talked about the bone."

Some physiological evidence and numerous patient anecdotal reports suggest that CI users use context rather late, to retroactively correct mistakes that might occur during perception of a sentence. This puts the listener at risk for missing the next utterance, and puts the experimenter and clinician at risk for overestimating a patient's success in the real world where utterances are not heard one at a time. This study explored whether slower speaking rate would enable CI listeners to access context before the end of the sentence, thereby reducing the risk of missing the next utterance. The quickness of the use of context was assessed by measuring the time at which reduction in pupil size for high context sentences (relative to low-context sentences) could be observed in data averaged for 25 sentences per context type per speaking rate.

Results were highly variable across participants, with some showing earlier signatures of context benefit with slower speech rate, and others showing no appreciable differences. To date, no listener has shown reduced context benefit at slower speaking rates. All listeners showed shallower slope of pupil dilation for slower sentences, demonstrating intentional allocation of cognitive resources appropriate for the expected time spent listening. The lack of quicker access to context for slowing speaking rate might be due to a well-practiced disposition of CI listeners to wait until the end of an utterance before engaging in full language processing.

TH39: DISRUPTION OF THE BENEFIT OF SENTENCE CONTEXT IN LISTENERS WITH COCHLEAR IMPLANTS

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Hearing loss may lead not only to decreased speech intelligibility, but may also alter when listeners utilize cues such as semantic context. For example, when asked to repeat sentences, listeners with cochlear implants appear to use semantic context retroactively in order to correct for perceptual ambiguity in what was heard. Moreover, results from pupillometry studies suggest that the cognitive load remains high even after a sentence is presented. This suggests that the short time period after a sentence may be crucial for optimal use of semantic context in listeners with cochlear implants. Here, we address this question by measuring the benefit of context, and whether those benefits are reduced when additional stimuli are presented in that time period immediately after a sentence is presented. We presented recipients of cochlear implants with both high and low-context sentences followed by the presence of silence, noise, or words. Preliminary results suggest that CI listeners have reduced benefit of context when test sentences are followed by babble noise or words, compared to when sentences are followed by an equivalent amount of time in silence. These results suggest that real-world use of semantic processing may be disrupted as sentences are typically followed by noise or more utterances during everyday communication. This in turn may contribute to the increased listening effort reported by many recipients of cochlear implants when listening in their daily environment.

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TH40: SEMANTIC CUE AND EAR EFFECTS ON PERCEPTUAL RESTORATION OF SPEECH IN ADULT COCHLEAR-IMPLANT USERS

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For cochlear-implant (CI) users, understanding speech in noise is the most often-reported difficulty. Previous research has shown that though intermittent noise can disrupt understanding of a spoken sentence, normal-hearing listeners repair and accurately interpret interrupted speech via a speech-repair mechanism called “perceptual restoration.” This mechanism is believed to be the result of an interaction between high-quality bottom-up acoustic information and top-down linguistic knowledge and contextual expectations. Perceptual restoration produces the sensation that the speech continues intact through the interrupting noise burst, an illusion that contributes to improved speech understanding beyond that which is obtained with speech interrupted with silent gaps. Some CI users have previously been shown to have atypical perceptual restoration ability, potentially due to the poor-quality bottom-up acoustic information they receive via their processors. We hypothesized that providing a semantic cue prior to a sentence could bolster the application of top-down linguistic information to a poor-quality signal, and thus increase restoration in CI users.

Bilateral CI users were presented either silent-gap interrupted or noise-burst interrupted sentences via their sound processors. Speech was interrupted at a 5-Hz rate and 80% duty cycle at -10-dB SNR. Text was presented visually prior to each sentence, either semantically-related to the upcoming sentence (e.g., “FISH”) or containing no semantic information (e.g., “XXXX”) to examine the effects of semantic cues on perceptual restoration. In addition, each ear was tested separately, allowing for analysis of ear effects (which may vary in their quality of encoded bottom-up acoustic information).

Preliminary data in 8 participants show that ears with overall poor performance (<15% words correct across the study) showed no restoration: performance with silent-gap interrupted speech was higher than with noise-burst interrupted speech. Ears with overall mid-range performance (20-40% words correct) showed an average 10% restoration benefit with semantic cues and 0.9% benefit without semantic cues: performance was higher with noise-interrupted speech than with silent-gap interrupted speech. Ears with high performance (>40% words correct) showed no restoration. Thus, only participants with ears with mid-range performance showed perceptual restoration, with the strongest effects seen when semantic cues were available.

These data suggest that some CI users may experience perceptual restoration similarly to what is reported for normal-hearing listeners, in that an interaction of bottom-up acoustic information and top-down linguistic information may boost speech repair with noise-interrupted sentences. However, this interaction is less possible with very poor-performing ears and, possibly, high-performing ears, suggesting that CI users may often be unable to repair speech via restoration. Planned analyses of the impact of cognitive and vocabulary factors may improve our understanding of the interplay between bottom-up and top-down mechanisms in perceptual restoration in CI users.

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TH41: PERCEPTUAL ADAPTATION TO FORMANT CHANGES ASSOCIATED WITH VOWEL CATEGORIES OR VOCAL TRACT LENGTH: IMPLICATIONS FOR SPEECH PERCEPTION IN COCHLEAR IMPLANT USERS.

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Background: Perceptual analysis of speech requires processing two complementary and parallel dimensions. On one side, various acoustic parameters provide access to information about voice properties (vocal characteristics, speaker identity, gender, emotional state...). On the other side, listeners process sounds into phonological categories (phonemic classes / distinctive features). These two dimensions interact strongly in both speech production and perception. For speakers with different vocal tract lengths (VTLs), a shorter VTL would be associated with higher formant frequencies overall. Similarly, a single speaker contrasting the vowels /o/~/u/ would lower both the first and second formants by changing the shape of one's own vocal tract. Evidence for speaker adaptation in speech perception was first provided by Ladefoged & Broadbent (1957), and later confirmed by Sjerps et al. (2013). They showed that systematic shifts of the formant frequencies in the initial part of a sentence affect the interpretation of the following vowel. For example, in the sentence "Please say this word again: bet", increasing the frequency of the first formant (F1) on the initial sentence (excluding the final word) leads listeners to identify the final word as "bit" rather than "bet". It has also been shown that variations in individual voices can significantly hinder performance for speech identification tasks in the laboratory (Goldinger, 1996). According to Chang & Fu (2006), both cochlear-implant (CI) users performance and vocoded-speech perception in normal hearing (NH) listeners are particularly affected by multi-speaker conditions. As stated by Chang & Fu (2006), "acoustic variations among talkers may be confused with acoustic differences between phonemes" as a consequence of CI low spectro-temporal resolution. However, as originally observed by Ladefoged & Broadbent (1957), phonological changes induced by voice properties are not necessarily detrimental: they also form a basic mechanism which is perfectly adapted for speech perception in natural conditions.

