2023 Conference on Implantable Auditory Prostheses

Lake Tahoe sits on the traditional ancestral lands of the Washoe Tribe. The Washoe – the aboriginal stewards of the land in and around the Lake Tahoe Basin since the beginning of time, continue to protect and preserve the Washoe peoples' homelands. We offer gratitude for the land itself, and for the opportunity to learn, work, and be in community with this land.

9 to 14 July 2023

Granlibakken Conference Center

Lake Tahoe, CA

V0.1

2023 CONFERENCE ON IMPLANTABLE AUDITORY PROSTHESIS

Scientific Program

Conference Chair:	**Deborah Vickers**
Conference Co-chair:	**Waldo Nogueira**

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Administrative Coordinator:	**Wendy James**
Webmaster:	**Qian-Jie Fu**
Sound and Vision:	**John J. Galvin III**
Accessibility Advisor:	**Lina Reiss**
Trainee Leaders:	**Nina Aldag, Cynthia Lam**

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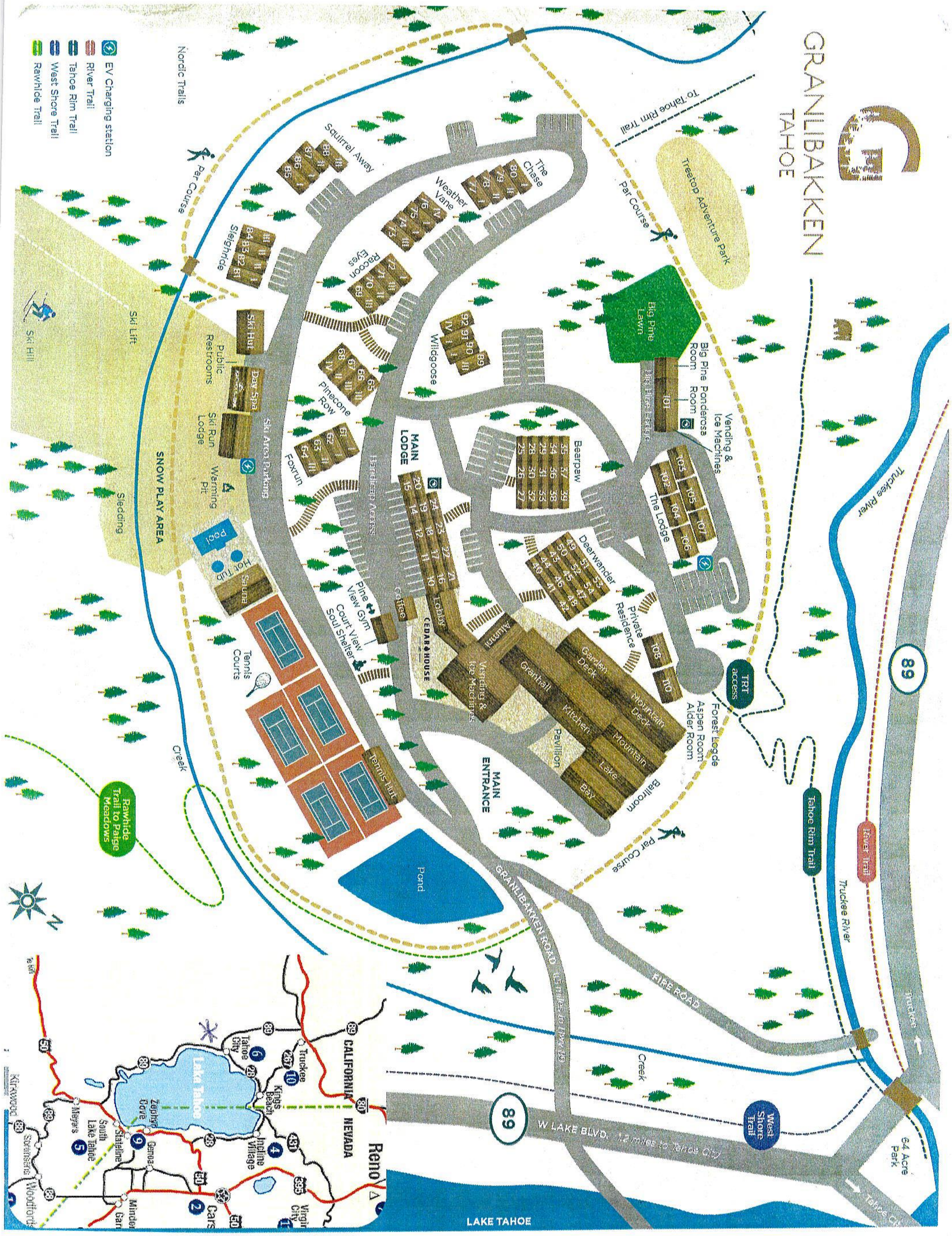

GRANLIBAKKEN TAHOE
EV Charging station
River Trail
Tahoe Rim Trail
West Shore Trail
Rawhide Trail
Nordic Trails
To Tahoe Rim Trail
Treetop Adventure Park
Par Course
Squirrel Away
The Chase
Weather Vane
Racoon Eyes
Sleighride
Ski Hut
Day Spa
Public Restrooms
Ski Run Lodge
Ski Area Parking
Ski Lift
Ski Hill
SNOW PLAY AREA
Warming Pit
Sledding
Big Pine Lawn
Big Pine Lodge
Big Pine Room
Ponderosa Room
Vending & Ice Machines
Widgoose
Pinecone Row
Foxrun
MAIN LODGE
Handicap Access
Bearpaw
The Lodge
Deerwander
Private Residence
Pool
Hot Tub
Sauna
Pine View Gym
Court View Soul Shelter
Tennis Courts
Tennis Hut
Lobby
Coffee
Alumni
CEDAR HOUSE
Vending & Ice Machines
Granhall
Kitchen
Garden Deck
Mountain Deck
Mountain
Lake
Bay
Ballroom
Pavilion
Forest Lodge
Aspen Room
Alder Room
TRT access
MAIN ENTRANCE
Pond
Creek
Rawhide Trail to Paige Meadows
Tahoe Rim Trail
River Trail
Truckee River
GRANLIBAKKEN ROAD
FIRE ROAD
W LAKE BLVD. 1.2 miles to Tahoe City
89
West Shore Trail
64 Acre Park
LAKE TAHOE
Lake Tahoe
CALIFORNIA
NEVADA
Reno
Truckee
Tahoe City
Kings Beach
Incline Village
Zephyr Cove
Stateline
South Lake Tahoe
Meyers
Genoa
Minden
Kirkwood
Woodfords

TABLE OF CONTENTS

Pages

PROGRAM OVERVIEW

Sunday 9 July

15:00 - 22:00	Registration
18:00 - 19:00	Dinner
19:00 - 00:00	Welcome Reception

Monday 10 July

07:00	Breakfast Opens
08:15 - 08:30	Welcome and Introductions / Code of Conduct Policy
08:30 - 12:00	Session 1: Combining information across Ears
12:00 - 13:00	Lunch
16:00 - 18:00	Poster Viewing
18:00 - 19:00	Dinner
19:00 - 21:00	Session 2: Data driven and computational modelling approaches
21:00 - 00:00	Poster Viewing and Socializing

Tuesday 11 July

07:00	Breakfast Opens
08:30 - 10:00	Session 3a: Neural function
10:30 - 12:00	Session 3b: Memorial for Ning Zhou
12:00 - 13:00	Lunch
13:30 - 16:00	Industry and regulatory presentations
16:00 - 18:00	Poster Viewing
18:00 - 19:00	Dinner
19:00 - 21:00	Session 4: Innovation and clinical interventions
21:00 - 00:00	Poster Viewing and Socializing

Wednesday 12 July

07:00	Breakfast Opens
08:30 - 10:00	Session 5a: Mixed modalities
10:30 - 12:00	Session 5b: Speech and language
12:00 - 13:00	Lunch
14:00 - 15:30	Mentoring Session
13:00 - 14:00	Poster Viewing
15:30 - 18:00	Poster Viewing
18:00 - 19:00	Dinner
20:00 - 00:00	CIAP Social, Music, Dance Party and Poster Viewing

Thursday 13 July

07:00	Breakfast Opens
08:30 - 12:00	Session 6: Physiological measurements
12:00 - 12:15	Group Picture / Student Picture
12:15 - 13:00	Lunch
16:00 - 18:00	Poster Viewing
18:00 - 19:00	Dinner
19:00 - 21:00	Session 7: Biological therapies
21:00 - 00:00	Poster Viewing and Socializing

Friday 14 July

07:00	Breakfast Opens
08:30 - 12:00	Session 8: Advances in technologies and applications
12:00 - 13:00	Lunch
13:00	Conference End

PODIUM PROGRAM

Sunday 9 July

15:00-22:00	**Registration**
18:00-19:00	**Dinner**
19:00-00:00	**Welcome Reception**

Monday 10 July

07:00	**Breakfast Opens**
08:15-08:30	**Welcome and introductions / code of conduct policy**

Session 1a: Combining information across ears — Chair Lina Reiss

08:30-09:00	**P1:** Auditory skills of children with single-sided deafness and a cochlear implant. **Tine Arras,** Birgit Philips, Christian Desloovere, Jan Wouters, Astrid van Wieringen
09:00-09:15	**P2:** Objective measures of binaural processing based on cortical auditory evoked potentials. **Yibo Fan**, Rene Gifford
09:15-09:30	**P3:** Speech perception and sound localization ability in CI subjects with electric-acoustic stimulation and contralateral normal hearing. **Tobias Weissgerber**, Monika Koertje, Timo Stoever, Uwe Baumann
09:30-10:00	**P4:** Asymmetric hearing impacts binaural hearing in children who use bimodal devices. **Melissa Polonenko**, Karen Gordon
10:00-10:30	**Break**

Session 1b: Combining information across ears — Chair Hongmei Hu

10:30-11:00	**P5:** Spatial hearing with mismatched information across the ears in bilateral cochlear implant listeners. **Ben Williges,** Noah Havers, Iwan Roberts, Nicola Hatton, Manohar Bance, Deborah Vickers
11:00-11:15	**P6:** Sensitivity to envelope and pulse timing interaural time differences in prosthetic hearing. Shiyi Fang, Fei Peng, Bruno Castellaro, Muhammad Zeeshan, Nicole Rosskothen-Kuhl, **Jan Schnupp**
11:15-11:30	**P7:** Finding the "best place" to deliver binaural cues to maximize spatial-hearing benefits when fitting bilateral cochlear implant users with a “mixed rate” strategy. **Agudemu Borjigin,** Stephen R. Dennison, Tanvi Thakkar, Alan Kan, Ruth Y. Litovsky
11:30-11:45	**P8:** Synergy of rate-pitch and interaural-time-difference cues for voluntary stream segregation in bilateral cochlear-implant listeners. **Martin Lindenbeck,** Lisa Frohmann, John Middlebrooks, Bernhard Laback
11:45-12:00	**P9:** Tinnitus is associated with increased cross-modal neural plasticity in single-sided deafness cochlear implant users. Mina Stojanovic, Joseph Chen, Trung Le, Vincent Lin, **Andrew Dimitrijevic**

12:00-13:00	**Lunch**
16:00-18:00	**Poster Viewing**
18:00-19:00	**Dinner**
Session 2a: Data driven & computational modeling approaches	Chair Tobias Göhring
19:00-19:30	**P10:** New models of human hearing via machine learning. **Josh McDermott**
19:30-19:45	**P11:** Deep learning for speech enhancement with cochlear implants: joint compensation of noise and reverberation with one or more microphones. **Clement Gaultier**, Tobias Goehring
19:45-20:00	**P12:** The TEMPORAL project: optimizing speech coding strategies by using models. **Jacob de Nobel**, Thomas Baeck, Jeroen Briaire, Anna Kononova, Johan Frijns, **Savine Martens**
20:00-20:15	**Break**
Session 2b: Data driven & computational modelling approaches	Chair Tobias Göhring
20:15-20:45	**P13:** How models serve as physical and digital twins to help us understand the cochlear-implant neural interface. **Manohar Bance**, Iwan Roberts, Tim Brochier, Chen Jiang, George Malliaras, Filip Hrciriik, Paul Charlesworth, Sarantos Mantzagriotis, Ilkem Sevgili, Chloe Swords, Botian Huang, Robert Carlyon, Deborah Vickers, Simone de Rijk
20:45-21:00	**P14:** Cochlear implant electrical impedance tomography **Tania Hanekom**, Friedemarie Kuschke
21:00-00:00	**Poster Viewing and Socializing**

Tuesday 11 July

07:00	**Breakfast Opens**
Session 3a: Neural function	Chair Julie Arenberg
08:30-09:00	**P15:** Assessing neural health with inter-phase gap measurements. **Dyan Ramekers**, Stefan Strahl, Henk Vink, Huib Versnel
09:00-09:15	**P16:** Polarity dependent excitation profiles with cochlear implant stimulation: relation to neuro-anatomy and implications for biphasic stimulation. **Peter Baumhoff,** Wiebke Konerding, Andrej Kral
09:15-09:30	**P17:** Model predictions of the effects of spiral ganglion neuron loss and axonal demyelination on ECAP refractory recovery and neural synchrony metrics. **Ian Bruce**, Jeffrey Skidmore, Shuman He
09:30-10:00	**P18:** The effects of neural adaptation in cochlear implant listeners. **Miriam Marrufo-Perez**, Deborah Vickers, Enrique Lopez-Poveda
10:00-10:30	**Break**

Session 3b: Memorial for Ning Zhou	Chair Brian Pfingst
10:30:10:40	**P19:** Remembering Ning Zhou, scientist, colleague, and friend. **Bryan Pfingst**
10:40-10:52	**P20:** Ning's Contributions to Mandarin Tone Recognition Research with Cochlear Implants. **Xin Luo**
10:52-11:04	**P21:** Perception-production links in lexical tones and prosodic expression. **Monita Chatterjee**
11:04-11:16	**P22:** Translating markers of cochlear health from animals to humans. **Kara Schvartz-Leyzac**, Deborah Colesa, Bryan Pfingst
11:16-11:28	**P23:** An international experiment for Ning: exploring the relationship between multi-pulse integration and spatial selectivity in cochlear implant users. **Robert Carlyon**, Julie Arenberg, Andrew Oxenham, Heather Kreft, Francois Guerit, Charles Hem, John Deeks
11:28-11:40	**P24:** Clinical implications of sensitivity to pulse phase duration in cochlear implants. Ning Zhou, Zhen Zhu, Lixue Dong, David Bakhos, Bradford Backus, Manuel Segovia Martinez, David Landsberger, **John Galvin**
11:40-11:50	**P25:** Memories of my five years in Dr. Zhou's lab: a tribute to my mentor and friend Ning Zhou. **Lixue Dong**
11:50-12:00	**P26:** Perspectives from research participants. **Recordings** from Former Research Subjects
12:00-13:00	**Lunch**
13:30-16:00	**Industry and regulatory presentations** — Chair Debi Vickers
13:30-14:00	Advanced Bionics: "30 years of Advanced Bionics' Innovation", **Patrick Boyle**
14:00-14:30	Cochlear, Ltd: "Opportunities and Challenges towards a Smarter and Distributed Care Model" **Filiep Vanpouke**
14:30-15:00	MEDEL: "MED-EL's Research Opus", **Stefan Strahl**
15:00-15:30	Oticon Medical: "New Frontiers in Hearing Outcomes", **Manuel Segovia-Martinez** Yue Zhang, Jan Margeta and Bradford Backus
15:30-15:45	CCi Mobile: "CCi-MOBILE Research Platform: Supporting Science & Engineering Driven CI Innovation", **John Hansen**
15:45-16:00	FDA: "FDA Regulation of Investigational Studies for Auditory Prostheses", **Lindsay DeVries, AuD, PhD, Joyce Lin, PhD**
16:00-18:00	**Poster Viewing**
18:00-19:00	**Dinner**

Session 4a: Clinical innovation and interventions		Chair Astrid Van Wieringen
19:00-19:30	**P27:** Using a NAO robot for speech audiometry testing of cochlear implanted children. **Gloria Araiza-Illan,** Bert Maat, Gera Nijhof, Francien Coster, Deniz Baskent	
19:30-19:45	**P28:** Perception of simultaneous and sequential musical harmony in cochlear implant listeners. **Marie-Luise Augsten**, Martin Lindenbeck, Bernhard Laback	
19:45-20:00	**P29:** Pitch, timbre, and quality with a cochlear implant: insights from vocal mimicry. **David Landsberger**, Natalia Stupak, Rahul Sinha, Gabriel McDerment, Aaron Johnson, John Galvin	
20:00-20:15	**Break**	
Session 4b: Clinical innovation and interventions		Chair Astrid Van Wieringen
20:15-20:45	**P30:** Influence of electric frequency-to-place mismatches on monaural and binaural hearing. **Margaret Dillon,** Emily Buss, Margaret Richter, Meredith Rooth, Kevin Brown	
20:45-21:00	**P31:** Novel acoustic models of cochlear implants are reliably obtained using interactive genetic algorithms (iGA). **Ariel Edward Hight**, Nicole Capach, Jonathan Neukam, Robert Froemke, Mario Svirsky	
21:00-00:00	**Poster Viewing & Socializing**	

Wednesday 12 July		
07:00	**Breakfast Opens**	
Session 5a: Multisensory communication		Chair Matt Winn
08:30-09:00	**P32:** The nature of perceptual processing in vocal production. **Sophie Scott**	
09:00-09:15	**P33:** The electrophysiology of audiovisual speech processing in aging cochlear implant users. **James Dias**, Kara Schvartz-Leyzac, Kelly Harris	
09:15-09:30	**P34:** The impact of visual speech cues on listening effort for listeners with cochlear implants. **Justin Fleming**, Mathew Winn	
09:30-09:45	**P35:** Contralateral speech interference with single sided deafness CIs: a general selective-attention deficit to asymmetric experience? **Joshua Bernstein**, Danielle Zukerman Schopf, Taylor Beinke, Marina Cox, Matthew Goupell	
09:45-10:00	**P36:** Tactile stimulation enhances auditory speech perception in normal-hearing and cochlear-implanted listeners. **Alina Schulte**, Jeremy Marozeau, Andrej Kral, Hamish Innes-Brown	
10:00-10:30	**Break**	

Session 5b: Speech and language	Chair: Jeremy Marozeau
10:30-11:00	**P37:** Perceptual accommodation across sensory domains supports language learning via cochlear implantation. **Heather Bortfeld**
11:00-11:15	**P38:** The predictive value of multi-sensory communicative behaviour of infants in the first year of life to later language development: Implications to infants with cochlear implants. **Liat Kishon-Rabin**, Bonnie Levin-Asher, Ronen Perez
11:15-11:30	**P39:** How do the everyday speech-language environments of preschoolers with and without cochlear implants predict their vocal maturity outcomes? **Meg Cychosz**, Jan Edwards, Rachel Romeo, Jessica Kosie, Rochelle Newman
11:30-11:45	**P40:** Pediatric auditory brainstem implantations and cortical development features in congenital deafness children after ABI surgery. **Hao Wu**
11:45-12:00	**P41:** Assessment of speech comprehension with semantically anomalous sentences in cochlear implant users. Valeriy Shafiro, Jasper Oh, David Pisoni, **Aaron Moberly**
12:00-13:00	**Lunch**
13:00-14:00	**Poster Viewing**
14:00-15:30	**Mentoring Session**
15:30-18:00	**Poster Viewing**
18:00-19:00	**Dinner**
20:00-00:00	**CIAP Social, Music, Dance Party and Poster Viewing**

Thursday 13 July	
07:00	**Breakfast Opens**
Session 6a: Physiological measurements	Chair Michelle Hughes
08:30-09:00	**P42:** Peripheral and cortical encoding of electrical stimulation and their associations with auditory perception in adult cochlear implant users. **Shuman He**
09:00-09:15	**P43:** Postoperative Impedance-Based Estimation of Cochlear Implant Electrode Insertion Depth. **Stephan Schraivogel**, Philipp Aebischer, Stefan Weder, Marco Caversaccio, Wilhelm Wimmer
09:15-09:30	**P44:** Electrocochleography and cochlear implants. **Douglas Fitzpatrick**, Craig Buchman, Oliver Adunka
09:30-09:45	**P45:** Polarity effect and ECAP measures over time and correlation with hearing preservation. **Holden Sanders**, Brittany Wilson, Sachin Gupta, Yael Raz, Jack Noble, Benoit M Dawant, Lina Reiss
09:45-10:00	**P46:** Neurophysiological correlates for the objective determination of stimulation levels in cochlear implant users. **Elise Verwaerde**, Wouter David, Julian Schott, Robin Gransier, Jan Wouters
10:00-10:30	**Break**
Session 6b: Physiological measurements	Chair Karen Gordon
10:30-11:00	**P47:** Investigating the electrophysiology of audiovisual speech integration under naturalistic conditions. **Ed Lalor**
11:00-11:15	**P48:** Electric acoustic integration in bimodal cochlear implant users. **Hanna Dolhopiatenko**, Waldo Nogueira
11:15-11:30	**P49:** Larger maladaptive activation of auditory cortex during lip-reading tasks at device switch-on predicts poorer future speech understanding outcomes for cochlear implant recipients. **Tommy Peng**, Mica Haneman, Jamal Esmaelpoor, Jessalynn Sukamto, Robert Luke, Maureen Shader, Colette M McKay
11:30:12:00	**P50:** Intracranial electrophysiology of clear and degraded speech processing in the human cortex. **Kirill Nourski,** Mitchell Steinschneider, Ariane E Rhone, Joel I Berger, Hiroto Kawasaki, Matthew A Howard
12:00-12:15	**Group picture / student picture**
12:00-13:00	**Lunch**
16:00-18:00	**Poster viewing**
18:00-19:00	**Dinner**

Session 7a: Biological therapies	Chair Andrej Kral
19:00-19:30	**P51:** Preclinical development of an investigational genetic medicine for otoferlin gene-mediated hearing loss: AK OTOF. **Aaron Tward**
19:30-20:00	**P52:** Precise targeting of GJB2 cells results in safe and efficacious gene therapy for hearing loss due to GJB2 deficiency (DFNB1). **Kathryn Ellis**, Gabriela Pregernig, Yoojin Chung, Kasey Jackson, Joseph Goodliffe, Chris Thompson, Sarah Cancelarich, Meghan Drummond
20:00-20:15	**Break**
Session 7b: Biological therapies	Chair Andrej Kral
20:15-20:45	**P53:** Rincell-1: first-in-human, pluripotent stem cell-based therapy for hearing loss. **Douglas Hartley, Marcelo Rivolta**
20:45-21:00	**P54:** Combined optical and electrical stimulation in the cochlea for high spatial and temporal resolution. Elise Ajay, Ajmal Azees, Alex Thompson, Andrew Wise, David Grayden, James Fallon, **Rachael Richardson**
21:00-00:00	**Poster viewing and socializing**

Friday 14 July

07:00	**Breakfast Opens**
Session 8a: Advances in technologies and applications	Chair James Fallon
08:30-09:00	**P55:** Drug delivery to the inner ear for cochlear implants and beyond. **Andrew Wise**
09:00-09:15	**P56:** In vivo characterization of novel channel rhodopsin variants for the optogenetic activation of the auditory pathway by blue light. **Lennart Roos**, Aida Garrido-Charles, Bettina Julia Wolf, Anupriya Thirumalai, Antoine Huet, Kathrin Kusch, Thomas Mager, Tobias Moser
09:15-09:30	**P57:** Real-time simulation of active cochlear implant and its insertion. Lingxiao Xun, Yinoussa Adagolodjo, Gang Zheng, Alexandre Kruszewski, Christian Duriez
09:30-09:45	**P58:** Progress and challenges with implantable microphones for cochlear implants. **John Zhang**, Emma Wawrzynek, Song Cheng, Jeffrey Lang, Ioannis Kymissis, Elizabeth Olson, Hideko Heidi Nakajima
09:45-10:00	**P59:** Investigating an alternative to electrical hearing: Ultrasound stimulation of the peripheral auditory system. **Olivier Macherey**, Emilie Franceschini, Vinay Parameshwarappa, Elena Brunet, Eric Debieu, Pierre-Olivier Mattei, Yves Cazals
10:00-10:30	**Break**

Session 8b: Advances in technologies and applications	Chair Jay Rubinstein
10:30-11:00	**P60:** Development and translation of a new auditory nerve implant. **Meredith Adams, Thomas Lenarz**
11:00-11:15	**P61:** New developments in vestibular implants: electrical stimulation of the otolith organs. **Andrzej Zarowski**, Morgana Sluydts, Marc Leblans, Floris Wuyts, Fergio Sismono, Joost van Dinther, Frans Erwin Offeciers, Angel Ramos De Miguel, Maurizio Barbara, Raquel Manrique-Huarte, Manuel Manrique, Angel Ramos Macias
11:15-11:30	**P62:** Magnetic intracochlear stimulation: towards next-generation cochlear implants. **Jae-Ik Lee**, Ryan Bartholomew, Victor Adenis, Merritt Christian Brown, Daniel Lee, Julie Arenberg, Shelley Fried
11:30-12:00	**P63:** The importance of CIAP for auditory science. **Bob Shannon**
12:00-13:00	**Lunch**
13:00	**Conference ends**

POSTER PROGRAM

Monday 10 July

M1: [1561] Cochlear implants for single sided deafness: improved sound-localization performance without processing of binaural cues. Martijn Agterberg, Adriane Smit

M2: [1612] Temporal adjustment in bimodal listeners - improvement of sound localization but not of spatial unmasking of speech. Stefan Zirn, Julian Angermeier, Sebastian Roth, Franz-Ullrich Mueller, Werner Hemmert

M3: [1616] Simultaneous implantation may facilitate binaural fusion better than sequential implantation for bilateral cochlear implant users. Biao Chen, Jingyuan Chen, Yongxin Li, John J. Galvin, Qian-Jie Fu

M4: [1617] Factors affecting binaural summation and utilization of talker sex cues in cochlear implant users and normal hearing listeners. Jingyuan Chen, Biao Chen, Yongxin Li, John J. Galvin, Qian-Jie Fu

M5: [1624] What you deliver is not what you get: alteration of interaural correlation post-stimulation. Justin M. Aronoff, Simin Soleimanifar, Prajna BK

M6: [1643] The effects of interaural cochleotopic asymmetry and interaural correlation on interaural time difference sensitivity. Jordan Deutsch, Mona Jawad, Julia Anodenko, Josephine LaPapa, Justin M Aronoff

M7: [1653] The effect of head shadow enhancement for speech understanding in bimodal cochlear implant users in a diffuse noise field. Nienke C. Langerak, H Christiaan Stronks, Jeroen J. Briaire, Johan H.M. Frijns

M8: [1676] Comparisons of interaural-time-difference tuning curves using monopolar and partial tripolar configurations in adult bilateral cochlear-implant users. Obada Jamal AlQasem, Matthew Joseph Goupell, Ruth Litovsky, Tanvi Thakkar, Alan Kan, Danielle Addington

M9: [1677] Modelling the benefit of bilateral signal processing for bimodal CI recipients. Josef Chalupper, Nicolas Furnon

M10: [1679] Effects of impaired selective attention on binaural unmasking or interference of masked speech in bilateral and single-sided-deafness cochlear-implant users. Matthew J. Goupell, Erin Catob, Sandeep Phatak, Joshua G. W. Bernstein

M11: [1692] Models for correcting interaural mismatch in bilateral and single-sided-deafness cochlear-implant listeners. Paul G Mayo, Danielle Zuckerman Schopf, Miranda Cleary, Kristina DeRoy Milvae, Matthew J Goupell

M12: [1703] Sensitivity of inferior colliculus to interaural time and level differences in neonatally deafened rats. Muhammad Zeeshan, Fei Peng, Bruno Castellaro, Shiyi FANG, Nicole Rosskothen-Kuhl, Jan W.H Schnupp

M13: [1707] Design and testing of a front-end implementation of a binaural audio processing strategy inspired by the medial olivocochlear reflex. Enrique A. Lopez-Poveda, Almudena Eustaquio-Martin, Milagros J. Fumero, Jose Manuel Gorospe, Christian Wirtz, Reinhold Schatzer, Joshua S. Stohl, Peter Nopp

M14: [1718] Raiders of the lost arktivation - exploring the bilateral CI users' localization potential. Dietmar Michael Wohlbauer, Wai Kong Lai, Norbert Dillier

M15: [1746] Binaural fusion and the effects of place of stimulation and interaural cross correlation. Prajna BK, Justin Aronoff

M16: [1780] Relationship between peripheral spread of excitation and binaural fusion in bilateral cochlear implant users. Lina A.J. Reiss, Logan M. Remington, Holden D. Sanders

M17: [1786] Stability of electrical stimulation parameters in a large cohort of Canadian children with bilateral cochlear implants. Carina J Sabourin, Sharon L Cushing, Blake C Papsin, Karen A Gordon, Stephen G Lomber

M18: [1792] Can ITDs and BILDs predict EAS benefit in CI users? Jonathan D Neukam, Yibo Fan, Michael Z Burchesky, Rene H Gifford

M19: [1815] The effects of monaural acoustic glimpse criteria on binaural unmasking and contralateral interference in cochlear implants. Bobby E Gibbs II, Matthew J Goupell

M20: [1831] Characterizing the rate limit of bilateral CI users using electroencephalography. Hongmei Hu, Ben Williges, Deborah Vickers

M21: [1839] Effects of hearing aid use and residual hearing on bimodal hearing in children. Hanne Bartels, Melissa J. Polonenko, Jaina Negandhi, Sharon L. Cushing, Blake C. Papsin, Karen A. Gordon

M22: [1842] Characterizing spatial auditory localization strategies in children who use cochlear implants. Robel Zelalem Alemu, Alan Blakeman, Sharon Cushing, Blake Papsin, Karen Gordon

M23: [1852] Examining the relationship between interaural asymmetry, perceptual fusion, and binaural unmasking in adults with bilateral cochlear implants. Emily A. Burg, Sean R. Anderson, Ruth Y. Litovsky, Matthew B. Fitzgerald

M24: [1857] Microphone directionality in bimodal listening. Brett Swanson, Amanda Fullerton, Marian Jones

M25: [1879] Binaural-bimodal stimulation degrades neural coding of interaural time differences. Maike Vollmer, Merle Berents, Andreas Schulz, Andrew W. Curran, Frank W. Ohl

M26: [1901] Borderline candidacy: too bad for a conventional hearing aid and too good for a cochlear implant (CI). Karolina Kluk, Mark Sladen, Iain Bruce, Simone Schaefer, Jaya Nichani, Yuhan Wong

M27: [1903] The benefits of bimodal hearing in children and adolescents: a systematic review and narrative synthesis. Yuhan Wong, Iain Bruce, Josef Schlittenlacher, Karyn L Galvin, Karolina Kluk-de Kort

M28: [1626] Clinical outcomes for adult single-sided deafness cochlear implantees exceeding the 5% candidacy criterion. Elicia M. Pillion, Joshua G. W. Bernstein, Anthony M. Tolisano

M29: [1740] Contralateral unmasking for single-sided-deafness cochlear-implant users with shifted frequency assignments to reduce interaural place mismatch. Joshua G.W. Bernstein, Megan M. Eitel, Phatak A. Sandeep, Kenneth Kragh Jensen, Elicia M. Pillion, Coral E. Dirks, Matthew J. Goupell

M30: [1753] How do family factors affect cochlear implantation in children with single-sided deafness? Amanda Griffin, Rachel Landsman, David Faller, Megan Herlihy, Greg Licameli

M31: [1844] Investigating the effects of peripheral spectral asymmetry using simulations of cochlear implant listening. Lukas Suveg, Tanvi Thakkar, Ellen Peng, Ruth Litovsky

M32: [1850] Cochlear implantation in single-sided deafness: outcomes and its association with frequency-place mismatch. Shaza Mahmoud Saleh, Mariam Alamro, Yassin Abdelsamad, Fida Muhawas, Salman Alhabib, Abdulrahman Abdullah Hagr

M33: [1633] A computational modeling framework for assessing information transmission with cochlear implants. Thibaud Leclere, Peter T. Johannesen, Aswin Wijetilake, Manuel Segovia-Martinez, Enrique A. Lopez-Poveda

M34: [1714] Automatic landmark localization in CT images using deep learning. Yifan Wang, Thomas Lenarz, Andrej Kral, Samuel John

M35: [1724] A computational model of the electrically and acoustically evoked compound action potential in hybrid cochlear implant users. Daniel Kipping, Yixuan Zhang, Waldo Nogueira

M36: [1725] Multipolar vs. monopolar stimulation in a cochlear implant: a simulation study. Albert Markus Croner, Jonas Geissdoerfer, Siwei Bai, Werner Hemmert

M37: [1726] Modelling of electrophysiological assessment of auditory nerve fiber damage. Werner Badenhorst, Petra van Blerk, Hanekom Tania, Johan J Hanekom

M38: [1756] Watching hearing with a neuro-implant: ultra-high-resolution models of neural activity in the human inner ear. Siwei Bai, Albert Croner, Carmen Marie Castaneda Gonzalez, Ali Saeedi, Rudolf Glueckert, Anneliese Schrott-Fischer, Werner Hemmert

M39: [1766] Model-based inference of electrode position and neuronal density from measured detection thresholds in cochlear implant listeners. Julie G. Arenberg, David J. Perkel, Joshua H. Goldwyn

M40: [1771] The potential of advanced deep learning models to evaluate speech information in vocoder simulations. Rahul Sinha, Mahan Azadpour

M41: [1798] GSP cochlea: a graph signal processing model of the cochlea with application to cochlear implants. Melia E Bonomo, Santiago Segarra, Robert M Raphael

M42: [1827] Parameterization and prediction of intra-cochlear structures. Joshua Thiselton, Tania Hanekom

M43: [1834] Neural network models clarify the role of plasticity in cochlear implant outcomes. Annesya Banerjee, Mark Saddler, Josh McDermott

M44: [1864] Towards next-generation scalable cochlear implants. Abraham Akinin, Erin Graf, Michael Triplett, Raziul Haque

M45: [1556] Signal processing strategy for cochlear implant based on feature extraction. Manuel Segovia-Martinez, Behnam Molaee-Ardekani, Yue Zhang, Aswin Wijetillake, Marianna Vatti, Julian Felding

M46: [1594] An approach for determining individual frequency allocation map in cochlear implant users using cochlea CT-scans. Behnam Molaee-Ardekani, Raabid Hussain, Marianna Vatti, Hanna Dolhopiatenko, Waldo Nogueira, Manuel Segovia Martinez

M47: [1619] Turning on the cochlear implant: anatomy-based fitting versus standard frequency map. Uwe Baumann, Marten Geisen, Tobias Weissgerber, Timo Stoever, Silke Helbig

M48: [1621] Acute effects of a Lombard effect-based sound coding strategy for cochlear implant listeners. Juliana N. Saba, John H.L. Hansen

M49: [1627] Phoneme-based reverberant speech enhancement for cochlear implant users. Boyla O. Mainsah, Kevin M. Chu, Leslie M. Collins

M50: [1634] Comparison of performance for cochlear-implant users with audio processing strategies based on short-time FFT or spectral feature extraction. Yue Zhang, Peter T. Johannesen, Behnam Molaee-Ardekani, Aswin Wijetilake, Alejandro Soler Valcarcel, Manuel Segovia-Martinez, Enrique A. Lopez-Poveda

M51: [1657] Neural model-based fine structure coding for cochlear implants. Bernhard U. Seeber

M52: [1760] CCi-CLOUD: a framework for community based remote cochlear implant user experiments based on the CCi-MOBILE research platform. Hazem Younis, John Hansen

M53: [1705] Intelligibility and speech information of a talking agent for CI users. Samuel Oghenetega Okei, John Hansen

M54: [1706] CCi-MOBILE: validation of a research platform for wireless data communication and transmission. Samuel Oghenetega Okei, John Hansen

M55: [1801] Non-linguistic sound source identification and localization for cochlear implant users with ecological momentary assessment. Taylor Lawson, John H. L. Hansen