Method: In order to get a better understanding of how effects of perceptual adaptation to voice variation influence the perception of vocoded speech, a partial replication of the seminal study by Ladefoged & Broadbent (1957) has been conceived. A set of 15 Dutch monosyllabic word-pairs were selected and recordings were collected from 2 speakers (1 male, 1 female). For each vowel contrast (word pairs), an acoustic continuum was computationally generated on the basis of the actual formant frequencies (F1/F2/F3). Each word on this continuum was concatenated at the end of a short fixed carrier sentence (eng. tr.: "Please say what this word is:"). The carrier sentence was submitted to various acoustic manipulations (changes in F1 frequency alone, in the F1/F2/F3 plane along the continuum dimension, and in VTL). All modifications were equal in size (±5 semitones) and paralleled with an unmodified condition. In a "natural-speech" experiment we investigate how perception of the vowel continuum is differently impacted by the 3 modification types (F1, F1/F2/F3, VTL). In the "vocoded-speech" experiment, we compare the effects of these manipulations with their "natural-speech" counterpart.

The results are currently being collected. Our hypotheses are that natural speech stimuli should give rise to context adaptation in all 3 conditions but that VTL changes should affect perception only when they are performed on a dimension that is compatible with an appropriate phonetic interpretation of the continuum. When using vocoded speech, our expectations are that adaptation effects will either be reduced or suppressed for the various manipulation types but that exact patterns of alteration should depend on whether adaptation is induced by independent (phonologically-based) formant changes or by consistent (VTL-related) formant manipulations. The observed results should therefore inform us about which mechanisms are precisely involved in processing speech variation. Moreover, they will provide heuristics for understanding how cochlear-implant users process this variability.

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TH42: FOREIGN-ACCENTED SPEECH PERCEPTION BY COCHLEAR IMPLANT USERS: EFFECTS OF TALKER VARIABILITY

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Compared to normal hearing (NH) listeners, cochlear implant (CI) users have more difficulty with talker variability and with perception of foreign-accented speech. However, the extent to which foreign-accented speech is affected by talker variability remains unclear. The present study addresses this question by testing (1) whether CI users have more difficulty than NH listeners in identifying foreign-accented talkers, and (2) whether talker variability disproportionately impairs CI perception of foreign-accented speech.

We assessed CI users' abilities to detect whether a talker was native- or foreign-accented and compared their results to NH controls. Listeners heard 20 randomly presented sentences spoken by five native talkers of American English and five Mandarin-accented talkers (two sentences per talker). Following each sentence, listeners selected whether the sentence was spoken by a native- or a foreign-accented talker. Our preliminary results show that accent detection was less accurate and more variable for CI users compared to NH listeners.

We also compared CI users' perception of foreign-accented sentences in single- and multiple-talker conditions to NH listeners presented with 9-channel tone-vocoded sentences or unprocessed speech. Each group heard 40 sentences (presented randomly and sequentially) spoken by either five different Mandarin-accented talkers or by a single talker (randomly selected from the aforementioned five Mandarin-accented talkers). Preliminary results indicate that intelligibility was the lowest for CI users, higher for NH listeners perceiving vocoded speech, and the highest for NH listeners perceiving unprocessed speech. The multiple-talker condition further reduced performance compared to the single-talker condition.

These combined results suggest that, compared to NH listeners, CI users face more difficulty in perceiving foreign-accented speech, and this difficulty is further accentuated by talker variability. These difficulties facing CI users are likely due to their limited access to voice pitch and other fine structure cues that are specific to each talker. The present results are important considering the increasing interactions between native and foreign-accented talkers in everyday life.

TH43: THE "TWO-SENTENCE PROBLEM": COMMUNICATION REQUIRES UNDERSTANDING SPEECH BLOCKS LONGER THAN A SINGLE SENTENCE

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Many cochlear implant (CI) users who do quite well in standard clinical tests of speech perception report that a great amount of effort is required when listening in real-world situations. We hypothesize that the combined constraints of the sharply degraded signal provided by a CI and finite cognitive resources may lead to a "tipping point" when listeners are confronted with complex sentences or with continuous discourse arriving at normally rapid speech rates, instead of the single words or single sentences that are used in clinical tests. Beyond this tipping point, communication may become too difficult, even for CI recipients whose standard speech intelligibility scores are above average. This study explores the tipping point hypothesis in one specific scenario: the "two-sentence problem". The question is whether speech identification performance is affected when two sentences are presented sequentially before requesting a subject response, instead of doing it one sentence at a time.

We tested 15 CI users (average age: 53, range: 20 to 78 years). Those who had residual hearing were tested in the CI-only condition through direct audio input. The testing material included AzBio sentence lists (presented in quiet) that are not normally used in standard clinical testing. There were three conditions: hear-and-recall a single sentence, hear-and-recall a sequence of two-sentences, and a two-sentence/repeat-one condition, where subjects heard two sentences and then were randomly prompted to repeat either the first or the second sentence. Speech perception accuracy was measured at the word level.

On average, the single sentence condition yielded the highest percentage correct (83%), followed by the two-sentence condition (71%), and then the two sentence/repeat one condition (67%). In other words, the error rate was almost doubled in the two- sentence/repeat one condition with respect to the one-sentence condition. Normal hearing controls typically scored close to ceiling under all conditions. Taken together, these results suggest that speech perception in CI users may be quite fragile, even in the face or relatively minor manipulations that only represent a small fraction of the complexity encountered in real-world situations. The present pilot results will be discussed in the context of a more comprehensive experiment that will include additional conditions as well as simultaneous pupil dilation data.

TH44: WORD AND NONWORD READING FLUENCY IN POSTLINGUALLY DEAF ADULT COCHLEAR IMPLANT USERS

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Cochlear implants (CIs) have been very successful in restoring hearing and improving speech recognition in many profoundly deaf adults. However, a great deal of unexplained variability in speech recognition outcomes is still widely observed in this clinical population. Traditional demographic factors have been found to account for some variability in outcomes, but our knowledge of the underlying information processing mechanisms that contribute to outcomes is limited. Previous research has suggested that weak phonological processing skills contribute to poor speech recognition outcomes, and may be influenced by the deterioration of robust phonological representations during long periods of hearing loss (HL). Impaired phonological processing may also be reflected in measures of reading fluency; hearing-impaired (HI) individuals may be less able to take advantage of grapheme-phoneme correspondences in building stable phonological representations in verbal short-term memory from written words. As such, non-auditory measures of lexical or phonological processing may be helpful in predicting outcomes in CI users who rely upon degraded auditory input.

The current study investigated reading fluency in adult, postlingually deafened experienced CI users (ECIs) and older, normal-hearing listeners (ONHs), using the Test of Word Reading Efficiency (TOWRE-2) task. The TOWRE-2 is a timed measure of rapid sight word reading (word subtest) and phonological decoding (nonword subtest). One goal of the study was to determine the extent to which lexical and phonological processing, measured via the timed word and nonword reading scores, respectively, are affected by HL and CI use. A second goal was to assess the relations between timed word and nonword reading on the Towre-2 task and additional non-auditory and auditory measures (untimed word reading, vocabulary size, spectral resolution, visual perceptual closure, and auditory sentence recognition - in quiet for ECIs, vocoded for ONHs). We also examined traditional demographic factors (e.g., duration of deafness). Results demonstrated that ECIs showed significantly poorer timed word reading scores than ONHs, but no differences were found in timed nonword reading. In the ECIs, timed word and nonword scores were strongly correlated with each other and with untimed reading skills. Similarly, CI users' timed word and nonword reading scores were found to be related to vocabulary size, spectral resolution, and visual perceptual closure, while these measures were more strongly correlated with timed nonword reading scores for the ONHs. Sentence recognition scores were related to timed word reading scores in CI users, but timed nonword reading scores in ONH listeners. Demographic factors were not related to either TOWRE-2 scores in ECIs.