M56: [1802] CCi-MOBILE: deep source separation and non-linguistic sound enhancement in competing scenarios: advancements for cochlear implant recipients. Ram Charan M. Chandra Shekar, John H.L. Hansen

M57: [1713] A cochlear implant speech coding strategy integrating temporal masking effects: Extension to realistic listening conditions and clinically used devices. Lidea Shahidi, Robert P. Carlyon, Deborah A. Vickers, Tobias Goehring

M58: [1735] The impact of electrode-specific compression functions on outcomes with a cochlear implant. Andreas Buechner, Lutz Gaertner, Thomas Lenarz

M59: [1567] Development of a machine learning system for predicting cochlear implant performance: analysis of a large retrospective dataset. Alexey Demyanchuk, Eugen Kludt, Thomas Lenarz, Andreas Buechner

M61: [1566] Cochlear implant electrode impedance subcomponents as biomarker for residual hearing. Stephan Schraivogel, Philipp Aebischer, Stefan Weder, Marco Caversaccio, Wilhelm Wimmer

M62: [1575] Real-time analysis of intraoperative electrocochleography with simultaneous impedance measurements using linear state-space models. Raphael Raschid Andonie, Wilhelm Wimmer, Reto Andreas Wildhaber, Marco Caversaccio, Stefan Weder

M63: [1605] Vocoders and objective measures: how much to trust for designing new sound coding strategies in cochlear implants? Behnam Molaee-Ardekani, Yue Zhang, Rafael Attili Chiea, Manuel Segovia Martinez

M64: [1636] Developing a new test-bench for screening effective next-generation speech processing algorithms for cochlear implants. Anais Donzeau, Tobias Goehring, Yue Zhang, Manuel Segovia-Martinez

M65: [1720] Streamlined cochlear image analysis: enhancing an ai-powered tool for large-scale population statistics and accurate 3D modelling. Jan Margeta, Raabid Hussain, Behnam Molaee-Ardekani, Reda Kamraoui, Roger Calixto, Octavio E. Martinez Manzanera, Paula Lopez Diez, Francois Patou, Chadlia Karoui, Michel Hoen, Charles Raffaeli, Clair Vandersteen, Nicolas Guevara

M66: [1759] Waveform morphology of intraoperative electrocochleography. Raphael Raschid Andonie, Wilhelm Wimmer, Philipp Aebischer, Reto Andreas Wildhaber, Marco Caversaccio, Stefan Weder

M67: [1810] Principal components analysis of amplitude envelopes from spectral channels: comparison between music and speech. Agnieszka Duniec, Olivier Crouzet, Elisabeth Delais-Roussarie

M68: [1811] Estimation of intracochlear electrode position from cochlear implant impedance telemetry. Christopher Bennett, Ryan O. Melman, Zachary M. Smith

M69: [1812] Automatic classification of congenital inner ear malformations from CT images using unsupervised deep metric learning for 3D shapes. Paula Lopez Diez, Jan Margeta, Khassan Diab, Francois Patou, Rasmus R. Paulsen

M70: [1896] A novel, validated CI electrode location prediction method for improved preoperative planning Daniel Schurzig,Felix Repp, Max Timm, Cornelia Batsoulis, Thomas Lenarz, Andrej Kral

Tuesday 11 July

T1: [1558] Determination and comparison of two measurement paradigms of electrically evoked cochlear nerve responses and their correlation to cochlear nerve cross-section in infants with cochlear implant. Tobias Rader, Leonhard Schrank, Jennifer Lee Spiegel

T2: [1589] Developing cochlea-on-a-chip model for advancing cochlear implant performance and electrode-nerve interface study. Ilkem Sevgili, Iwan Roberts, Botian Huang, Manohar Bance

T3: [1593] Investigating the electrode-electrolyte interface modelling in cochlear implants. Behnam Molaee-Ardekani, Mary J. Donahue

T4: [1600] Responsiveness of the electrically stimulated cochlear nerve in children with incomplete partition type 2. Yi Yuan, Jeffery Skidmore, Shuman He

T5: [1613] Utility of the pitch ranking procedure in the individualized mapping of cochlear implant recipients. Margaret E Richter, Margaret T Dillon

T6: [1625] The assessment of electrode-neuron interface in children and adults with cochlear implants. Mohammad Maarefvand, Roya Karimipour

T7: [1640] Investigating electrochemical safety limits of neural stimulating electrodes. Prabhakar Sidambaram, Roger Calixto

T8: [1658] Getting more auditory-nerve bang for your facial-nerve buck: effects of pulse shape on loudness and facial-nerve activation in cochlear-implant listeners. John Deeks, Iwan Roberts, Simone de Rijk, Dorothee Arzounian, Manohar Bance, Robert Carlyon

T9: [1730] Effects of stimulus polarity on latency of the evoked potential in patients with an auditory brainstem implant. Lutz Gaertner, Anne Schroeder, Marko Takanen, Konrad Schwarz, Thomas Lenarz, Andreas Buechner

T10: [1752] CI stimulation parameters play a key role in reducing facial nerve stimulation. Lutz Gaertner, Bradford C. Backus, Nicolas Le Goff, Anika Morgenstern, Thomas Lenarz, Andreas Buechner

T11: [1748] Impact of aging and the electrode-to-neural interface on temporal processing ability in cochlear-implant users. Anhelina Bilokon, Bobby E. Gibbs II, Miranda Cleary, Matthew J. Goupell

T12: [1764] Assessing the neural interface and auditory functionality of ABI electrodes to inform electrode selection for speech processing. Mahan Azadpour, Rahul Sinha, Jonathan Neukam, Nicole Capach, William Shapiro, Thomas Roland, Mario Svirsky

T13: [1800] A novel tool for faster psychophysical tuning curve measurement in cochlear implant listeners: data from listeners with normal hearing. Meisam K. Arjmandi, Andrew J. Oxenham, Charlotte Morse-Fortier, Julie G. Arenberg

T14: [1830] Relating electrophysiological (auditory chance complex) and behavioral measures of amplitude modulation rate discrimination to speech in noise perception in cochlear implant users. Deborah Vickers, Nick Haywood, Marina Salorio-Corbetto, Jaime Undurraga, Ben Williges

T15: [1853] Electrophysiological and psychophysical tuning comparisons in adult cochlear implant listeners. Nicole T Jiam, Charles Hem, Faten Awwad, Julie Arenberg

T16: [1855] A large-scale analysis of speech recognition, aging, electrode location, and estimates of neural health in adult cochlear implant recipients. Kara C Schvartz-Leyzac, Carolyn M McClaskey, Kelly C Harris, Bryan E Pfingst

T17: [1875] An investigation of the effect of changes in IPG on the amplitude growth function in cochlear implant recipients. Greg D Watkins, Orsolya Kekesi, Ying Shen, Melvile da Cruz, Gregg J Suaning

T18: [1876] Electrical stimulation of cochlear implant promotes activation of macrophages and fibroblasts under inflammation. Hongzheng Zhang, Dingling Zhang

T19: [1881] Reaction times capture temporal interactions in electrical hearing. Ignacio Calderon De Palma, Andy J Beynon, John van Opstal, Joerg Pesch, Emmanuel EAM Mylanus, Marc M van Wanrooij

T20: [1885] Modelling SGN responses to non-rectangular stimuli based in patch clamp experiments of intracellular and extracellular stimulation. Sarantos Mantzagriotis, Manohar Bance, Ilkem Sevgili, Paul Charlesworth, Jeremy Marozeau, Bastian Epp

T21: [1654] The effects of multi-mode monophasic stimulation with capacitive discharge on the facial nerve stimulation reduction in young children with cochlear implants: intraoperative recordings. Fabiana Danieli, Miguel Angelo Hyppolito, Raabid Hussain, Jan Margeta, Chadlia Karoui, Michel Hoen, Ana Claudia Mirândola Barbosa Reis

T22: [1675] Interrelationships among eCAP refractory recovery, maximum amplitude, and AGF slope. Michelle L. Hughes

T23: [1843] Escude and Avci et. al. revisited. Cochlear microanatomy from a database of 1100 ears. Roger Calixto, Attila Frater, Nicolas Guevara, Raabid Hussain , Jan Margeta

T24: [1860] Pulse timing interval sensitivity in the inferior colliculus of cochlear implanted rats. Fei Peng, Shiyi Fang, Muhammad Zeeshan, Bruno Castellaro, Qinjie Zhang, Jan W.H. Schnupp

T25: [1886] Optimizing EEG preprocessing pipelines for cochlear implant artifact removal: challenges and solutions. Nour Alsabbagh, Francis Smith, Phillip Gander, Joel Berger, Bob McMurry, Timothy Griffiths, Inyong Choi

T26: [1887] Comparison of speech in noise processing in hearing impaired populations using O-15 Water PET. Laura Kiskunas, Phillip Gander, Joel Berger, Bob McMurray, Inyong Choi, Laura Ponto, Tim Griffiths

T27: [1629] The effect of pulse shape on pitch sensitivity of cochlear implant users. Niyazi Omer Arslan, Xin Luo

T28: [1641] Assessing the electrode-neural interface using focused stimulation and spatial tuning curves in cochlear-implant users. Heather A Kreft, Andrew J. Oxenham

T29: [1648] How do listeners with mismatched ear quality lateralize ITDs and ILDs for complex sounds? Jarett Henry Knoepker, Tanvi Thakkar

T30: [1660] Temporal pitch perception in CI users: channel independence in apical cochlear regions. Andreas Griessner, Reinhold Schatzer, Viktor Steixner, Gunesh P. Rajan, Clemens Zierhofer, Dayse Tavora-Vieira

T31: [1709] Pitch and quality of sound perception of modulated and unmodulated pulses as a function of place and rate of stimulation. Viktor Steixner, Andreas Griessner, Sonja Karg, Reinhold Schatzer, Christian Wirtz, Peter Nopp, Werner Hemmert, Clemens Zierhofer

T32: [1712] The upper limit of temporal pitch perception for apical stimulation in cochlear implant recipients. Evelien De Groote, John M. Deeks, Robert P. Carlyon, Olivier Macherey

T33: [1715] Fast, continuous estimation of spectrotemporal modulation sensitivity. Snandan Sharma, Andrea Russo, Marc Van Wanrooij

T34: [1757] Effects of rate training on pitch discrimination and modulation detection thresholds. Ravinder Singh, Susan Bissmeyer, Ray Goldsworthy

T35: [1758] Characterization of a psychophysical test battery for the evaluation of novel speech coding strategies in cochlear implants. Bram Knipscheer, Jeroen J. Briaire, Johan H.M. Frijns

T36: [1770] Spectral resolution and its effects on spectral ripple discrimination and speech understanding in a vocoder. Sean R Anderson, Sara I Duran, Harish Krishnamoorthi, Zachary M Smith, Christopher J Long

T37: [1777] Characterizing the effect of phase duration on pitch: is it place-pitch? Natalia Stupak, David M. Landsberger, Joshua S. Stohl

T38: [1795] Psychophysical tuning curves in cochlear implant listeners: comparing a fast, novel method to a traditional approach. Charles Hem, Andrew Oxenham, Meisam Arjmandi, Heather Kreft, Julie G. Arenberg

T39: [1782] Developing personalized intervention informed by the viability of the electrode-neural interface. Jason Tzu-Hsien Lien, Ben Williges, Deborah Vickers

T40: [1837] Spatial release from masking for small spatial separations between the target and the maskers for simulated cochlear implant processed speech. Nirmal Srinivasan, SaraGrace McCannon, Chhayakant Patro

T41: [1750] The impact of pulse rate, electrode location and cross-channel interaction on pitch perception and frequency discrimination in CI users. Yue Zhang, Behnam Molaee-Ardekani, Rafael Attili Chiea, Peter T Johannesen, Enrique A Lopez-Poveda, Manuel Segovia-Martinez

T42: [1698] Should cochlear implant loudness be more like a hearing aid? Adam Hersbach, Amanda Fullerton, Zachary Smith

T43: [1803] Transformer-based monaural speech enhancement for cochlear implant (CI) users via complex spectral mapping. Nursadul Mamun, John Hansen

T44: [1832] Current spread and channel numbers limit disyllabic word and tonal recognition in simulated auditory brainstem implants. Qinjie Zhang, Huan Jia, Haoyue Tan, Qinglin Meng, Sui Huang, Hao Wu

T45: [1836] Design and optimization of an end-to-end deep learning sound coding strategy for cochlear implants through a computational model and perceptual tests. Waldo Nogueira, Franklin Alvarez, Tom Gajecki

T46: [1840] Effect of microphone directionality setting on speech understanding in noise in bilateral CI recipients. Thomas Wesarg, Konstantin Wiebe, Susan Arndt, Antje Aschendorff, Horst Hessel, Maximilian Haider

T47: [1871] A generic signal processing framework for speech redundancy manipulation algorithms in speech perception studies. Fanhui Kong, Huali Zhou, Qinglin Meng, Nengheng Zheng

T48: [1882] Pitch and lexical tone perception in quiet and noise using F0-rate coding strategies. Andrew E. Vandali, Zachary M. Smith, Komal Arora, Lei Xu, Jianfen Luo, Ruijie Wang, Xiuhua Chao, Yi Zheng

T49: [1883] Deep neural network-based noise reduction for cochlear implants. Amanda Fullerton, Adam Hersbach, Harish Krishnamoorthi, Tim Brochier, Zachary Smith

T50: [1682] Sound of metal: a real-time vocoder audio plugin for cochlear implant simulations. Shaikat Hossain

T51: [1719] A comparative study of music preprocessing strategies for cochlear implant listeners. Johannes Gauer, Anil Nagathil, Benjamin Lentz, Christiane Voelter, Rainer Martin

T52: [1734] Frequency discrimination and music enjoyment in adult cochlear implant users. Cheuk-Chee Cynthia Lam, Nicholas Haywood, Brian C.J. Moore, Ben Williges, Deborah A. Vickers

T53: [1742] Exploring rate-coded pitch perception in CI users vs. a wavelet vocoder using the Oticon Medical research platform. Bradford C. Backus, Tobias Herzke

T54: [1745] Individualized optimization of a music remixing method for cochlear implant users. Anil Nagathil, Johannes Gauer, Sinnthujan Jeyachandran, Rainer Martin

T55: [1813] Melodic contour identification through CI simulations using efficient coding filter banks. Agnieszka Duniec, Olivier Crouzet, Elisabeth Delais-Roussarie

T56: [1816] Effects of manipulating channel interaction on music perception in adults with cochlear implants. Katelyn Berg, Ray Goldsworthy, Jack Noble, Rene Gifford

T57: [1819] Feature information transmission analysis of musical timbre perception. Rudolph C Uys, Johan J Hanekom

T58: [1858] Exploring melodic contour identification with spectrally reduced stimuli for improved cochlear implant music perception. Avamarie Brueggeman, Juliana N Saba, John H. L. Hansen

T59: [1888] Music emotion perception with cochlear implants. Eleanor E Harding, Etienne Gaudrain, Robert Harris, Barbara Tillmann, Bert Maat, Rolien Free, Deniz Baskent

T60:

T61: [1583] Optical coherence tomography for image-guided cochlear implantation and diagnostics: a near future? Nicolas Verhaert, Lore Kerkhofs, Anastasiya Starovoyt, Tristan Putzeys, Jan Wouters, Greet Kerckhofs

T62: [1595] Impact trial: a multicenter randomized controlled trial evaluating the efficacy of a parent-implemented therapy on language development in children with cochlear implants. Efstratia Papoutselou, Trish Hepburn, Jayne Ramirez-Inscoe, Angela Maxwell, Sarah Paganga, Samantha Harrison, Guangting Mai, Colleen Ewart, Douglas Hartley

T63: [1662] Personalized cochlear implantation using real-time fluoroscopy and intraoperative ECAP measurements. Nadine Buczak, Eugen Kludt, Silas Ewald, Rolf Salcher, Kerstin Willenborg, Andreas Buechner, Andrej Kral, Thomas Lenarz

T64: [1708] Feasibility of extracochlear stimulation to induce hearing and reduce tinnitus. Rahel Bertschinger, Leanne Sijgers, Marlies Geys, Lorenz Epprecht, Adrian Dalbert, Christof Roeoesli, Flurin Pfiffner, Alexander Huber

T65: [1711] Auditory diagnostics and error-based treatment: working towards a performance-driven fitting paradigm. Enrico Migliorini, Nikki Philpott, Jan-Willem Wasmann, Bas van Dijk, Birgit Philips, Emmanuel Mylanus, Wendy Huinck

T66: [1808] Exploring the effect of change to electrical threshold setting and rate of stimulation to the perception of soft intensity speech cues and speech in experienced adult cochlear implant users. Terry B Nunn, Tim Green, Dan Jiang, Patrick Boyle, Deborah A Vickers

T67:

T68: [1814] An alternative method for drug-coating preparation on electrode array of cochlear implant portable electrospinning of PCL/PEO. Haoyue TAN, Qinjie ZHANG, Huan JIA

T69: [1824] translational anatomy in cochlear implant research. Rene Baron, Tania Hanekom, Andre Uys, Kalisha Beehmraj, Shavana Govender

T70: [1878] Developing and validating virtual-audio clinical tools for assessing spatial-listening skills for children with bilateral cochlear implants. Marina Salorio-Corbetto, Bhavisha Parmar, Jennifer Bizley, Stuart Rosen, Tim Green, Lorenzo Picinali, Ben Williges, Deborah Vickers

Wednesday 12 July

W1: [1669] Loudness enhancement for cochlear implant users with tactile stimulation. Scott C. Aker, Kathleen F. Faulkner, Hella D. Flocken, Hamish Innes-Brown, Jeremy Marozeau

W2: [1680] Visual plasticity throughout rehabilitation with a cochlear implant. Andrea J DeFreese, Katelyn A Berg, Eric Larson, Adrian K.C. Lee, Mark T Wallace, Rene H Gifford

W3: [1744] Investigating cross-modal plasticity and speech outcomes in CI users using EEG. Brandon T. Paul, Andrew Dimitrijevic

W4: [1833] Effect of audiovisual asynchrony on speech intelligibility in CI users and typical hearing controls. Cailey A Salagovic, Ryan A Stevenson, Blake E Butler

W5: [1854] Assessing the relative benefit of real time captioning for speech in noise benefit. Gavriel D Kohlberg, Yi Shen, Adrian KC Lee, Jay T Rubinstein, Les E Atlas, Richard A Wright

W6: [1582] The use of frequency importance functions in predicting speech perception in adult cochlear implant and normal hearing listeners. Malia Henderson, Douglas Sladen, Adam Bosen

W7: [1601] Bilateral cochlear implant users have more difficulty controlling vocal intensity when using both devices. Simin Soleimanifar, Justin M Aronoff

W8: [1609] Effects of talker variability and linguistic content on speech-perception scores. Priya K Premkumar, Molly S Pangestu, Laurencia Santillan, Delaney J Skretta, Michelle L Hughes

W9: [1622] Links between perception and production of emotional prosody by prelingually deaf children with cochlear implants. Ava Feller, Aditya M Kulkarni, John J Galvin 3rd, Monita Chatterjee

W10: [1628] How children and adults with normal hearing or cochlear implants use voice pitch and duration cues for emotional prosody identification. Aditya M Kulkarni, Denis Fitzpatrick, Monita Chatterjee

W11: [1630] Does speech production relate to speech perception in adult cochlear implant users? Victoria A. Sevich, Aaron C. Moberly, Terrin N. Tamati

W12: [1733] Speech-in-noise ability is differentially predicted by neural responses in auditory and prefrontal cortex of cochlear implantees. Joel I Berger, Phillip E Gander, Laura L Ponto, Jae-hee Lee, Laura Kiskunas, Camille Dunn, Bruce J Gantz, Bob McMurray, Inyong Choi, Timothy D Griffiths

W13: [1747] Age-related temporal processing deficits in cochlear-implant listeners interact with presentation level to alter perception of speech contrasts. Anna R. Tinnemore, Erin M. Doyle, Pallavi Atluri, Chengjie G Huang, Miranda I Cleary, Matthew J Goupell

W14: [1762] Perception of prosodic cues for contrastive focus in sentences. Harley Wheeler, Tereza Krogseng, Matthew Winn

W15: [1773] Increased lexical competition during spoken word recognition by children with cochlear implants. Christina M Blomquist, Jan R Edwards, Rochelle S Newman

W16: [1775] Attributes of vocal emotion perceived through a cochlear implant. David M. Landsberger, Natalia Stupak, Rahul Sinha, Aaron M. Johnson, John J. Galvin

W17: [1787] Spectral resolution and speech production in pediatric cochlear implants users. Mackenzie A. Lighterink, Rene H. Gifford, Stephen M. Camarata, Ferenc Bunta

W18: [1793] Transmission of acoustic cues in consonant confusions and its relationship to spectral resolution in listeners with cochlear implants. Destinee M Halverson, Anisha Noble, Mariette S Broncheau, Olga Peskova, Jay T Rubinstein, Lynne A Werner, David L Horn

W19: [1805] Relationships between perception and production errors in normal hearing children, pediatric cochlear implant users and children listening to vocoder simulations. Olga Peskova , Abbey L. Thomas, Peter F. Assmann, David L. Horn

W20: [1822] Amplitude envelope cues to vocal emotion recognition with cochlear implants. Xin Luo, John J. Galvin, Monita Chatterjee

W21: [1825] The effect of bimodal hearing on speech intonation production of adult cochlear implant users. Chang Ai, Xin Luo

W22: [1869] The contributions of harmonicity in speech-on-speech recognition with cochlear implants. Mingyue Shi, Huali Zhou, Jiawen Li, Yefei Mo, Qinglin Meng, Nengheng Zheng

W23: [1581] Developmental effects of concurrent auditory and vestibular impairments on working memory, language, and academic abilities in children with bilateral cochlear implants. Melissa Hazen, Sharon L Cushing, Karen A Gordon

W24: [1620] Development of frequency resolution and spectral-modulation sensitivity in infants who use cochlear implants. David Louis Horn, Mariette Broncheau, Destinee Halverson, Jay Rubinstein, Lynne Werner

W25: [1710] Phonological discrimination for the learning of novel words: a study in children with cochlear implants. Julia SC Chiossi, Elaine HN Ng, Kathleen Faulkner, Lone M Percy-Smith, Bjorn Lyxell

W26: [1785] Changes in infants' and toddlers' vocal activity before and immediately after cochlear implant activation. Margaret Cychosz, Ana Marija Sola, Chiara Scarpelli, Jihyun Stephans, Kayla Kolhede, Dylan K. Chan

W27: [1848] Pediatric cochlear implant users' speech and language performance: the role of socioeconomic factors and third-party support. Heo yujin, lee changhee, moon il joon, chung won-ho, cho yang-sun, cho young sang

W28: [1580] Measuring the timing and duration of listening effort needed to mentally repair misperceptions in cochlear implant listeners. Michael L. Smith, Matthew B. Winn

W29: [1584] Cochlear implant listening effort: a difference of efficiency rather than magnitude. Matthew Brandon Winn

W30: [1587] Measuring the timeline of retroactive sentence repair in listeners with cochlear implants. Steven P. Gianakas, Matthew B. Winn

W31: [1608] When do cochlear implant users "give up"?: the impact of SNR, peripheral auditory sensitivity and central cognitive profile on CI users' speech recognition and listening effort. Yue Zhang, Amparo Callejon-Leblic, Ana M Picazo-Reina, Francois Patou, Serafin Sanchez-Gomez

W32: [1644] The role of listening effort in mitigating rollover effects of speech-in-noise perception in cochlear implant users. Chengjie Huang, Samira Anderson, Matthew Goupell

W33: [1647] Reducing listening effort with cochlear implant simulation via auditory training. Seeon Kim, Yi Zhou, Xin Luo

W34: [1665] Oscillatory alpha activity as a neuronal correlate of working memory, in adult cochlear implant recipients with different degrees of speech perception performance. Loes Beckers, Anna Ruhe, Birgit Philips, Wendy Huinck, Emmanuel Mylanus, Andreas Buechner, Andrej Kral

W35: [1691] Gated word recognition: effects of spectral resolution and electro-acoustic stimulation. Ellen Shephard, Ariana Bennaim, Nirmal Srinivasan, Chhayakant Patro

W36: [1701] Dual-task performance of normal-hearing adults, cochlear implant users, and hearing aid users in a listening effort dual-task paradigm. Dorien Ceuleers, Freya Swinnen, Nele Baudonck, Katrien Kestens, Sofie Degeest, Ingeborg Dhooge, Hannah Keppler

W37: [1738] Differences in neural correlates of auditory working memory between cochlear implant users and normal hearing controls. Priyanka Prince

W38: [1739] Neural entrainment of a naturalistic conversation in varying working memory loads. Priyanka Prince

W39: [1779] Differences in cortical processing of meaningful and semantically anomalous sentences in adult CI users: the effects of "neural context gain" on sentence recognition scores. Maureen J Shader, Leroy Medrano

W40: [1791] Identifying the neural responses to auditory and audiovisual speech during movie watching using optical neuroimaging. Jonathan E Peelle, Emily N Milarachi, Arefeh Sherafati, Michael S Jones, Noel Dwyer, Aahana Bajracharya, Jill B Firszt, Joseph P Culver

W41: [1818] Comparing cognitive performance between individuals with cochlear implants and acoustic hearing on a neuropsychological battery with accommodations for hearing loss. Rebecca Kelly, Miranda Cleary, Anjeli Inscore, Dux Moira, Aditya Kulkarni, Nicole Nguyen, Jacob Blumenthal, Anna Tinnemore, Matthew J Goupell

W42: [1835] Neural mechanisms of spatial release from masking in vocoded and non-vocoded environments. Benjamin Richardson, Barbara Shinn-Cunningham, Jana Kainerstorfer, Christopher Brown

W43: [1559] Variability in clinicians' prediction accuracy for outcomes of adult cochlear implant users. Nikki Philpott, Birgit Philips, Rogier Donders, Emmanuel A Mylanus, Wendy J Huinck

W44: [1576] Use of machine learning to predict adult cochlear implant benefit using reliable change index. Aaron C Moberly, Patrick J Lawrence, Terrin N Tamati, Xia Ning

W45: [1635] The influence of stimulus polarity on outcome prediction with measures of cochlear neural health and their relationship with age. Heval Benav, Ladan Zamaninezhad, Carolyn Garnham, Berkutay Mert, Jochen Tillein, Uwe Baumann

W46: [1655] Comparison of tonotopic maps for cochlear implant fitting: a study on 149 patients from MHH hospital. Raabid Hussain, Anika Morgenstern, Behnam Molaee-Ardekani, Jan Margeta, Andreas Buechner

W47: [1700] Investigation of the auditory, visual, and cognitive abilities: differences between normal-hearing adults, hearing aid users, and cochlear implant users and the proposition of an AVC-profile. Dorien Ceuleers, Hannah Keppler, Sofie Degeest, Nele Baudonck, Freya Swinnen, Katrien Kestens, Ingeborg Dhooge

W48: [1732] Gathering ecological data to assess real-life benefits of cochlear implants. Lelia Erscoi, Yue Zhang, Manuel Segovia-Martinez

W49: [1737] Effect of frequency-to-place mismatch and frequency warp on speech and music sound quality in acoustic cochlear implant simulation. Louis Villejoubert, Lorenzo Picinali, Kathleen Faulkner, Deborah Vickers

W50: [1761] An extraordinary auditory brainstem implant (ABI) user: strengths, weaknesses, and milestones. Carolyn Herbert, William G. Kronenberger, Rick F. Nelson, Kim Wolfert, Charles Yates, David Pisoni

W51: [1778] On the development of a questionnaire towards understanding barriers to adult CI uptake: a literature review. Jonathan D Neukam, Ankita Patro, Aaron C Moberly, Terrin Tamati

W52: [1784] Do social networks relate to speech recognition and real-world functioning in adult cochlear implant users? Terrin N. Tamati, Victoria A. Sevich, Aaron C. Moberly, Sara Conroy

W53: [1797] Effects of inter-implant delay and auditory experience on spatial release from masking in children with bilateral cochlear implants. Nimesha Didulani Dantanarayana, Shelly P Godar, Sara M Misurelli, Ruth Y Litovsky

W54: [1804] A prospective, multi-center case-control trial examining factors that predict variable clinical performance in post lingual adult CI recipients (PREVA). Pam Dawson, Amanda Fullerton, Harish Krishnamoorthi, Kerrie Plant, Andreas Buchner, Robert Cowan

W55: [1845] Beliefs toward current and increased sound processor wear time in adult CI users. Birgit Philips, Griet Goovaerts, Cherith Campbell-Bell, Val Roman, Jim May

W56: [1859] Improving the CI-aided audiogram: is it worth measuring electrical thresholds? Nicole Hope Capach, Noam Zigdon, Jonathan D Neukam, William H Shapiro, Mario A Svirsky

W57: [1868] Effect of inner ear malformations on relationships between intraoperative ECAP responses and postoperative auditory performances. Ye-Jin Suh, Jeong-Seo Kim, Il Joon Moon

W58: [1872] Assessment of cochlear implant hearing outcomes using ecological momentary assessment (EMA) in both controlled and real-world settings. Zachary M. Smith, Qingqing Meng, Marisa Poulos, Jessica Monaghan, Jorge Mejia

Thursday 13 July

Th1: [1565] Feasibility of interbrain synchrony between cochlear implanted children and their mother: a fNIRS study. Hilal Dogan, Douglas Hartley, Ian Wiggins, Samantha Harrison, Efstratia Papoutselou, Guanting Mai

Th2: [1571] Electrically evoked compound action potentials as marker for spiral ganglion neuron damage and degeneration. Wiebke Susanne Konerding, Julie G. Arenberg, Andrej Kral, Peter Baumhoff

Th3: [1577] Bone density-based selection of optimal stimulation sites for bone conduction implants. Emile Talon, Franca Wagner, Marco Caversaccio, Wilhelm Wimmer

Th4: [1585] A robust method for removing artifacts from recordings of electrically evoked compound action potentials evoked by single pulse and pulse train stimulation. Jeffrey Skidmore, Yi Yuan, Shuman He

Th5: [1596] Towards objective electrode-selection strategies based on neural temporal envelope encoding in cochlear-implant users. Wouter David, Elise Verwaerde, Robin Gransier, Jan Wouters

Th6: [1598] The effect of stimulation waveform on electrically elicited stapedius response threshold (eSRT) in neuro cochlear implants. Behnam Molaee-Ardekani, Anika Morgenstern, Lutz Gaertner, Andreas Buechner, Manuel Segovia Martinez

Th7: [1645] Pupillometry and subjective ratings of task difficulty yield conflicting results in CI users when using the Dutch-Flemish matrix test. H Christiaan Stronks, Annemijn L. Tops, Kwong Wing Quach, Jeroen J. Briaire, Johan H. M. Frijns

Th8: [1656] Assessing array-type differences in current spread in cochlear implant users using the panoramic ECAP method. Charlotte Garcia, Robert P Carlyon

Th9: [1661] Recording of cortical potentials evoked acoustically and electrically directly through a cochlear implant. Joseph Attias, Suhail HabibAllah, Chen Chen

Th10: [1663] Fourier filter enhanced averaging applied on ECAP amplitude growth functions. Konrad Schwarz, Lutz Gaertner, Timo Braecker, Marko Takanen, Stefan Strahl, Angelika Dierker, Kathrin Lauss, Philipp Spitzer

Th11: [1664] Investigating the effect of blurring and focusing current on estimates of current spread in cochlear implant users with the panoramic ECAP method. Charlotte Garcia, Charlotte Morse-Fortier, Francois Guerit, Tobias Goehring, Robert P Carlyon, Julie G Arenberg

Th12: [1672] Does simple impedance reflect intrascalar tissue in the implanted cochlea? Deborah J. Colesa, Katie L. Colesa, Yuki Low, Don L. Swiderski, Yehoash Raphael, Bryan E. Pfingst

Th13: [1678] Using an app-based data collection tool to measure impedances remotely in everyday life. Rene Gifford, Robert Dwyer, Time Schoof, Sridhar Kalluri, Courtney Butler, Jourdan Holder

Th14:

Th15: [1695] CT-based mapping at initial activation: a longitudinal crossover study of music and speech perception. Melanie L Gilbert, Mickael L D Deroche, Patpong Jiradejvong, Charles J Limb

Th16: [1696] Towards using cochlear implant electrodes to record cortical responses to sustained high-rate stimulation. Charlotte Garcia, Dorothee Arzounian, Francois Guerit, John M Deeks, Robert P Carlyon

Th17: [1704] Predicting electrode-modiolar distances in cochlear implant recipients using monopolar, three-point and four-point impedance measurements. Leanne Sijgers, Alexander Huber, Marlies Geys, Christof Roeoesli, Norbert Dillier, Patrick Boyle, Adrian Dalbert, Flurin Pfiffner

Th18: [1722] New insights in the electrically evoked compound action potential. Stefan Strahl, Konrad Schwarz, Marko Takanen, Philipp Spitzer, Angelika Dierker, Henk Vink, Huib Versnel, Dyan Ramekers

Th19: [1723] Cortical tracking of speech perception: Effects of intelligibility and spectral degradation. Alexis Deighton MacIntyre, Robert P Carlyon, Tobias Goehring

Th20: [1727] Assessment of binaural interaction in SSD CI users from auditory brainstem responses. Sebastian Roth, Julian Angermeier, Antje Aschendorff, Thomas Wesarg, Werner Hemmert, Stefan Zirn

Th21: [1728] The potential of objective T-level determination in CI recipients using envelope following responses. Julian Schott, Robin Gransier, Marc Moonen, Jan Wouters

Th22: [1729] Insights from multi-level ECochG recorded across the full electrode array. Patrick Joseph Boyle, Shaza Salec, Farid Alzahrani1, Rana Alshihri

Th23: [1743] Detection of changes in amplitude modulation depth and rate can predict speech understanding in cochlear implant users – a behavioral and electrophysiological study. Nina Aldag, Waldo Nogueira

Th24: [1763] Superior sound localization abilities with bilateral middle ear implants for patients with bilateral conductive hearing loss. Martijn Agterberg, Daniela Hollfelder, Louise Straatman, Karl-Ludwig Bruchhage, Anke Leichtle

Th25: [1769] Electrophysiological measures of temporal pitch processing in an animal model of cochlear electric stimulation. Matthew L Richardson, Robin Gransier, Francois Guerit, Jan Wouters, Robert P Carlyon, Harrison W Lin, John C Middlebrooks

Th26: [1772] Exploring the use of Otoplan to assist with planning ECOG intraoperative monitoring strategies. Rachel A Scheperle, Christine P Etler, Camille C Dunn, Alexander D Claussen, Bruce J Gantz, Marlan R Hansen

Th27: [1789] Inter-brain synchrony between children with cochlear implants and their mother: an fnirs study. Hilal Dogan, Efstratia Papoutselou, Samantha Harrison, Guangting Mai, Douglas E H Hartley

Th28: [1817] Multifrequency electrocochleography and electrode scan to monitor hair cell function during cochlear implant electrode placement. Aniket A Saoji, Madison K Graham, Matthew L Carlson, Brian A Neff, Colin L W Driscoll, Weston J Adkins, Douglas C Fitzpatrick

Th29: [1884] Fast tracking early intervention for infants with hearing loss. Colette McKay, Tommy Peng, Julia Wunderlich, Onn Wah Lee, Gautam McKay, Darren McKay

Th30: [1560] The importance of hearing preservation in children with cochlear implants and preoperative residual hearing. Lisa Park, Margaret Dillon, Margaret Richter

Th31: [1603] Comparison of spread of activation and interaction between channels during electrical and optogenetic stimulation in the mouse cochlea. Ajmal A Azees, Alex C Thompson, Elise A Ajay, Andrew K Wise, Patrick Ruther, David Garret, Anita Quigley, James B Fallon, Rachael T Richardson

Th32: [1638] Predicting cochlear implant outcomes in candidates with residual hearing. David R Friedmann, David M Landsberger, Emily R Spitzer

Th33: [1652] Three-dimensional analysis of the effects of tissue response on hearing. Ella P Trang, James Firth, Gabriela Segal-Wasserman, Ellie Cho, Andrew Wise, James Fallon

Th34:

Th35: [1681] Behavioral discrimination of simple speech sounds in cats with partial hearing and a cochlear implant. James Firth, Alex C Thompson, Anu Sabu, David B Grayden, Dexter RF Irvine, James B Fallon

Th36: [1702] Wide-field calcium imaging for evaluating cochlear implant stimulation strategies in the auditory cortex. Bruno Castellaro

Th37: [1847] Determining the required number of high-frequency electrical stimulation channels to improve speech intelligibility in individuals with residual low-frequency hearing. Isabel N. Herb, Emily A. Burg, Jay Dhuldhoya, Francis Wong, Matt B. Fitzgerald

Th38: [1891] Towards extracochlear electric-acoustic stimulation of the auditory system. Benjamin Krueger, Aenne Grosskopf, Waldo Nogueira

Th39: [1721] Towards a cell-based treatment for hearing loss; exploring the views of patients and the public. Efstratia Papoutselou, Faizah Mushtaq, Rachel Haines, Douglas Hartley

Th40: [1693] Dendritic complexity of layer III and V pyramidal cells in the congenitally deaf auditory cortex. Lea Sollmann, Ana Bedalov, Damir Kovacic, Andrej Kral

Th41: [1694] Cortical development features in congenital deafness children after auditory brainstem implant. Hao Wu

Th42: [1717] Assessing speech processing during a functional near-infrared spectroscopy task in normal hearing listeners and cochlear implant users. Andras Balint, Wilhelm Wimmer, Marco Caversaccio, Christian Rummel, Stefan Weder

Th43: [1755] Neural correlates of post-activation changes in loudness perception by adult cochlear implant recipients. Dorothee Arzounian, Francois Guerit, John M. Deeks, Charlotte Garcia, Evelien de Groote, Manohar Bance, Robert P. Carlyon

Th44: [1781] White-matter microstructure differences between cochlear implant candidates and their hearing peers: a pilot diffusion tensor imaging study. Yingying Wang, Jordan Bollinger, Lauren Secilmis, Michelle Hughes, Hongying Daisy Dai

Th45: [1867] Neuroplasticity in rats and humans with cochlear implants. Ariel Edward Hight, Erin G. Glennon, Julia Scarpa, Nicole Capach, Jonathan Neukam, Yew-Song Cheng, Michele Insanally, Robert C. Froemke, Mario A. Svirsky

Th46: [1890] Cochlear implant users improvising on the piano: a new method for training perception in multiple domains. Eleanor E Harding, Etienne Gaudrain, Robert Harris, Barbara Tillmann, Bert Maat, Rolien Free, Deniz Baskent

Th47: [1569] 3D printed cochlea model for electrode insertion bench test. Guillaume Tourrel, Julie Foncy, Renato Torres, Yann Nguyen

Th48: [1579] Controlled curvature electrode array with ionic electro active polymer-based micro-actuators for cochlear implantation. Ahmad Itawi, Guillaume tourrel, Renato Torres, Prabhakar Sidambaram, Sofiane Ghenna, Sebastien Grondel, Yann Nguyen, Eric Cattan

Th49: [1637] Oticon Medical research tools – practical examples of their utilization. Rafael Attili Chiea, Behnam Molaee-Ardekani, Yue Zhang, Manuel Segovia-Martinez

Th50: [1650] Development of 32-channel cochlear implant. Kyou Sik Min, Hoseung Lee, Woojin Ahn, Soowon Shin, Jeongwoo Lim

Th51: [1686] Visualization system for real-time monitoring of electrode array insertion into the human cochlea. Joaquin Cury, Claus-Peter Richter

Th52: [1688] A novel prototype: the hybrid opto-electrical cochlear implant for hearing restoration. Joaquin Cury, Matthew Joo-yoon Kim, Xiaodong Tan, Claus-Peter Richter

Th53: [1690] Optical properties of the human cochlea bone. Joaquin Cury, Claus-Peter Richter

Th54: [1684] Coding strategy for opto-electrical hybrid cochlear implant. Claus-Peter Richter, Joaquin Cury

Th55: [1606] In-silico evaluation of sound encoding of optogenetic cochlear implants. Lakshay Khurana, Petr Nejedly, Lukasz Jablonski, Tobias Moser

Th56: [1829] Robot-assisted electrode array insertion for cochlear implantation: technique note and 3-year review. Huan Jia, Haoyue Tan, Qinjie Zhang, Zhihua Zhang, Zhaoyan Wang, Mengda Jiang, Hao Wu

Th57: [1863] Development of novel stimulation strategies and techniques for direct electrical stimulation of the auditory nerve using a penetrating electrode array. Inderbir Sondh, Hubert Lim

Th58: [1877] Zwitterion modified cochlear implants resist postoperative infection and inflammation. Hongzheng Zhang, Anning Chen

PODIUM ABSTRACTS

P1: AUDITORY SKILLS OF CHILDREN WITH SINGLE-SIDED DEAFNESS AND A COCHLEAR IMPLANT

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Congenital single-sided deafness (SSD) affects approximately 25 newborns per year in Flanders. These children have profound hearing loss in one ear (> 90 dB HL) and normal hearing in the other ear. As such, they have no access to binaural hearing, which typically causes limited sound localization and impaired speech perception in noise. In addition, the children are at risk for speech-language delays, socio-emotional difficulties, and academic underachievement. Furthermore, SSD can affect the children’s cortical development and lead to asymmetric auditory processing.