Findings indicate that ECIs displayed slower lexical access speed than ONHs. The broad pattern of correlations between both TOWRE-2 scores and the additional measures suggest that ECIs are less flexible in using lexical and/or phonological strategies in reading. Further, for ECIs, speed of lexical access from degraded speech signals may be crucial for successful speech recognition, while for ONHs, adaptation to vocoded speech may rely on tuning and readjustment at the phonological level. These findings suggest that CI use may help to restore compromised phonological representations. In contrast, how lexical items are accessed and organized in memory may be altered by listening to degraded speech signals. Alternatively, despite long-term acquired HL, some ECIs may have maintained stronger phonological representations through visual-based phonological processing (lip-reading). Therefore, a necessary next step is to assess reading fluency in CI candidates pre-operatively and measure changes that occur after implantation. Additional research examining how non-auditory information processing skills relate to auditory speech recognition will provide new fundamental knowledge of the core foundational information-processing factors that underlie individual differences in CI outcomes.

TH45: EFFECTS OF SPECTRAL RESOLUTION OF AUDITORY FEEDBACK ON VOWEL PRODUCTION

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Studies have shown that auditory feedback plays an important role in speech motor control and that the brain continuously monitors speech output to ensure intelligible and accurate speech production. For cochlear implant (CI) users, their auditory feedback is greatly degraded in spectral and temporal resolution, which may have both long- and short-term effects on speech production. This study investigated the effects of spectral resolution of auditory feedback on vowel production in normal-hearing (NH) listeners, with the goal to identify acoustic features of vowel production that may be sensitive to the spectral resolution of auditory feedback.

The classical off-line noise vocoder for CI simulation was implemented with a frame size of 5.3 ms using the real-time signal processing toolbox in Matlab. NH listeners' AzBio sentence recognition in quiet with the off-line and real-time noise vocoders with 1, 2, 4 and 8 channels was tested for comparison. In pre-test with the original unprocessed auditory feedback, NH subjects were familiarized with the testing procedure and were asked to produce "head" and "had" 15 times in random order, which were used to create a 5-step continuum of "head"-"had". After the pre-test, five experimental conditions with the original unprocessed, 1-, 2-, 4-, and 8-channel noise-vocoded auditory feedback were tested in random order. The vowel production test with each experimental condition was always preceded by a vowel production test with the baseline 1-channel noise-vocoded auditory feedback. In each vowel production test, subjects were asked to produce "heed", "hid", "head", "had", "hod", "hood", and "who'd" 15 times in random order. For vowel perception test, the "head"-"had" continuum was tested 10 times in random order with the experimental condition.

AzBio sentence recognition with the real-time noise vocoders was similar to that with the off-line noise vocoders and both significantly improved with the number of channels. Psychometric functions of the identification of "head"-"had" continuum showed a steep "S" shape only in the original unprocessed and 8-channel noise-vocoded conditions. Fundamental frequencies, formant frequencies, intensities, and durations of vowels produced in each experimental condition did not show consistent changes relative to those in the base-line 1-channel noise-vocoded condition for individual subjects, possibly due to the short exposure to each experimental condition.

Future studies providing longer exposure to experimental conditions and focusing on the production of supra-segmental speech features are needed to further test the effects of spectral resolution of auditory feedback on speech production. The real-time noise vocoder developed in this study allowed for the manipulation of many other parameters including but not limited to the temporal envelope cutoff frequency, frequency mismatch between analysis and synthesis filters, and residual low-frequency acoustic hearing. Results of future studies may indicate the potential of using speech production to evaluate the effects of different CI processing strategies and clinical maps.

TH46: DEVELOPMENT OF AN fNIRS-BASED OBJECTIVE MEASURE OF SPEECH PERCEPTION IN PAEDIATRIC COCHLEAR IMPLANT RECIPIENTS

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Paediatric cochlear implant (CI) users with poor speech perception could be identified from their brain responses to speech earlier than is currently possible with behavioural assessments. In an ongoing study, we are investigating cortical responses to a range of auditory and visual stimuli in CI recipients with good or poor speech perception skills. We are exploring whether some CI users have poor speech skills due to cross-modal activation of auditory brain regions by visual speech or due to an inability to decipher between intelligible and unintelligible auditory stimuli. This research uses functional near-infrared spectroscopy (fNIRS), an optical neuroimaging technique that is safe for repeated use with CI users of all ages.

Children aged 6-12 years with bilateral CIs underwent fNIRS neuroimaging (n=10 tested to date). Normal speech, signal-correlated noise, steady speech-shaped noise and visual speech were presented in an event-related format. Brain activity was measured using 18 optodes arranged in two 3 x 3 arrays, targeting both cerebral hemispheres. Children also completed automated speech perception testing in quiet and noise.

We will calculate the group-averaged beta weight contrasts for each measurement channel across both hemispheres. We hypothesise that, compared with poor CI users, CI users with good speech perception scores will have: (i) greater activation in superior temporal brain regions in response to normal speech than visual speech; (ii) greater activation in posterior temporal brain regions in response to normal speech than signal-correlated noise, and (iii) greater activation in superior temporal brain regions in response to signal-correlated noise than steady speech-shaped noise.

This study extends our ongoing work that aims to develop an fNIRS-based objective measure to evaluate speech perception in paediatric CI recipients. By investigating the relationship between how well CI users can perceive speech and their cortical responses to modulated vs. unmodulated, intelligible vs. unintelligible and auditory vs. visual stimuli, we can not only learn about which stimulus combinations offer the greatest functional contrast between good and poor CI users, but also explore cortical mechanisms that may influence CI outcome. This work is supported by an Action on Hearing loss and Cochlear Ltd. PhD studentship to the first author, and the NIHR.

TH47: CROSS-MODAL ACTIVITY IN AUDITORY AND VISUAL CORTICES AND SPEECH RECOGNITION OUTCOMES IN POST-LINGUAL COCHLEAR IMPLANT USERS: A FUNCTIONAL NEAR-INFRARED SPECTROSCOPY (fNIRS) STUDY

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Introduction: Cortical reorganisation as a result of deafness has been proposed as a potential contributor to variability in cochlear implant (CI) outcomes. Specifically, cross-modal activity in auditory and visual cortices has been shown to correlate with auditory-only speech understanding in post-lingually deaf CI users. However, it remains unclear whether these associations are adaptive' or 'maladaptive' for functional outcome, with varied associations reported. Importantly, there has been variability across studies in the types of visual and auditory stimuli used, e.g. ‘basic’, such as gratings and noise, vs. ‘speech-based’ visual and auditory stimuli, which are likely to engage different cortical networks. Furthermore, as speech is inherently multisensory, it is of interest to understand whether these adaptations may relate to audiovisual speech processing. This study therefore aimed to 1) examine cross-modal cortical activations to both basic and speech-based visual and auditory stimuli in the same cohort of post-lingually deaf CI users, aged 50-75 (n=20) and a group of age-matched, normally-hearing controls (n=20), and 2) investigate whether the type of visual stimulus (basic vs. speech) used to examine cross-modal activation influences the relationship with speech recognition measures in an auditory-only, visual-only and audiovisual condition.