Children with SSD may benefit from a cochlear implant (CI) in their deaf ear. This treatment option could restore bilateral hearing and may even enable binaural hearing. Early implantation is likely of key importance to achieve optimal outcomes, given the sensitive period for brain development early in life. Unfortunately, many countries worldwide (including Belgium) provide no reimbursement for CIs for this population.

In our ongoing multicenter study (Leuven, Antwerp, and Ghent), we assess the impact of a CI on the development of 20 young children with prelingual SSD. The average age at implantation was 15.2 ± 5.6 months (range 8-26 months), which is well within the generally accepted window of opportunity. At regular intervals, we document multiple aspects of the children’s development, including spatial hearing, language, and cognitive skills. We hypothesized that the CI would support spatial hearing as well as language and cognitive development, resulting in overall improved outcomes compared to a control group of non-implanted peers with SSD.

In this talk, I will focus on the auditory skills of our group of implanted children. In particular, I will present longitudinal results for spatial speech perception in noise and sound localization from 16 children with SSD and a CI aged 4 years or older. Their results will be compared to those of two control groups: peers with SSD without a CI, and children with bilateral normal hearing. I will also present some data regarding the children’s ability to understand speech in quiet using only their CI.

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P2: OBJECTIVE MEASURES OF BINAURAL PROCESSING BASED ON CORTICAL AUDITORY EVOKED POTENTIALS

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Electric and acoustic stimulation (EAS) is an auditory intervention combining cochlear implant and hearing aid technology within and across ears to optimize broadband auditory access. EAS is an increasingly prevalent cochlear implant (CI) intervention for patients with precipitously sloping high-frequency hearing losses. However, much like other CI configurations, EAS yields outcomes that are variable at across patients and this variability is not explained by the underlying audiogram (Gifford et al., 2013, 2014). Instead, research has shown that EAS benefit is significantly correlated with binaural cue sensitivity—interaural time differences (ITD)—in the acoustic hearing domain with the most robust effect observed for fine structure ITD sensitivity (Gifford et al., 2013, 2014; Gifford & Stecker, 2020). Currently, ITD sensitivity is typically measured using behavioral methods that are time-consuming and require listener training, which limits the feasibility of measuring ITD thresholds in everyday clinical practice. However, previous research has demonstrated the efficacy of using interaural phase differences (IPDs)—equivalent to ITDs for steady periodic tones—to identify binaural cue sensitivity with cortical auditory evoked potentials (Papesh et al., 2017; Ross et al., 2007).

In this research, we measured ITD sensitivity using both cortical auditory evoked potentials (CAEPs) and behavioral methods on 10 participants with normal hearing. For behavioral ITD thresholds, we used a 250-Hz tone and assessed thresholds via psychometric function generated with a method of constant stimuli. For CAEPs, we used a binaurally presented stimulus incorporating carrier sinusoids of 250 Hz and 1000 Hz with imposed sinusoidal amplitude modulation at a rate of 40 Hz. IPDs of 0, 45, 90, 135, or 180 degrees is imposed at stimulus midpoint in one ear.

Our results indicated that: 1) The strength of the participants' acoustic change complex (ACC) measured by subtracting the peak from valley value was positively correlated with IPD values. 2) The strength of the participants' ACC measured by calculating the energy of the response value is also positively correlated to IPD values. 3) The participants' IPD sensitivity as measured via ACC was positively correlated with behavioral ITD thresholds. In summary, given the relationship observed between behavioral and objective measures of binaural cue sensitivity, it is possible that the use of the ACC with IPD could help identify CI users with bilateral acoustic hearing who might benefit from EAS and could potentially be administered in the preoperative period to gauge binaural cue sensitivity. Future directions include ongoing research in the EAS population to investigate whether this relationship is maintained for individuals with bilateral sensorineural hearing loss.

P3: SPEECH PERCEPTION AND SOUND LOCALIZATION ABILITY IN CI SUBJECTS WITH ELECTRIC-ACOUSTIC STIMULATION AND CONTRALATERAL NORMAL HEARING

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Introduction: The use of electric-acoustic stimulation (EAS) is an established treatment in patients with partial deafness and residual hearing in the low frequencies. Several studies have demonstrated better speech perception in noise and better sound quality (especially when listening to music) compared to cochlear implant (CI) users with electrical stimulation only. In unilateral deafness or unilateral partial deafness with contralateral normal hearing, the lack of ability to localize sound, decreased speech perception in noise, and increased hearing effort lead to the desire for cochlear implantation. The aim of the present study was to assess hearing abilities in subjects with single-sided partial deafness using EAS stimulation.

Method: EAS users with contralateral normal hearing or mild hearing loss participated in this study. Up to now, 15 subjects with EAS stimulation in the ipsilateral ear and normal hearing in the contralateral ear were implanted at our department. Speech reception thresholds (SRTs) in noise were assessed with the German Oldenburg matrix test (OLSA) in different spatial noise conditions and for different noise characteristics. Additionally, SRTs were measured in the presence of reverberation (T60=0.8 sec). SRT measurements were conducted with EAS stimulation and compared with acoustic stimulation of the contralateral ear alone. Combined with the SRT measurements, an adaptive categorical scaling method to rate subjective listening effort was established (combined OLSA+ACALES). Mean error in sound localization was measured with an LED pointer method.

Results: Improved SRTs with EAS stimulation in simultaneous and spatially separated masker conditions were observed. In contrast to previous studies, EAS users showed no adverse effect of EAS/CI stimulation on glimpsing in modulated noise conditions. In more diffuse noise conditions and in the presence of reverberation, no beneficial effect of EAS stimulation on SRT was found. However, subjective listening effort with EAS was lower compared to unilateral acoustic hearing even for positive SNRs (which are typically present in everyday life). Mean localization error using EAS was improved by 28.5° in the range of normal hearing listeners.

Conclusion: Even for patients with contralateral normal hearing, EAS can improve speech perception in noise, restore sound localization and reduce listening effort in everyday life. While sound localization abilities in the horizontal plane were comparable to normal hearing, SRTs were still worse than in normal hearing participants.

P4: ASYMMETRIC HEARING IMPACTS BINAURAL HEARING IN CHILDREN WHO USE BIMODAL DEVICES

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Communication in everyday acoustic environments is facilitated by the ability to locate, separate, and process speech from different locations. We do this by combining information picked up from both ears. Typically, the auditory system does not simply relay information delivered by both ears; rather, bilateral information is combined through elaborate binaural pathways in the brainstem and cortex. These pathways have sensitive periods during which access to binaural cues is needed so that these complex pathways can develop and provide the foundation for spatial hearing skills. Asymmetric hearing disrupts the binaural cues coming from both ears and drives neuro-adaptive changes to the auditory system. This talk will discuss the benefits and challenges of using bimodal devices to treat asymmetric hearing loss in children, including the underlying brainstem and cortical processing of binaural cues and the implications for spatial hearing.

This work was funded by the Canadian Institutes of Health Research (CIHR) fellowship to MP and grant to KG, and Restracomp and Clinician-Scientist Training Program to MP from the SickKids Research Institute

P5: SPATIAL HEARING WITH MISMATCHED INFORMATION ACROSS THE EARS IN BILATERAL COCHLEAR IMPLANT LISTENERS

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Bilateral cochlear implant (CI) users enjoy some, but not all benefits of spatial hearing compared to their normal (binaural) hearing peers. There are well documented improvements in spatial speech perception, localization, lateralization, and quality of life compared to unilateral CI listening. Among the factors thought to be influential are: Access to binaural cues (distortions by directional microphones, sound coding strategies), the time-interval between receiving both CIs, aural preference for a stronger vs. weaker ear, integrity of the electrode neuron interface on both sides (e.g. neural survival and channel interaction) and the complex interplay between the ascending and descending auditory pathways (inferior colliculus, MOC, plasticity of cortical representations). Quite often, it is assumed that both ears are the same, although in practice this isn’t necessarily the case, due to e.g. different neural survival between the ears, or different depths of insertion of the CI electrode array.

In the first experiment we investigated the influence of interaural mismatch in terms of channel interaction across ears. For both localization and spatial speech intelligibility, a dual task paradigm was employed using a vocoder capable of simulating varying degrees of channel interaction. Coding strategies and insertion depth were held constant, and the extent of channel interaction was varied between the ears. Having a poorer ear due to increased current spread led to a decrease in localization skills, but not in spatial speech intelligibility.

In the second experiment, it was assessed if these effects of weaker and stronger ear are relevant for a patient population when multiple factors are involved, using a retrospective analysis of bilaterally implanted children. For 77 bilaterally implanted children, depth-of-insertion angle estimates were obtained from post-op x-ray images, and the overall interaural insertion depth mismatch calculated. Using data from 12 months post-activation, no significant effects of interaural insertion depth mismatch were found for the sub-set of children for whom localization (n=19) or spatial speech intelligibility (n=16). However, the number of datasets is too small (under-powered) for us to draw strong conclusions and estimates of insertion depth using x-rays is prone to error. We are exploring further interactions between absolute insertion depth, length of electrode array, and interaural insertion depth mismatch and we are also developing automated methods for improving the accuracy of insertion depth estimates.

Taken together, this highlights the need for innovative approaches to enable binaural hearing in bilateral CIs. Given the remarkable plasticity of the central auditory pathways to adapt to CI stimulation, approaches for targeted training, introduction of binaural cues, such as interaural time differences and even biological interventions may show promise.

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P6: SENSITIVITY TO ENVELOPE AND PULSE TIMING INTERAURAL TIME DIFFERENCES IN PROSTHETIC HEARING

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Binaural cues, such as interaural time difference (ITD), play a crucial role in localizing sound sources in the auditory system. However, contemporary cochlear implant (CI) processors use a coding strategy that only conveys the ITD information contained in the envelope of the sound (envelope ITD) to the cochlear implant (CI) user. As a result, the ITD information contained in the temporal fine structure of the sound (pulse-timing ITD) is not transmitted, which may contribute to the poor spatial hearing perception of CI users.

To investigate the sensitivity of CI-implanted rats to envelope and pulse timing ITD, we designed a stimulus comprising a 900pps pulse train modulated by a 20 Hz sine envelope in which pulse timing ITD (PT_ITD) and envelope ITD (ENV_ITD) could vary independently from the values {-0.1, 0, 0.1 ms}. We recorded neural activity from the inferior colliculus (IC) of anesthetized neonatal deafened rats using a multi-channel silicon probe. For each multi-unit, we first applied a Wiener filter method to remove electrical artifacts, and then computed the analog multi-unit activity (AMUA) over the onset response window (0-50 ms) and the baseline window (150-200 ms). Any multi-unit with a peak amplitude in the onset window AMUA larger than the average plus 5 times the standard deviation of the baseline window AMUA was identified as responsive to the CI stimulation. For every responsive multi-unit, the proportion of variance explained by PT_ITD and ENV_ITD was computed to reveal the effect of envelope and pulse timing ITD on AMUA intensity.

Our study recorded a total of 332 responsive multi-units, with 83% of them being sensitive to PT_ITD, while only one multi-unit was found to be sensitive to ENV_ITD. This indicates that CI-implanted rats exhibit far greater sensitivity to pulse timing ITD than envelope ITD. These findings suggest that the current CI stimulus strategy is not providing effective ITD information that CI users are sensitive to, and that CI users have the potential for better sound localization ability.

P7: FINDING THE "BEST PLACE" TO DELIVER BINAURAL CUES TO MAXIMIZE SPATIAL-HEARING BENEFITS WHEN FITTING BILATERAL COCHLEAR IMPLANT USERS WITH A "MIXED RATE" STRATEGY

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Bilateral cochlear implants (BiCIs) do not restore sound localization abilities to the full extent exhibited by typical hearing (TH) listeners, especially in noisy settings. This is partly because clinical strategies adopt high-rate stimulation across most electrodes and do not encode interaural time differences (ITD) well. While high-rate stimulation is important for speech intelligibility, low-rate stimulation is needed for ITD sensitivity. Studies have shown that “mixed rate” strategies, directing low- and high-rate stimulation to separate cochlear locations, could restore ITD sensitivity to a certain extent while maintaining speech understanding. However, when using a “mixed rate” strategy, the cochlear locations for the delivery of ITDs may have to be carefully considered. Previous work on “mixed rate” strategies did not focus on individualized approaches to selecting cochlear locations for the low-rate stimulation, which we hypothesize is a key factor in maximizing benefits from such strategies. The present study investigates whether the channel selection in a “mixed rate” strategy needs to be customized for each individual such that the low-rate stimulation is delivered to the “best” place with good ITD sensitivity, in order to perceive a well-lateralized auditory object.

BiCI listeners were tested using a bilaterally-synchronized portable research processor, the CCi-MOBILE. For each listener, three “mixed rate” strategies were designed, each with 10 electrode pairs: “interleaved”, “best”, and “worst” “mixed rate” strategies. The “interleaved” strategy had low and high-rate stimulation delivered at every other channel in an interleaved fashion (i.e., 5 low-rate and 5 high-rate electrode pairs in total), as previously described by Thakkar et al. (2018). In the current study, ITD sensitivity was first determined for each participant at low rates for 5 electrode pairs. The “interleaved” strategy used the same 5 electrode pairs for low-rate stimulation, plus 5 additional pairs for high rate stimulation. The pair with the best ITD sensitivity was chosen to receive low-rate stimulation in the “best” strategy, while the pair with the worst ITD sensitivity was chosen as the low-rate channel for the “worst” strategy. For the “best” and “worst” strategies, there is only one low-rate channel, with the remaining 9 pairs of electrodes receiving high-rate stimulation. The location of the electrode pair that received low-rate stimulation in the “best” and “worst” strategies varied from individual to individual. An “all-high” strategy with the same 10 pairs of electrodes receiving high-rate stimulation was also created for each individual as a control strategy. Using these three “mixed rate” strategies, as well as an “all-high” strategy as control, listeners were then presented with a CNC word, or complex tone, in silence. Both stimulus types were presented with ITDs of +/- 800, 400, 200, and 0 us. Using a lateralization task, listeners were asked to indicate the intracranial position of the stimulus.

Preliminary data suggests that the introduction of low-rate stimulation in the “mixed rate” strategies improves the lateralization performance with both speech and complex tone stimuli, as compared to the “all-high” strategy. The lateralization performance was better with complex tone than with speech. With complex tone stimulus, the “interleaved” strategy outperformed the other strategies, while the “best” strategy tended to excel for the speech stimulus. It indicates that place specificity might be important for the “mixed rate” strategies in lateralizing sounds that are more common in real-world listening.

P8: SYNERGY OF RATE-PITCH AND INTERAURAL-TIME-DIFFERENCE CUES FOR VOLUNTARY STREAM SEGREGATION IN BILATERAL COCHLEAR-IMPLANT LISTENERS

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Bilateral users of cochlear implants (CI) have severely limited access to temporal cues such as rate pitch and interaural time differences (ITDs) in everyday multi-electrode stimulation with clinical processors. Furthermore, even under highly controlled laboratory conditions with single-electrode stimulation via research interfaces, both rate-pitch and ITD sensitivity are at least an order of magnitude worse in CI listeners compared to normal-hearing controls. These limitations confine their ability to perform auditory stream segregation and, ultimately, result in severely reduced selective-hearing capability.

In the present study, we investigated voluntary stream segregation in seven bilateral CI listeners using the rhythmic masking release (RMR) paradigm introduced by Middlebrooks & Onsan (2012). In the RMR paradigm, a target and a distractor rhythm are interleaved such that they form an entirely regular pattern of tone bursts in the baseline condition. Introducing a difference between target and distractor bursts, in our case either a pulse-rate difference (PRD, in %, Weber fraction), an ITD (in µs), or both, provides the listeners with a cue to identify one of two possible rhythms. Hence, the RMR paradigm employs a one-interval two-alternative forced-choice rhythm discrimination task. Tone bursts were unmodulated pulse trains with a nominal rate of 118 Hz and presented at a single interaurally ITD-matched electrode pair.

When testing RMR with a rate cue alone and PRDs between 0 and 100% (i.e., up to an octave), sensitivity improved with increasing PRD, exceeding chance for PRDs > 12%. For an ITD cue alone (from 100 to 2000 µs), sensitivity was much worse, with only a minority of CI listeners being better than chance performance even for large ITDs. Finally, for the combination of PRD (6, 12, and 27%) and ITD (500, 1000, and 2000 µs), in light of considerable variability between listeners we found three patterns in the data. For the most difficult conditions (e.g., 6% and 500 µs), sensitivity was consistent with the prediction of ideal-observer integration of rate and ITD cue, suggesting additivity of cues. For conditions with intermediate difficulty (e.g., 12% and 1000 µs), sensitivity was significantly higher than predicted by ideal-observer integration, suggesting supra-additivity of cues. Third, for easy conditions (e.g., 27% and 2000 µs), performance for the rate-cue only already approached the ceiling, and was at the ceiling for the combined cues.

Taken together, these results show that CI listeners combine two purely temporal cues in a synergistic manner, if at least one cue is salient when presented in isolation. When both cues are weak when presented in isolation, CI listeners combine these cues at least in an additive manner. The results suggest that even a subtle ITD cue can contribute considerably to voluntary stream segregation when combined with a pitch cue at overall low rates.

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P9: TINNITUS IS ASSOCIATED WITH INCREASED CROSS-MODAL NEURAL PLASTICITY IN SINGLE-SIDED DEAFNESS COCHLEAR IMPLANT USERS.

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Background
Numerous studies have shown that many patients with hearing loss that have a cochlear implant (CI) experience a suppression of tinnitus when their CI is turned on. However, the neural correlates of this suppression are currently unknown. Additionally, CI patients exhibit higher degrees of cross-modal plasticity than normal-hearing (NH) individuals. Cross-modal plasticity can be quantified as the degree of auditory cortex activation to a visual stimulus. This study compares the brain activity using high density EEG (electroencephalography) related elicited by visual stimuli in conditions where CI users with single-sided deafness (SSD) were experiencing tinnitus versus no tinnitus. We hypothesized that CI users with SSD that experience greater degrees of self-reported tinnitus suppression will also have greater degrees of cross-modal plasticity than SSD CI patients with less or no suppression of tinnitus.

Methods
64-channel EEG recordings were performed while SSD CI users performed a visual discrimination task with and without the CI turned on. Visual stimuli consisted of four different stimulus conditions: upright face, upside down face, upright house, and upside down house. Participants were required to indicate via keyboard press whether a house or face was perceived. Evoked potentials and subsequent source analysis was performed. Left and right auditory cortex regions of interest were examined for activity related to cross-modal plasticity.

Results
SSD CI users clustered into 2 groups, with and with tinnitus suppression when the CI was turned on. In those with tinnitus suppression, reduced right auditory cortex in response to visual stimulation was observed compared to CI users with no tinnitus suppression.

Conclusions
These data suggest that tinnitus in SSD CI users may arise from “maladaptive” cross modal activation that is reduced once the CI is switched on.

P10: NEW MODELS OF HUMAN HEARING VIA MACHINE LEARNING

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Humans derive an enormous amount of information about the world from sound. This talk will describe our recent efforts to leverage contemporary machine learning to build neural network models of our auditory abilities and their instantiation in the brain. Such models have enabled a qualitative step forward in our ability to account for real-world auditory behavior and illuminate function within auditory cortex. They also open the door to new approaches for designing auditory prosthetics and understanding their effect on behavioral abilities.

P11: DEEP LEARNING FOR SPEECH ENHANCEMENT WITH COCHLEAR IMPLANTS: JOINT COMPENSATION OF NOISE AND REVERBERATION WITH ONE OR MORE MICROPHONES

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Background and Aims: The combined effects of noise and reverberation can negatively affect speech perception for people listening with cochlear implants (CIs) [1, 2]. Previous work reported significant improvements in speech-intelligibility for CI recipients in noisy situations with deep-neural- network (DNN) algorithms [3]. Along with recent improvements in end-to-end learning techniques [4] and multi-microphone approaches, powerful speech enhancement strategies can now be developed to cope with more realistic listening situations. We evaluated single- and multi-microphone DNN algorithms for enhancing speech for CIs in difficult listening situations with both noise and reverberation.

Method: Three different algorithms based on the Dual-Path Recurrent Neural Network (DP-RNN) [4] were developed to jointly alleviate noise and reverberation. The algorithms were trained on simulated sound scenes using either single- or multi-microphone recordings from behind-the-ear devices. Performance was assessed using objective measures and a listening test on reverberant mixtures of speech in babble noise at several Signal-To-Noise Ratios (SNRs). We evaluated Speech-Reception-Thresholds (SRTs) for the 3 algorithms in comparison to unprocessed and ideal processing conditions. Both CI listeners and participants using CI simulations [5] (n=15) took part in the study.

Results: All approaches showed improved objective measures over the unprocessed condition, even at very low SNRs for the algorithms using multiple microphones. Objective metrics indicated better signal to distortion ratios and predicted intelligibility using the multi-microphone over the single-microphone approach, especially in the noisiest situations. Experimental results from participants with typical hearing using CI simulations (n=15) showed significant improvements of up to 7 dB in SRTs between the multi-microphone approach over both the unprocessed case and the single-microphone approach.

Conclusion: Multi-microphone speech enhancement algorithms based on deep-learning showed strong potential to improve the intelligibility of speech in realistic situations with babble noise and reverberation for cochlear implant listeners. This was the case even when restricting the processing to unilateral microphones. Further work should investigate the effect of such strategies on preserving auditory awareness of the environment whilst enhancing speech intelligibility.

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P12: THE TEMPORAL PROJECT: OPTIMIZING SPEECH CODING STRATEGIES BY USING MODELS

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The multidisciplinary TEMPORAL project involves three Ph.D. students and aims to enhance speech coding strategies, specifically focusing on temporal fine structure, using computational models of normal and electrical hearing via artificial intelligence. The Bruce et al. (Hear Res 2018) model is employed to simulate normal hearing, while in-house biophysical models (Kalkman et al., Hear Res 2022) and a phenomenological model (van Gendt et al., Hear Res 2020) are used to simulate electrical hearing. This pipeline generates simulated spike trains in response to pulse trains from a speech coding strategy, implemented on a highly flexible speech processor model. By optimizing the characteristics of the speech coding strategy in silico, we want to minimize the differences in the spiking patterns produced by the normal hearing model and the model of electrical hearing when presented with the same sound input. The optimized speech coding strategies will be validated through patient testing.

A first step within this project has been to make the pipeline computationally less expensive, such that it can be used in large-scale optimization experiments. In De Nobel et al. (Hear Res 2023), a surrogate was developed to replace the costly active nerve fiber model, which reduced simulation duration by five orders of magnitude. The surrogate was able to emulate the behavior of the biophysical model with near-perfect precision (R^2> .99). It was used to optimize the shape of the stimulus waveform for energy efficiency, which indicated potential energy savings of 8%–45% compared to a square wave. Results were validated with the original active nerve model, which demonstrates the robustness of the approximation by the surrogate to new waveform types.

To reduce the computational complexity of the phenomenological model, the original implementation, which uses a power law to compute the neural properties of accommodation and adaptation, has been replaced with a double exponential smoothing function, which only requires a single operation per time step. The parameters for this exponential smoothing function have been optimized to match the temporal behavior of the power law implementation closely, and the model has been re-validated on several experimental data sets.

In parallel, we analyzed the neurograms of the two models with two implementations of the spectrally modulated ripple test (SMRT; Aronoff & Landsberger, JASA 2013). The original SMRT was created with a carrier density of 33/octave, but these stimuli gave a distorted view of the spectral resolution threshold of listeners, as Resnick et al. (JASA 2020) showed that spectral aliasing occurred around 16 ripples-per-octave (RPO). From neurograms created with the normal hearing model of Bruce et al. (Hear Res 2018), we could indeed infer that aliasing transpired around 16 RPO. As well, we could gather from neurograms created with the electric hearing pipeline that spectral resolution is severely limited for a cochlear implant user when compared to normal hearing.

We conclude that our models can successfully reproduce spiking behavior in normal and electric hearing for complex sounds, thereby forming a foundation for using computational models to create an optimized speech coding strategy. We have developed a computational pipeline to expedite the optimization process and started aligning the output of the two computational models. Going forward, our work will concentrate on optimizing known speech coding strategies and designing novel ones through this framework.

P13: HOW MODELS SERVE AS PHYSICAL AND DIGITAL TWINS TO HELP US UNDERSTAND THE COCHLEAR-IMPLANT NEURAL INTERFACE

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The cochlear implant-neural interface is difficult to interrogate in living CI users, and in animals the interface can differ significantly because of the size and shape of the cochlea, and different implants.

CI users present with varying symptoms and complaints, and to back project to the underlying cause requires some methods to understand what is happening at the CI-neural interface. We have used a variety of models to try to understand how changes at this interface might manifest in terms of hearing performance, cross stimulation of other structures, or insertion trauma. The types of models I will discuss are:

1) Computational models which try to understand how nerves are activated by CIs, and the physical spread of current in the cochlea.

2) Physical 3D printed which help us understand insertion trauma forces, and electric field distribution inside the cochlea.

3) Cadaveric models which allow us to make measurements in realistic human like geometries.

4) Cellular models which let us measure responses of neurones to different types of stimulation, and also to simulate scarring and fibrosis.

I will discuss the lessons learned from these various models, and the clinical applications of what we have learnt.

P14: COCHLEAR IMPLANT ELECTRICAL IMPEDANCE TOMOGRAPHY

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Clinical imaging of live cochleae is still not able to render the internal structures of the cochlea. Electrical impedance tomography (EIT) is a safe, low-cost alternative medical imaging technique, with applications in a variety of clinical scenarios. EIT was investigated as a potential method to image and extract the centre of gravity of the modiolus in vivo using a cochlear implant (CI) electrode array. If successful, the information could be used to augment present postoperative medical imaging techniques to investigate the cochlea. The application of this technique could also provide a more accurate basis upon which to base three-dimensional, person-specific computational models of the cochlea. The proposed CI-EIT system was simulated by modelling user-specific electrode array trajectories within a simplified geometry. The method included an adapted adjacent stimulation protocol for data collection. An image reconstruction parameter analysis was conducted to find the most appropriate combination of EIT parameters for imaging the cochlear modiolus. The methodology was validated at different noise levels for a number of electrode array trajectories.

P15: ASSESSING NEURAL HEALTH WITH INTER-PHASE GAP MEASUREMENTS

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The electrically evoked compound action potential (eCAP) has been studied for decades in both animals and humans. Being a direct measure of the electrical excitability of the auditory nerve, the eCAP offers a relatively simple but uniquely fundamental insight into the electrode-nerve interface of a cochlear implant (CI). Animal research has shown that the eCAP is a robust predictor of neural health, as its N1-P2 amplitude generally correlates well with the extent of auditory nerve degeneration. In human CI users, however, it is believed that simple eCAP measures are not informative of neural health because of the heterogeneity of the population (in terms of age, duration and etiology of deafness, and duration of implantation), the non-neural state of the cochlea (fibrosis, ossification), and CI-related variables (e.g., shape of the electrode array, stimulation settings). Several more sophisticated eCAP measures are being studied that overcome these non-neural factors. One of these is the inter-phase gap (IPG) effect. Introducing an IPG in the biphasic current pulse generally results in more effective neural excitation (i.e, the IPG effect). Crucially, the magnitude of this effect is dependent on neural survival in deafened guinea pigs. For over a decade now the IPG effect has been studied in humans, but the results have not been consistent. In all likelihood, since histological data from a CI user's auditory nerve is not available, the alternatively used indirect psychophysical measures often obscure any effects. Moreover, differences between species may limit the usefulness of the IPG effect for clinical purposes. Alternatively, a better understanding of the mechanisms underlying the IPG effect, of the gradual process of auditory nerve degeneration, of the influence of stimulus parameters (including pulse width and polarity) and artifact reduction strategy, and of eCAP processing might lead to more consistent outcomes. In this talk our experience with IPG effects in guinea pigs will be discussed in the context of developing a reliable clinical diagnostic tool for the assessment of neural health in CI users.

P16: POLARITY DEPENDENT EXCITATION PROFILES WITH COCHLEAR IMPLANT STIMULATION: RELATION TO NEURO-ANATOMY AND IMPLICATIONS FOR BIPHASIC STIMULATION

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Electric stimulation of the auditory nerve by cochlear implants (CIs) results in significant outcome variability for measures like speech understanding in noise or pitch discrimination. In all CI product lines biphasic charge-balanced pulses (of opposite phase polarity) are used to transmit auditory information. The anodic and the cathodic phase are known to preferentially activate different portions of the spiral ganglion cells: anodic phase excites spiral ganglion cells at or central to the soma, while cathodic stimuli preferentially activate peripheral processes. Here we studied whether the different polarities also stimulate different cochleotopic positions and evaluated potential impacts on and prospects for electric hearing performance.

We used 12 normal hearing (acutely deafened), anaesthetized guinea pigs of either sex (6 female) to analyze the multi unit activity in the inferior colliculus (IC) in response to electric stimulation via a 6-contact guinea pig CI (0.7 mm contact spacing; MedEl Comp.). All stimuli were presented in monopolar configuration at apical to basal CI contacts. We used either asymmetric, pseudo-monophasic pulses (psm, n=8, phase ratio 8:1, 50 µs short phase duration) or symmetric, biphasic pulses (n=4, 50 µs per phase) with alternating anodic and cathodic polarity. Recordings in the IC were performed with penetrating multielectrode arrays along the tonotopic axis. The cochlear origin of neural activity was determined according to the guinea pig Greenwood-function, based on characteristic frequency (CF) positions in the IC. We analysed responses from stimulation threshold to 6dB above stimulation threshold. We reconstructed the intracochlear position of the stimulating electrode contacts from computed micro tomography (µCT) imaging of the implanted cochlea to compare the cochleotopic position of the CI contacts to the cochleotopic origin of the IC excitation pattern. We define off-site stimulation as more than 0.7 mm (0.3 octaves) remote from the centre of the stimulating CI contact.

We found a polarity-dependent off-site stimulation for psm pulses at supra threshold levels: The main excitation for anodic psm-stimulation originated from up to 3.5mm (~1.5 octaves) apical (low CF) to the µCT reconstruction of the contact position, while cathodic psm stimulation led to an activation of up to 3.5mm (~1.5 octaves) basal (high CF) to the contact position. Broader activation patterns were found for anodic than for cathodic psm-stimulation. The CF difference between the focus of activation for anodic and cathodic stimulation was commonly more than 2 octaves. Shifting the stimulation site from apical to basal contact positions expanded the excitation for anodic psm-stimuli to include CF originating more basally while conserving apical response strength. Shifting cathodic stimulation sites, on the contrary, shifted the main excitation range to more basal positions, leading to a relative reduction in apical response strength. A change of the leading phase in biphasic stimuli from cathodic to anodic led to less pronounced changes in the midbrain activation patterns; however, even here cathodic leading stimuli caused slightly more basal activation than anodic leading stimuli (particularly discernible close to stimulation threshold). The IC response patterns for biphasic stimuli had a reduced dynamic range compared to psm-stimuli (3dB vs. 5dB). Additionally, with biphasic stimuli we observed different temporal response patterns in the IC than with psm stimuli: biphasic stimuli caused an additional late (10ms-15 ms) IC response commonly not present for psm-stimuli.

We conclude that anodic and cathodic polarity cause a pronounced difference in evoked excitation patterns. The strongest excitation (highest firing rates) and lowest thresholds were systematically observed apical (anodic pulse) or basal (cathodic pulse) to the position of the stimulating electrode contact ('offsite' stimulation). We hypothesize that such offsite stimulation is based on the mutual anatomic relation of the electrical field and the spiral ganglion neurons. Symmetric biphasic pulses by involving both the anodic and cathodic "best spot", are generating a broader excitation profile, which likely causes a broader and more ambiguous percept. This suggestion is further supported by the additional late IC activation with biphasic stimulation, documenting further auditory processing beyond pure place coding.

** PB and WSK contributed equally to this work*

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P17: MODEL PREDICTIONS OF THE EFFECTS OF SPIRAL GANGLION NEURON LOSS AND AXONAL DEMYELINATION ON ECAP REFRACTORY RECOVERY AND NEURAL SYNCHRONY METRICS

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A number of different eCAP-based metrics have been proposed for the estimation of neural health in human cochlear implant (CI) users (e.g., [1]), based on animal studies in which histology can be performed to assess loss of spiral ganglion neurons (SGNs). However, it is difficult to tell from some of the animal studies whether the changes in responses properties at the level of a population of SGNs, as quantified by the eCAP, are solely due to the loss of SGNs or if degeneration of the remaining neurons also contribute to the observed differences. Importantly, several modeling studies have indicated how partial degeneration or demyelination of SGN axons can cause substantial changes in their response to electrical stimulation [1–6].

In this study, we have modeled a population of SGNs using the phenomenological model of Joshi and colleagues [7] and predicted eCAPs by convolving the summed SGN spike trains with a human “unitary response” function [8]. Although the Joshi model only has one compartment each for the peripheral and central axons, partial demyelination can be approximated by scaling of the resting membrane capacitance and conductance for each compartment [1]. In our preliminary investigations, we have considered cases of: i) various degrees of uniform loss of SGNs along the cochlea, and ii) various degrees of uniform demyelination of both the peripheral and central axons of all surviving SGNs.

To examine the effects of SGN loss and demyelination on eCAP refractory function, we have followed the stimulation paradigm of [9], in which He and colleagues found that children with cochlear nerve deficiency had delayed refractory recovery of the eCAP for single-pulse maskers and probes compared to children with normal sized cochlear nerves. Our simulation results indicate that loss of SGNs has minimal impact on the model’s eCAP refractory recovery function, consistent with the guinea pig data of [10], whereas partial demyelination greatly delayed the model’s eCAP refractory recovery, consistent with the mice data of [11].

The second analysis that we have conducted is of the model’s variability in inter-peak latency (VIL) of the eCAP, a measure of SGN dyssynchrony that Skidmore and colleagues showed has a strong negative correlation with psychophysical gap detection thresholds in adult CI users [12]. Once again, the simulation results showed very little impact of SGN loss on the predicted VIL, whereas partial demyelination leads to a substantial increase in the model’s VIL.

Together, these simulation results suggest that eCAP refractory recovery and neural synchrony are strongly affected by even partial demyelination, making them complementary to eCAP measures that are sensitive to loss of SGNs.

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P18: THE EFFECTS OF NEURAL ADAPTATION IN COCHLEAR IMPLANT LISTENERS

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It can be challenging to have a conversation in a noisy environment. However, normal-hearing (NH) listeners are able to recognize words better when words are delayed from the noise onset, with progressive improvement with increase in delay. This phenomenon, known as ‘adaptation to noise’, also occurs for the detection of short pure tones or amplitude modulated (AM) tones and has been hypothesized to reflect some form of neural adaptation elicited by the noise. It has been hypothesized that auditory neurons adapt their dynamic range to the most prevalent level in noise that precedes the target stimulus, potentially enhancing the neural encoding of the stimulus spectrum and/or its amplitude modulations. Here, I will present some experiments that aimed at shedding light on the mechanisms involved in adaptation to noise as well as investigating if cochlear implant (CI) users show (and benefit from) adaptation to noise. In the first experiment we show that NH listeners demonstrate adaptation in speech recognition when the level of the noise preceding speech is steady but not when it is highly fluctuating, which suggests that adaptation depends on the noise level statistics. In the second experiment we show that CI listeners also demonstrate this adaptation effect to the same extent as or potentially greater than NH listeners, suggesting adaptation to noise even in the absence of inner ear processes. In the third experiment I will describe our ongoing data collection with NH and CI listeners using electroencephalography to elucidate to what extent adaptation to noise reflects an improvement in the neural representation of the stimulus as it is delayed in the noise.

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P19: REMEMBERING NING ZHOU, SCIENTIST, COLLEAGUE, AND FRIEND

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In response to the tragic death of Dr. Ning Zhou, scientist, colleague, and friend of many in the cochlear implant field, we present this celebration of her career. The presentations will highlight the innovative research contributions of Dr. Zhou and show how her work has motivated additional studies that are moving our field forward.

Ning received a master's degree in Linguistics (June, 2005) and a PhD in hearing science (June, 2010) at Ohio University. In the process, she launched a very productive career with her studies of the perception and production of tonal languages, focusing on mandarin-speaking children. Together with her mentor Li Xu and others, she authored or co-authored more than 20 peer reviewed papers on this and related topics, which inspired additional work that will be highlighted in Part 1 of our tribute session: Tonal-Language Perception and Production.

Ning joined the Pfingst Auditory Prosthesis Perception and Psychophysics laboratory at the University of Michigan as a postdoctoral fellow in June of 2010 and soon began making innovative contributions to our efforts to understand the importance of cochlear health for speech perception with cochlear implants. Ning’s studies helped establish the psychophysical multipulse integration (MPI) measures, which we developed in guinea pigs, as useful tools for estimating cochlear health in humans. She developed and tested several within-subject designs for determining the relevance of this measure for speech recognition and demonstrated its utility for improving speech-processor maps.

After her postdoctoral fellowship, Ning became a faculty member at East Carolina University and established her own lab where she excelled as a productive scientist and teacher. She continued her research on multipulse integration as a cochlear health measure and explored other measures of cochlear health. She also, initiated several new studies exploring the mechanisms underlying the relationship of MPI and speech recognition, including work on the roles of electrode configuration and spread of excitation. Ning’s innovative research in these areas has inspired additional studies using these measures in animal and human subjects, including work in progress in our lab using fixed-rate thresholds and various electrode configurations and experiments that will be discussed in the talks in Part 2 of our session: Markers of Health of the Implanted Cochlea.

Ning was admired by her students, colleagues, and the cochlear implant recipients who were essential to her work and ultimately benefited from the results of her experiments. Her research greatly advanced our understanding of cochlear implants and served as an inspiration for other scientists in our field. We miss her deeply but know that her spirit lives on in her publications, in the ongoing research that her work has inspired, and in our found memories.

P20: NING'S CONTRIBUTIONS TO MANDARIN TONE RECOGNITION RESEARCH WITH COCHLEAR IMPLANTS

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Both coming from China, Ning and I shared a common research interest in Mandarin tone recognition with cochlear implants (CIs). More than seven million people in China are qualified for CIs, but only ~70,000 of them have been implanted. There were 11,000 CI surgeries in China in 2021 and the yearly number increases by ~20% each year. This fast-growing patient population speaks Mandarin Chinese, which uses pitch variations (i.e., tones) to convey lexical meanings. Although current CIs support satisfactory speech recognition in quiet, they do not accurately convey pitch cues for Mandarin tone recognition. It is critical to understand the acoustic cues, psychophysical abilities, and demographic factors related to Mandarin tone recognition with CIs, so that speech processing, device configuration, and aural rehabilitation can be developed to improve CI users' Mandarin tone recognition. Studies on Mandarin tone recognition also have important implications for the recognition of linguistic and emotional prosody, which rely on similar cues (primary cues: pitch; secondary cues: amplitude and duration).

Together with her Ph.D. advisor Dr. Li Xu and collaborators in China, Ning studied Mandarin tone recognition in children with CIs extensively. I would like to highlight three of the many influential studies to which she contributed: (1) Xu, Zhou et al. (2009) tested 107 children with CIs aged 2 to 16 years old. The large sample size allowed for the most powerful study of family, implant, educational, and demographic factors for Mandarin tone recognition. It turned out that only demographic factors were significant predictors of tone recognition performance. The results have important implications, in that tone recognition performance tends to improve with more CI experience, and early implantation may facilitate this development. (2) Han, Liu, Zhou et al. (2009) tested potential benefits of the HiRes 120 clinical processing strategy to Mandarin tone recognition. Although HiRes 120 uses current steering to encode more spectral details, it did not yield significantly better tone recognition performance than conventional strategies. This partially motivated our work on single-electrode dynamic pitch perception with current steering and amplitude modulation frequencies, and raised important questions about the gaps between psychophysical advantages and speech perception benefits for novel stimulation strategies. (3) Wang, Zhou, Xu (2010) found a significant correlation between musical pitch discrimination and Mandarin tone recognition in CI users, indicating that the two tasks may share common pitch perception mechanisms. These results echo the general link between music and speech perception, and suggest that music training may improve Mandarin tone recognition in CI users (which has been confirmed by others).

Ning has left us too soon, but we will continue to be inspired by her work to study Mandarin tone recognition (e.g., longitudinal trajectory of development, performance in noise and reverberation, novel training paradigms/device configurations), with the goal of bringing better hearing to the fast-growing population of Mandarin-speaking CI users.

P21: PERCEPTION-PRODUCTION LINKS IN LEXICAL TONES AND PROSODIC EXPRESSION

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I initially came to know Dr. Ning Zhou because of our shared interest in psychophysical measures of spectral and temporal envelope encoding in cochlear implants, and my admiration for her work on site selection with Dr. Bryan Pfingst. I later came to realize that we had another thread of research in common, relating to the perception and production of suprasegmental cues in speech. Dr. Zhou extensively investigated predictors of lexical tone perception and production in a series of studies in pediatric cochlear implant patients, initially with her research mentor Dr. Li Xu, and later with other collaborators. These studies showed significant correlations between tone perception and production and underscored the importance of early implantation in children for lexical tone communication.

In recent work, Dr. Zhou and collaborators found that lexical tones produced by pediatric bimodal cochlear implant users were more accurate than those produced by counterparts without residual hearing. These findings are consistent with the idea that difficulties in perception experienced by children are echoed by difficulties in production. This idea was confirmed in our studies of lexical tone perception and production by pediatric cochlear implant recipients, in which we examined the utilization of different acoustic cues in lexical tone communication. We found that compared to normally hearing counterparts, voice pitch contour cues were utilized less by children with cochlear implants to identify tones, while the reverse was true for duration cues. Acoustic analyses of tone productions showed that, consistent with the perception data, children with cochlear implants used duration cues more and voice pitch cues less to produce lexical tones, compared to normally hearing peers.

In very recent work, Dr. Zhou and colleagues investigated the benefit of access to suprasegmental/prosodic cues for perceiving speaker sincerity. They found that cochlear implant patients had difficulty in this domain, and again, that access to voice pitch cues via residual acoustic hearing benefited performance. In our studies of acoustic cues used by cochlear implant patients for emotional prosody perception and production, we are finding perception-production links involving the utilization of voice pitch cues. Consistent with Dr. Zhou and colleagues' work on speaker sincerity, we found that when presented with both lexical-semantic cues and prosodic cues to emotion, cochlear implant users relied more strongly on lexical-semantic cues to identify the talker's intended emotion, suggesting missed opportunities to identify sarcasm (which may be communicated via an intended conflict between prosodic and semantic cues to emotion).

I have been inspired by Dr. Zhou's work throughout and I now regret not seizing more opportunities to work with her directly. Her ideas and findings influence my work today as they have done for many years now, and I know this will continue into the future. Regardless, this untimely loss of a treasured colleague will not be easy to overcome.

P22: TRANSLATING MARKERS OF COCHLEAR HEALTH FROM ANIMALS TO HUMANS

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Ning Zhou joined the Pfingst Auditory Prosthesis Perception and Psychophysics Laboratory at the University of Michigan as a postdoctoral fellow in the summer of 2010. During her postdoctoral years she designed and conduced innovative experiments that advanced our efforts to measure the health of the inner ear in people who use cochlear implants and applied the results to improve hearing in cochlear implant users. Her work focused on the use of a psychophysical measure, multipulse integration (MPI), that had been shown in guinea pigs to be predictive of the survival of spiral ganglion neurons near the stimulating electrode. To estimate the health of the cochlea near individual electrodes along the cochlear implant electrode array and determine its relationship to speech recognition ability in human subjects, Ning used several within-subject designs. For example, comparing estimates of cochlear health to speech recognition across ears, within a participant. The importance of within-subject designs is that they minimize effects of cognitive and central processing that, independent of cochlear health, can have large effects on speech recognition. Thus, within-subject designs allow us to focus on the effects of cochlear-health variables. Within-subject designs used by Ning included site selection, site-specific rehabilitation, between-ear comparisons in individuals with bilateral implants, and innovative use of confusion matrices. These innovative within-subject research designs have subsequently been applied to other measures for estimating cochlear health including the electrically-evoked compound action potentials and post-operative imaging. These studies manipulate programming of the cochlear implant based on individual measures across the electrode array, then compare outcomes within each participant (Schvartz-Leyzac and colleagues and Noble and colleagues). These methods use a personalized medicine approach, allowing us to maximize performance outcomes for each person.

After her postdoctoral studies, Ning continued her research on cochlear health measures, and their use to improve speech recognition in cochlear implant users, at East Carolina University. One such measure was low-rate pulses to estimate neural health via psychophysical measurements. We will hear about these other measures in subsequent talks. Although Ning was not able to continue this work herself, her work has clearly made a lasting impact on our field and will continue in laboratories throughout the world.

P23: AN INTERNATIONAL EXPERIMENT FOR NING: EXPLORING THE RELATIONSHIP BETWEEN MULTI-PULSE INTEGRATION AND SPATIAL SELECTIVITY IN COCHLEAR IMPLANT USERS

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Starting with her post-doc with Bryan Pfingst more than 10 years ago, Ning Zhou pioneered the use of multi-pulse integration (MPI) as a measure of neural health and of the spatial spread of excitation in cochlear implant (CI) listeners. Earlier studies on MPI (the difference in detection threshold between two pulse trains of different rates) in guinea pigs revealed a correlation with neural survival. Ning's research with human CI participants focussed on the use of MPI as a correlate of spatial selectivity. She provided evidence in support of this relationship by demonstrating significant correlations between MPI and both the width of psychophysical tuning curves and electrode-modiolar distance. In addition, she manipulated spatial spread by comparing monopolar (MP) to bipolar (BP) stimulation and found greater MPI for MP, as predicted. Inspired by her observation that there is only limited evidence that BP stimulation reduces spatial spread compared to MP, we adopted a different way of manipulating spatial spread. To do so we increased spread by stimulating multiple electrodes simultaneously. In this study, we will compare MPI for single-electrode MP stimulation with that for 7 adjacent electrodes presented simultaneously ("blur7") in CI users implanted with the Advanced Bionics device. Previous experiments have shown that blurred stimuli degrade speech perception and attributed this to broadening of excitation patterns compared to MP stimulation. Hence if Ning's hypothesis is correct, the blur7 stimulus, which will span electrodes centred on the comparison, single-electrode, stimulus, should increase MPI. As Ning pointed out, it is important to control for differences in the slope of psychometric functions between conditions, and so thresholds for 160- and 640-pps pulse trains will be measured using two interleaved 1up-1down adaptive procedures, with the relative sizes of the "up" and "down" steps adjusted so as to converge on 65% and 90% points of the psychometric function. Threshold and psychometric-function slope for each combination of pulse rate and stimulus (single-electrode vs blur7) will be estimated from the mean and difference of these two thresholds respectively. As an additional test we will loudness-balance the 640-pps single-electrode and blur7 stimuli at a comfortably loud level and measure forward-masked thresholds for a probe presented on the same electrode as the single-electrode masker (equal to the centre electrode of blur7). Previous evidence has shown that this on-site masking is greater for maskers that produce narrow excitation patterns, and we predict that the difference in forward masking between single-electrode and blur7 maskers will correlate positively across participants with the difference in MPI between those two stimuli.

P24: CLINICAL IMPLICATIONS OF SENSITIVITY TO PULSE PHASE DURATION IN COCHLEAR IMPLANTS

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In cochlear implants (CIs), pulse amplitude (PA) or pulse phase duration (PPD) can be used to increase loudness. Loudness grows more slowly with increasing PPD, resulting in a larger dynamic range (DR). Slow loudness growth with PPD may be related to "leaky" charge integration associated with neural degeneration and as such, may be a marker of neural health across stimulation sites and/or CI recipients. We developed a method to characterize neural health at different stimulation sites in terms of "charge integration efficiency" (CIE), which was defined as the log difference in DR with increasing PPD or increasing PA, after converting to charge: $CIE=20 \log((PPD\ DR)/(PA\ DR))$.

The basic methodology described in Zhou et al. (2020) was to increase PA or PPD relative to a common threshold (T) anchor with a fixed PA and a short PPD. The PA or PPD was then increased until achieving maximum acceptable loudness (MAL). The DR calculated between T and MAL was converted to charge before calculating CIE. Larger values of CIE were thought to indicate potentially poorer neural health, as loudness grew to slowly with increasing PPD. In general, DRs in charge were larger and loudness grew more slowly with increasing PPD than with increasing PA. There was substantial inter-subject variability in CIE that was significantly associated with CI users' duration of deafness (r=0.9, p=0.007).

In Zhou et al. (2020), CIE was measured for a single electrode in the middle of the array. It is likely that neural health is non-uniform across the array. As such, CIE was measured for all available electrodes in Zhou et al. (2021) using the same methods as above. Substantial and significant across-site variability in CIE was observed within subjects. The variability in CIE was unrelated to absolute threshold levels (e.g., the geometry of the electrode-neural interface). The across-site variance in CIE was significantly associated with CI users' sentence recognition in noise (r= -0.76, p=0.007), suggesting that greater uniformity in neural health across the array was associated with better speech performance. The across-site mean in CIE was significantly associated with duration of hearing loss (r=0.74, p=0.009), suggesting that, similar to the single-electrode measurements in Zhou et al. (2020), sensitivity to PPD across the array may be a useful indicator of neural health across CI users.

We planned to continue this initial work by looking at other factors that might affect CIE, such as stimulation mode (broad vs. focused), stimulation rate (multi-pulse integration), etc. We were lucky enough to receive funding from the William Demant Foundation. We expanded the research to include Oticon CI devices, where PPD is used to code intensity in speech processors. But for various reasons, it took a while to get the project started. And then the worst scenario imaginable…Right up to the end, Ning worked to ensure that the research would continue. And it will, as one of many tributes to our dear colleague and friend, lost way too soon.

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P25: MEMORIES OF MY FIVE YEARS IN DR. ZHOU'S LAB: A TRIBUTE TO MY MENTOR AND FRIEND NING ZHOU

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Dr. Zhou didn't fit in the stereotype of a professor or a mentor because she was always gentle and elegant, like a friend; however, it didn't prevent her from becoming a good mentor who was smart, dedicated, hard-working herself, and caring, supportive, and inspiring to the students. The first time I met Dr. Zhou was in 2014 in her office at East Carolina University (ECU), before I applied to the audiology program in the Department of Communication Sciences and Disorders, where she worked since 2013. At that time, I was fascinated by the device named cochlear implant and was quite excited to find out that ECU has a professor who does research on cochlear implants. During my graduate studies, I was very fortunate to be supported by Dr. Zhou to be one of the research assistants in her lab for the entire four years. Dr. Zhou also hired me as a part-time research audiologist the first year after I graduated. In those 5 years, under Dr. Zhou's mentoring and supervising, I and my fellow audiology students took part in various research projects and learned the basics of doing research. Dr. Zhou would first explain the main ideas and objects of each research project and then instruct us on how to carry out the experiments she designed. We enjoyed working with CI users and running various tests. Many of the CI users were from out-of-state and had participated in Dr. Zhou's research for years and became friends of her. Dr. Zhou also encouraged and supported us to present our research studies at the meetings or conferences. Attending those meetings with Dr. Zhou was especially exciting and memorable and we sure had a lot of fun. All of the audiology students who worked in Dr. Zhou's lab were inspired by her love to individuals who are hard of hearing and her passion to help them hear better, and we will carry on the passion on our everyday work as an audiologist.

P27: USING A NAO ROBOT FOR SPEECH AUDIOMETRY TESTING OF COCHLEAR-IMPLANTED CHILDREN

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Repetitive tasks such as speech audiometry may sometimes be challenging, potentially resulting in decreased participant engagement and test performance. Especially for vulnerable populations, such as cochlear-implanted (CI) children, both factors are utmost important in their speech audiometry measurements. Human-robot interaction (HRI) has been proposed in literature as a tool to provide an engaging experience when performing repetitive tasks, perhaps related to the novelty effect of interacting and collaborating with a robot. We propose the use of a humanoid NAO robot as an alternative interactive interface to conduct two clinical speech audiometry tests typically run on a computer and external speaker, and widely used in the Netherlands: the digits-in-noise (DIN) test and the Nederlandse Vereniging voor Audiologie (NVA) monosyllabic-words-in-quiet lists. Both tests are usually scored by a clinician via correctly identified digits presented in background noise, producing a speech reception threshold; and phonemes in words, producing a percent correct speech recognition, respectively. The main aim of this research was to help facilitate a high level of engagement and positive experience of children when interacting with the robot during the speech audiometry tests.

The child-robot interaction consisted of three stages: 1) introduction to the robot, 2) a tactile activity triggering random warble tones (ranging from 250 to 5000 Hz) at a comfortable level to stimulate the children to touch the robot, and 3) the speech audiometry test (at least one NVA list or one DIN test). All three stages were applied during the clinical follow-up sessions of twenty-six CI children (4-15 years old) at the outpatient clinic in the Department of Otorhinolaryngology, University Medical Center Groningen, Netherlands. All child-robot interactions were video-recorded by two cameras, one capturing body postures and one focusing on facial expressions. The behavioural analysis of CI children's HRIs was performed by two independent coders using the Behavioural Observation Research Interactive Software (BORIS).

Engagement and positive experience were measured through the quantification of multiple non-verbal cues (amused, bored, distressed, distracted and nodding facial expressions and body language; as well as movement towards and away from the robot, and the number of times the children touched the robot during the warble tones stage), the number of completed speech audiometry tests per child and the verbal feedback obtained through informal interviews between the clinicians, the children and the family of the children (present during the study). All children were able to finish between 1-4 speech audiometry tests. In general, the observed behaviours (higher count of instances for amused facial expressions, nodding and leaning towards the robot than the rest of the evaluated behaviours) and positive verbal feedback of CI children when interacting with the robot while performing repetitive speech audiometry tests, suggest that a high level of engagement may be maintained throughout such tasks, providing them with a positive experience during their clinical follow-up sessions.

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P28: PERCEPTION OF SIMULTANEOUS AND SEQUENTIAL MUSICAL HARMONY IN COCHLEAR IMPLANT LISTENERS

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Musical harmony is essential in Western music perception. However, in cochlear implant (CI) listeners, harmony perception is assumed to be severely limited. One potential limitation in CI listeners is that the simultaneous occurrence of music chord components (voices) leads to complex interactions between electrodes in the cochlea, especially for stimuli composed of broadband real-world sounds such as piano tones. Furthermore, a perceptual limitation aggravates pitch discrimination in CI listeners for stimulation rates beyond approximately 300 Hz. Prior research often concluded that harmony perception in CI listeners is severely degraded. However, most of these studies a) did not consider the rate limit and b) used broadband harmonic complex (HC) tones. Although the use of real-world sounds is undoubtedly valuable, conclusions regarding perceptual capabilities of CI listeners beyond technical limitations might not be drawn. In the present research, we studied harmony discrimination while addressing these limitations by varying spectral complexity and considering the rate limitation. We also investigated the effect of temporal synchrony of chord components. The rationale is that a sequential (i.e., arpeggio-like) instead of simultaneous presentation of harmony components further reduces spectral complexity and, thus, electrode interactions in the cochlea while the separate voices may still be integrated into a percept of harmony.

Four post-lingually implanted CI listeners and four normal-hearing (NH) controls were tested in a two-alternative forced-choice paradigm in which participants judged two consecutively presented triads as same or different. Triad voices were composed of HC tones, each consisting of three, five, or nine harmonics and with F0s ranging from 116 to 311 Hz. For NH listeners triads were presented against bandpass-filtered white background noise at a signal-to-noise ratio of -6 dB. Triads were presented either simultaneously or sequentially. In the sequential condition, the time interval between individual voices of a triad was varied (50%, 75%, and 100% duty cycle). We hypothesized that performance would be better when presented sequentially. Voice changes had a fixed magnitude of one semitone and occurred either in the highest, the lowest, or both the highest and lowest voice. We hypothesized that performance would be best for the lowest spectral complexity, particularly in CI listeners, and for changes in the highest or both the highest and the lowest voice (due to the high-voice superiority effect).

Results confirmed our hypotheses regarding spectral complexity and changed voice(s). In both CI and NH listeners best performance in the simultaneous condition was observed for three-component HC (HC3) triads with changes in the highest and lowest voices, followed by HC3 triads with changes in only the highest voice. Triads with changes in the lowest voice yielded no sensitivity. Sequentially presented triads yielded no sensitivity regardless of the duty cycle in CI listeners, but variability between listeners was high. NH listeners showed slightly better performance in the sequential than the simultaneous condition.

We conclude that CI listeners can achieve high chord discrimination performance when stimulus parameters are optimized according to their demands. The lack of an advantage of sequential chord presentation in CI listeners may suggest an issue with temporal integration of music tone information. Further data will be collected.

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P29: PITCH, TIMBRE, AND QUALITY WITH A COCHLEAR IMPLANT: INSIGHTS FROM VOCAL MIMICRY

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While cochlear implants (CIs) do not faithfully represent pitch, timbre, or sound quality of music, the specifics of these distortions remain unknown. Studying these attributes of sound with a CI is difficult as quantitative and qualitative descriptions of music perception are highly dependent on the listener's musical ability and memory of music before cochlear implantation. We have developed a technique - vocal mimicry - which provides a new method of exploring the perceptual attributes of a CI.

Vocal Mimicry Task: A stimulus was presented via direct audio input only to the CI ear of a listener who is single-sided deaf (SSD); as such, SSD CI users cannot hear the sound with their acoustic hearing ear. Participants are instructed to vocally mimic the pitch and sound quality of the stimulus heard through their CI; as such, SSD CI users can only hear their vocalizations through their acoustic hearing ear. Vocalizations are recorded and analyzed for multiple attributes, including fundamental frequency (F0) and spectral tilt. As a control condition, vocal mimicry was also performed in response to stimuli presented to their acoustic hearing ear. Using this technique, we have gained insights into two critical questions:

Question 1: What is the contribution of temporal (rate of stimulation) and place (electrode) information to pitch and timbre? Stimuli consisted of a sequence of three single-electrode pulse trains. The three pulse trains consisted of: A) 100% amplitude modulation (AM) at 98, 131, and 196 Hz on a fixed electrode, B) fixed amplitude (no AM) pulse trains at 2000 pulses/second on three different electrodes, or C) 100% AM (same modulation rates as above) on three different electrodes. Vocalizations in response to a change in modulation rate (condition A) on a single electrode or a change in electrode place without AM (condition B) differed primarily in the produced F0. However, a change in electrode place with fixed AM rate (condition C) resulted in little-to-no change in the produced F0, but a distinct change in sound quality characterized by increased high-frequency energy (timbre). Results suggestthat while temporal and place cues can convey pitch, when combined, pitch is dominated by temporal cues and place cues are perceived as changes in timbre. Recordings of the vocalizations will be presented and provide clear insight into pitch and timbre attributes of single electrode stimulation.

Question 2: What is the perceived pitch and sound quality of single notes played by musical instruments when presented through the clinical CI sound processor? Vocal mimicry was performed with single-note stimuli presented to the CI ear of listeners with SSD. The stimuli consisted of piano, cello, harp, and brass samples ranging in F0 from 131 Hz (C3) to 1047 Hz (C6). The mimicked F0s were highly correlated with stimulus F0s below ~300 Hz. However, when the F0 of the stimuli were >300 Hz, increases in stimulus F0 did not correspond to increases in reproduced F0. It is suggested that pitch with the CI is dominated by temporal cues because pitch was reasonably well encoded for lower but not higher F0s. This interpretation is reinforced by pilot data which suggests that changes to acoustic-to-electric frequency allocation changed the sound of the vocalizations, but not the reproduced F0. The vocalizations also revealed other attributes of the stimuli, such as attack (piano) and vibrato (cello).

P30: INFLUENCE OF ELECTRIC FREQUENCY-TO-PLACE MISMATCHES ON MONAURAL AND BINAURAL HEARING

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The monaural and binaural hearing outcomes for cochlear implant (CI) and electric-acoustic stimulation (EAS) device users vary widely across individuals. These individual differences in performance may be due in part to the wide variability across CI recipients in the angular insertion depth (AID) of the electrode array, which is related to the array design, cochlear morphology, and surgical approach. The default mapping procedures for CI and EAS devices do not consider array placement relative to the cochlear place frequency, resulting in electric frequency-to-place mismatches in the majority of CI recipients. Electric mismatches have been shown to negatively impact the monaural speech recognition of CI and EAS users, though some listeners demonstrate acclimatization to electric mismatches with training or long-term device use. Electric mismatches can also create discrepancies in the auditory cues presented in combination with the contralateral ear, which can negatively influence binaural hearing abilities. Better monaural and binaural hearing abilities may be observed for CI and EAS users listening with a place-based map that aligns the electric filter frequencies to the cochlear place frequency to eliminate electric mismatches. The present investigation assesses the monaural and binaural hearing of CI and EAS users listening with either default or place-based maps within the initial year of device use to determine the influence of electric mismatch on performance.

Adult CI recipients of lateral wall electrode arrays were randomized to receive maps with either the default filters or place-based filters at initial CI or EAS activation. Postoperative imaging was used to calculate the AID and estimate the cochlear place frequency for each electrode contact. Participants listened exclusively with either default or place-based maps during the first year of device use. Monaural and/or binaural hearing abilities were assessed at initial activation and at 1, 3, 6, and 12 months post-activation. The monaural hearing tasks included vowel recognition and consonant-nucleus-consonant (CNC) word recognition. The vowel recognition stimuli were presented via direct audio input at a comfortably loud volume. The CNC words were presented in the sound field at 60 dB SPL with masking presented to the contralateral ear, when warranted. Binaural hearing was assessed with a masked sentence recognition task. Performance was assessed with AzBio sentences in a 10-talker masker presented at 0 dB SNR with the target presented at 0 degrees azimuth and the masker either collocated with the target, presented 90° towards the implanted ear, or presented 90° towards the contralateral ear.

Preliminary data suggest poorer monaural and binaural hearing abilities for CI and EAS users with larger magnitudes of electric mismatch. CI and EAS users may experience better performance within the first year of device use when electric mismatches are minimal, such as with a place-based map. Investigation is ongoing to confirm these preliminary trends, determine whether different patterns in performance growth occur on measures of monaural versus binaural hearing, and determine whether CI and EAS users with larger magnitudes of electric mismatches eventually acclimate to the spectrally-shifted information and achieve similar speech recognition as observed for those with little or no electric mismatches.

P31: NOVEL ACOUSTIC MODELS OF COCHLEAR IMPLANTS ARE RELIABLY OBTAINED USING INTERACTIVE GENETIC ALGORITHMS (IGA)

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Background: Cochlear implant (CI) sound quality is significantly distorted compared to normal hearing. This distortion may be related to cochleotopic mismatch in spectral tuning of healthy vs CI ears (Landsberger, Svirsky, Dorman), broad and asymmetrical tuning of CI electrodes (Arenberg et al. 2010), aberrant encoding of intensity (Zeng and Shannon 1994) and fine structure, and reduced spectral resolution. Moreover, subjects report significant distortion at initial activation compared to later timepoints (anecdotal), suggesting that both sensory encoding and neuroplasticity within the central auditory system may contribute to sound quality. We are investigating the nature and extent of sound quality distortions by CIs by having single-sided deaf (SSD) cochlear implant users select an acoustic representation (delivered to their normal ear) that provides the best match to what they hear through the cochlear implant. We have previously found that it is possible to obtain listener-selected models that have a high degree of similarity to the CI and result in similar levels of speech perception as the CI (Capach et al. 2020). We ask whether it is possible to obtain even more precise acoustic models. First, we explored acoustic carriers other than typically used tones and narrowband noise (e.g., PSHC, Hilkhuysen and Macherey 2014; low-noise noise, Kohlrausch et al. 1997; SPIRAL, Grange et al. 2017). Second, we also obtained optimized acoustic models of single electrodes in a process that may be considered an enhanced form of electroacoustic pitch matching. In order to conduct these studies we developed an interactive genetic algorithm for optimizing user-selected acoustic models.

Methods: An interactive genetic algorithm was developed for optimizing acoustic models and was based on software previously used for optimizing CI mapping (Lineaweaver and Wakefield 2011). Our combined software allows for optimizing acoustic model parameters, including but not limited to cochleotopic mismatch, electrode tuning bandwidth, and type of acoustic carrier. The software initially randomizes a pool of acoustic models, and the genetic algorithm uses a combination of principles of biological evolution such as gene crossover, selective insertion, and random mutation, which balance the exploration of large parameter spaces while leveraging users' selections. After optimizing acoustic models, double blind questionnaires were conducted to obtain ratings for the similarity between the acoustic model and the CI.

Results: We tested 18 SSD-CI human subjects and ran 101 iterations of the GA (21 full array and 80 single channel models). The average time to convergence for each model was 29 minutes. Acoustic models optimized with the GA were compared to a) models optimized using the method of adjustment and b) traditional acoustic models where the analysis and synthesis filters had the same center frequency and bandwidth. In all tested subjects, models optimized by the GA were deemed closer to the sound of the CI compared to both traditional and self-selected models optimized via method of adjustment. Lastly, we found significant differences in acoustic models optimized across subjects in terms of cochleotopic mismatch, bandwidth, and acoustic carriers. Moreover, multiple repeated questionnaire ratings revealed significant preference for unique acoustic carriers over others.

Conclusions: Results reveal our interactive genetic algorithm enables a principled approach for optimizing acoustic models across a large parameter space. Secondly, expanding our parameter search to include novel acoustic carriers often enabled better rated acoustic models than those with tone and narrowband carriers. Similarly, modeling of single electrodes often enabled better rated models than those used in electroacoustic pitch matching (pure tones). Lastly, acoustic models may be an effective method for tracking changes in sound quality of cochlear implants following initial stimulation.

P32: THE NATURE OF PERCEPTUAL PROCESSING IN VOCAL PRODUCTION

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In this talk I will map out the neurobiology of human vocal control, addressing both voluntary and involuntary vocalisation networks. Within these, I will identify points in the networks where perceptual information, particularly auditory information, is providing input into speech motor control networks. I will use this to explore the ways in which perceptual information is used to guide voluntary vocalisations, such as speech production, and the ways that altered auditory information can affect speech production.

P33: THE ELECTROPHYSIOLOGY OF AUDIOVISUAL SPEECH PROCESSING IN AGING COCHLEAR IMPLANT USERS

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INTRODUCTION: Aging cochlear implant (CI) users and non-users are more reliant on visible speech information to identify audiovisual speech than their younger counterparts. In aging adults with normal to mild-to-moderate sensorineural hearing loss, this multisensory benefit is reflected in their speech-evoked electrophysiological potentials (SEPs). However, little is known about the neurophysiology that underlies this multisensory benefit in aging CI users or the degree to which they engage the same neural mechanisms as age-matched controls. We hypothesize that the multisensory benefit observed when aging CI users identify audiovisual speech will reflect their SEPs, similar to what is observed in aging non-CI-users.