Methods: fNIRS was employed as a non-invasive technique, which is not susceptible to electrical or magnetic artifacts common to other neuroimaging methods such as EEG and fMRI. Two test paradigms were administered in a block design, using 1) basic auditory and visual stimuli - modulated speech-shaped noise and morphing concentric gratings, and 2) speech stimuli - concatenated IEEE sentences presented in an auditory-only and a visual-only condition. Responses were measured via optode arrays positioned bilaterally over auditory and visual regions of interest (ROIs). Speech recognition performance on IEEE sentences was assessed in an auditory-only, visual-only and audiovisual condition. Relevant cognitive abilities were also assessed using a visual-based, computerized test battery.

Results: Preliminary analysis of grand-average time-course data of haemodynamic responses from 16 normally-hearing control subjects shows evidence of intra-modal and cross-modal activations to both basic and speech-based stimuli in auditory and visual ROIs. Analysis of time-course data from 8 CI users at the individual level also shows evidence of intramodal and cross-modal activations to both stimuli. Further ROI analysis of fNIRS data using a general linear model (GLM) will be performed for both control and CI groups. We will present our findings examining reported associations between cross-modal activity to both types of visual and auditory stimuli and speech recognition in auditory-only, visual-only and audiovisual conditions.

Conclusions: Preliminary findings show evidence of cross-modal activity in both CI users and control subjects. Understanding how cortical activity may relate to functional speech outcomes could enable more targeted interventions to be developed to optimise auditory rehabilitation or better predict outcomes after cochlear implantation.

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TH48: USE OF fNIRS FOR OBJECTIVE PROGRAMMING OF COCHLEAR IMPLANTS

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Background. A totally objective and reliable method to program a cochlear implant (CI) is crucially needed in the CI clinic, especially for infants. Standard ECAP measures alone have proven inadequate for this purpose, while cortical measures such as cortical auditory evoked potentials show more promise but are inefficient. Our earlier published work with normal-hearing adults showed that hearing thresholds and comfortably-loud levels could be estimated using functional near-infrared spectroscopy (fNIRS) responses.

Objective. In this study we extend this work to develop an objective method to program a CI using fNIRS.

Methods. Adults with existing CIs participated and were imaged while listening to tones via direct audio-input into a calibrated research processor to objectively estimate T and C levels. The estimates were compared with the behaviourally-determined T and C levels. fNIRS responses were recorded in the bilateral auditory and pre-frontal cortices.

Results and conclusions. The fNIRS response is easy to measure in CI users and is not subject to electrical artefacts. Preliminary data with CI users are consistent with our earlier work using acoustic stimuli in normal and hearing impaired adults and children, and shows promise for objective programming of CIs.

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TH49: USE OF fNIRS FOR IMPROVED PROGNOSIS FOR COCHLEAR IMPLANT CANDIDATES

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Background

The large variability in speech understanding by adult cochlear implant (CI) users remains a challenge in spite of technical advances. Only around 10% of this variability can be explained by subject factors such as duration of deafness. Recent brain imaging research suggests that plastic changes in the cortex due to auditory deprivation may play a crucial role in CI outcomes.

Objective. This study used functional near-infrared spectroscopy (fNIRS) in a longitudinal study in adult CI candidates to determine how brain plastic changes due to periods of deafness and due to re-activation of the auditory pathways after implantation influence speech understanding outcomes.

Methods. 20 adult CI candidates were imaged before implantation and at 1, 3, and 12 months post-implantation while listening to speech, or speech-reading. Speech perception tests were carried out at the same times and a cognitive assessment performed.

Results. Preliminary results indicate that the pattern of activation of the auditory cortex by visual and auditory speech stimuli is correlated with speech understanding at 12 months post-implant. Furthermore, the changes of this pattern over time after implantation are correlated with changes in speech understanding.

Conclusions. fNIRS shows promise for improving prognosis before implantation and for investigating the reasons for poor recovery of speech understanding post-implantation in individuals. fNIRS can reveal significant changes in the function of the language-associated networks in the cortex, and these changes influence the ability to adapt to CI stimulation after implantation.

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TH50: CORTICAL CORRELATES OF SPEECH INTELLIGIBILITY MEASURED USING FUNCTIONAL NEAR-INFRARED SPECTROSCOPY (fNIRS)

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Aims: Cochlear implants (CIs) can partially restore hearing following severe-to-profound deafness, yet the ability of implanted patients to understand speech varies widely. Part of the reason for this variability may be differences in how well speech information provided through the CI is transmitted to the brain. We examined whether fNIRS, a non-invasive functional neuroimaging technique, can be used to obtain an objective and reliable measure of speech intelligibility in normally-hearing listeners.

Methods: In twenty-three normally-hearing adult participants we measured (1) fNIRS activation in the superior temporal, inferior frontal and inferior parietal cortex bilaterally and (2) behavioural speech intelligibility. Listeners heard noise-vocoded sentences targeting five equally spaced levels of intelligibility between 0 and 100% correct.

Results: A statistically significant positive linear relationship was identified between the strength of cortical activation in superior temporal regions and speech intelligibility. Superior temporal activation was also predictive of individual differences in intelligibility in a challenging listening condition. Beyond superior temporal cortex, we identified regions in which activation varied non-linearly with intelligibility. For example, in left inferior frontal cortex, activation peaked in response to heavily degraded, yet still somewhat intelligible, speech.

Conclusion: Our findings indicate that cortical responses measured with fNIRS correlate with behavioural measures of speech perception. fNIRS therefore has the potential to provide an objective measure of speech intelligibility in normally-hearing adult listeners. Should these results be found to apply similarly in the case of individuals listening through a CI, fNIRS would demonstrate potential for a clinically useful measure not only of speech intelligibility, but also of listening effort. We are currently in the process of analysing the behavioural and fNIRS neural correlates of speech intelligibility in a group of normally-hearing children. The paediatric population, especially those with a CI, is a cohort that would particularly benefit from an objective measure of speech understanding.

TH51: EVALUATING THE EFFECT OF FOCUSSED STIMULATION ON EXCITATION PATTERNS IN HUMANS AND CATS: PSYCHOPHYSICS AND DEVELOPMENT OF AN EEG PARADIGM

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The spread of current along the cochlea is one of the main factors limiting speech understanding for Cochlear Implant (CI) users. Animal physiological recordings suggest that tripolar stimulation can reduce such spread of current. However, attempts to use tripolar stimulation in human CI users have not shown such a clear and consistent advantage. This might be due to anatomical differences, but also differences in the methods, since some paradigms are not easily comparable across species. Here, we develop a paradigm to measure tripolar and monopolar excitation patterns in both humans and cats, for use with both psychophysics and EEG. The aim is to identify which factors are important for a large benefit of tripolar stimulation to be observed. In addition, by validating EEG methods against psychophysical data, we will develop an objective measure of selectivity that can be applied in animal experiments without the need for extensive training.