METHODS: We recruited 15 post-lingually deafened CI users between the ages of 49 and 83 years (SD=8.921) and 23 age-matched controls (55-80 years of age, SD=8.043). All participants had normal or corrected-to-normal sight. The hearing of our controls varied from normal hearing to mild-to-moderate sensorineural hearing loss. Participants completed an audiovisual speech-in-noise identification task, identifying words presented auditory-only (AO), visual-only (lipreading, VO), or audiovisual (AV). SEPs were recorded in all participants while they were passively presented consonant-vowel syllables AO, VO, or AV. We employed independent component analysis (ICA) – a computational approach that separates the subcomponents of a multivariate signal – to identify and remove CI artifacts from the summated data, leaving the potential evoked by the speech stimuli.

RESULTS: The results support our hypothesis. Both CI users and age-matched controls demonstrated audiovisual enhancement when identifying speech-in-noise, supporting past findings. This audiovisual enhancement was reflected in the SEPs recorded in both groups, such that the SEPs evoked by AV stimuli were smaller in amplitude than those evoked by AO or VO stimuli. Smaller amplitudes of this nature have in the past been interpreted to represent more efficient neural processing of multisensory stimuli. Additionally, the audiovisual enhancement measured in the behavioral and electrophysiological data exhibit a superadditive effect in both CI and control participants, with CI users demonstrating more auditory-visual superadditivity when identifying speech in noise.

CONCLUSIONS AND IMPLICATIONS: The results suggest that CI users engage similar neurophysiological mechanisms to age-matched controls when processing audiovisual speech and that cross-sensory information can facilitate the processing of speech information delivered through a CI device. This facilitation is more than would be expected from AO and VO responses, demonstrating a superadditive benefit that is greater for CI users. Based on these findings, aging CI users may benefit from engaging in face-to-face communication more than their age-matched peers, helping to alleviate the difficulty experienced by some understanding the speech they receive through their device.

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P34: THE IMPACT OF VISUAL SPEECH CUES ON LISTENING EFFORT FOR LISTENERS WITH COCHLEAR IMPLANTS

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The ability to see a talker's face substantially improves speech intelligibility, both for listeners with normal hearing (NH) and especially those with hearing loss. However, previous research on audiovisual speech perception has not produced a clear answer on how visual speech cues affect listening effort. Critically, the existing literature has focused on listeners with NH, and has also relied heavily on simple stimuli such as single words or highly constrained sentences, which are not ideal for eliciting effort. In this project, we measured the impact of visual cues on realistic speech processing using pupillometry as a signature of the magnitude and timing of effort. Listeners with cochlear implants (CIs) and age-matched NH participants perceived and verbally repeated audio-visually presented sentences. On half the trials, visual information was removed by selectively blurring the mouth, which preserved luminance and dynamics of the visual stimuli so pupil size could be compared across conditions. The stimuli were designed to impose a mental repair process for half the sentences by replacing one of the words in the sentence with noise, requiring the listener to reconstruct the missing word from later context. Preliminary results indicate that the mental repair process elicited elevated pupil size relative to the intact-audio condition, even when visual speech cues were available. The need to repair a missing word also reduced intelligibility, with increased repetition errors on both the missing word and words later in the sentence. However, errors of both types were mitigated when the mouth was visible, reflecting the intelligibility benefits of visual speech cues. Importantly, pupil size was also smaller when the mouth was visible across auditory conditions, indicating that visual cues reduced overall listening effort. We suggest that visual speech cues allowed listeners to process the sentential context more clearly, leading to the observed reduction in effort when context was needed to recover from mistakes. This highlights the importance of including context effects in the study of audiovisual speech perception, as single-word tasks or stimuli without semantic coherence are unlikely to draw out the full complement of visual perceptual benefits.

P35: CONTRALATERAL SPEECH INTERFERENCE WITH SINGLE-SIDED DEAFNESS COCHLEAR-IMPLANTS: A GENERAL SELECTIVE-ATTENTION DEFICIT OR SPECIFIC TO ASYMMETRIC EXPERIENCE?

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Single-sided deafness cochlear implants (SSD-CIs) provide clear benefits for spatial hearing but with large variability in outcomes. We have identified a key factor— "contralateral speech interference"—that might contribute to variability in speech understanding in competing-talker situations by reducing the head-shadow benefit that SSD-CIs would otherwise provide. This interference is revealed by a paradigm designed to examine binaural integration for SSD-CI speech perception. In the monaural condition, target and interfering speech are presented to one ear. In the bilateral condition, a copy of the interfering speech is also presented to the other ear. With target speech in the acoustic-hearing ear, most SSD-CI users show a benefit from bilateral masker presentation. In contrast, with the target in the CI ear, bilateral performance is poorer than monaural for many (especially older) SSD-CI users. In other words, masking speech in the acoustic ear often interferes with CI-ear speech understanding.

This study examined if SSD-CI contralateral speech interference reflects a general, aging-related "selective-attention" deficit (difficulty attending to target speech while ignoring an interferer) or if it is specific to experience with asymmetric hearing. Contralateral interference for SSD-CI listeners was compared to that for listeners with bilateral normal hearing thresholds (NHT) through 4 kHz. Both groups had a wide range of ages (SSD-CI: 36-74; NHT: 20-84) and thus a wide range of expected selective-attention ability. NHT listeners were presented SSD-CI vocoder simulations to test whether acute simulation of asymmetric hearing would produce interference of similar magnitude. Contralateral interference was compared to (1) listener age and (2) the ability to take advantage of gender differences to perceptually separate competing talkers presented monaurally to a NHT ear (a task thought to reflect selective-attention ability).

Results for 16 (of 25 planned) NHT listeners showed a moderate, significant correlation with gender benefit ($p=0.012$) and a trend toward a correlation with listener age ($p=0.054$), suggesting a role for selective-attention deficits. However, the interference was substantially smaller than for the 13 SSD-CI users, unless the stimuli were distorted to produce much poorer monaural speech understanding than for SSD-listeners' CI ears alone.

Overall, the results suggest that selective-attention deficits for older listeners, independent of asymmetric-hearing experience, can partially explain SSD-CI contralateral inference. Since this does not fully explain SSD-CI interference, there might also be a contribution from maladaptive plasticity to asymmetric hearing. Future work will explore if rehabilitation targeted at enhancing selective attention to the poorer ear can reduce interference.

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P36: TACTILE STIMULATION ENHANCES AUDITORY SPEECH PERCEPTION IN NORMAL-HEARING AND COCHLEAR-IMPLANTED LISTENERS

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Only little research on how tactile stimulation influences auditory speech perception has been conducted so far. While a few studies report enhancement of speech intelligibility under the presence of related somatosensory stimulation, this effect is not present consistently in all published investigations.

The present study aimed to replicate previously reported results to investigate the robustness of a tactile benefit for speech intelligibility. We extended the paradigm of Fletcher et al. (Scientific Reports, vol 9., 2019) by adding a second difficulty level and an audio-tactile control condition in which a tactile stimulus was presented, but whose information content was unrelated to the speech stimulus.

Speech intelligibility was measured in 23 German native speakers with normal hearing (NH) and 14 cochlear implant (CI) patients, using the Hochmair-Schulz-Moser speech-in-noise test. Sentences were presented in a 2x3 task design with auditory alone, auditory + tactile envelope, and auditory + tactile noise conditions played in 2 difficulty levels (easy and difficult SNR), respectively.

The statistical analysis focused on the three conditions with difficult SNRs, in which we expected the facilitatory effect of the tactile stimulus to be largest. For both participant groups, we found significantly improved speech understanding scores for sentences presented in the auditory + tactile envelope compared to the auditory alone condition (5.3% for NH and 5.4% for CI participants). In line with the principle of inverse effectiveness, the amount of tactile enhancement was significantly negatively correlated with the auditory-alone performance in the group of NH, but not in CI users.

These findings replicate previously observed tactile enhancement effects, which seem to be present to a similar extent in NH participants as in CI users. Additional analyses aim to relate the speech test results to neural correlates of audio-tactile speech and audio-tactile integration effects, measured with functional near-infrared spectroscopy.

P37: PERCEPTUAL ACCOMMODATION ACROSS SENSORY DOMAINS SUPPORTS LANGUAGE LEARNING VIA COCHLEAR IMPLANTATION

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In language learning, establishing joint attention is a crucial step, and caregivers play a crucial role in scaffolding their children's language learning. This process involves communicating in a way that supports their child's attentional allocation, which includes the use of both auditory and visual cues. In hearing-hearing dyads, this communication occurs primarily through spoken language and visual cues such as eye contact, facial expressions, and gestures. In deaf-deaf dyads, communication occurs primarily through manual language, such as American Sign Language (ASL), and visual cues. However, when a hearing parent interacts with a deaf child who is a candidate for cochlear implantation but who has not yet been implanted, the communication process becomes more complex. In our research examining how hearing parents accommodate their deaf child's hearing status, we have observed that to successfully establish joint attention, hearing parents of deaf children use multiple sensory modalities with their children, including auditory, visual, and tactile cues. Secondary analyses revealed that hearing parents of deaf children used shorter utterances while initiating joint attention than did hearing parents of hearing children. Hearing parents of deaf children also touched their children twice as often throughout the play session than did hearing parents of hearing children. These findings demonstrate that parents differentially accommodate the specific needs of their hearing and deaf children in subtle ways to establish communicative intent. In other research, we have been examining how typically developing infants and young children process degraded auditory speech with and without crossmodal (i.e., audiovisual) support. Based on this work, we have identified the point in developmental time at which children start to effectively use phonetic information to match a speech sound with one of two articulating faces. By examining the underlying mechanisms of speech processing in children with and without hearing loss in infancy and across early childhood, our research has theoretical and practical implications for understanding speech processing in a multimodal world, informing the development of effective interventions for children with hearing loss who learn spoken language via cochlear implant.

P38: THE PREDICTIVE VALUE OF MULTI-SENSORY COMMUNICATIVE BEHAVIOR OF INFANTS IN THE FIRST YEAR OF LIFE TO LATER LANGUAGE DEVELOPMENT: IMPLICATIONS TO INFANTS WITH COCHLEAR IMPLANTS

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Background: While there is consensus regarding the importance of early diagnosis of hearing loss (at birth), early fitting of hearing aids (before six months of age) and early cochlear implantation (CI; by 9-10 months of age), there is still much-unexplained variance in performance in language skills and cognitive abilities for children who have no risk factors for developmental delays other than hearing loss (HL). One possible explanation relates to communicative behaviors acquired in the first few months of life by typically developing infants, which are known to contribute to brain organization and later language development, and may be missing out by infants with HL. In addition to preverbal vocalizations, these communicative behaviors involve eye gaze, facial expressions (e.g., smiles), and hand gestures, all of which are part of the adult communication cycle and considered crucial for establishing early multi-sensory and motor integration of the neural circuits. The goals of the present study were: (1) to characterize multisensory and motor behavior in dyadic communication at 3 and 6 months of age in infants with normal hearing (NH) and with hearing loss (prior to CI); (2) to compare communicative behaviors in infants with NH and HL in their natural environment at 3 and 6 months of age; and (3) to relate early performance to language ability at 15 months of age.

Method: 33 NH & 7 HL were tested at 3 and 6 months of age. Six 2-minute dyad episodes were filmed (infants and adults). The four modality behaviors were coded and analyzed using Interact software. The exposure of infants to verbal interaction in daily life was monitored by LENA™. At 15 months of age, language development was assessed using a standardized parent questionnaire.

Results: In NH, 20% of the most frequent behavioral combinations resulted in about 80% of the total occurrence. Following principal component analysis (PCA), the two clusters of behavioral patterns observed at 3 months old and by the mothers were predictive of language expression at 15 months of age. Different patterns of behavior were observed with HL. Counting of LENA recordings showed fewer infant vocalizations and conversational turn-taking in HL compared to NH at both ages.

Conclusions: NH infants at 3 months old show multi-sensory and motor behavioral patterns in a communication cycle, which is predictive of later language development. Infants with HL showed significant differences from NH in their communicative behavioral patterns, which may suggest deficits in multisensory integration and consequent brain organization which may not be reversible once provided with a CI.

P39: HOW DO THE EVERYDAY SPEECH-LANGUAGE ENVIRONMENTS OF PRESCHOOLERS WITH AND WITHOUT COCHLEAR IMPLANTS PREDICT THEIR VOCAL MATURITY OUTCOMES?

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Compared to children with typical hearing (TH), children with severe to profound deafness who receive cochlear implants (CIs) must develop speech and language on a compressed timescale. In typical development, the home speech-language environment can facilitate speech-language growth: children who hear more words in their environments, and engage in more contingent interactions with caregivers, process words faster (Newman et al., 2016), develop stronger phonological working memory skills (Cychosz et al., 2021), and grow larger vocabularies (Lew-Williams & Schwab, 2016; Rowe, 2012). This same facilitative effect could exist for children with CIs, but the home language environment likely differs between children with CIs and TH (Holt et al., 2013). These differences would be due both to the absence of auditory input in the children's environments pre-implantation, but also the degraded speech signal transmitted by the CI(s) post-implantation. It is unclear how the home environment facilitates speech-language development among young children with CIs.

This study (1) characterized the everyday speech-language environments of preschoolers with and without CIs and (2) evaluated how the children's environments predicted their vocal outcomes. Eighteen children with CIs (31-65 chronological months; 12-54 hearing age months) were matched to two groups of TH controls: chronological age controls and hearing age controls. Each pair was additionally matched for child gender and socioeconomic status. Children completed a single daylong audio recording (appx. 16 hrs./child; >730 hours of observation) where they wore a lightweight recorder for an entire day as they went about their daily activities. Estimates of the home language environment (e.g., quantity of caregiver input, number of conversational turns between the child and an adult), as well as child vocal outcomes (e.g., quantity, duration, intensity of child vocalizations, and quantity of vocalizations contingent with caregiver speech) were semi-automatically derived from each recording and compared across groups.

Results show few differences between hearing groups in measures of the home environment (number of words from caregivers, conversational turns). However, the children with CIs produced less mature (shorter) vocalizations than chronological age matches, but not hearing age matches. Vocal maturity also grew more slowly with development (chronological and hearing age) for the children with CIs than TH. Finally, we compared how the home speech-language environment predicted the children's vocal outcomes: all children produced a greater number of contingent vocalizations in response to louder received caregiver speech, but measures of the language environment (words, conversational turns) were less predictive of vocal productivity in the children with CIs than either TH group. Together these results suggest that the home language environment may be less predictive of outcomes for children with CIs, and may reflect their developmental stage less closely.

P40: PEDIATRIC AUDITORY BRAINSTEM IMPLANTATIONS AND CORTICAL DEVELOPMENT FEATURES IN CONGENITAL DEAFNESS CHILDREN AFTER ABI SURGERY

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Objectives: The aim of this study is to present our experience and results of auditory brainstem implantation in children with congenital non-tumor deafness and to investigate the cortical developmental and functional connection features after ABI in children, and their relations to behavioral outcomes.

Materials and Methods: Retro-sigmoid or retro-labyrinthine approach was applied for ABI surgery. EABRs was intraoperatively performed to find out optimizing position of electrode paddle on the cochlear nucleus, and was postoperatively applied during activation and following fitting to determine the objective function of each electrode. The pure tone listening test (PTA), categories of auditory performance (CAP), infant-toddler meaningful auditory integration Scale (IT-MAIS), the meaningful use of speech scale (MUSS), speech intelligibility rate (SIR) and charge level of threshold of electrically evoked auditory brainstem responses (eABRs) were assessed in participants. The electroencephalogram (EEG) and functional near-infrared spectroscopy (fNIRS) were used to record cortical neural responses to auditory mismatch negativity (MMN) paradigm.

Results: ABI was successfully performed in all cases without intra-operative and post-operative major complications. The average active electrode ratio was 83% ±19% at first activation (n=49) and 76% ±15% at 12 months after 1st fitting (n=21). At 24 months after 1st fitting, 61.5% reached CAP-II≥5; 69.2% reached IT-MAIS/MAIS≥35 and 38.5% reached IT-MAIS/MAIS 40; 46.2% reached MUSS≥25; 92.3% children presented improvement on SIR and 30.8% reached SIR≥3. The fNIRS oxygen concentration analyses revealed more efficient functional-connections between the left auditory cortex and other cortices with longer implantation duration. The functional coherence of left auditory and frontal cortex was positively correlated to CAP (Spearman r=0.67 P=0.0019), IT-MAIS (Spearman r=0.69 P=0.0020) and SIR (Spearman r=0. 47 P=0.017) scores.

Conclusion: Cortical plasticity in congenital deafness children after ABI may contribute to the auditory and speech behavioral development, especially the connection between left temporal and frontal lobe. Auditory brainstem implantation has been a safe and feasible technique in young children who are contra-indicated to cochlear implantation, to restore the hearing and promote speech development.

P41: ASSESSMENT OF SPEECH COMPREHENSION WITH SEMANTICALLY ANOMALOUS SENTENCES IN COCHLEAR IMPLANT USERS

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Assessment of speech perception in cochlear implant (CI) users usually relies on speech intelligibility, which is typically measured based on the number of words repeated correctly. Less attention is given to speech comprehension which requires understanding the meaning of sentences, and is more representative of everyday speech communication. However, the relationship between speech intelligibility and speech comprehension is not well understood. Our previous research revealed considerably reduced ability of CI users in discriminating semantically anomalous and semantically regular sentences in a task that requires understanding sentence meaning (e.g. “the wrong shot led the farm” vs. “the hot sun warmed the ground”). When experienced postlingual CI users were asked to select one semantically anomalous sentence from three sentences heard on a given trial, their average accuracy was 55.4% correct, compared to 90.7% correct for normal hearing older peers. The present study further investigated factors that may influence the ability to discriminate sentences based on their semantic coherence. To examine the influence of working memory load and processing time, the number of sentences on a given trial was varied between three and two, while the interstimulus interval between the sentences varied between 500 msec and 750 msec. However, these manipulations did not have a significant effect on performance accuracy of discriminating sentences, suggesting a limited role of working memory load for this task. A follow-up analysis revealed that the ability to detect semantically anomalous sentences was strongly associated with CI users’ speech intelligibility. When a stricter intelligibility criterion was applied to require all words in a sentence to be repeated correctly, the intelligibility of semantically anomalous sentences was considerably lower than the intelligibility of semantically regular sentences. These findings indicate the augmentative role of semantic context in sentence intelligibility, support the use of more stringent scoring criteria in measuring sentence intelligibility, and suggest potential clinical utility of a binary discrimination test based on semantic coherence of sentences.

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P42: PERIPHERAL AND CORTICAL ENCODING OF ELECTRICAL STIMULATION AND THEIR ASSOCIATIONS WITH AUDITORY PERCEPTION IN ADULT COCHLEAR IMPLANT USERS

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The overall goal of this line of research is to better understand auditory neural encoding of electrical stimulation and its association with auditory perception outcomes in post-lingually deafened adult cochlear implant (CI) users. In this presentation, results from three sets of studies will be reported. The first set of studies aimed to identify response properties/parameters of the cochlear nerve (CN) that were important for speech perception outcomes. We identified that the quality of the electrode-to-neuron interface (ENI) and the speed of recovery from adaptation of the CN were two predictors for speech perception outcomes in CI users. Poorer ENIs and/or prolonged adaptation recovery of the CN were associated with worse speech perception performance, especially in noise. The speed of neural adaptation of the CN explained additional unique variance in speech perception scores. Overall, these three parameters explained more variance in speech perception scores for conditions with higher noise levels and accounted for ~ 50% of the variance in speech recognition scores measured at a +5 dB signal-to-noise ratio. The second set of studies evaluated whether the across-electrode variation in amplitude modulation (AM) rate discrimination thresholds (AMRDTs) and within-channel gap detection thresholds (GDTs) measured in individual CI users was due to the difference in sensitivity to AM cues and adaptation recovery of the CN, respectively. Our results showed that the difference in these two response properties of the CN was not the primary factor accounting for the across-electrode variation in GDTs or AMRDTs in individual CI users. These across-electrode variations were also not due to the difference in cognitive function because they were measured in the same CI users. Most recently, we developed a method for quantifying neural synchrony across CN fibers in human CI users. This new method was used in the third set of studies to characterize neural synchrony in the CN and to assess its association with cortical encoding of and auditory percentual sensitivity to temporal envelope cues, as well as speech perception outcomes in CI users. Our preliminary results showed substantial variations in neural synchrony in the CN among CI users. Lower neural synchrony in the CN was associated with prolonged within-channel GDTs and larger negative effects of noise on speech perception outcomes in CI users.

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P43: POSTOPERATIVE IMPEDANCE-BASED ESTIMATION OF COCHLEAR IMPLANT ELECTRODE INSERTION DEPTH

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Introduction: Anatomy-based fitting of audio processors or monitoring of electrode migration during follow-up are promising applications in cochlear implants. Currently, electrode positioning is measured using radiography. The aim of this study is to develop and validate an alternative method for measuring cochlear implant electrode positioning, which could serve as a radiation-free and cost-effective alternative to radiography. The study also aims to evaluate the reliability of the new method over time during postoperative follow-up over several months.

Methods: To validate the impedance-based method, we obtained postoperative computed tomography scans from 56 patients who had undergone cochlear implantation with an identical lateral wall electrode array. Impedance telemetry records were collected from the day of implantation up to 60 months post-surgery. Using a phenomenological model, we estimated the linear and angular insertion depths of the electrodes and compared them to the ground truth values to calculate the accuracy of the model.

Results: The analysis using linear mixed-effects models showed that tissue resistances remained stable over time except for the 2 most basal electrodes, which increased significantly over time (electrode 11: ∼10 Ω/year, electrode 12: ∼30 Ω/year). However, the phenomenological models based on early and late impedance telemetry recordings were not different. The estimated insertion depths of all electrodes had an absolute error of 0.9 mm ± 0.6 mm or 22° ± 18° (mean ± standard deviation).

Conclusion: This study demonstrated that the impedance-based method is reliable for estimating electrode insertion depths during postoperative follow-up by comparing 2 postoperative computed tomography scans of the same ear. Our results confirm that the impedance-based position estimation method can be applied to postoperative impedance telemetry recordings. However, future research needs to address extracochlear electrode detection to improve the accuracy of the method.

P44: ELECTROCOCHLEOGRAPHY AND COCHLEAR IMPLANTS

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Electrocochleography (ECochG) as a way to monitor the status of hair cells and the cochlear nerve is being used in conjunction with cochlear implants in ways that are impacting the science and practice of their use. I will describe three ways that this impact is occurring. ECochG was initially envisioned by several groups as a means to monitor the health of hair cells and the auditory nerve in order to improve hearing preservation during electrode insertion. The idea was that if responses from these elements decrease during insertion the surgeon could take corrective action to preserve hearing. Studies of this kind have now been conducted in numerous locations and continue as an ongoing effort to realize the potential of this technology. Each implant manufacturer has provided tools to perform the recordings through the electrode contacts of the array as it advances. Due to the need to utilize the often small responses obtained from ears with severely comprised function and to provide real-time feedback during a procedure that typically takes only minutes, a simple stimulus consisting of a 500 Hz tone is most commonly used. A problem realized early on was that when the recordings are from the apical contact as it advances the responses can decrease for reasons other than trauma, since, for example, they can increase again with further insertion despite no intervention by the surgeon. Modest correlations with the degree of hearing preservation between cases with larger or smaller response drops have been seen, so the technique does detect a degree of trauma, but tissue response as a cause of hearing loss is a major factor that may or may not be related to surgical trauma. Stronger correlations may emerge when robotic insertions, coupled with drug-eluting electrodes are combined with the information from ECochG.

A second use of ECochG is in accounting for the high variability in speech perception outcomes. Current results indicate that a single measure, called the Total Response (TR), that takes but a few minutes prior to or during the surgery to obtain, can alone account for nearly 50% of the variability in monosyllabic word scores outcomes among all implant candidates. Coupled with information about insertion depth and electrode type the amount of variability accounted for can be as high as 70%. Cognitive factors have also been shown to be significant when used in combination with the TR, particularly in conjunction with noise. The TR is the sum of responses obtained to tones of different frequencies from 0.25-4 kHz. Why is the TR predictive of speech perception outcomes while pre-implant hearing is not? The difference appears to be due to the presence of a high degree of cochlear synaptopathy in cochlear implant subjects, so that the ECochG is detecting the presence of functional hair cells not connected to auditory nerve fibers that provide hearing. With this interpretation, the TR is a measure of overall cochlear health which is then correlated with spiral ganglion function that can be utilized by the CI.

A third potential use of ECochG is to provide a personalized description of the distribution of surviving hair cells and auditory nerve neurons in individual cases. Coupled with the understanding that the presence of functional hair cells can indicate the health of underlying spiral ganglion cells, this information can impact mapping and treatment choices on a case-by-case basis.

P45: POLARITY EFFECT AND ECAP MEASURES OVER TIME AND CORRELATION WITH HEARING PRESERVATION

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Background: While cochlear implants have been successful in treating many patients with severe-profound hearing loss, there remains significant variability in outcomes. Factors associated with poorer pre-operative neural health, such as long duration of deafness, have been associated with worse outcomes. One factor that has not been investigated is post-operative changes in neural health over time. The polarity effect (PE) and electrically-evoked compound action potential (ECAP) are two measures that evaluate aspects of the peripheral auditory nerve. The PE is a measure of the difference in electric threshold between anodic and cathodic pulses, and is thought to reflect peripheral neurite survival and/or myelination of the axon (Rattay et al., 2001; Resnick et al., 2018). The PE may correlate with residual hearing preservation, since peripheral neural innervation is required for acoustic transmission. The ECAP interphase gap (IPG) slope and offset effects (i.e. difference in ECAP between a long and a short IPG) are correlated with spiral ganglion cell counts (Rattay et al., 2001; Resnick et al., 2018).

Objective: We hypothesized that neural health measures would show changes over time after implantation, indicating further damage from implantation and/or recovery from trauma. A secondary hypothesis was that changes in the polarity effect would correlate with residual hearing preservation.

Methods: Six adult CI patients (seven ears; 3 Cochlear, 4 Med-El; 3 females, 3 males; age range 41-75 years) were recruited prior to surgery. All subjects had residual hearing with ≤ 80 dB HL through 1000 Hz in the ear to be implanted and had normal cognitive function. Audiograms were measured pre-operatively and post-operatively along with PE and ECAP at initial activation, and at 1 week, 1 mo, 3 mos, 6 mos, and 12 mos post-activation. Computed Tomography (CT) scans were measured and modeled in order to estimate electrode depth and placement within the cochlea (i.e. scala vestibule, scala media, or scala tympani). ECAP amplitude growth functions were recorded for two inter-pulse gaps (IPGs), 7-10 (short) and 30 (long) microseconds, in order to measure the IPG slope and offset effects. For the PE, thresholds for anodic and cathodic stimuli were measured psychophysically using a three-alternative forced choice (3AFC) procedure (e.g. Macherey et al., 2017; Jahn and Arenberg, 2019).

Results: PE and ECAP generally changed over time after implantation, with direction and degree of change varying across subjects and electrodes. Changes in PE were also positively correlated with loss of hearing thresholds between 1 and 3 mos post-activation for the most apical electrode, where there was the most residual hearing to lose. No correlations were seen between ECAP measures and hearing changes.

Conclusions: As hypothesized, neural health measures show changes over time after implantation. In addition, changes in polarity effect appear correlated with changes in residual hearing for at least the most apical electrode during one of the earliest time points in recovery following cochlear implantation. More research with a larger population of cochlear implant recipients with pre-operative residual hearing is needed to better understand to what extent for which this relationship exists.

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P46: NEUROPHYSIOLOGICAL CORRELATES FOR THE OBJECTIVE DETERMINATION OF STIMULATION LEVELS IN COCHLEAR IMPLANT USERS

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Although the cochlear implant (CI) is considered to be the most successful bionic prosthesis, the electrical stimulation levels used in everyday stimulation are highly variable across CI users. Moreover, these stimulation levels are determined based on the subjective feedback of the CI recipient. It is challenging to use this method in CI populations who are unable to give adequate behavioral feedback, e.g., infants. An objective method to determine the electrical stimulation parameters could be a potential solution to enable an easier and less time-consuming fitting procedure and to ensure reproducibility across centers and clinicians. Several auditory potentials [i.e. evoked compound action potential, auditory evoked brainstem response] have been investigated in the past to objectively determine electrical thresholds, however, only with limited success. One of the main reasons is that in-place clinical and previously explored methods use low-rate pulse trains to evoke the neural responses, however, in everyday stimulation the CI operates at high pulse rates. One potential objective measure that can be used for objective fitting is the electrically evoked auditory steady-state response (eASSR). eASSRs are phase-locked responses from subcortical and cortical regions of the auditory pathway and can be evoked with amplitude-modulated (AM) stimuli. Previous research confirms that AM stimuli elicit neural responses with a high signal-to-noise ratio (SNR) in adults. Furthermore, it has been shown that this measure represents temporal envelope encoding across the auditory pathway and can be measured with high pulse rate stimuli. Measuring neural responses, evoked with high pulse rate stimuli with clinical CI parameters, i.e., high pulse rates and a monopolar stimulation configuration, is challenging due to the high stimulation artifacts that corrupt the EEG. New methods recently developed at our lab do enable to measure these responses with clinical CI parameters in CI users. However, it is unknown if these measures can also be used to effectively determine electrical threshold levels in individual CI users.

The goals of this study are to provide insight into using electrophysiological measures as a clinical feasible objective method to determine threshold levels in CI users. The validity of the eASSR-based method is evaluated through test-retest reliability. If successful, this research can be the starting point for the development of a fitting routine based on eASSRs, which in turn reduces the workload for clinicians and results in reproducible CI outcomes across centers/clinicians. In the present study, we measured 40-Hz eASSRs and evaluated temporal envelope encoding across the dynamic range of fifteen unilateral adult CI users with a Cochlear™ Nucleus implant. AM stimuli were presented at 900 pulses per second (pps) and in monopolar mode on a single CI electrode for two stimulation paradigms, a continuous and intermittent stimulation paradigm. EEG was recorded with a custom BioSemi hyper-rate sampling system with a sampling frequency of 262 kHz to limit distortion due to stimulation artifacts.

Results show that it is feasible to measure artifact-free electrical growth functions when using a clinically relevant pulse rate of 900 pps and a monopolar mode. The majority of electrophysiological thresholds derived from the temporal envelope encoding growth functions were within the lowest quartile of the dynamic range. Furthermore, for most participants a match exists between electrophysiological and behavioral stimulation levels. Similar results were obtained for both stimulation paradigms within participants across EEG sessions. This study provides the first proof of concept that eASSR responses can be used to derive electrical thresholds from artifact-free growth functions in adult CI users and show their potential for an objective fitting routine.

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P47: INVESTIGATING THE ELECTROPHYSIOLOGY OF AUDIOVISUAL SPEECH INTEGRATION UNDER NATURALISTIC CONDITIONS.

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Seeing a speaker’s face significantly improves speech comprehension, particularly in noisy environments. This is attributed to the brain’s ability to integrate information from auditory and visual modalities through a process called multisensory integration. However, the mechanisms involved in this process remain incompletely understood – particularly in the context of natural, continuous audiovisual speech. In this talk, I will describe a program of research aimed at addressing this question based on modeling EEG responses to natural audiovisual speech. I will show that these models can be used to index multisensory integration and how that integration varies as a function of task and listening conditions. This will include discussion of studies aimed at exploring the integration of audio and visual speech under quiet and noisy conditions. I will also describe efforts to test the hypothesis that multisensory integration occurs in parallel at different levels of the speech processing hierarchy. Finally, I will present the results of a series of recent experiments aimed at examining how multisensory integration and “cocktail party” attention interact. These experiments differ in complexity and in the number and location of audiovisual stimuli and show strong effects of top-down attention on indices of audiovisual speech integration and a strong influence of multisensory integration on participants’ ability to solve the cocktail party problem. Overall, our results suggest that the integration of natural audio and visual speech is a flexible, multistage process that adapts based on the current listening conditions and the goals of the listener.

P48: ELECTRIC ACOUSTIC INTEGRATION IN BIMODAL COCHLEAR IMPLANT USERS

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Bimodal stimulation combines electric stimulation through a cochlear implant (CI) and acoustic stimulation on the opposite side through the residual acoustic hearing. Bimodal CI users can combine electric and acoustic information to improve speech understanding. However, the observed benefit presents high variability across subjects. This variability may be associated with the effectiveness of the integration between electric and acoustic stimulation. The effectiveness of bimodal integration might be affected not only by individual characteristics of the user but also by the time processing delay or frequency mismatch between the CI and the acoustic side. Moreover, there are still debates whether bimodal CI users can obtain binaural integration by combining electric and acoustic stimulation across opposite ears. The understanding of electric acoustic integration at neural level might contribute to the optimal fitting of bimodal devices and consequentially to improve bimodal hearing.

In the first study, we investigated methods to assess bimodal integration. A behavioral paradigm based on speech understanding performance and an electrophysiological paradigm based on selective attention decoding were conducted in bimodal CI users. Speech material for both paradigms were presented to the CI side (CIS) alone, the acoustic side (AS) alone and to both sides simultaneously (CIS+AS). This study demonstrated that it is indeed possible to decode selective attention in CI users. Moreover, an increase in selective attention decoding was observed with better speech understanding.

In the second study, we investigated cortical auditory evoked potentials (CAEPs) in normal hearing listeners and CI users. It was hypothesized that CAEPs are impacted by the temporal delay and frequency mismatch between electric and acoustic stimulation in bimodal CI subjects. CAEPs were measured in five bimodal subjects when listening with CIS alone, AS alone and with both sides together (CIS+AS). When listening with CIS+AS, different delays between the stimuli presented electrically and acoustically were presented. Afterwards, CAEPs were measured across different frequency allocation maps for CIs. Maps were created based on the clinical map and the CI tonotopic frequencies estimated from computed tomography. To validate the hypothesis that CAEPs change significantly with interaural delay and frequency allocation, pilot measurements were conducted in eleven normal hearing listeners.

The impact of interaural delays and frequency mismatch on CAEPs in both subject groups was investigated through analysis of N1P2 complex and global field power. In NH, a change in cortical response with interaural delay and frequency mismatch was observed. Preliminary analysis in bimodal CI users showed greater cortical response when temporal delay between electric and acoustic side was compensated. Moreover, we observed a tendency towards greater response when frequency mismatch was corrected.

The current work shows that it is possible to measure cortical response in bimodal CI users. Moreover, it has been shown that cortical processing of combined electric and acoustic information depends on temporal delay and frequency mismatch between both listening sides.

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P49: LARGER MALADAPTIVE ACTIVATION OF AUDITORY CORTEX DURING LIP-READING TASKS AT DEVICE SWITCH-ON PREDICTS POORER FUTURE SPEECH UNDERSTANDING OUTCOMES FOR COCHLEAR IMPLANT RECIPIENTS

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Background: Activation of the auditory cortex in response to visual-only speech stimuli has been widely observed in cochlear implant (CI) users. In CI recipients, such cross-modal activations are thought to arise due to neural plasticity during the post-deafness period, where the cortical region for auditory processing is deprived of sensory inputs and maladaptive take-over of the region occurs.

While there exists active discussion within the literature on how such brain reorganization affect CI user outcomes, a consensus is yet to be reached. In this longitudinal study, we uncover post-implantation brain reorganization using functional near infrared spectroscopy (fNIRS) recorded during a naturalistic audio-visual story task. We hypothesize that, larger maladaptive activation in the auditory cortex during visual-only task segments leads to poorer speech understanding outcomes in CI recipients.

Methods: Fifteen post-lingually deaf adult new CI recipients were recruited for this study. fNIRS recordings were recorded during two sessions: 1) within two weeks of implant switch-on and 2) approximately one-year after implant switch-on. The audio-visual task consisted of 18 blocks of audio-only (sound-only, fixation cross on screen), 18 blocks visual-only (a video of a female speaker, no sound), and 10 blocks of control (fixation cross only, no audio) trials. Trials were presented as a continuous story in a block design with 10-16s blocks with a 15-30s interstimulus interval. In this poster, we focus on analyzing the recording segments from the visual-only trials from recording channels within the left Heschl's Gyrus region of interest. General linear modelling and waveform averaging were performed for fNIRS channels within the a-priori auditory cortex region of interest to quantify the amount of activation present. At one-year after implant switch-on, speech perception outcomes were assessed using Bamford-Kowal-Bench (BKB) sentences in babble noise.

Results: Data from the 15 new cochlear implant users suggest that ($R^2 = 0.348$, $p = 0.0205$) larger visual-only stimulus activation of the auditory cortex within two weeks of device switch-on is associated with poorer speech understanding outcomes in CI users one-year post-implantation. However, this trend is not present when correlating the activation of the auditory cortex at one-year post-implantation and speech understanding outcomes in CI users at one-year.

Conclusion: Combining fNIRS with visual-speech tasks at CI switch-on offers a promising new method for predicting CI recipient speech understanding outcomes in the long term. This insight can be used to inform appropriate recipient-specific rehabilitation strategies and potentially reduce the negative impact of maladaptive visual take-over of auditory brain regions post-deafness.

P50: INTRACRANIAL ELECTROPHYSIOLOGY OF CLEAR AND DEGRADED SPEECH PROCESSING IN THE HUMAN CORTEX

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Electrical stimulation of the auditory nerve with a cochlear implant (CI) is the method of choice for treatment of severe-to-profound hearing loss. Understanding how the human cortex responds to both clear and degraded speech may be useful in facilitating development of CI stimulation paradigms and rehabilitation strategies. Using spectrally degraded stimuli in normal-hearing individuals may provide a model of cortical processing of speech by CI users (Nourski et al., Hear Res. 2019, 371:53-65).

Intracranial electroencephalography (iEEG) in neurosurgical epilepsy patients offers an opportunity to study auditory processing at multiple levels of the cortical hierarchy with high spatiotemporal resolution (Nourski, Laryngoscope Investig Otolaryngol. 2017, 2:147-56). Systematic iEEG investigations demonstrate that core auditory cortex within the posteromedial portion of Heschl's gyrus represents spectrotemporal features of speech with high precision and short onset latencies, wherein activity is minimally modulated by task demands. Non-core areas within superior temporal gyrus (STG) facilitate transformation of acoustic attributes of speech into phonemic representations. Auditory-related temporo-parietal and prefrontal cortex exhibit complex response patterns related to stimulus intelligibility, task relevance, and behavioral performance.

Feasibility of iEEG during CI stimulation was established in a case study in a neurosurgical epilepsy patient with a 20-year history of deafness and CI use (Nourski et al., J Assoc Res Otolaryngol. 2013, 14:435-50). Activity recorded from the lateral STG was stable across recording sessions, exhibited phase locking to temporal stimulus modulations, and was abolished under general anesthesia. The responses were comparable to those obtained from normal hearing participants, suggesting that prolonged deafness with CI use did not result in gross maladaptive changes in auditory cortical processing.

Cortical responses to spectrally degraded speech were studied in 14 intracranially-implanted hearing individuals. Noise-vocoded utterances /aba/ and /ada/ yielded chance identification performance when degraded to 1-2 spectral bands, variable performance in the 3-4 band conditions, and near-ceiling in the clear condition. Analysis of iEEG responses revealed regional differences in cortical activation with respect to spectral complexity and intelligibility. Better task performance in the 3-4 band conditions was associated with broadband gamma (30-150 Hz) activation in the posterior portion of the STG and alpha (8-14 Hz) suppression in the supramarginal gyrus in response to all vocoded stimuli.

Direct recordings from the human brain reveal a hierarchical organization of speech processing within and beyond canonical auditory cortex. Examination of responses to noise-vocoded speech can provide insights into the neural bases of variability in speech perception in CI users. Future studies may aid the development of novel objective measures to assess CI performance and of neuromodulation-based rehabilitation strategies.

P51: PRECLINICAL DEVELOPMENT OF AN INVESTIGATIONAL GENETIC MEDICINE FOR OTOFERLIN GENE-MEDIATED HEARING LOSS: AK OTOF

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Background: Millions of people worldwide have disabling hearing loss due to mutations in one of their genes that result in loss of expression or generation of an incorrect version of a protein required for hearing. The otoferlin gene (OTOF) encodes otoferlin, a protein critical for afferent signaling at the inner hair cell (IHC) synapse; individuals with biallelic mutations in OTOF typically present with congenital, Severe to Profound sensorineural hearing loss. Recent advances in genetic medicine and Akouos's development of a novel delivery approach support the potential to restore hearing in individuals with OTOF-mediated hearing loss by enabling IHCs to produce otoferlin using a one-time, local administration of AK-OTOF (AAVAnc80-hOTOF). Here, we describe the preclinical development strategy and key nonclinical studies that support the translation of AK-OTOF and an investigational delivery device designed for intracochlear administration to clinical development.

Methods: The approach to deliver genetic medicines to the inner ear, including the design of a dual adeno-associated viral (AAV) vector, the Akouos delivery device, and an intracochlear administration procedure, was evaluated in in vitro studies, as well as in in vivo studies in otoferlin knock-out (Otof -/-) mice and non-human primates (NHPs). Nonclinical studies were conducted to inform the design of clinical investigation of AK-OTOF, including demonstration of biological plausibility by the intended clinical route of administration, evaluation of intervention window (with respect to otoacoustic emission [OAE] status), identification of biologically active dose levels, assessment of onset and durability of functional recovery, and evaluation of safety.

Results: A one-time intracochlear administration of a dual AAVAnc80 vector encoding human otoferlin (hOTOF), under control of a ubiquitous promoter, to mice and NHPs results in robust expression of full-length hOTOF in the target IHCs (and not in other cell types). The Otof -/- mouse phenotype supports its utility for preclinical development, including determination of biologically active dose levels of AK-OTOF that restored auditory function by 2 weeks post-administration, and through at least 6 months post-administration (the longest survival duration evaluated), and determination of potential for restoration of auditory function based on status of cochlear integrity (as evaluated by OAEs). Evaluation of safety and otic tolerability of AK OTOF was conducted in both NHPs and mice; no adverse effects were observed in clinical pathology, otic pathology, systemic histopathology, and/or cochlear / auditory function, demonstrating that AK-OTOF was systemically and locally well tolerated.

Conclusions: The strategy employed for preclinical development of AK-OTOF, leading to FDA clearance for a clinical trial in pediatric individuals with OTOF-mediated hearing loss, can serve as an exemplary path to achieving the broader goal of developing precision genetic medicines with the potential to restore, improve, and preserve high-acuity physiologic hearing for individuals worldwide who live with disabling hearing loss.

P52: PRECISE TARGETING OF GJB2 CELLS RESULTS IN SAFE AND EFFICACIOUS GENE THERAPY FOR HEARING LOSS DUE TO GJB2 DEFICIENCY (DFNB1)

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Background: Mutations in Gap junction beta protein 2 (GJB2) are the leading cause of non-syndromic, prelingual deafness (DFNB1) worldwide. One major challenge in developing a gene replacement therapy is the ability to replicate the endogenous expression pattern in the cochlea, as GJB2 is expressed in a variety of cell types at different expression levels. A successful DFNB1 gene therapy must provide benefit by sufficiently targeting the diverse set of GJB2-expressing nonsensory cells but also must avoid toxicity by excluding expression from critical sensory cells. Here we demonstrate that selective targeting of GJB2-expressing cells results in robust and durable hearing restoration in a translationally relevant mouse model of GJB2 deficiency.

Methods: Adult or neonatal mice were injected via the posterior semicircular canal with AAV encoding GJB2 or nuclear GFP driven by a ubiquitous promoter or GJB2 regulatory elements. Hearing function was assessed using ABR or DPOAE. After animal sacrifice, immunohistochemistry was performed to assess cochlear morphology and transgene expression.

Results: We evaluated whether off-target GJB2 expression was detrimental to hearing by delivering AAVs encoding hGJB2 under control of a ubiquitous promoter (AAV-CMV-hGJB2) to the cochlea of adult wildtype mice. Three quarters of injected animals had elevated hearing thresholds. Histological analysis showed accumulation of GJB2 protein in inner hair cells after just 1 week, followed by almost complete loss of these cells by 2 weeks. We identified a combination of GJB2 proximal and distal regulatory regions which mirrors endogenous GJB2 expression. Integrative bioinformatic analyses of bulk and single cell epigenomic datasets were leveraged to select candidate regulatory regions, and proximal promoter/enhancer designs were screened in neonatal cochlear explants, identifying a series of combinations which successfully drive expression in GJB2-expressing cells while excluding expression from hair cells and neurons. In vivo experiments confirmed that our regulatory elements closely replicated the endogenous GJB2 expression pattern in both mouse and non-human primate, and they eliminated off-target toxicity observed with CMV in adult wildtype mice.Next, we evaluated the ability of our various regulatory elements to restore hearing in a mouse model of GJB2 deficiency. We achieved robust hearing restoration in ears injected with human GJB2 compared to contralateral ears and naïve controls, achieving wildtype thresholds in some animals. We demonstrate that this hearing recovery is stable and durable for at least six months.

Conclusions: Our results underscore the importance of using the proper regulatory elements to drive GJB2 expression and avoid toxicity in AAV-based gene therapy for the most common form of genetic deafness, and they highlight the power of bioinformatics to achieve a successful design. The robust and durable recovery observed in mice with our vector represents significant progress towards the development of a gene therapy to restore natural hearing to DFNB1 patients.

P53: RINCELL-1: FIRST-IN-HUMAN, PLURIPOTENT STEM CELL BASED THERAPY FOR HEARING LOSS

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Almost half a billion people worldwide have disabling hearing loss, and this number has been projected to double by 2050 with our aging population. Furthermore, there is a misconception that hearing loss arises solely from hair cell loss and, until recently, loss of auditory neurons has been largely ignored. However, the commonest cause of hearing loss, presbycusis, is associated with a significant loss of auditory nerve fibres that is almost three times steeper than loss of hair cells or spiral ganglion neurons. Indeed, people loose almost half of their auditory neurons by 60 years old, and two-thirds of neurons by 90 years old. Rarely hearing loss can arise from auditory neuropathy that is characterised by abnormal neural processing of sounds, in the presence of normal hair cell function. Despite the huge disease burden from presbycusis, auditory neuropathy and other forms of hearing loss, there are currently no disease modifying therapeutics available and, instead, deafness is usually treated with hearing devices, including hearing aids or cochlear implants, that do not address the loss auditory neurons.

Over a decade ago, Professor Rivolta and his colleagues at the University of Sheffield showed in an animal model of auditory neuropathy that gerbil auditory brainstem responses can be recovered following an injection of otic neuro progenitor cells derived from human embryonic stem cells. Subsequently, Rinri Therapeutics was established in 2018, to translate Prof. Rivolta's work for patient benefit. Whilst, Rinri's pipeline includes induced pluripotent stem cell-derived products and hair cell regenerative therapies, Rinri's first in human trial will begin with Rincell-1, a population of otic neuroprogenitor generated from human embryonic stem cell to target loss of auditory neurons. Rinri has developed strong preclinical data, manufacturing processes and a clinical strategy that has gained positive feedback from regulators, including the MHRA
.
The first-in-human trial of Rincell-1 will be conducted as an adjunct to cochlear implantation in two groups of patients: those over 60 years old with presbycusis and adults with auditory neuropathy. Stage 1 include a pilot study, comparing Rincell-1 with historical controls, and if it is shown to be safe, we will proceed to a randomised control study that will compare Rincell-1 as an adjunct to cochlear implantation, with standard care alone (cochlear implantation).

During the development of the trial, a novel, safe and effective surgical approach to inject Rincell-1 into the internal auditory canal via the round window has been developed. Furthermore, the necessary outcome measures for the clinical trial have been established, including to enable cochlear implant recipients to self-assess cochlear health, by recording daily electrically evoked compound action potentials to evaluate the health of the surviving neurons within the cochlea. Furthermore, in ongoing studies we are evaluating magnet-associated image artefacts in cochlear implant recipients towards using this technique to monitor for tumorigenesis following the administration of Rincell-1. In preparation for the first in human trial of Rincell-1, we are also conducting an extensive programme of patient, public and professional engagement.

P54: COMBINED OPTICAL AND ELECTRICAL STIMULATION IN THE COCHLEA FOR HIGH SPATIAL AND TEMPORAL RESOLUTION

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BACKGROUND: Optical stimulation is a paradigm-shifting approach to modulation of neural activity. While electrical stimulation is the convention for evoking neural activity in deafened cochlea, the electrical current spreads out from the stimulating electrodes and activates a broad region of the cochlea, making it difficult to provide fine temporal structure of sound at all stimulating sites. For cochlear implant recipients, this equates to difficulty in understanding speech in noise, reduced music appreciation and an inability to recognize speakers. More focused activation can be achieved by optical stimulation, either with high power infrared radiation or lower power visible light facilitated by the genetic modification of neurons with channelrhodopsin light sensitive ion channels. This study examines channelrhodopsin expression in auditory neurons in mice for optical activation after hearing loss, examining activation thresholds, spread of activation, and temporal characteristics of the auditory nerve response for optical stimulation, electrical stimulation, or the combination of these (hybrid stimulation).

METHODS: This study used mice that were transgenic for the channelrhodopsin variant ChR2-H134R, as well as wild-type mice that were injected with an Anc80 viral vector to express ChR2-H134R and other opsins in auditory neurons. Mice were acutely or chronically deafened via perfusion of neomycin through the cochlea. Light and electrical stimuli were delivered to the cochlea via a laser-coupled optical fibre and platinum electrodes, respectively. Stimuli were presented at 4 Hz or as a burst over 300 ms at 100 pulses per second. Light (1 ms) was set to different levels relative to threshold, and 25 µs biphasic electrical pulses were presented at a range of intensities below myogenic threshold and were delayed by 1 ms relative to the start of the optical pulse. Thresholds and temporal characteristics of the auditory nerve responses to optical, electrical, and hybrid stimulation were recorded using electrodes positioned on the bony wall of the cochlea and the back of the neck. Spread of activation was examined via multiunit recordings from the inferior colliculus of the auditory midbrain. Channelrhodopsin expression in the auditory neurons was examined by immunohistochemistry.

RESULTS: Transduction of auditory neurons by the Anc80 viral vector was most successful when injected at a neonatal age, with up to 89% of neurons transduced in 90% of injected mice. Responses to optical stimuli were detected in a cochleotopic manner in all mice with ChR2-H134R expression, with lower activation thresholds in mice with greater transduction. Hybrid stimulation (sub-threshold optical stimulation combined with sub- or supra-threshold electrical stimulation) lowered the threshold for electrical activation. Spread of activation was also significantly reduced with hybrid stimulation compared to electrical-only or optical-only stimulation ($p<0.01$). Hybrid responses demonstrated electrical-like temporal precision when the optogenetic stimulus was close to activation threshold but increasing the optogenetic power worsened temporal precision.

CONCLUSIONS: By combining optogenetic stimulation with electrical stimulation, the light stimulus can be used to ‘prime’ the neurons to a sub-threshold level of excitability that lowers the electrical activation threshold, thus reducing the spread of activation compared to electrical-only stimulation, and higher temporal precision than can be achieved with optical stimulation alone.

P55: DRUG DELIVERY TO THE INNER EAR FOR COCHLEAR IMPLANTS AND BEYOND

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Cochlear implants provide useful auditory function for most recipients. In particular, implant performance is typically better for recipients who have residual hearing, whereby users can combine remaining acoustic and electrical input to achieve better speech recognition. However, the implantation of the electrode array has the potential to cause the deterioration of sensory function, in addition to potential ongoing pathological changes as a consequence of the existing aetiology of deafness.

The development of therapeutic drug technology to protect or to restore lost sensory function, or to improve the interface of the electrode array with the neural elements within the cochlea, is likely to lead to meaningful clinical improvements for implant recipients. This talk will cover the clinical opportunities likely to benefit from a successful drug treatment strategy and discuss some of the current challenges and options in developing therapeutic treatments for use with cochlear implantation. The talk will discuss the unique opportunity that exists when combining drug treatment along with a cochlear implant. In particular, the capacity to deliver therapeutic agents directly into the cochlea and the potential to use the implant for an objective assessment of treatment outcomes.

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P56: IN VIVO CHARACTERIZATION OF NOVEL CHANNELRHODOPSIN VARIANTS FOR THE OPTOGENETIC ACTIVATION OF THE AUDITORY PATHWAY BY BLUE LIGHT

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According to the World Health Organization an increasing number of 0.5 billion people, worldwide, are currently suffering from disabling hearing loss. Considered the most successful neuroprosthesis to date, the electrical cochlear implant (eCI) provides partial hearing restoration to individuals with severe to profound sensorineural hearing loss by direct electrical stimulation of spiral ganglion neurons (SGNs). To address the wide-spread electrical SGN excitation associated with eCIs, optogenetic stimulation of SGNs promises an alternative to overcome this bottleneck. Utilizing light-gated ion channels, so-called Channelrhodopsins (ChRs), SGNs can be excited optically. To approach the temporal fidelity of physiological sound encoding in the cochlea, it is critical to employ ChRs with fast kinetics, large photocurrents, and low desensitization. Here, we recently engineered ChR variants for the optogenetic stimulation of SGNs (ChR2- and Chronos-mutants) and evaluated their optogenetic utility in the auditory nerve in mice. Transduction of SGNs was achieved by local administration of non-pathogenic, adeno-associated viruses (AAVs) via the round window of the cochlea (rw) of neonatal mice (postnatal day 6). AAVs enabled transgenic ChR-expression under the human synapsin promotor with sequences aimed to enhance membrane targeting – enhancement of trafficking signal (TS) and ER export signal (ES)). Six to fourteen weeks after injections, a laser-coupled fiber (473nm) was inserted into the rw to measure for optically evoked auditory brainstem responses (oABRs). Subsequently, the cochleae were extracted for immunohistological analysis by confocal and lightsheet microscopy to evaluate the number of transduced cells as well as membrane expression profiles with or without enhancement of membrane targeting.

Electrophysiological data sets of 48 animals, injected with 4 different ChR-variants, show optical activation in three out of four data sets enabling evaluation of auditory nerve responses to varying light pulse characteristics (light pulse intensity, duration, and repetition rates) regarding auditory brainstem response thresholds, amplitudes, and response latencies for a given candidate. In summary, we can present a novel optogenetic actuator with in vivo thresholds below 2mW and sustained activation of SGNs for fast light-drive cochlear responses up to 300Hz. In combination with transduction rates greater than 80%, preliminary data highlights a lead candidate out of our 4 ChR variants for the optogenetic blue-light activation of the auditory pathway for auditory research and future optogenetic cochlear implants.

P57: REAL-TIME SIMULATION OF ACTIVE COCHLEAR IMPLANT AND ITS INSERTION

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Introduction: The insertion of the flexible electrode array into the patient's cochlea is undeniably the most challenging aspect of cochlear implant surgery. Once this feat is achieved, the implant begins to stimulate the auditory nerve, enabling hearing. However, manual operation and limited visibility within the cochlea can often lead to incomplete insertion. The consequences of such an occurrence can be dire, resulting in frequency distortions and damage to the cochlea. These complications can ultimately lead to speech difficulties or hearing loss.

Method and results: This work is motivated by the development of an actuated cochlear implant that can facilitate the insertion. To evaluate the design and the benefit of such active implant during the insertion, we have developed a realistic and fast simulation. Accurately predict the deformation and force during insertion can be used to improve the design and control. Thus, we used a mechanical model of the implant to forecast changes in contact force with cochlear tissue during implantation. Given the elongated shape of the cochlear implant, it can be treated as a single beam and analyzed its deformation and force using a discrete Cosserat beam model that considers its three-dimensional (bending and torsion) of the deformation.

This model has high accuracy and low dimensionality, enabling real-time force analysis of the cochlear implant. The simulated active cochlear implants actively bend thanks to electro-responsive polymers to follow the cochlea's curvature and reduce contact force with the cochlear tissue. To predict the relationship between the control voltage and deformation, this work proposes a high-precision electromechanical coupling model for the polymers. This model accurately predicts the deformation under voltage control, laying the foundation for subsequent implantation control and active implantation simulations. Preliminary results of these activities have been published in [1]. Finally we opted to regulate the contact and friction force between the implant and the cochlear wall during insertion. The use of this model presents a multitude of benefits. Its high accuracy and low degree of freedom allow us to perform real-time simulations that are well suited for our intended medical application. Therefore, we can analyze the benefit of active implants and control them to reduce the contact forces on the cochlea.

Conclusion: The main objective of this project is to propose a solution based on physical simulation that can simplify the process of cochlear implantation. To achieve this, we have developed a multiphysics model that effectively minimizes the contact between the implanted device and the side wall of the cochlea during the insertion process. This contact has already been identified as a major cause of poor implant insertion. Our proposed solution has been extensively tested through various simulation scenarios, and we have also analyzed the different force curves that occur with different insertion angles. Moving forward, our next step is to conduct experimental evaluations.

[1] Ahmad Itawi et al.. Smart electrode array for cochlear implants. 36th International Conference on Micro Electro Mechanical Systems (IEEE MEMS 2023), IEEE, Jan 2023, München, Germany. 4 p., ⟨10.1109/MEMS49605.2023.10052348⟩. ⟨hal-03946253⟩

P58: PROGRESS AND CHALLENGES WITH IMPLANTABLE MICROPHONES FOR COCHLEAR IMPLANTS

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We have developed implantable microphones that could be used in a fully implantable cochlear implant. Our microphones operate by picking up the sound signal via the motion of the ossicular umbo or via intracochlear pressure. Hearing assistive devices using implantable microphones can enable enhanced and directional hearing by making use of the natural filtering of the ear. Implantable microphones would enable the use of hearing assistive devices in all environments, day and night.

The transduction mechanism of our implantable microphones is based on the piezoelectric properties of polyvinylidene fluoride (PVDF), a common engineering plastic that can be manufactured as a piezoelectric film. PVDF is a biologically compatible polymer that has been used in medical devices, for example surgical sutures. A custom low-noise charge amplifier with differential input is used with our microphones to maximize signal and reduce noise and susceptibility to electromagnetic interference.

The umbo microphone is two layers of PVDF separated by a backing and detects the sound signal via bending. This output is the amplified difference between the two signals from the PVDF layers thus providing good common mode rejection. The signal-to-noise characteristics of the cantilever microphone are comparable to those of hearing aid microphones.

The cochlear microphone works through deformation of the PVDF material due to the fluid pressure in the Scala Tympani. A long slender strip of PVDF is inserted into the Scala Tympani alongside an electrode array. The possibility of integration with cochlear implant electrode arrays and the ability to use existing surgical procedures are attractive features of this design.

For all our microphone designs, future challenges are making the devices fully biocompatible, ensuring robustness and durability, ensuring low pick-up of environmental EMI, minimizing cross-sensitivity, and designing and testing bracing mechanisms and integration strategies.

We would like to acknowledge our funding sources NIDCD/NIH R01DC016874, NSF GRFP Grant No. 1745302, and the Edwin S. Webster Graduate fellowship.

P59: INVESTIGATING AN ALTERNATIVE TO ELECTRICAL HEARING: ULTRASOUND STIMULATION OF THE PERIPHERAL AUDITORY SYSTEM

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The poor spatial selectivity of electrical stimulation is often cited as the most limiting factor in cochlear implant performance. In the past two decades, research on alternatives has mostly focused on optical stimulation and promising results have been obtained using optogenetics techniques. Here, we investigate if focused ultrasound (US) stimulation can stimulate spiral ganglion neurons (SGNs). It has been shown in several in vitro and in vivo studies that certain neurons can respond to US waves although the exact underlying mechanisms remain unclear. However, so far, there has been no demonstration that SGNs can respond to US. Ten anesthetized normal hearing guinea pigs were implanted with a recording electrode in their right inferior colliculus. The left bulla was opened and a focused US transducer was placed above the exposed cochlea. Burst US waves at frequencies ranging from 3 to 21 MHz were applied with pressure levels ranging from 0.08 to 1.32 MPa and durations ranging from 1 to 100 µs. US-evoked inferior colliculus potentials were obtained in all animals, showing an increase in amplitude as a function of pressure level and also as a function of duration. To investigate if the responses reflected direct neural stimulation, 4 additional guinea pigs were chronically deafened and tested one month later using the same protocol. In this case, no US-evoked response was obtained despite the fact that the neurons were still functional, as shown by electrically stimulating them using an electrode at the round window niche. This shows that the responses obtained in the normal hearing animals were mediated by hair cells. One possible explanation is that the US waves sent on the bony shell of the cochlea induce bone vibrations containing energy in the hearing frequency range of the animal which then make the hair cells vibrate. To test this hypothesis, cochlear bone vibrations were measured postmortem with a laser vibrometer pointing on the apex of the cochlea in two guinea pig heads. The vibration signal lasted for several milliseconds (i.e. much longer than the US stimulus) and, interestingly, showed some energy in the hearing frequency range of the animal. From this set of experiments, it appeared that US waves can easily activate the auditory system of normal hearing guinea pigs but that the excitation process is mediated by hair cells and does not arise from direct neural stimulation.

Does this mean that spiral ganglion neurons cannot respond to US waves or that we did not use the right parameters to do so? To address this question, calcium imaging experiments were conducted on primary cultures of SGNs to optically monitor their activity during US stimulation. The US stimulus consisted of a 20 MHz sinusoidal signal and both acoustic pressure and pulse duration were varied. Calcium responses were consistently obtained across multiple experiments with success rates (%age of neurons responding) reaching 70-80% in some stimulus parameter conditions. The potential mechanisms underlying US neurostimulation will be discussed.

P60: DEVELOPMENT AND TRANSLATION OF A NEW AUDITORY NERVE IMPLANT

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Cochlear implants are considered one of the most successful neural prosthetics and have been treating patients with hearing loss for more than 40 years. They have been successful in restoring speech perception, especially in quiet environments; however, there remain limitations in nosier backgrounds and for appreciating more complex inputs, such as music and multiple talkers. One key limitation for cochlear implants in achieving better hearing capabilities has been attributed to the electrode-neural interface. The cochlear implant electrode array is implanted into the cochlea and electrical current must be transmitted from the electrodes through the bony wall to reach the target auditory nerves, which results in spread of current and diffuse neural activation. With recent advances in neural technologies and neurotological surgical approaches, there are greater opportunities for pursuing an intracranial auditory prosthesis that targets the auditory nerve between the cochlea and the brainstem (auditory nerve implant, ANI). The ANI can be directly implanted into the auditory nerve with the aim to achieve more focused activation and greater transmission of auditory information to the brain compared to the cochlear implant. Initially, the ANI can be implanted in deaf patients who cannot be successfully implanted or sufficiently benefit from a cochlear implant due to anatomical malformations, obstruction of the cochlea, or facial nerve side effects. An NIH BRAIN Initiative grant has been awarded across five institutions and two medical device companies (MED-EL and Blackrock Microsystems) to develop and translate a new ANI through pre-clinical studies (UG3 Phase), and then implant the ANI in three deaf patients through a pilot clinical trial (UH3 Phase). Our team's approach for intraneural stimulation is to integrate well established neural technologies already being used in human patients for other clinical applications and neural targets. This integration includes the Utah Slanted Electrode Array (USEA; Blackrock Microsystems), which is merged with the MED-EL SYNCHRONY 2 cochlear stimulator. In this talk, we will present the technology and surgical developments over the past several years of developing our ANI system that can be implanted in human patients who are no longer eligible for a cochlear implant. The ANI electrode array will be positioned into the auditory nerve through a modified translabyrinthine procedure. A newly developed infralabyrinthine-infracochlear hybrid approach that can potentially preserve vestibular function is being developed in parallel for future patients beyond this NIH BRAIN project to enable access to a larger patient population. The various device components have been evaluated initially in animal models, including non-human primates and cats, which will be presented in terms of surgical approach, neurophysiological outcomes, and device stability. Preliminary results will also be presented from device handling and testing experiments in acute intraoperative surgeries directly in humans. Future opportunities for novel stimulation strategies and perceptual testing of ANI patients will also be discussed. The success of this project will not only open new directions for auditory prosthetics but will also provide improved neural technologies for other clinical applications relevant to the neural engineering community.

Funding: NIH BRAIN Initiative UG3 NS107688, MED-EL, Blackrock Microsystems, Lions International Hearing Foundation.

P61: NEW DEVELOPMENTS IN VESTIBULAR IMPLANTS: ELECTRICAL STIMULATION OF THE OTOLITH ORGANS.

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Introduction:
Bilateral vestibular areflexia is a severe disability leading to chronic instability and oscillopsia, a multiple increase in the risk of falls and a significantly reduced quality of life. The possible etiologies are ototoxicity, autoimmune damage to the inner ears, bilateral Menière's disease, genetic disorders (e.g. DFNA9), neurodegenerative diseases, meningitis, etc. In patients with bilateral vestibulopathy, the classic treatment options, such as medication and/or vestibular rehabilitation, are often insufficient. Therefore, electrical vestibular stimulation (EVS) is a possible alternative for restoring peripheral vestibular functions. Three approaches to EVS are currently being investigated: galvanic vestibular stimulation (GVS), vestibular co-stimulation with a cochlear implant (CI) and the direct vestibular stimulation with a vestibular implant (VI). The classic VI approach involves stimulating the ampullas of the semicircular channels. This presentation describes a new approach based on stimulation of the otolith organs.

Material and Methods:
So far, 12 patients have been implanted with a follow-up period of 9 -24 months as part of the European Horizon 2020 project. In all patients, double ipsilateral vestibular and cochlear implantation was performed with a new Nucleus CI-VI 19+3 system. The cochlear stimulation is performed by a Contour AOS electrode. For vestibular stimulation, a full-band straight electrode array is used with three band electrode contacts with a width of 0.3 mm and a diameter of 0.4 mm at the electrode tip. The distance between the electrode contacts is 0.2 mm. The VI electrode is placed via a small-hole stapedotomy along the anterior wall of the vestibule in the vicinity of the inferior vestibular nerve. Vestibular stimulation is performed with a constant pulse train delivered interleaved to all 3 vestibular contacts.

Results:
Most patients show good improvement in vestibular functions, especially in the dark and on unstable surfaces. This was confirmed by significant improvements in the Dizziness Handicap Inventory (DHI), the Dynamic Visual Acuity (DVA), the Timed Up and Go Test (TUG), the Dynamic Gait Index (DGI) and the Subjective Visual Vertical (SVV) scores and the results of the posturography. In all cases, vestibular electrical responses (vestibular eCAPs and VEMPs) were recorded. All patients use their systems throughout the day and do not show significant dizziness when the system is switched off.

Conclusion:
EVS with VI is feasible and gives a chance of rehabilitation in patients with bilateral vestibular dysfunction. Stimulation of the otolith organ is an interesting alternative to stimulation of the ampullary nerves and opens up new possibilities for generating observations of gravito-inertial accelerations by electrical stimulation.

P62: MAGNETIC INTRACOCHLEAR STIMULATION: TOWARDS NEXT-GENERATION COCHLEAR IMPLANTS

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Background: Hearing outcomes with cochlear implants (CIs) have plateaued in part due to spectral blurring with multichannel electrical stimulation. Our team recently evaluated a novel intracochlear stimulation modality—microcoil magnetic stimulation—and quantified the spread of auditory pathway activation by recording multi-unit activity (MUA) from inferior colliculus (IC) in deafened mice. Compared to electric intracochlear stimulation, magnetic stimulation had narrower spectral spread of activation and increased dynamic range. Comparison of multichannel systems to simulate clinical prostheses in our animal model, however, has been constrained by the small size of the murine cochlea.

Objective: To determine if spread of activation measured in IC is narrower with magnetic stimulation using a multichannel microcoil array compared to a multichannel electrical CI array in guinea pig.

Methods: Anesthetized guinea pigs were used for acute studies. A 16-channel recording array was inserted along the right IC tonotopic axis and confirmed by recording MUA during left ear acoustic stimulation. The left ear was then acutely deafened with intracochlear neomycin as confirmed by lack of evoked auditory responses. Next, magnetic and electric stimulation were delivered via microcoil and electrode arrays, respectively, sequentially inserted into the left basilar turn via the round window. MUA was recorded while varying stimulus intensity and microcoil/electrode location. Spread of excitation across IC was quantified using a discrimination index (d') analysis.

Results: Preliminary data suggest that magnetic stimulation delivered by individual channels of a 2 channel microcoil CI produced robust and tonotopically appropriate responses: the basal-most microcoil evoked MUA in the high characteristic-frequency region of the IC while coils positioned more apically evoked MUA in the lower characteristic-frequency region. Magnetic stimulation also produced a narrow spread of excitation along the tonotopic axis. Comparatively, electrical monopolar stimulation from individual channels of a multichannel electrode CI produced a wider spread of activation and a less clear tonotopic shift between adjacent electrodes.

Conclusions: Magnetic intracochlear stimulation produces narrower tonotopic activation than electrical stimulation as measured in IC. A future CI based on a multichannel magnetic microcoil array may offer enhanced spectral resolution compared to traditional implant designs.

P63: THE IMPORTANCE OF CIAP FOR AUDITORY SCIENCE

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The Conference on Implantable Auditory Prostheses (CIAP) evolved from a series of regional meetings, and from an NIH-sponsored contract program in the early days of cochlear implant development. The original meetings were hosted by the research teams on the west coast of the US and rotated among the groups from the University of Washington (Seattle), UC San Francisco, Stanford University (Palo Alto), the Huntington Medical Research Institutes (Pasadena), and the House Ear Institute (Los Angeles). The NIH Neural Prosthesis Program provided contracts for basic research to lay the groundwork for a diverse portfolio of prosthetic devices (brain, spinal cord, eye, ear, bladder, muscle). Contract recipients attended an annual progress report meeting held at the National Library of Medicine on the NIH Campus in Bethesda. As materials science developed electrode materials and device packaging, applications to human were initiated in the 1970s.

In 1983, Robert White from Stanford obtained funding to start a separate meeting on cochlear implants as a Gordon Conference. CIAP split off from the Gordon Conference organization in 1989 and has been run as an independent organization for 34 years. The basic science necessary for CI development involves widely diverse fields from electrochemistry to speech science. Development of such a complex device required collaboration and cross-fertilization across many fields of specialization. The goal of CIAP meetings is to build and foster a community of science to forge a friendly community that can solve difficult and complex problems in a collaborative way. The development of CIs and ABIs provided new insights into basic auditory function and the interactions between the ear and brain in complex auditory perception. The CIAP Conference structure has been highly successful, advancing the science of implantable auditory prostheses and building a community of science that is a model for other fields.

MONDAY POSTER ABSTRACTS

M1: COCHLEAR IMPLANTS FOR SINGLE SIDED DEAFNESS: IMPROVED SOUND-LOCALIZATION PERFORMANCE WITHOUT PROCESSING OF BINAURAL CUES

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Objectives
Patients with single-sided deafness (SSD) experience difficulties with speech perception in noise and sound localization. Potentially they can benefit from fitting a cochlear implant (CI), in particular when they are suffering from tinnitus. The literature reports improved subjective benefits and improved sound localization abilities when listening with a CI. However, patients rather “lateralize” sounds instead of localizing sounds. The term “lateralization” is used to describe that the patient reports that the sound appears from the left or right, rather than from any position.

Methods
Sound localization in both the horizontal (-70° to 70° azimuth) and vertical (-35° to 40° elevation) plane is measured in a sophisticated setup by measuring the natural head-pointing response towards perceived sound locations. In this setup loudspeakers are not visible so subjects can only rely on auditory information enabling to test binaural hearing.

Results
We demonstrate that on average CI listeners benefit from the CI. However, the inter-subject variability in sound localization abilities varies significantly in both the aided and unaided condition and is related to high-frequency hearing loss in the hearing ear. Binaural hearing is not restored. In the unaided condition patients can localize sounds in the horizontal plane by using monaural spectral pinna cues, loudness and timbre.

Conclusion
We conclude that it is important to improve counseling and discuss the expectations of implantation in detail with the patients. We advise to share the information that there is no consensus on how to treat single sided deadness, that speech understanding in complex listening situations will remain difficult and that non-invasive options to improve speech understanding in specific situations are available.