For the EEG, we measure the cortical Masked Onset Response (MOR) elicited by 50-ms probes in the presence and absence of different maskers. Forward-masking paradigms are not well suited for measuring the MOR, because the masker offset can also elicit a cortical response. We therefore use a simultaneous-masking paradigm. The paradigm was first validated in two groups of 12 normal-hearing human listeners and a group of 5 normal-hearing cats. For this validation, the probe was a 50-ms pure tone and we simulated tripolar and monopolar maskers with a 1/8th- and 1-octave band noise, respectively. Results showed a good agreement between psychophysical detection thresholds and the MOR in the human participants, and roughly similar MOR patterns between the humans and cats.

For the CI experiment, we investigate the excitation patterns of three different maskers: partial-tripolar, monopolar and a novel three-electrode “ralopirt” masker in which the current on the flanking and central electrodes have the same polarity, thereby broadening the excitation pattern. The masker is always a continuous pulse train at 400 pps presented on a given electrode X. The probe is a 50-ms, 400-pps partial-tripolar pulse train, shifted in time by 1.25 ms and presented on electrodes X-2, X-1, X, X+1 and X+2. We adjust the level of the masker to elicit the same detection threshold when both probe and masker are on electrode X. For the psychophysical task, we measure detection thresholds for masked and unmasked conditions. For the EEG, we measure the change in MOR for the masked condition, relative to the unmasked condition. In order to check for possible effects of facilitation, we present the masker and probe with all possible combination of leading-phase polarity.

Preliminary results with human CI users indicate no sign of facilitation, hence validating the use of a simultaneous-masking paradigm. They also show no evident differences between the psychophysical masked excitation patterns of the tripolar and monopolar maskers. We will compare psychophysical and EEG results in the same participants, and, in future, will obtain both psychophysical and EEG results in cats. This will allow us to determine the extent to which a large benefit of tripolar stimulation depends on methods, stimuli, and species.

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TH52: RECORDING EEG FROM COCHLEAR IMPLANT ELECTRODES

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Improvements in CI fitting are expected from objective audiometry, in which responses to auditory stimulation are collected without the need for active participation. Electroencephalography (EEG) is an essential tool to acquire such brain responses due to its high temporal resolution and relatively low cost. A key innovation towards objective audiometry with CIs is the ability to record EEG using the implant itself. This removes the need for scalp electrodes and enables chronic monitoring of the patient outside of the clinic. Current commercial CIs already have basic telemetry capabilities, but are limited to very short recording windows, which can only capture measures of the auditory periphery. Objective measures that capture auditory processing on the cortical level require longer recording windows, or even continuous recordings.

In this study, we recruited CI users with a percutaneous connector, providing direct access to the implanted electrodes. This allowed us to perform continuous EEG recordings from the implanted electrodes while simultaneously stimulating on other electrodes in the same ear. We characterized the intra-cochlear EEG and how it is influenced by acquisition parameters. We measured electrically evoked auditory brainstem responses (EABRs) and cortical evoked potentials (ECEPs), and varied parameters such as the stimulation mode, and the stimulation/ recording electrode pairs. Furthermore, we investigated the occurrence and removal of the stimulus artifact, which is exceptionally large when recording in the cochlea.

The targeted neural responses were successfully recovered from the continuous EEG recordings. Their morphologies and amplitudes varied for different choices of stimulation and recording pairs. These results allow to make informed decisions regarding the required recording parameters in future integrated CI-EEG systems. Furthermore, the results may guide the placement of the reference electrodes during cochlear implantation surgery, which is currently dictated by personal preference of the surgeon, for optimal recording of neural responses.

In conclusion, this study demonstrates for the first time the continuous recording of EEG from the implanted electrodes of a CI. The technique was validated using different EEG-based neural responses. These developments aid in paving the way towards future applications such as remote fitting and self-fitting “closed loop” cochlear implants.

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TH53: SINGLE-TRIAL EEG ALPHA RHYTHMS TRACK CHANGES OF LISTENING EFFORT IN COCHLEAR IMPLANT USERS DURING SPEECH IN NOISE PERCEPTION

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Background and aims. Profoundly deaf adults who use a cochlear implant (CI) commonly indicate that a significant amount of listening effort (LE) is required to overcome difficulty with understanding speech in challenging environments, such as in noise or with competing talkers. However, the physiological processes underlying LE are not well understood, and there is no objective marker of LE that can guide clinical practice. Our past research in both normal-hearing (NH) and CI users has however found that inter-individual differences in frontal alpha oscillations (8-12 Hz brain rhythms) in the electroencephalogram (EEG) explained differences of self-reported LE in a speech-in-noise perception task, suggesting this activity is a neural marker of LE. In contrast to inter-individual differences, the goal of the current study is to determine if intra-individual changes in alpha activity can explain different degrees of LE exerted within the same CI user.

Methods. In an 8-speaker free field, 15 CI users were presented three spoken digits in multi-talker babble noise at different signal-to-noise ratios (SNRs). Owing to large individual differences in speech in noise understanding, the range of SNRs was adjusted on an individual basis so that they were scaled to each CI user's range of effort ability. For each of the 180 trials, listeners verbally reported the digits that they heard, and rated LE on a 1-10 scale. During this time we recorded the 64-channel EEG. We used beamforming to extract sources of single-trial alpha activity during digit presentation, which thereafter were correlated to LE ratings using partial Spearman (rank) correlations in order to control for the changing SNR levels. These analyses were performed on the single-subject level.

Results. Cluster-based permutation tests on these correlations revealed significant relationships between self-reported listening effort and alpha activity in the left inferior frontal gyrus (IFG) in 13 of the 15 participants ($p = 0.007$).

Conclusions. Results suggest that alpha activity in left IFG tracks self-reported listening effort, and can be used as an objective neural marker of LE in CI users. Project support provided by MED-EL.

TH54: NEURAL REPRESENTATIONS OF ENVELOPE INTERAURAL TIME DIFFERENCES

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Background: The ability to process interaural time differences (ITDs) is essential to listening in complex acoustic environments. Accordingly, several reports show that bilateral CI-users benefit from binaural input: speech perception in noise usually improves due to 'better ear' listening, whilst interaural level differences (ILDs) provide information about the source location. Nevertheless, spatial listening remains poor in most bilateral CI-users, because sensitivity to ITDs is poor. This is largely due to the fact that current CI-fitting procedures take no account of the requirement to match inputs from the two devices. There is considerable interest in enhancing binaural benefit from bilateral CI by matching the input from the CI electrodes between the two ears. This study assesses whether the interaural phase modulation following response (IPM-FR) – i.e. an EEG response to periodic transitions of interaural phase differences (IPDs) – can be used to identify CI-electrode pairs with maximum binaural sensitivity, using CI-simulations in normal hearing listeners.

Methods: Eleven normal hearing listeners have been included. IPDs were conveyed in the envelope of band-filtered click trains. IPMs switched between 0° to 180° IPD, at a rate of 7.1 Hz. To assess whether frequency mismatches affect neural processing of envelope ITDs, the centre frequency of the filter varied in the left ear (3.5, 4.5, or 5.5 kHz band-pass filter), while kept constant in the right ear (4.5 kHz). These conditions are referred to as -1, 0, and +1 kHz frequency offset, respectively.