M2: TEMPORAL ADJUSTMENT IN BIMODAL LISTENERS - IMPROVEMENT OF SOUND LOCALIZATION BUT NOT OF SPATIAL UNMASKING OF SPEECH

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Previous work has shown that the sound localization ability of bimodal listeners provided with a cochlear implant and a hearing aid can be improved if the constant interaural time delay is reduced. This time delay is caused by different processing delays in the devices and different stimulation sites.

In normal-hearing listeners, a reduction in spatial unmasking of speech in noise is also seen when such a constant interaural time delay is introduced. Spatial unmasking corresponds to the difference in speech reception thresholds when speech and noise come from 0° from the front compared to speech from 0° and noise from 90°. Our own measurements have shown that spatial unmasking is as large as 8-9 dB for normal-hearing listeners. As soon as a constant interaural time delay is introduced, this threshold difference decreases. At 7 ms (typical latency offset for bimodal users) about 4 dB remain.

However, for bimodal listeners, our measurement results show no dependence of speech reception thresholds to a constant interaural time delay. The reasons for this are due to the usability of ITD and ILD in bimodal listeners, which can be examined by manipulating head-related impulse responses in normal-hearing listeners.

M3: SIMULTANEOUS IMPLANTATION MAY FACILITATE BINAURAL FUSION BETTER THAN SEQUENTIAL IMPLANTATION FOR BILATERAL COCHLEAR IMPLANT USERS

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Introduction: Binaural fusion may benefit bilateral cochlear implant (CI) users' ability to use spatial cues to segregate competing speech. Theoretically simultaneous bilateral implantation may promote better binaural fusion, as bilateral CI users must adapt to the electric stimulation patterns in both ears simultaneously. With sequential bilateral cochlear implantation, CI users must adapt to the electric hearing in the second implanted ear relative to the adaptation in the first ear, which may limit or slow the development of binaural fusion. The present study investigated whether segregation of spatially separated competing speech was better in simultaneously implanted than in sequentially implanted bilateral CI users.

Methods: Speech recognition thresholds (SRTs) were adaptively measured for monaural (target and two maskers presented to one ear) and dichotic listening conditions (target presented to one ear and the two maskers presented to both ears). Theoretically, if the maskers presented to two CI ears are binaurally fused, this would provide a useful spatial cue with which to segregate the target and masker speech ("source-separation advantage"). The source-separation advantage was calculated as the difference in SRTs between the monaural and dichotic listening conditions. SRTs were measured for target speech presented to the better or poorer CI ear.

Results: There was no significant difference in SRTs between simultaneous and sequential bilateral CI users within the better CI ear or the poorer CI ear conditions. When the target was presented to the better CI ear, the source-separation advantage was 0.4 dB and -3.0 dB for simultaneous and sequential bilateral CI users, respectively. When the target was presented to the poorer CI ear, the source-separation advantage was reduced to -0.8 dB and -6.5 dB for simultaneous and sequential bilateral CI users, respectively. The source-segregation advantage was significantly higher for simultaneous than for sequential bilateral CI users ($p=0.03$). The negative source-separation advantage in the sequential bilateral CI users indicates that the maskers were not fused across ears, possibly because of limited adaptation to interaural frequency mismatch.

Conclusion: While there was no significant difference in SRTs between simultaneous and sequential bilateral CI users, the source-segregation advantage data suggest that simultaneous bilateral implantation may provide some advantage over sequential implantation in terms of binaural fusion. For sequential bilateral CI users, adjusting the frequency allocation to reduce interaural frequency mismatch may be necessary to improve binaural fusion.

M4: FACTORS AFFECTING BINAURAL SUMMATION AND UTILIZATION OF TALKER SEX CUES IN COCHLEAR IMPLANT USERS AND NORMAL HEARING LISTENERS

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Introduction: The evidence for the advantage of binaural hearing over unilateral hearing in speech perception has been well documented in normal hearing (NH) listeners and cochlerar implant (CI) users with different configurations of binaural inputs, including bilateral CIs, bimodal CIs, and CI users with single-sided deafness (SSD) or asymmetrical hearing loss (AHL). Previous studies have shown that the benefits for binaural summation may be affected by inter-aural frequency mismatch in simulations of bilateral CIs and in real bimodal CI users. However, binarual summation for speech recognition is commonly studied in quiet or in steady noise. Binaural summation effects for competing speech in CI users are less clear. The goal of the present study was to evaluate the factors affecting binaural summation and utilization of talker sex cues for segregation of competing speech by CI users and NH listeners.

Methods: Speech recognition thresholds (SRTs) were measured in the presence of two-taker speech maskers within each ear or with both ears in bilateral, AHL, and SSD CI users, and in NH listeners. The two speech maskers had either the same sex (SS) or different sex (DS) as the male target. Binaural summation benefits were calculated as the difference in SRTs with both ears and SRTs with better-performing ear only. The benefits of talker-sex cues were calculated as the difference in SRTs between the SS and DS maskers within the unilateral or bilateral listening conditions.

Results: Across all listeners, the mean binaural summation benefits were 0.73 dB and 1.52 dB for the SS and DS maskers, respectively; however, a paired t-test revealed no significant difference in summation benefit between the SS and DS maskers. Greater binaural summation benefits were observed with SS maskers than with DS maskers for bilateral and AHL CI users, but the opposite pattern was observed for SSD CI users and NH listeners. For bilateral CI users, the benefit of talker-sex cues for summation was significantly lower for the better (1.18 dB) than for the poorer ear (3.82 dB). For AHL and SSD CI users, the benefit of talker-sex cues for summation was significantly higher for the better (acoustic) ear than poorer (CI) ear. For CI-only listening condition, the benefit of talker-sex cues for summation was significantly larger for bilateral CI users (2.50 dB) than for AHL/SSD CI users (0.83 dB). A significant correlation was observed between SRTs in the poorer ear and binaural summation benefits only for bilateral CI users.

Conclusion: The availability of normal acoustic hearing in one or two ears allows for better utilization of talker sex cues in terms of binaural summation benefit. However, the availability of acoustic hearing may limit the utilization of talker sex cues when listening only with the CI ear. Poor-performing CI users may benefit more from bilateral hearing with a second implant.

M5: WHAT YOU DELIVER IS NOT WHAT YOU GET: ALTERATION OF INTERAURAL CORRELATION POST-STIMULATION

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Signals presented through the cochlear implant (CI) have a relatively high interaural correlation even in asymmetrically reverberant environments. This high interaural correlation should be sufficient to yield binaural fusion. Despite this, there is considerable variability in binaural fusion across CI users, including some individuals who often do not fuse signals in their everyday life. This suggests that there may be further interaural decorrelation of the signal beyond the point of stimulation, potentially reflecting interaurally different temporal or intensity distortions by the auditory system.

To investigate this, bilateral cochlear implant users were tested on two tasks designed to determine how identical signals are processed by the two ears. In one task, interaurally different temporal distortions were investigated by having participants pitch-match amplitude modulated pulse trains with varying amplitude modulation rates presented to the right and left ear. In a second task, interaurally different intensity distortions were investigating by having participants judge the loudness of speech-shaped noise presented to either ear alone through the participants' speech processors.

For the pitch-matching task, participants generally indicated that stimuli with the same amplitude modulation frequency in each ear were pitch-matched, e.g., participants pitch-matched a pulse train with a 125 Hz amplitude modulation in one ear with one with a 125 Hz amplitude modulation rate in the other ear. This suggests that temporal distortions, if they exist, are similar for both ears.

Loudness judgments typically followed a psychometric curve. For most participants, the slope of the psychometric curve and/or the point where the psychometric curve asymptotes differed across ears. This means that the similarity of loudness across ears varied based on the intensity of the signal. This suggests that there are interaurally different intensity distortions for many CI users.

The results suggest that interaurally correlated signals may be perceived as partially decorrelated because of differences in loudness growth across ears. This suggests that, for many CI users, there is decorrelation of the signal beyond what occurs in the stimulation pattern itself, driven by distortions in the auditory system.

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M6: THE EFFECTS OF INTERAURAL COCHLEOTOPIC ASYMMETRY AND INTERAURAL CORRELATION ON INTERAURAL TIME DIFFERENCE SENSITIVITY

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Binaural abilities depend on having similar locations stimulated in the left and right cochlea (interaural cochleotopic symmetry) and having similar signals delivered to both ears (interaural correlation). Sending interaurally decorrelated signals and/or sending signals that are delivered to interaurally asymmetric locations can decrease performance on binaural tasks. This study aims to measure the interaction between interaural cochleotopic asymmetry and interaural correlation to determine how they both affect performance on sensitivity to interaural time differences (ITDs).

Normal hearing listeners were tested with vocoded signals. The stimuli used a single vocoded channel per ear, with varying levels of interaural correlation and varying magnitudes of interaural cochleotopic asymmetry. ITD sensitivity was measured using a descending series protocol, where the initial stimulus had a 4000 µs ITD and the ITD was decreased by 2 dB every two trials, with a total of 20 trials. Participants were presented with four stimuli and had to choose which of the two middle stimuli had a non-zero ITD (four interval, two alternative forced choice task). The first and last stimuli always had an ITD of zero. The resulting percent correct score was converted into an estimated threshold in µs.

Preliminary results suggest that, consistent with previous research, the more interaural cochleotopic asymmetry, the poorer participants did on the task. Unexpectedly, when both interaural cochleotopic asymmetry and interaural correlation were manipulated together, the results were primarily dominated by interaural cochleotopic asymmetry. This may have been because of the limited range of interaural correlations used. Future research will examine the effects of using a larger interaural correlation range.

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M7: THE EFFECT OF HEAD SHADOW ENHANCEMENT FOR SPEECH UNDERSTANDING IN BIMODAL COCHLEAR IMPLANT USERS IN A DIFFUSE NOISE FIELD

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Objectives: The objective of this study was to investigate the benefit of side beamformers on speech recognition in noise in bimodal listeners. Bimodal listeners use a cochlear implant (CI) on one side and a hearing aid (HA) on the other. Side beamformers enhance the head shadow effect and can potentially increase interaural level differences to create more awareness of relevant sounds from the periphery in noisy environments. Coupling of the automatic gain control between both devices can also have a positive effect on speech understanding by synchronizing the sound level scaling. In addition to testing two types of side beamformers, we assessed the bimodal benefit, with the goal to see whether better speech understanding with the non-implanted ear, can be a predictive value for the amount of bimodal benefit.

Methods: 18 adult bimodal CI users participated in this study. They performed the Dutch/Flemish Matrix speech-in-noise-test with omnidirectional microphone settings, and two newly developed side beamformers, i.e., a binaural side beamformer and a monoaural side beamformer. Measurements were also performed for these three microphone settings combined with synchronized automatic gain control between CI and HA. Testing comprised four to five sessions and were performed in a diffuse field of eight-talker babble noise. The target speech originated from the front (0°), CI side (90°) or HA side (-90°). The outcome measure was the speech reception threshold, i.e., the SNR where speech recognition is 50%. Outcomes were statistically analyzed in a linear mixed model. To test the bimodal benefit and the effect of the performance of the HA ear, all participants performed an additional test and retest for speech from the front with only their CI or only their HA. The bimodal benefit was represented as SRT CI only minus SRT bimodal.

Results: Overall, no statistically significant detrimental or beneficial effect of the side beamformers with and without synced automatic gain control was seen ($P>0.05$). Speech understanding in noise was significantly better for speech from the front or from the CI side than from the HA side ($P<0.005$). The bimodal fitting had a mean benefit of 2.4 dBA relative to the CI only condition. Regression analysis showed a significant linear relationship ($P<0.005$, $R2= 0.64$), where a better performing HA ear, in terms of speech understanding, led to a higher bimodal benefit.

Conclusion: In a field of diffuse noise, head shadow enhancement did not show a detrimental nor a beneficial effect on speech recognition. The concept of enhancing head shadow has been shown to increase speech intelligibility by others, when speech was presented frontally and noise on one side. We show that even in the most challenging conditions, the algorithms did not negatively affect hearing performance. The bimodal benefit was comparable with earlier studies performed in our lab, and speech understanding with HA only turned out to have predictive value for bimodal benefit. An upcoming study at our department will assess the effect of the algorithms on hearing performance under more favorable conditions, e.g., when the noise source is directed to one ear only.

M8: COMPARISONS OF INTERAURAL-TIME-DIFFERENCE TUNING CURVES USING MONOPOLAR AND PARTIAL TRIPOLAR CONFIGURATIONS IN ADULT BILATERAL COCHLEAR-IMPLANT USERS

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Interaural time differences (ITDs) provide one of the two primary cues that contribute to spatial hearing, which is important for sound-source localization and speech understanding in complex acoustic environments. Listeners with bilateral cochlear implant (BiCI) have limited access to ITD cues, which leads to relatively poor horizontal-plane sound localization compared to listeners with acoustic hearing. ITD sensitivity in BiCI listeners has so far only been investigated using research processors that deliver monopolar (MP) stimulation, which has a broad electrical current spread and poor peripheral tuning. However, the extent to which ITD sensitivity and peripheral tuning are affected by stimulation that is intended to reduce the amount of current spread is unknown. Therefore, we investigated ITD sensitivity and tuning using partial tripolar (pTP) stimulation, which has a narrower current spread. We hypothesized that BiCI listeners would be sensitive to ITD using pTP stimulation and would demonstrate sharper ITD tuning curves compared to MP stimulation.

BiCI users of Advanced Bionics devices who had adult onset of deafness participated in the study. ITD sensitivity and tuning curves were measured using MP and pTP stimulation. Using research processors, we presented listeners with bilaterally synchronized 100-pulse-per-second pulse trains at single electrode pairs. Listeners performed a left-right discrimination task in an adaptive staircase procedure. In experiment 1, MP and pTP ITD discrimination thresholds were measured as a function of place of stimulation (base, middle, and apex). In experiment 2, MP and pTP ITD tuning curves were measured using a reference electrode at a fixed location in the middle of the array in one ear and a range of comparison electrodes in the other ear (i.e., interaural place mismatch was introduced).

Preliminary data showed that four BiCI listeners were sensitive to ITDs using MP and pTP stimulation. ITD thresholds for pTP stimulation were similar or worse than when using MP stimulation. However, the effect depended on the place-of-stimulation, which was variable across listeners. Listeners showed variable changes between MP and pTP ITD tuning curves. At least one listener showed a pTP ITD tuning curve that was much sharper than the MP ITD tuning curve. In other listeners, MP and pTP ITD tuning curves were similar in shape and bandwidth. In conclusion, our study shows that BiCI listeners are sensitive to ITD when using pTP stimulation. However, it remains to be seen whether pTP stimulation will always improve ITD tuning in BiCI users. Further investigation is needed to determine the factors that affect ITD tuning and the potential benefits of pTP stimulation for spatial hearing.

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M9: MODELLING THE BENEFIT OF BILATERAL SIGNAL PROCESSING FOR BIMODAL CI RECIPIENTS

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Background:
By wirelessly transmitting audio signals between two hearing device, signal processing algorithms can be implemented that process information from both sides. This class of binaural signal processing algorithms includes, for example, AGC synchronization, binaural directional microphones and methods for processing localization features (interaural time and level differences). The benefit provided by these algorithms depends on the characteristics of the acoustic situation (e.g. level, signal-to-noise ratio, number and direction of sources) and the hearing instrument user (e.g. aided threshold, temporal and spectral resolution). A model which allows to predict these effects would therefore be very desirable to allow for efficient design of behavioral experiments and situation-specific real-time control by the hearing system.

Methods:
In this contribution, the capability of a model of binaural speech intelligibility to predict the benefit of new binaural signal processing algorithms - both for hearing aid wearers and users of cochlear implants (CI) - is investigated. Main extensions of the model compared to existing approaches (Lavandier et al. 2010 and Beutelmann et al. 2010) are a) the inclusion of individual aided sound-field threshold, b) the condition-specific optimization of a spectral importance function and c) setting interaural phase-based binaural advantages to zero. Exemplarily, behavioral results obtained with an algorithm to enhance the head-shadow effect are modelled. Specifically, data from published (Dieudonné et al. 2018) and new experiments with vocoded and human bimodal listeners are compared with the output of the model.

Results:
Even though the algorithm technically improves signal-to-noise ratio equally at both ears, experimental data show different results when target speech is presented from the hearing aid side or the cochlear implant side. The model predicts behavioral results on a group level with a precision of < 0.5 dB – primarily due to inclusion of individual aided threshold and optimized spectral importance. For most subjects, even individual predictions of improvement in speech reception threshold are within a range of 1 dB.

Conclusion:
Improvements in speech reception thresholds due to interaural beamforming in bimodal listeners can be explained to a large extent by audibility, spectral importance and better ear listening and thus, are predictable by rather simple models incorporating the aforementioned aspects.

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M10: EFFECTS OF IMPAIRED SELECTIVE ATTENTION ON BINAURAL UNMASKING OR INTERFERENCE OF MASKED SPEECH IN BILATERAL AND SINGLE-SIDED-DEAFNESS COCHLEAR-IMPLANT USERS

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Having two ears is highly beneficial, which is why bilateral (BI) or single-sided-deafness (SSD) cochlear implants (CIs) are becoming more common. While there is improved spatial release from masking when CI users gain access to sound in the second ear, the magnitude of that benefit is highly variable. One possible source contributing to this variability is a phenomenon where the second ear actively works against the target ear, termed "bilateral speech interference." We hypothesized that for BI-CI and SSD-CI listeners, impaired selective attention reduced the benefits provided by having two ears. This could be compounded by functionally asymmetric ears; in other words, CI listeners cannot fully ignore a more salient masker talker when attending to a less salient target in spatial-hearing and dichotic listening tasks.

BI-CI, SSD-CI, and normal-hearing control listeners were asked to report back colors and numbers in a closed-set speech corpus. Binaural benefit was measured using a contralateral-unmasking paradigm. The male target talker was presented to one ear, and a male interferering talker was presented to the same ear ("monaural"), or to both ears ("bilateral"), with binaural benefit defined as the performance difference (bilateral−monaural). To test our hypothesis, binaural benefit was compared to dichotic listening ability. The male target talker was presented alone to one ear with no interfering speech ("quiet") or with an interfering male talker presented to the other ear ("dichotic"), with dichotic listening ability defined as the performance difference (quiet−dichotic). For all conditions, both the left and right ears were tested as the target ear, and the target-to-masker ratio was either 0 or +8 dB. In a separate test, each ear's functional performance was assessed with a monaural spectral-temporal modulation processing task. The monaural modulation-processing difference served as an additional predictor to evaluate the contributions of monaural asymmetry to both measures.

Preliminary results suggest that the magnitude of binaural benefit is variable across groups, across listeners, and across ears in individual listeners. If that variability relates to dichotic listening ability, this would suggest binaural benefit is limited in part by selective attention ability. The results will help to identify the similarities and differences in spatial-hearing benefits across BI-CI and SSD-CI listeners.

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M11: MODELS FOR CORRECTING INTERAURAL MISMATCH IN BILATERAL AND SINGLE-SIDED-DEAFNESS COCHLEAR-IMPLANT LISTENERS

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Bilateral (BI-CI) and single-sided deafness (SSD-CI) cochlear-implant listeners perform poorer than normal-hearing (NH) listeners on binaural listening tasks. These deficits are partially due to interaural place-of-stimulation mismatch. SSD-CI listeners also experience much broader excitation patterns in their implanted ear than their NH ear due to current spread. Programming could be used as an approach to reduce this mismatch, yet programming practices do not account for it in BI-CI listeners nor attempt to match the filter characteristics (e.g., center frequency, bandwidth) of the NH ear for SSD-CI listeners. This study focused on developing programming adjustment methods for reducing interaural mismatch using computed-tomography (CT) scans, which contain precise electrode place information. For BI-CI listeners, we hypothesized that reducing interaural place mismatch would improve the binaural representation of signals compared to the clinical map. For SSD-CI listeners, we hypothesized that reducing frequency-to-place mismatch and more focused stimulation would improve the binaural representation of signals.

A computational model was developed that measured the interaural cross-correlation of the envelope along the length of the cochlea for BI-CI and SSD-CI listeners. For BI-CI listeners, each simulated cochlear place received input from multiple electrodes using a model of current spread. For SSD-CI listeners, the NH ear used a gammatone filter-bank to simulate peripheral filtering, and the CI ear was simulated for three levels of current spread. The binaural representation was simplified to a single value, the average interaural cross-correlation of the envelope across the cochlea weighted by the energy at each place. Inputs to the model were CT scan information and clinical maps for 15 BI-CI listeners. Each ear was then independently used to simulate 30 SSD-CI listeners. Results show that for BI-CI listeners, cross-correlation increased compared to the clinical map when correcting for interaural place mismatch while preserving CI filter bandwidths. Surprisingly, cross-correlation decreased when precisely matching place of stimulation. For SSD-CI listeners, precisely matching place of stimulation increased cross correlation compared to the clinical map, with further improvements for more focused stimulation. Unlike BI-CI listeners, preserving interaural bandwidth alone had no effect for all levels of current spread. That is, more focused stimulation had an effect, but only when also matching for place.

The results of this study provide guidance for how to approach BI-CI and SSD-CI programming with an emphasis on improving binaural hearing. It was more important to preserve interaural bandwidth for BI-CI listeners than precisely match place of stimulation. In contrast, it was more important to correct for frequency-to-place mismatch in SSD-CI listeners than preserve interaural bandwidth or use more focused stimulation. Since a clear next step will be to determine if these methods improve behavioral performance, sound localization and speech perception in noise in a subset of the BI-CI subjects will be presented.

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M12: SENSITIVITY OF INFERIOR COLLICULUS TO INTERAURAL TIME AND LEVEL DIFFERENCES IN NEONATALLY DEAFENED RATS

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Cochlear implants (CIs) are an advanced treatment for patients with profound sensorineural hearing loss. Over the last few decades, bilateral CIs are increasingly used to restore binaural hearing. However, human bilateral CI users usually exhibit poor sensitivity to interaural time differences (ITDs) in particular. The reasons for this poor ITD sensitivity are still only poorly understood. We suspect that the manner in which ITDs interact with Interaural Level Difference (ILD) cues may play a role, given that conventional CI stimulation provides CI users with impoverished ITD cues, so that they become increasingly reliant on ILD and insensitive to ITD. To investigate this possibility, we first need to document ITD and ILD sensitivity and their interactions in the naive auditory pathway.

We deafened the rats neonatally with kanamycin injections intraperitoneally (from day 9 to 20) and verified by measuring the auditory brainstem responses. Biphasic pulse train stimuli at rates of 1, 100, and 900 pps with different ITD (±0, ±0.04, ±0.08, ± 0.12 ms) and ILD (±0, ±1, ±4 dB) combinations were delivered through bilaterally implanted CIs. Inferior colliculus (IC) multiunit responses were recorded extracellularly, and analyzed for statistically significant ITD or ILD sensitivity using Kruskal-Wallis tests. At pulse rates of 1, 100 and 900 Hz, 85.6%, 99.7% and 97.2% respectively of multiunits were found to be ITD sensitive, 88.5%, 96.4% and 88% were ILD sensitive, and 76.8%, 96.1%, 85.5% were sensitive to both. We conclude that sensitivity to both ITDs and ILDs was very widespread in the IC of our naive, neonatally deafened rats, that it can be observed at a wide range of pulse rates, and that multiunits sensitive to one type of cue are invariably sensitive to the other type of cue too.

M13: DESIGN AND TESTING OF A FRONT-END IMPLEMENTATION OF A BINAURAL AUDIO PROCESSING STRATEGY INSPIRED BY THE MEDIAL OLIVOCOCHLEAR REFLEX

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Objectives. Users of cochlear implants (CIs) still find it harder than normal to understand masked speech or to localize sound sources, even with bilateral devices. We have previously argued that this could be partly because CI users lack the effects and benefits of the medial olivocochlear (MOC) reflex, and shown that, compared to using two functionally independent devices, binaural CI audio processing inspired by the MOC reflex can improve hearing in noise (Lopez-Poveda et al., 2016, Ear Hear 37:e138-e148) and sound localization for CI users (Lopez-Poveda et al., 2019, Hear Res 379:103-116). Though promising for improving CI outcomes, however, the MOC strategy has properties, such as the need to link bilateral pairs of channels, that may limit its clinical applicability. Here, we present a version of the MOC strategy designed to not operate on pairs of linked channels, but at the front-end of processing, referred to as the MOCFE.

Design. The MOCFE strategy was implemented and tested in combination with a pair of functionally independent bilateral MED-EL FS4 audio processors. CI user performance was compared for MOCFE as well as for two reference strategies: the standard FS4 (STD) strategy and a back-end MOC strategy. The MOCFE and MOC strategies were implemented with fast contralateral inhibition (time constants = 2 ms). Tests included (1) speech reception thresholds for sentences in fluctuating and steady-state noise, in unilateral and bilateral listening modes, and for three different speech levels; and (2) sound source localization in quiet and in noise. Five bilateral users of MED-EL CIs participated in the tests.

Results. (1) For speech intelligibility in a fluctuating masker, the MOCFE was as beneficial (re STD) as the back-end MOC strategy, except for one specific spatial configuration (S-60N-60), where the MOCFE produced no benefits while the MOC strategy did. (2) Neither the MOCFE nor the MOC strategies improved intelligibility in a steady-state noise, possibly because they involved fast rather than slow contralateral inhibition. (3) The binaural MOCFE and MOC strategies tended to improve sound source localization slightly relative to the STD strategy.

Conclusion. The MOCFE can become a successful alternative to the MOC strategy, as it can be applied to a broader range of clinical map configurations.

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M14: RAIDERS OF THE LOST ARKTIVATION – EXPLORING THE BILATERAL CI USERS' LOCALIZATION POTENTIAL

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The spatial hearing performance of cochlear implant (CI) users is worse than that of normal hearing (NH) listeners. The decreased accuracy of sound perception in space may be attributable to various factors. For instance, degraded spectral signal information manifests itself through low numbers of active CI channels and the broad electrical signal crosstalk at the electrode-neuron interface. Temporal information is compromised by the missing synchronization between bilateral CI processors and the independence of current signal processing strategies. Although partially compensated by the brain's ability to fuse and interpret the degraded bilateral signals, the preservation of the original acoustic content is crucial for accurate spatial judgments.

The aim of this study is to improve the spectrotemporal gap in CI processing and consequently spatial hearing performance. Our novel CI sound coding strategy, denoted as InterlACE, attempts to synchronously preserve the maximally available channels throughout the bilateral CI processors while minimizing the electrical crosstalk of the individual electrodes. InterlACE is based on the Advanced Combination Encoder (ACE) strategy, implemented in Cochlear's Nucleus MATLAB Toolbox (NMT) and transmitted via Nucleus Implant Communicator (NIC).

Five experienced bilateral CI users took part in several challenging synthetic and real-life localization experiments in quiet and background noise. Three target stimuli conditions were assessed: 1) Synthetic low-frequency one-third octave bandpass filtered white noise with a center frequency of 500 Hz, 2) Synthetic high-frequency one-third octave bandpass filtered white noise with a center frequency of 2.87 kHz, and 3) Alto saxophone tone of pitch A4 and F0 of 440 Hz with a complex harmonic structure and broad signal spectrum. Post-processing stimuli with behind-the-ear (BTE) binaural room impulse responses, recorded on a KEMAR manikin in a cafeteria environment, provided controlled listening situations with the various localization targets. Stationary stimuli were placed on the frontal horizontal plane (20° intervals, -80° to +80° azimuth). Background noise consisted of bandstop filtered white noise with cutoff frequencies tailored to the synthetic target stimuli, and ambient cafeteria noise for the real-life listening situation.

Localization results were similar in InterlACE and the reference ACE with large angular localization offsets and root mean square (rms) errors observed throughout all experimental conditions. However, there were large individual variations and participants reported an overall subjective preference for the InterlACE strategy.

Bilaterally activating CI channels in interlaced patterns increases transmitted information while minimizing disturbing signal interactions. In addition, the link between the processors contributes to the synchronized signal presentation at the electrode-neuron interface. In summary, the novel spectrotemporal coding adjustments evaluated in these experiments increase the users' access to spatial cues in synthetic and complex localization tasks.

M15: BINAURAL FUSION AND THE EFFECTS OF PLACE OF STIMULATION AND INTERAURAL CROSS CORRELATION

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Binaural fusion is the phenomenon where signals arriving at the two ears of a listener are combined into a single auditory percept. Fusion increases when signals arriving at the two ears are more correlated (i.e., there is an increase in the interaural cross correlation; ICC). However, potential differences in temporal encoding across the cochlea may alter sensitivity to ICC in apical versus mid versus basal regions. We hypothesize that the apical region, which may be more sensitive to temporal information, may have greater sensitivity to ICC, meaning that changes in ICC in signals delivered to this region will have a greater effect on binaural fusion. The purpose of this study is to investigate how the region of stimulation in the cochlea affects fusion for varying electrode pairs of stimulation and ICC of the signal.

Six individuals who are bilateral cochlear implant (CI) users and use Cochlear brand CIs were presented with 1000 Hz pulse trains. The interaural correlation of the envelopes of the pulse trains were altered to manipulate the interaural correlation of the signal. Electrodes 3, 11 and 19 in one ear were selected as reference to represent the apical, mid and basal regions, respectively. To identify, for each reference electrode, the optimal electrode pair that produces maximum fusion, each reference electrode was paired with 5 electrodes in the contralateral ear, spread across the array. Listeners indicated the spatial diffuseness of the sound they perceived and whether they perceived a unitary auditory “image” or two auditory images by rotating a dial to manipulate a visual representation of their perception superimposed on a picture of a head.

Preliminary results indicate that, when stimulating optimally paired electrodes, fusion increases similarly for apical, mid and basal regions of the cochlea with increasing ICC. Further, the results indicate that the degree of fusion is comparable for all three cochleotopic regions when optimally paired electrodes are stimulated with interaurally correlated signals. This does not support our prediction that fusion in apical regions will be more sensitive to changes in ICC.

M16: RELATIONSHIP BETWEEN PERIPHERAL SPREAD OF EXCITATION AND BINAURAL FUSION IN BILATERAL COCHLEAR IMPLANT USERS

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Binaural fusion is the fusion of auditory stimuli across the ears into a single auditory object. Many individuals with hearing aids and/or cochlear implants (CIs) experience abnormally broad binaural pitch fusion, fusing sounds that differ greatly in pitch across ears (Reiss et al., 2014, 2016, 2018). Such abnormal binaural fusion has been shown to lead binaural interference for speech in quiet, and difficulties with separating different voice streams in a multi-talker environment (Reiss et al., 2016; Oh et al., 2022). However, there is significant variability, with some experiencing narrow fusion and others experiencing broad fusion. It is unclear if the variation arises from central or peripheral differences. The objective of this study was to determine the role of peripheral differences, specifically whether variation in overlap of peripheral spread of excitation (SOE) between ears can explain the variation in binaural fusion in bilateral CI users.

The electrically-evoked compound action potential (ECAP) is an objective measure that can be used to record the population auditory nerve response to electric stimulation. The amount of forward masking of the ECAP response to a probe electrode by various preceding masker electrodes provides an objective estimate of the SOE. In this study, we recruited seven adult bilateral CI recipients, with Cochlear Nucleus CI24RE or later. ECAP SOEs were recorded for each even-numbered probe electrode in the comparison ear and for probe electrodes 6, 12, and 18 in the reference ear. SOEs were recorded with the probe and all maskers at the same comfort level (6,7, or 8 on a scale of 0-9).

Binaural pitch fusion was measured behaviorally at the same comfort level as the ECAP (6, 7, or 8) using a single interval procedure. Both reference and dichotic comparison electrodes were stimulated simultaneously for 1500-ms, with the reference electrode held constant in one ear and the comparison electrode in the contralateral ear varied in pseudorandom order across trials. At each trial, subjects were asked to indicate whether they heard a single fused sound or two different sounds in each ear. Binaural fusion functions were generated by the average of the responses.

A mathematical model was used to predict binaural fusion from the overlap between the SOEs from the two ears. For instance, the SOE for reference electrode 12 in the reference ear was multiplied by the SOE for electrode 2 in the comparison ear and summed to generate a prediction for binaural fusion between these two electrodes, and so on for other electrodes in the comparison ear. Preliminary results suggest that binaural SOEs can predict binaural fusion functions for some, but not all subjects and electrodes. The findings suggest that abnormally broad binaural fusion may not be explained solely by peripheral auditory resolution.

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M17: STABILITY OF ELECTRICAL STIMULATION PARAMETERS IN A LARGE COHORT OF CANADIAN CHILDREN WITH BILATERAL COCHLEAR IMPLANTS

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Introduction: Considerable clinical time is devoted to remapping the dynamic range of electric stimulation for cochlear implants (CIs). However, when it is necessary and optimal to adjust these values remains unclear. Moreover, the stability of these measures may differ based on developmental and implantation differences between patients and between ears for bilaterally implanted CI users. The aim of this project was to evaluate the stability of CI stimulation parameters over time in a large, diverse clinical population of paediatric bilateral CI users. The temporal evolution of other common clinical measures as well as how the stability differs based on a CI user's specific demographics and device specificities were also examined.

Methods: CI stimulation parameters (MAP levels), electrophysiological thresholds, impedance and trans-impedance measurements and other relevant clinical information were gathered retrospectively for a large cohort of children with bilateral CIs ($n = 699$ children, $n = 1392$ devices). Measures obtained intra-operatively and during routine follow-up visits between September, 2003 and July, 2022 were included. To account for repeated measures, a mixed effects modeling analysis was conducted to quantify the temporal stability of these measures.

Results: Analyses revealed stabilization of stimulation parameters and electrophysiological thresholds within months following implantation (as indicated by the plateau of a fitted logistic function). Whereas there was no effect of age at implantation on electrophysiological thresholds ($F(1, 2465.2) = 1.50$, $p = 0.22$), MAP levels varied based on the age at implantation ($F(1, 371705) = 20867.14$, $p < 0.05$ for T-levels; $F(1, 385468) = 44303.92$, $p < 0.05$ for C-levels). The clinical characteristics of individuals whose stimulation levels deviated from the common stable pattern were also investigated. Stimulation levels were also affected by the electrode array (antimodiolar vs perimodiolar array; $F(1, 398585) = 3537.14$, $p < 0.05$ for T-levels; $F(1, 398043) = 1771.76$, $p < 0.05$ for C-levels) and the position along the array (apical to basal; $F(21, 397685) = 83.18$, $p < 0.05$ for T- levels; $F(21, 397195) = 87.92$, $p < 0.05$ for C-levels). Effects of simultaneous versus sequential bilateral implantation ($F(3, 2072) = 281.62$, $p < 0.05$ for T-levels; $F(3, 1924) = 284.62$, $p < 0.05$ for C-levels) were also observed with more asymmetric parameters in the latter case for T-levels ($t(397832) = -0.32$, $p = 0.99$ for simultaneously implanted left versus right ear for T-levels; $t(398473) = 26.66$, $p < 0.05$ for first versus second sequentially implanted ear for T-levels; $t(397286) = -10.54$, $p < 0.05$ for simultaneously implanted left versus right ear for C-levels; $t(397570) = 20.64$, $p < 0.05$ for first versus second sequentially implanted ear for C-levels).

Conclusion: Despite initial changes in electric stimulation levels and electrophysiological thresholds, these measures were largely stable over time in a large cohort of children. Stability of electrophysiological measures suggests resilience of auditory nerve stimulation by electrical pulses from the implants in children and provides important information for guiding clinical device monitoring and setting stimulation programs.

M18: CAN ITDS AND BILDS PREDICT EAS BENEFIT IN CI USERS?