Results: IPM-FRs were obtained in seven out of eleven participants. In these seven subjects, response amplitude ranged from 0.2 to 0.6 μV. Pairwise comparison reveals significantly smaller responses for -1 than 0 kHz frequency offsets ($t(8.2)=-2.71$, $p=0.03$). The +1 and 0 kHz frequency offsets were not statistically different ($t(7.8)=2.04$, $p=0.08$).

Conclusions: IPM-FRs can be elicited by ITDs in the envelope of high-frequency sounds, albeit highly variable across subjects. The data suggest that the IPM-FR deteriorates when an interaural frequency mismatch is introduced. This finding may have repercussions for bilateral cochlear implant users, as it suggests that interaural electrode mismatches may be detrimental for spatial hearing.

TH55: NEURAL ENCODING OF EMOTION AND GENDER IN SPEECH

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For cochlear implant users, emotion and gender identification during speech processing is a challenge. In order to understand the neural signatures of each, we designed a paradigm that directs attention to gender and emotion separately. We hypothesize that such focused attention may help isolate the neural encodings necessary to identify emotion or gender; the encodings could then suggest ways to improve emotion or gender identification in CI users in the future.

EEG was recorded in normal hearing (NH) participants listening to short sentences embedded in a Gaussian white noise background at 15dB SNR. Before each sentence, a cue appeared indicating whether to attend to the emotion or the gender of the speaker. Following each stimulus, participants indicated whether the speaker was happy/angry or male/female with a key press.

Despite near ceiling behavioral performance in identification for gender and emotion in NH, preliminary EEG results suggest that the two processes require different neural resources. Specifically, alpha power prior to speech onset was greater when subjects were primed to differentiate the emotion of the speaker compared to the gender of the speaker. This could suggest that more noise suppression is required to identify emotion in speech. Further planned investigations of how prosodic pitch, timbre, and temporal modulations are represented in the brain during the two processes may reveal what acoustic aspects of the speech support and differentiate emotion and gender identification. Individuals with cochlear implants are currently being recruited, and comparisons with normal hearing individuals will be presented.

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TH56: NEURAL TRACKING TO SPEECH PROCESSED BY SINUSOIDAL SYNTHESIS MODEL FOR COCHLEAR IMPLANT USERS

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The sinusoidal model (SM) as proposed by McAulay and Quatieri (1986, 1989) only picks a small number of sinusoidal components to represent the complex speech signal. Likewise, the speech processing strategy in cochlear implants (CIs) also draws a similar scheme as that in the SM. Both speech processing strategies only encode limited, but important, speech information from complex speech signal. Hence it is of interest to explore the effect of the SM on speech perception in CI users.

This study behaviorally and physiologically examined the amount of speech intelligibility the CI users and normal hearing (NH) individuals are able to obtain from speech processed by SM with varying number of sinusoidal components (1, 2, and 6). Frequency range of speech was also varied by low-pass filtering with cut-off frequencies at 1 kHz, 1.5 kHz, 3 kHz, and 6 kHz to investigate the perceptual effect of sinusoidal peaks selected in restricted bandwidth (BW). Twelve NH listeners and 4 CI users were asked to perform speech recognition test (AzBio sentence lists) and rate the perceived sound quality (on the scale of 1 being distorted to 10 being most clear) of speech sentences processed in 12 different combinations of different number of sinusoidal components and BW. For physiological observation, cortical responses to speech sentences were recorded using a 64-channels electrode cap with our Brainvision electroencephalogram (EEG) system. We used regularized linear regression technique to derive the temporal response functions that map the fluctuations in speech envelope to the fluctuation in the corresponding cortical responses. The trained generative model was used to reconstruct the predicted EEG response from the envelope of the speech sentence. The mean square error (MSE) between original EEG response to the speech sentence and the reconstructed EEG response from the model was computed and tentatively used as a metric to quantify the degree of cortical entrainment to speech.

Our behavioral results showed that speech recognition score and perceived sound quality rating were systematically increased when the number of sinusoids and cut-off frequency of low-pass filters increase. Corresponding physiological result was found in only CI group where MSE were lower for the speech processed with more sinusoidal components and wider BW. NH group did not exhibit the same trend in their physiological result as that in CI group. More data collection is in progress to validate current observation. Our current result has provided some perceptual and physiological evidences on how spectrally reduced speech is perceived in CI mediated listening, which could be useful information for designing signal processing strategy in CI.

TH57: INVESTIGATION OF THE AUDITORY PATHWAY IN ASYMMETRIC HEARING IMPAIRED PATIENTS WITH [18F]FDG PET

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Introduction. The purpose of the present [18F]FDG PET study was to evaluate regional cerebral glucose metabolism as a marker of neural activity of the auditory pathway, especially the inferior colliculi and primary auditory cortex, in asymmetric hearing-impaired subjects.

Methods. The newest generation of fully-digital clinical PET/CT systems provides an improved spatial resolution that permits identification also of small brainstem nuclei. Regional glucose metabolism of two regions of interest (ROI), inferior colliculi and primary auditory cortices, was assessed in eleven subjects with asymmetric hearing impairment. By ROI analyses of the inferior colliculi and the primary auditory cortex, differences between ipsi- and contralateral normalized [18F]FDG uptake (reference: cerebellum) was analyzed. In addition, we investigated the associations between duration of hearing impairment and normalized [18F]FDG uptake.

Results. Regional metabolism of both inferior colliculi and primary auditory cortex was significantly reduced contralateral to the most impaired ear compared to the ipsilateral side ($p<0.01$ and $p<0.005$, respectively). The hypometabolism of the primary auditory cortex was attenuated with prolonged hearing impairment ($r=0,57$, $p=0.04$). Regional metabolism of the contralateral inferior colliculi predicted that of the contralateral primary auditory cortex only when adjusting for the duration of hearing impairment ($r = 0.61$, $p < 0.03$).

Conclusions. The use of newest-generation, fully-digital clinical PET scanners permits imaging and quantitative assessment of small brainstem nuclei such as the inferior colliculi. Asymmetric hearing loss and duration of deafness (possible indication of multimodal plasticity) have a significant impact on the regional neuronal activity of parts of the auditory pathway. This might be of clinical value regarding the prediction of the outcome after cochlear implantation.

TH58: DEVELOPING A MODEL OF MAGNETOENCEPHALOGRAPHY (MEG) SCAN FOR COCHLEAR IMPLANT RECIPIENTS

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To date there is no magnetoencephalography brain scan option for people using cochlear implants (CI). The main reason is that the CI system causes electromagnetic artifacts which can easily reach levels 1000 times larger than the brain activity we aim to measure. Previous works have failed to filter this magnetic interference out from MEG data and examples in the literature are of cochlear implant recipients who have had the magnet removed.

With this in mind, we set out to systematically characterize the noise sources arising from the different CI components using a customized MEG system (developed by Kanazawa Institute of Technology, KIT). In addition, we investigated the extent to which these noise sources can be filtered out to reveal auditory responses. In order to achieve this, we have constructed two phantom heads made of porcine gelatin (Sigma, Aldrich). The first head served as a baseline phantom containing a single equivalent current dipole which simulated the brain response from a “normal hearing” listener. The second phantom included a CI (Cochlear, Processor type CI522) implanted on the right side – serving as a “CI listener” model. Preliminary analyses indicate that sources can be localized correctly in both heads (goodness of fit of source localization > 84%).

We further scanned 24 normal hearing participants (11F, mean age= 24.6 ± 6.9 Years), delivering 500 Hz pure tone bursts to the left ear under different measurement conditions: 1. Baseline recording (to identify a normal auditory response); 2. With an internal CI magnet taped on the left side of the participant’s head; 3. With a CI custom-made emulator attached to the left side of the participants head; and 4. With both magnet and CI emulator on the left side of the participant’s head. We will present data from these normal hearing participants where we have filtered artifacts stemming from the magnet and CI (radio-frequency artifacts). These data and noise reduction methods may serve as a significant tool enabling MEG scans for CI recipients with a magnet containing system for the first time.

This research was funded by the HEARing CRC grant

TH59: EFFECT OF MODULATION DEPTH ON THE 40-HZ AUDITORY STEADY-STATE RESPONSE AND AUDITORY CHANGE COMPLEX IN CI USERS AND NORMAL-HEARING LISTENERS

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Temporal envelope modulations (TEMs) are the primary cues that cochlear implant (CI) users utilize to perceive speech intelligibly. Clinical fitting paradigms, however, do not assess the ability of the stimulated neural ensembles to encode TEMs. Nevertheless, several behavioral studies have shown that the ability to encode TEMs is associated with CI outcome, especially in adverse listening situations (see Pfingst et al. 2015). We recently found that the 40-Hz auditory steady-state response (ASSR) can be used to probe TEM encoding of each stimulated neural site noninvasively from the subcortical structures of the auditory pathway. Furthermore, we found that the variability in TEMs encoding across the CI array is correlated with the speech-perception-in-noise outcome. An objective measure that provides clinicians with insight in the TEM encoding ability of CI users can therefore be beneficial when fitting CIs. ASSRs are, however, difficult to obtain in CI users due to the stimulation artifacts that corrupt the EEG recording, especially for clinically used pulse rates (i.e. > 900 pps). A potential alternative for the 40-Hz ASSR is the auditory change complex (ACC). The ACC is a transient cortical response evoked by a change in stimulus characteristics and can also be evoked when a modulation is present in the deviant stimulus (Han & Dimitrijevic 2015). Here we investigate the applicability of ASSRs and ACCs as an electrophysiological measure for TEM encoding in the auditory system.

We assessed the response strength of each neural measure as a function of stimulus modulation depth (MD) to investigate how well each electrophysiological measure reflects TEM encoding in the auditory pathway. Measurements were done in 5 adult CI users and 10 normal-hearing listeners. We assessed the response strength to five different MDs ranging from 0.125 to 1. A 900-pulses-per-second, biphasic pulse train was used as a carrier in the CI study, whereas a broadband noise was used in the normal-hearing study. Stimuli consisted of 300 blocks of a 2 s in duration unmodulated section followed by a 2 s in duration 40-Hz amplitude modulated section. This paradigm evokes both an ACC (i.e. the change from the unmodulated to modulated section and vice versa) and an ASSR (i.e. the envelope following response to the envelope of the modulated section). We used a high-sampling EEG system to record the responses and used linear interpolation to remove the CI stimulation artifacts.

Data will be presented and discussed about, (1) the effectiveness of artifact removal for clinically relevant pulse rates, (2) the relationship between the 40-Hz ASSR and ACC MD-dependent growth functions, and (3) comparison of the electrophysiological responses obtained from the normal-hearing listeners with those of the CI recipients. These results may facilitate the choice of electrophysiological measures to optimally assess TEM encoding in CI users.

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TH60: AUTOMATED INTER-SCALAR SHIFT DETECTION FOR THE HIFOCUS MID-SCALA FROM CT SCANS

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Over the years the inclusion criteria for cochlear implantation (CI) have been expanded and currently patients with a substantial amount of residual hearing are being implanted. For this reason, it has become increasingly important to prevent intracochlear trauma during CI insertion. One form of trauma that can be identified on postoperative CT images, is an inter-scalar shift from the scala tympani to the scala vestibuli. This is associated with severe trauma to the basilar membrane and the osseous spiral lamina. It is, however, difficult to determine the cochlear anatomy from postoperative images alone due to the metallic artefacts. This can be improved by obtaining the anatomy from pre-operative images and determining the CI position from aligned post-operative images. In previous studies we have shown that this method is reliable, but time-consuming, in the hands of expert evaluators. The goal of the present study is to develop and test the reliability of an automated algorithm, which can do this with a minimum of human effort.

To this end, a custom-made MATLAB software package was developed to detect inter-scalar shift form clinical CT scans. The software automatically localises electrode contact positions from postoperative CT scans and segments the cochlear morphology from preoperative CT scans. By aligning both scans, the intracochlear position is determined and a model of the basilar membrane position is used to assess scalar position.
For validation of the automated method we compared it to manual data gathered for a previous study. We included 159 HiFocus Mid-Scala implants and 34 were manually labelled as having an inter-scalar shift. The automated method misclassified 9 implants resulting in an accuracy of 94%.

Our algorithm for the automatic detection of translocations is reliable and fast enough to be used as part of a clinical routine. It will give valuable feedback to the CI surgeon, which may help to further reduce intra-cochlear trauma. Furthermore, it enables further research into the cause and effects of intra-cochlear trauma as well as intra-operative trauma detection methods other than imaging (Dong et al, CIAP 2019).

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TH61: INFLUENCE OF ANGULAR INSERTION DEPTH AND THE DEFAULT ELECTRIC FREQUENCY FILTER ASSIGNMENTS ON FREQUENCY-TO-PLACE MISMATCH IN COCHLEAR IMPLANT AND ELECTRIC-ACOUSTIC STIMULATION DEVICE USERS

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BACKGROUND: The spatial position of the electrode array determines the spectral cues provided to the cochlear implant (CI) recipient. The angular insertion depth (AID) of the electrode array and the electric frequency filter assignments may create a discrepancy between the place of electric stimulation and natural cochlear tonotopicity, known as a frequency-to-place mismatch. AID can vary substantially across patients due to patient (e.g., cochlear duct length) and device (e.g., array length) variables. The default mapping procedures for CI-alone and EAS devices do not incorporate AID into the assignment of the electric frequency filters, which influences the magnitude of the frequency-to-place mismatch.

OBJECTIVES: To investigate the variability in AID associated with MED-EL (Innsbruck, Austria) Flex24 (24 mm), Flex28 (28 mm), and FlexSOFT/Standard (31.5 mm) lateral wall arrays, and the associated frequency-to-place mismatch with the default electric frequency filter assignments for CI-alone and EAS devices.

METHODS: Ninety-one adult CI recipients (100 ears) underwent postoperative computed tomography to determine the AID of each electrode contact. The AID was used to estimate the cochlear place frequency using the spiral ganglion (SG) map. The relationship between default frequency filter assignments, AID, and estimated cochlear place frequencies of each array in CI-alone (n=76) and EAS device users (n=24) was subsequently examined.

RESULTS: The mean AID was 423° ± 43.1° for Flex24 (n=10), 571° ± 66.7° for Flex28 (n=45), and 632° ± 46.7° for FlexSOFT/Standard (n=45) arrays. In CI-alone device users, deep lateral wall insertions align closely with the SG map when using default frequency filter assignments. EAS device users experienced the least frequency-to-place mismatch when the AID of the most apical electrode contact aligned the default frequency filter information with the cochlear place frequency, regardless of array type. Subjects with arrays at shallow insertions with minimal or no residual hearing experience the greatest degree of frequency-to-place mismatch.

CONCLUSIONS: For CI-alone device users, differences in array AID influence the magnitude of the frequency-to-place mismatch, with some long array recipients experiencing minimal frequency-to-place mismatch with the default frequency filter assignments. EAS device users demonstrate wide variability in frequency-to-place mismatch with the default mapping procedure. Among EAS device users, mismatch can be reduced by: 1) achieving insertion depths that tonotopically match the default low-frequency cutoffs determined by unaided hearing thresholds, 2) place-based mapping procedures using postoperative imaging algorithms to determine the cochlear place function for frequency filter assignments, and 3) plasticity, whereby pitch is remapped. An interesting consideration for EAS device users is that they may have reduced plasticity for electrically represented frequency perception with the acoustic portion serving as an anchor for cochlear place. Further studies are required to assess how this unique variation in frequency-to-place mismatch impacts audiologic outcomes in EAS device users.
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TH62: PRE-OPERATIVE PROMONTORY STIMULATION AND CORTICAL RECORDING IN DIFFICULT CI CANDIDATES

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Pre-operative electrical stimulation on the promontory (PromStim) or round window (RW) niche is a useful tool to demonstrate the presence and excitability of the auditory pathway in difficult cochlear implant (CI) candidates [1].

In the last decades, PromStim together with the evaluation of the objective measure has several advantages compare to the subjective PromStim test, and can be used in children, in patient not able to cooperate or with long auditory deprivation [2].

Electrical auditory brainstem response (EABR) consists of electrically elicited auditory response from the auditory nerve and brainstem, and it can be elicited during PromStim test in local or general anesthesia, confirm objectively the auditory nerve stimulation [3].

In some patients, when the electrical artifact generated by the stimulation covers the small EABR amplitude, or in case of auditory dyssynchrony when the EABR peaks are smeared out during averaging, a definitive patient assessment cannot be successfully performed, which may lead to a false negative interpretation.

Cortical auditory potential (CAEP) are responses from the upper part of auditory pathway, primary and secondary cortex. They can be elicited acoustically and also electrically via the CI stimulation [4].

Here we show a case where pre-operative PromStim EABR was present, and in addition PromStim CAEP was clear and reproducible. Stimulation and recording setting with MED-EL system and patient outcomes after implantation will be shown.

PromStim CAEP seems to be a valid additional tool to PromStim EABR protocol, extending the pre-operative patient assessment with the evaluation of the upper part of the auditory pathway.

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TH63: CLASSIFICATION OF ELECTROPHYSIOLOGIC RESPONSES TO SPEECH PROCESSED THROUGH AN ACOUSTIC SIMULATION OF A COCHLEAR IMPLANT

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To maximize speech understanding, post-lingually deafened recipients of cochlear implants (CI) face a lengthy period of adaptation to a signal that is degraded relative to that heard by individuals with normal hearing (NH). CI recipients often have difficulty accurately describing what they hear, and when they fail to identify a sound, it is unclear whether they are receiving insufficient information from the implant or have not learned the appropriate label for a given sound. Thus, both clinicians and researchers would benefit from objective methods to assess sound identification regardless of the reporting ability of a patient. The frequency following response (FFR) is an obligatory evoked potential that closely tracks the stimulus features of a sound. We have previously demonstrated in NH individuals that a classification algorithm applied to the FFR can predict stimulus labels to both syllables and musical stimuli. As a first step toward extending this approach to clinical populations, we investigate whether classification can accurately label responses to stimuli processed through a noise vocoder. Thirteen NH participants (aged 18-35) participated in a two-session experiment. In each session, we first recorded 2500 sweeps of the FFR to each of six vowel stimuli (/hɔ/, /hʌ/, /hi/, /hɪ/, /hu/, and /hʊ/). Participants subsequently completed a vowel identification task using these same stimuli without feedback. In one session (vocoded condition), the vowels were vocoded using an 8 of 22 channel peak-picking noise vocoder with 8 dB per octave filter slopes; the other session used the unaltered vowels (intact condition). No participant reported prior exposure to vocoded speech, and the order of each condition was randomly assigned. Vowel labels were predicted from FFRs using a classification algorithm (linear discriminant analysis); resulting confusion matrices were then compared to perceptual responses. Participants identified vowels with high accuracy in both intact (77-98% for single vowels) and vocoded conditions (50-92%). The FFR classification algorithm also labeled vowels in the intact condition, but with a lower accuracy (70-89%). Notably, the classification algorithm was more accurate for the vocoded condition (92-100%). These results suggest that vocoding preserves and may enhance features of the vowels that contribute to accurate classification. While our findings suggest that a classification approach may be feasible with hearing impaired individuals who receive a degraded signal, we need to better understand the relationship between perceptual responses and the neural features on which the classification algorithm bases its predictions.

TH64: TWIST AND SHOUT – A CASE SERIES OF CI, MRI AND SURGICAL INTERVENTIONS

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Introduction. Quality of life is connected with our health. It has been shown that hearing loss, on one or both ears, is often linked to social deprivation. Cochlear Implants (CI) have gained significance in the rehabilitation of hearing. Meanwhile, the Magnet Resonance Imaging (MRI) has gained significance in imaging diagnostics. MRI is used to diagnose, to follow-up and for prevention. MRI in CI patients can be a interdisciplinary challenge.

Material and methods. The database of the Division of Otology and Neurotology of the department of otorhinolaryngology, Heidelberg University Medical Center was searched for patients with CI who underwent MRI and presented with complaints thereafter. We report on eleven patients from the last 18 months.

Results. Five of the eleven patients were female, six male. One patient was implanted bilaterally, ten patients were unilaterally implanted. All patients had received an implant from the Cochlear Company. Four patients had an MRI oft he spine, one an MRI of the shoulder, one of the abdomen and five patients MRI of the brain during a neurological work up. Ten of eleven patients did receive a wrapping bandage over the implant during the MRI. The manufacturer's recommendations were known to the radiologists, as they were either handed to them directly or via the patients. All eleven patients presented with headaches, sore skin or the feeling of a foreign body in the CI area. The physical exam, X-ray of CT-scans did show magnet dislocation in eight of the eleven patients. All patients did need surgical interventions to either reposition or to temporally remove and reinsert the magnet.

Conclusion. We can show a correlation between MRI and dislocation of the CI magnet. All eleven patients who needed magnet related surgery had had an MRI. The application of the head and to secure the magnet (as recommended by the manufacturer) could not prevent painful sensations or magnet dislocations. While there are these instructions in place, it seems that they are not standardized enough to prevent magnet dislocation in current MRI machines. MRI and CI seem to be an issue that does need better solutions.

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