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Hearing in noise is a complex process for human listeners. Typically, clinical tests for noise performance only consist of one configuration, collocated speech-in-noise, all the while the complaint of difficulty in noise is one of the most common frustrations of cochlear implant (CI) and hearing aid (HA) users. With the expansion of implantation criteria and the advancement of surgical techniques and electrode design, we are seeing many more patients that have preserved low-frequency hearing (hearing levels ≤ 80dB HL) that qualify for electroacoustic stimulation (EAS) in their CI ear. Combined EAS with binaural acoustic hearing can significantly aid speech perception in noisy situations as listeners have access to interaural time differences (ITDs) in the acoustic hearing domain. However, EAS benefit is variable and may not be evident from clinical tests which generally do not assess spatial hearing abilities. While tasks of spatial hearing may not be widely adopted for clinical assessments, the binaural intelligibility level difference (BILD) task reflects binaural cue sensitivity and can be executed as a clinically feasible speech receptive threshold (SRT). Thus, the primary purpose of this study was to assess psychophysical ITD sensitivity and BILD via acoustic hearing to investigate the relationship between these measures in an EAS population. The secondary purpose of this study was to determine whether performance on the BILD task was correlated with degree of EAS benefit for speech recognition in spatially complex listening scenarios. Our hypothesis was that there would be a significant relationship between ITD thresholds and BILD for adult EAS listeners and that the BILD task may serve as a surrogate marker for EAS benefit thereby informing clinicians about which patients may derive greatest benefit from EAS fittings.

Methods: Twelve EAS CI subjects with a mean age of 56.97 years (30 to 78 years) were tested. This cohort consisted of nine unilaterally implanted EAS CI users (CIHA + HA) and three bilaterally implanted EAS users (CIHA + CIHA). The low frequency pure-tone average (LFPTA), averaged across 125, 250, and 500Hz, was 57 dB HL for the implanted ears and 35 dB HL for the non-implanted ears. The BILD task incorporated phase correlated (N0S0) and phase inverted (N0Spi) conditions with broad-band noise fixed at 90 dB SPL and spondee words varied adaptively in a 1-down, 1-up tracking procedure. BILD was assessed in acoustic-only condition (CI OFF) under circumaural headphones. Interaural time difference (ITD) thresholds were also obtained in the acoustic-only condition for a 250-Hz tone also presented at 90 dB SPL in a 3-interval forced choice paradigm with 2-down, 1-up tracking. To calculate EAS benefit for speech perception, AzBio and HINT sentences in symmetrical noise (S0N45-315) were administered in the bimodal (CI+HA or CI+CIHA) and best-aided EAS conditions (CIHA+HA or CIHA+CIHA). We also obtained ITD thresholds and BILD for twenty adults with normal hearing (NH) (age range 18 to 70 years).

Results: The EAS CI group average BILD was 4.42 dB (SD = 2.98). Average ITD was 539 µs (SD = 615) with three subjects demonstrating an immeasurable threshold. The average AzBio in noise benefit was 7.24-percentage points (SD= 10.1), and the average HINT benefit was 2.67 dB (SD = 2.68). A significant ($p<0.05$) correlation was seen between BILD and ITD and between BILD and AzBio benefit, though we did not observe a significant correlation between BILD and HINT EAS benefit for this preliminary dataset. The NH group average BILD was 8.48 dB (SD = 1.79). Average ITD was 171 µs (SD = 93). As expected, a significant ($p<0.05$) correlation was observed between BILD and ITD for adults with normal hearing.

Conclusion: Though the literature supports EAS benefit for speech recognition and tasks of spatial hearing abilities, not all EAS users receive benefit from the added acoustic component. However, some subjects were able to gain benefit of more than 15-percentage points with AzBio sentences in noise and up to a 7-dB improvement for adaptive HINT. Of the entire cohort those that received less benefit also had higher ITD thresholds and a lower BILD. Given that three of the subjects had immeasurable ITD thresholds and that there was a significant correlation between ITD threshold and BILD, BILDs may be a clinical alternative to quickly assessing a patient’s ability to utilize low frequency acoustic information in a meaningful way after implantation.

M19: THE EFFECTS OF MONAURAL ACOUSTIC GLIMPSE CRITERIA ON BINAURAL UNMASKING AND CONTRALATERAL INTERFERENCE IN COCHLEAR IMPLANTS

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The acoustic information that supports intelligibility benefits due to spatial separation of speech maskers is likely distinct for acoustic compared to electric hearing. When symmetric masker configurations occur (e.g., ±90°) and a monaural head shadow advantage is not available, two mechanisms are thought to support spatial release from masking: 1) binaural unmasking, where interaural time and level differences enhance perceptual separation of target speech and 2) better-ear glimpsing, where the ear that contains the better target-to-masker ratio (TMR) at a given moment is tracked across the stimulus. Binaural unmasking and better-ear glimpsing are often assumed to occur regardless of the local TMR for defining a monaural glimpse. We investigate how this assumption holds for bilateral cochlear implant (BICI) listeners, who show smaller than expected spatial release from masking. In the worst cases, BICI listeners can even show contralateral interference (i.e., worse performance when listening with two implants vs one). Given evidence of generally reduced monaural glimpsing through CI processing, it is hypothesized that reduced binaural unmasking and contralateral interference are associated with limited monaural information extraction at local TMRs ≤ 0 dB.

This study investigates how criteria for defining a monaural glimpse affects binaural unmasking and contralateral interference in BICI processing compared to acoustic hearing. Speech intelligibility in different masking configurations is assessed for BICI listeners and typical acoustic hearing listeners presented with unprocessed and eight-channel-vocoded speech. The maskers are spatialized to be co-located or spatially separated via head-related transfer functions. The order of the vocoding (before or after spatialization) manipulates access to temporal fine structure. Spatial release from masking is compared in an idealized monaural condition that automatically performs better-ear glimpsing and a hybrid condition which adds information from the discarded worse-ear glimpses. The local TMR for defining a glimpse is variable (i.e., -4, -2, 0, 2, and 4 dB). As the hybrid condition adds binaural cues without improving the local TMR, increased performance in this condition reflects binaural unmasking; decreased performance reflects contralateral interference.

For unprocessed and temporal-fine-structure-preserving stimuli, we hypothesize that improved binaural unmasking and reduced contralateral interference will be associated with a tolerance for lower local TMRs. Higher local TMRs are hypothesized to be required for binaural unmasking when temporal fine structure is limited. The results may illuminate how combined noise reduction and binaural cue preservation techniques can eschew typical acoustic hearing assumptions to yield better BICI performance.

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M20: CHARACTERIZING THE RATE LIMIT OF BILATERAL CI USERS USING ELECTROENCEPHALOGRAPHY

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With increasing numbers of bilateral cochlear implant (CI) users, predominantly children, there are clinical demands for time efficient and reliable tests to objectively assess binaural hearing and to inform bilateral CI fitting. Our primary aim is to select and implement a clinical electroencephalogram (EEG) procedure to assess binaural hearing function at different levels in the auditory pathway. Previous studies have shown that the interaural time difference (ITD) discrimination abilities of bilateral CI users becomes very poor or non-existent at pulse rates above 300 pulses per second (pps). Our secondary goal aim is to investigate the pulse rate limit of ITD sensitivity using the selected EEG procedure.

For the primary goal, multiple responses were recorded simultaneously using the same EEG paradigm. The responses are the cortical auditory evoked potentials (CAEPs) evoked by the stimulus onset and offset, the acoustic change complex (ACC) responses, and the auditory steady state responses (ASSRs) that reflect processing more towards the subcortical level. For the secondary goal, the ability to detect a change in the ITD was measured at different pulse rates between 40 to 640 pps for both normal hearing (NH) listeners and bilateral CI users. In the NH experiments, filtered clicks (bandpass-filtered pulse trains) at different pulse rates were used. Such stimuli have been used to simulate CI performance, and were expected to evoke larger envelope ITD change responses than high-frequency sinusoidal amplitude modulated (SAM) tones. In the CI experiments, unmodulated biphasic pulses trains were used. A set of questionnaires, initial checks (e.g., impedances, clinic CI fitting maps), psychoacoustic experiments (e.g., speech in noise, loudness, centralization, left/right discrimination) were performed before EEG measurements.

Data collection is ongoing, thus far eight NH participants have completed Experiment 1 and three bilateral CI users have completed the first phase of Experiment 2. Initial results of NH group suggest the ACC responses evoked by the envelope ITD changes of filtered clicks were in general larger than those evoked by the high frequency SAM tones, however they were much smaller than those ACC responses evoked by the fine structure ITD changes of the low carrier frequency (<2000 Hz) SAM tones. The order of ASSR amplitudes for 40/80/160/320 pps was 160-Hz-ASSR>40-Hz-ASSR>80-Hz-ASSR>320-Hz-ASSR. We will expect to be able to report findings from a further three bilateral CI users.

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M21: EFFECTS OF HEARING AID USE AND RESIDUAL HEARING ON BIMODAL HEARING IN CHILDREN

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The objective of the present study was to investigate whether effects of early cochlear implantation on speech perception in quiet and noise are similar in children with single sided deafness (SSD)) as compared with peers who require a hearing aid in their non- implanted ear (bimodal devices). Cochlear implants (CIs) are provided to children with asymmetric hearing to avoid aural preference for the better hearing ear, limit the duration of deprivation in the deaf ear, and promote improved hearing. Previous work showed advantages of bimodal hearing in children for speech perception in quiet and noise, but many in that cohort had moderately severe to severe hearing loss in the non-implanted ear and delays to CI. More recently, CIs have been provided in the deaf ear in children whose better hearing ear had significant residual hearing and have included children with SSD who do not require a hearing aid in the better hearing ear. We hypothesize that the benefit of speech perception provided by early access to CIs does not significantly differ between children who use bimodal devices and children with SSD using a CI.

To test this hypothesis, speech perception was tested in 186 children who received a unilateral CI for asymmetric hearing loss. Of these, 44 (24%) had SSD with no clinical indication for a hearing aid in in the ear contralateral to the CI and the remaining 142 (76%) children used a hearing aid in the non-implanted ear (bimodal group). Children received their CI at a wide range of ages (0.6 to 18.6 years); age at implantation was positively skewed for both the SSD and bimodal group, with a median of 4.5 and 5.6 and interquartile range of 9.7 (Q1 = 2.0 years, Q2 = 11.7 years) and 7.7 years (Q1 = 3.3 years, Q3 = 11.0 years), respectively. Hearing in the acoustic hearing ear was measured by pure tone audiometry from 250 to 8000 Hz. Speech perception was measured using age-appropriate word recognition tests (n = 180) in at least 2 ear conditions (better hearing ear alone and bilateral hearing) and 2 noise conditions (quiet or with co-located speech weighted noise at SNR=+10 dBHL). Spatial release of masking was measured with speech awareness or recognition thresholds with noise at 3 positions (co-located with speech in front or moved to 90 degrees to the left or right) (n = 76) to assess benefits of spatial separation and to identify any aural preference.

Speech perception outcomes of cochlear implantation in this large cohort of children will determine whether aural preference can be mitigated by limiting unilateral deprivation and aural preference through CI in the deaf ear and whether bilateral benefits are different in children who do and do not require a hearing aid in the non-implanted ear.

M22: CHARACTERIZING SPATIAL AUDITORY LOCALIZATION STRATEGIES IN CHILDREN WHO USE COCHLEAR IMPLANTS

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Introduction: The present study aimed to explore head and eye movements used by children with hearing loss who use cochlear implant(s) (CIs) while localizing stationary and moving sound. Children with hearing loss who use CIs have poor access to binaural cues and have poor spatial hearing. Binaural cues are more disrupted in children using a CI in one ear and a hearing aid in the other ear (bimodal) than in children using bilateral CIs (BCIs). Head and eye movements during spatial localization can support altered binaural hearing but have yet to be explored and characterized in children using BCIs and bimodal hearing. Hypotheses are as follows:

1. Children using bimodal hearing have impaired spatial auditory localization compared to peers with BCIs, and

2. Effective use of head and eye movements facilitates improved spatial auditory localization.

Methods: Spatial auditory localization accuracy was measured using a test of sound localization along the frontal azimuthal plane. The auditory stimulus used was white-noise (filtered between 125-8000 Hz) presented within an arc of 120° in pseudo-randomized positions and balanced between the left and right hemispheres. Response was absolute position recorded using a videogame controller. Real-time head and eye movements were collected using wearable technology including an EDTracker gyroscopic sensor) and Pupil Labs Pupil Core eye-tracking glasses. For each trial, there is one stationary sound presentation (L1) followed by a moving sound presentation (L1-to-L2) with speaker movements of 40°, 20° and 0° in either left or right directions. Outcome measures include RMS error°, average response reaction time (s), perception of movement direction modeled using logistic regression, and head and eye displacement quantified by area under the curve [AUC°*s] (overall movement) and path length [°/s] (total distance traveled), relative to the left and right hemifields.

Results: Data were collected in 37 bimodal CI users [MAge(SD)=12.3(3.1)years], 32 BCI users [MAge(SD)=12.6(3.2)years] and 33 controls with typical hearing [MAge(SD)=13.0(2.6)years]. Localization of stationary sound was impaired in both hearing loss groups compared to controls [$F(2,129.6)=58.7$, $p<0.001$] but BCI users outperformed bimodal peers (Difference from BCI=9.79, SE=2.44, $p<0.001$). Both hearing loss groups had longer reaction times than controls [$F(2,124.9)=12.3$, $p<0.001$]. Perception of direction of movement was impaired in both hearing loss groups compared to peers with typical hearing [$F(2,88)=116.1$, $p<0.001$]. Children with hearing loss had reduced overall head and eye (AUC) movement compared to controls [stationary: $F(2,76.4)=5.97$, $p<0.01$; moving: $F(2,76.6)=2.79$, $p=0.06$]. All groups had more eye (path length) movement than head movement [stationary: $F(1,3350.4)=156.4$, $p<0.001$; moving: $F(1,1440.4)=59.67$, $p<0.001$] and bimodal CI users had the greatest overall pathlength [stationary: $F(2,77.8)=3.76$, $p<0.05$; moving: [$F(2,77.1)=7.03$, $p<0.01$].

Conclusions: Results indicate that auditory localization accuracy is impaired by early hearing loss but that children with bilateral CI have developed better abilities to localize stationary and moving sound than peers using bimodal devices. This likely reflects greater mismatches in binaural cues in bimodal users which is not well compensated by other strategies. The lack of effective head and eye movements during sound localization in children with hearing loss are further evidence of these hearing challenges but may offer a potential avenue to explore for training.

M23: EXAMINING THE RELATIONSHIP BETWEEN INTERAURAL ASYMMETRY, PERCEPTUAL FUSION, AND BINAURAL UNMASKING IN ADULTS WITH BILATERAL COCHLEAR IMPLANTS

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Binaural hearing is of crucial importance for sound localization and speech understanding in noisy environments. For individuals with normal hearing (NH), these abilities stem from the integration of information across ears and the ability to fuse a sound into a single auditory percept. In contrast, individuals with bilateral cochlear implants (BiCIs) may perceive two distinct representations of the same sound due to interaural differences in neural health, electrode placement, and processor settings, which is thought to hinder binaural processing. For example, BiCI listeners with large interaural asymmetries demonstrate reduced binaural fusion and are less likely to obtain binaural benefits such as binaural redundancy and binaural unmasking. To improve binaural outcomes in BiCI listeners, it is important to understand whether binaural performance in asymmetric listeners is limited more by the poorer ear, or by the degree of asymmetry across ears. Further, as binaural fusion is assumed to be a prerequisite for binaural unmasking, it is imperative to understand the extent to which unmasking is dependent upon fusion in BiCI listeners. Thus, the present study examined binaural unmasking of speech and binaural speech fusion in BiCI adults with varying degrees of interaural asymmetry.

Adults with BiCIs completed three tasks examining interaural speech asymmetry, binaural unmasking of speech, and binaural speech fusion. Interaural speech asymmetry was quantified by measuring speech intelligibility in quiet using open-set female-talker IEEE sentences, and asymmetry was defined as the difference in performance across ears. To examine binaural unmasking, speech intelligibility was measured using closed-set female-talker CRM sentences in two conditions: ipsilateral and dichotic. In the ipsilateral condition, one target and two masker sentences were presented to the same ear concurrently. In the dichotic condition, one target sentence was presented to one ear while two masker sentences were presented concurrently to both ears. Stimuli were presented at 65 dB SPL via circumaural headphones placed over participants' CI processors. Masker intensity was adjusted to create SNRs of 0, -4, and -8 dB and binaural unmasking was defined as the difference in performance between ipsilateral and dichotic conditions. To examine binaural speech fusion, three female-talker nonsense words with the form vowel-consonant-vowel were presented diotically or dichotically at 65 dB SPL via circumaural headphones placed over participants' CI processors. Participants were asked to report whether they heard one or two sounds. If they reported hearing one sound, they were then asked to select one of four pictures that best represented what they heard. The pictures illustrated four auditory perceptions: 1) one centered punctate sound, 2) one centered diffuse sound, 3) one left-lateralized punctate sound, and 4) one right-lateralized punctate sound. Participants were allowed to repeat the stimulus for each fusion trial as many times as needed before moving to next trial.

Prior results from young NH listeners using BiCI simulations showed that interaural speech asymmetries negatively affected both binaural unmasking and binaural fusion, and that performance was limited more by degree of asymmetry across ears than performance of the poorer ear. While preliminary, our results with BiCI listeners appear to show similar trends. This work will further our understanding of factors hindering binaural processing in BiCI listeners and ultimately facilitate improved clinical management of these patients.

M24: MICROPHONE DIRECTIONALITY IN BIMODAL LISTENING

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Bimodal hearing is defined as using a cochlear implant (CI) on one ear and a hearing aid (HA) on the other ear. This study investigated the effect of microphone directionality on speech understanding of bimodal listeners under several spatial configurations of speech and noise.

Firstly, the relative hearing performance of the CI and HA ears was characterized by scores for CNC words in quiet. Secondly, to validate a model of bimodal hearing proposed by Dieudonné and Francart (2020), Speech Reception Thresholds (SRTs) were measured for CI alone and bimodal listening, with speech (sentences) from the front, and speech-weighted noise either from the front or the HA side. Thirdly, SRTs were measured with three combinations of fixed directionality (dir) and omni-directional (omni) microphone configurations: 1) CI dir and HA dir, 2) CI omni and HA dir, 3) CI dir and HA omni. Speech was presented from either the front or the side, with noise from the other three cardinal directions.

Results will be presented for 23 bimodal listeners, encompassing a wide range of relative CI and HA hearing performance. Results were consistent with the Dieudonné and Francart (2020) hypothesis that bimodal listeners do not use binaural cues. Dual fixed directionality was better than asymmetric directionality for speech from the front, while asymmetric directionality was better in some conditions with speech from the side.

M25: BINAURAL-BIMODAL STIMULATION DEGRADES NEURAL CODING OF INTERAURAL TIME DIFFERENCES

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Unilateral cochlear implants (CIs) allow the functional restoration of binaural hearing in subjects with single-sided deafness (SSD). However, speech perception in noise and directional hearing in SSD-CI users is typically poorer than in normal hearing listeners, indicating suboptimal binaural integration of unilateral CI stimulation and contralateral acoustic hearing. In order to characterize the limitations in the neural representation of binaural cues in bimodal (combined electric/acoustic) stimulation, we quantitatively compared phenomenological aspects (tuning curves) and functional efficacy (Fisher information) of interaural time difference (ITD) coding of single neurons in the inferior colliculus in response to unimodal (bilateral acoustic) and bimodal stimulation. Mongolian gerbils were implanted unilaterally or bilaterally with round window electrodes. This approach allowed electric stimulation of auditory-nerve fibers while maintaining acoustic sensitivity of the implanted ears.

At the single-neuron level, the incidence of ITD-sensitive neurons was similar for unimodal acoustic and bimodal stimulation. However, responses to bimodal stimulation demonstrated a lower degree of ITD sensitivity (signal-to-total variance ratio), broader ITD tuning, and lower Fisher information when compared to unimodal stimulation. At the population level, within-ear balancing of response strength and adjusting for peripheral delay differences between responses to acoustic and electric stimulation shifted averaged bimodal ITD tuning towards the physiological range of ITDs. This shift was associated with an increase in Fisher information. However, maximum information in response to bimodal stimulation remained lower than that to unimodal stimulation.

Our results suggest that balancing the relative delay and binaural level cues between the two modes of stimulation can improve binaural benefits in bimodal stimulation. Nevertheless, both the representation of bimodal ITDs in the neural responses and the efficacy of this representation remained poor when compared to unimodal stimulation. As a result, additional strategies for enhancing the discrimination of bimodal ITDs need to be identified.

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M26: BORDERLINE CANDIDACY: TOO BAD FOR A CONVENTIONAL HEARING AID AND TOO GOOD FOR A COCHLEAR IMPLANT (CI)

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The aim of this project was to explore the 'real-life' benefit of hearing preservation cochlear implantation (HPCI) and bimodal listening in borderline paediatric CI candidates; and to evaluate the feasibility and compliance to the test battery in a paediatric population.

Two prospective studies are ongoing exposing participants to tests in spatial release from masking, complex pitch ranking, melodic error detection, perception of prosodic features in speech and cochlear dead regions. In study one, participants with HPCI are tested with and without access to their electro-acoustic or electro-natural hearing preservation by utilising an ear plug. In study two, the outcomes for bimodal users i.e., CI in one ear and a hearing aid in the contralateral ear, will be compared with bilateral hearing aid and bilateral cochlear implants users.

1) HPCI: We have collected data for 18/19 participants. Mean age =11.5 years (SD: 0.57, range: 9-16 yrs). The mean low-frequency (125, 250, 500 Hz) pure-tone audiometry average (LFPTA) was 51.20 dBHL (SD: 20.81, range: 16.67-87.5dBHL). There is a trend towards greater spatial release from masking, pitch discrimination, melody detection when using HPCI.

2) Bimodal: We have collected date for 15/30 participants (6 bimodal, 3 hearing aid and 6 CI user). Mean age =11.9 years (range: 7-16 yrs). All groups demonstrate spatial release masking. Bimodal users trend towards better melodic detection, CI user performed best in pitch perception, followed by bimodal then hearing aid user.

Our results suggest the addition of acoustic hearing alongside CI provides some benefit in "real-life" outcomes. HPCI gives greater access to spatial cues with improvement in speech recognition in noise, whereas addition of a hearing aid improves melodic perception.

M27: THE BENEFITS OF BIMODAL HEARING IN CHILDREN AND ADOLESCENTS: A SYSTEMATIC REVIEW AND NARRATIVE SYNTHESIS

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Background and aims: In the last two decades, cochlear implant (CI) candidacy criteria around the world have been expanded to include individuals with residual hearing. Unilateral CI recipients with residual hearing in the contralateral ear have been to benefit from a hearing aid in that ear (bimodal hearing). However, evidence of the real-life benefits of this combination of electric and acoustic hearing in the paediatric population varies. Moreover, there is a lack of evidence-based guidelines on whether a child with bimodal hearing should be considered for a second CI. In the UK, the latest National Institute for Health and Care Excellence (NICE) guidance for cochlear implantation in children (TAA566, 2019) has lowered the audiological criteria (pure tone audiometric threshold ≥80dBHL at 2 or more frequencies) but additionally stipulates that hearing loss must be bilateral. As such, children and adolescents with asymmetrical hearing losses where one ear is outside of audiological criteria may not have access to a CI. We aim to systematically review the literature on real-life outcomes of children and adolescents with bimodal hearing and how they compare with other hearing configurations (unilateral and bilateral CI).

Methods: A protocol for this review was registered on PROSPERO. Four databases were used for the literature search – MEDLINE, EMBASE, CINAHL and Cochrane. A search strategy was designed and inclusion/exclusion criteria were developed using the population, intervention, comparison, outcome and study design (PICOS) framework. Searches were carried out using keywords and subject headings around the population of interest (children and young people/adolescents) and the intervention (bimodal hearing). The quality of the evidence was assessed using the GRADE criteria and risk of bias with the ROBINS-I tools.

Results: Database searches yielded 433 results and 219 unique records after removing duplicates. After title and abstract screening, 63 studies were included for full-text screening, and 22 were found to meet the criteria. The outcome domains reported were speech perception in noise, speech perception in quiet, language development, pitch discrimination or accuracy, music perception, spatial hearing, and noise tolerance. While bimodal hearing outperformed unilateral CI in all studies comparing the two conditions, comparisons between bimodal hearing and bilateral CI yielded varied results.

Conclusion: This systematic review will aid multidisciplinary CI teams in their decision-making for individuals with borderline CI candidacy by extending current knowledge about bimodal hearing. Findings from this systematic review, along with an earlier review on the benefits of hearing preservation cochlear implantation, will be used in the design of a study on the benefits of combining electrical and acoustic hearing in paediatric cochlear implant patients.

M28: CLINICAL OUTCOMES FOR ADULT SINGLE-SIDED DEAFNESS COCHLEAR IMPLANTEES EXCEEDING THE 5% CANDIDACY CRITERION

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While single-sided deafness cochlear implants (SSD-CIs) are now approved by the U.S. Food & Drug Administration (FDA), candidate-ear candidacy criteria (no better than 5% word-recognition score, WRS) are stricter than for traditional CI candidates (50-60% speech recognition, best-aided condition). SSD implantation in our center began prior to FDA approval, using a criterion derived from traditional candidacy: 50% consonant-nucleus-consonant (CNC) WRS in the candidate ear. A retrospective analysis investigated whether SSD patients exceeding the FDA criterion nevertheless benefitted from CI.

A retrospective chart review assessed the clinical experience of a single CI center. Subjects consisted of adult CI recipients with SSD (>90% unaided WRS) or asymmetric hearing loss (AHL, 70-90% unaided WRS in the better ear) implanted since Sep 2019 with at least 3 months of post-operative follow-up. Subjects were divided into “Meets” or “Exceeds” groups, based on pre-operative CNC scores, measured under best-aided conditions with a behind-the-ear hearing aid in the sound field at 1 m from a front loudspeaker, with the better ear masked using an insert earphone with 45-50 dB HL speech-weighted noise. The clinical protocol also included AzBio sentences in the same conditions as CNC; binaural spatial testing (broadband-noise sound localization, SL, and matrix-sentence speech-reception thresholds in spatially separated noise, SIN) using a custom-built 7-speaker array; and a CI Quality of Life (CIQOL-35) survey. Spatial tests were completed with and without a device [pre-operative = contralateral-routing-of-signal (CROS) or BI-CROS hearing aid; post-operative = CI]. To evaluate CI benefit, pre-operative unaided performance was compared to post-operative binaural (acoustic ear + CI ear) performance at a clinic visit closest to 6 months post-surgery.

Results showed that of 28 SSD-CI recipients, 13 exceeded the 5% criterion. The Exceeds group improved on the 5 primary study outcome measures (CI-alone CNC and AzBio, binaural SIN and SL, and CIQOL) in similar proportion to the Meets group. For both groups, all but 1-2 patients improved in CNC, AzBio, SIN, and CIQOL, while all but 3-4 patients improved in SL. Mean improvement magnitude in CNC, AzBio, and SIN was slightly smaller for the Exceeds group, but only because pre-operative performance was better; post-operative scores were similar for the two groups. SL and CIQOL pre-operative scores, post-operative scores, and improvement magnitudes were similar for the two groups.

In summary, SSD-CI recipients exceeding FDA SSD-CI candidacy criteria improved in CI-alone speech perception, spatial hearing, and subjective outcomes in similar proportion and magnitude to those meeting the criteria. Larger-scale clinical trials should be completed to evaluate SSD-CI efficacy using a less-stringent candidate-ear criterion, such as the 50% speech score used for traditional CI candidates.

The views expressed in this abstract are those of the authors and do not reflect the official policy of the Department of Army/Navy/Air Force, Department of Defense, or U.S. Government.

M29: CONTRALATERAL UNMASKING FOR SINGLE-SIDED-DEAFNESS COCHLEAR-IMPLANT USERS WITH SHIFTED FREQUENCY ASSIGNMENTS TO REDUCE INTERAURAL PLACE MISMATCH

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For cochlear-implant (CI) users with single-sided deafness (SSD), standard clinical programming yields interaural place-of-stimulation mismatch because the electrode array does not reach the apex. Because binaural processing relies on frequency-matched inputs from the two ears, interaural mismatch might degrade spatial-hearing abilities. This study examined whether non-standard frequency-to-electrode assignment ("remapping"), designed to reduce mismatch, improves binaural perceptual segregation of competing talkers.

Remapped frequency-to-electrode assignments were derived from computed-tomography scans, which have been shown to provide an accurate estimate of interaural mismatch for binaural processing. Target speech (closed-set coordinate-response-measure corpus) was presented to the acoustic ear, and binaural benefit was assessed by comparing performance when two same-sex competing talkers were presented to just the acoustic ear versus to both ears. The resulting non-standard maps were presented acutely, i.e., without time for acclimatization. Because the target speech was presented to only the acoustic ear, such that binaural benefit in this task does not rely on understanding speech through the CI, it was hypothesized that benefits from remapping might be apparent even acutely. Subjects included ten experienced SSD-CI users.

For nine subjects with small (≤3-dB) initial binaural benefit, remapping yielded a small but significant (1-dB) mean increase in binaural benefit. However, remapping was detrimental for the one subject with very large initial binaural benefit (6 dB), which decreased to 2 dB following remapping. Possible reasons for the modest observed benefits include: too large of a change, lack of acclimatization period to adjust to a new map, large interaural time delays associated with the CI, or non-optimal level settings in the CI.

The results are discussed in the context of other SSD-CI hearing benefits that could be affected by remapping, including sound localization and speech understanding in noise. Overall, these acute results show that reducing interaural frequency mismatch could improve binaural benefits for speech understanding in situations with competing talkers, inspiring future studies to examine these effects longitudinally.

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M30: HOW DO FAMILY FACTORS AFFECT COCHLEAR IMPLANTATION IN CHILDREN WITH SINGLE-SIDED DEAFNESS?

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INTRODUCTION. Cochlear implantation (CI) has rapidly become an accepted medical intervention for the treatment of pediatric single-sided deafness (SSD) to promote binaural hearing functions. However, not all patients and families decide to move forward with this elective surgery, and not all patients who move forward become consistent users. It is well understood that a supportive, well-resourced family is a positive predictive factor in successful CI outcomes in children with bilateral deafness (Stern et al., 2005; Holt et al., 2012; Holt et al., 2013; Sarant et al., 2015). In the current study, we asked if socioeconomic status (SES) and parental education level was associated with patients who proceeded with CI at a tertiary pediatric hospital and further, if SES and parental education level was associated with CI wear time for children with SSD.

METHODS. All patients with SSD seen for CI informational consultations from October 2017 to December 2022 were eligible for the current study. The Area Deprivation Index (ADI) was used as a proxy for measuring SES (University of Wisconsin School of Medicine Public Health, 2015; Kind & Buckingham, 2018). The ADI accounts for socioeconomic disadvantage by assessing factors of income, education, employment, and housing quality in neighborhoods with a lower score representing a more resourced area. Parental education level was gathered through review of department intake forms and clinical notes. Daily wear time of the cochlear implant was gathered through review of stored datalogging values in subjects' most recent clinical CI mapping sessions.

RESULTS. 67 patients were deemed to be viable CI candidates in the study period. 51% (34/67) elected to move forward with CI for the treatment of SSD. State and national ADI was calculated for all subjects residing in the US, with 79% (52/66) of subjects residing in the state of Massachusetts. The mean state ADI, reported in decile, was 4.1 (SD=2.6) and the mean national ADI, reported in percentile, was 21.7 (SD=18.0). State ADI was statistically significantly higher (worse) for individuals who ultimately received a CI (M=4.8, SD=2.7) compared to those who elected not to move forward with surgery (M=3.4, SD=2.3), t(64)=2.4, p=0.02. Datalogging was available for 31/34 implanted subjects. The mean datalogging value was 5.2 hours/day (range=0–10.9). No significant correlation was found between state or national ADI and datalogging values. However, an unpaired Wilcoxon two-sample test showed that there was a significant difference in datalogging (p=0.04) between children with mothers with graduate-level degrees (masters, doctorate; median CI use=8.6 hrs/day, Q1=3.5, Q3=10.0) and those with less than graduate-level education (high school, some college, college degree; median=4.0 hrs/day, Q1=1.0, Q3=6.8). The same analysis was performed on paternal education level, and the findings were similar, demonstrating a significant difference in datalogging (p=0.04) between children with fathers with graduate-level degrees (median CI use=7.0 hrs/day, Q1=6.0, Q3=10.0) and without (median=2.0 hrs/day, Q1=1.0, Q3=7.0).

CONCLUSION. The current study begins to investigate how possible inequities may affect outcomes for children with SSD who use a CI. In the current sample, parental education level appeared to be a strong factor associated with increased use of the CI. ADI results suggest less resourced families are more likely to proceed with this elective surgery. Counseling regarding intervention options and support to promote full-time use need to be strengthened for less educated and resourced families. It is important to note that the findings of the current study may be exacerbated in other parts of the country that are significantly less resourced than the state of Massachusetts, a high-resource state. For example, 76% of the CI recipients had a national ADI in the 30th percentile or lower suggesting the majority of the group under investigation was better resourced compared to a national sample. Initial findings suggest future work is warranted to further investigate how family factors like parental education, SES, race/ethnicity, caregiver stress, family mental health, etc. may affect access to and success with a CI in this special population.

University of Wisconsin School of Medicine and Public Health. 2020 Area Deprivation Index v3.2. Downloaded from https://www.neighborhoodatlas.medicine.wisc.edu/ March 29, 2023

M31: INVESTIGATING THE EFFECTS OF PERIPHERAL SPECTRAL ASYMMETRY USING SIMULATIONS OF COCHLEAR IMPLANT LISTENING

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Objectives: Patients with single-sided deafness (SSD) have the greatest possible interaural asymmetry - one ear has clinically normal acoustic hearing while the other has no usable hearing. Although recipients with SSD and a cochlear implant (i.e., “SSD-CI”) can hear through both ears, the ability to integrate acoustic and electric stimulation from the typical and implanted ears, respectively, is highly variable. Given that multiple etiologies can result in SSD, there is variability in how well the implanted ear encodes incoming auditory information and subsequently transmits that information to be processed centrally. This observed variability is hypothesized to be reflected in the inability of SSD-CI users to 1) fuse speech information arriving at the two ears simultaneously and 2) the inability to accurately encode speech information presented to the two ears. To test this hypothesis, we used an inter-ear switching, or alternating pattern paradigm. Here, we employed a vocoder to understand the impact of this variability in normal hearing listeners before investigating it in SSD-CI users. Previous work suggests that this paradigm requires participants to modify their listening strategy depending on the rate of inter-ear switching (selective attention at low rates vs. attending to the “better” ear at relatively high rates). At high rates participants may fill in the gaps of the interrupted stimulus (i.e., via perceptual closure). However, intermediate rates represent a boundary between listening strategies and require the participant to integrate the input to each ear.

Design: Stimuli were vocoded speech sentences with simulated electric hearing presented to one ear and unprocessed speech sentences presented to the contralateral ear. The stimulus was designed to simulate aspects of CI processing using the SPIRAL vocoder (Grange et al. 2017), chosen to investigate the variability arising from peripheral encoding that varies in precision and spread of excitation across electrical channels. Participants were adults ranging in age from 18-35 years who all passed a hearing screening. The task used an alternating speech paradigm to switch the presentation of recorded sentences between ears at eight switching rates [0, 1, 2, 4, 6, 8, 12, 16 Hz]. Performance in the dichotic switching condition was compared to performance of each ear alone (i.e., monotic stimulation with periodic silent intervals at the same switching rates described above).

Conclusions: The vocoder manipulation used provides insight into factors that lead to variability in how listeners with asymmetric signal encoding integrate information.

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M32: COCHLEAR IMPLANTATION IN SINGLE-SIDED DEAFNESS: OUTCOMES AND ITS ASSOCIATION WITH FREQUENCY-PLACE MISMATCH

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Lack of access to binaural hearing negatively affects sound localization, speech perception, and the overall quality of life in people with single-sided deafness (SSD). SSD was also found to alter cortical asymmetries between hemispheres [Ponton et al., 2001, Hearing Research, 154(1–2), 32–44]. The treatments of SSD aim to restore the audiological and psychological benefits of binaural hearing and ultimately improve the quality of life [Lucas et al., 2018, International Journal of Audiology, 57(1), 21–30].

Pre-operative planning technologies such as OTOPLAN can help evaluate the frequency shift (FS) (also known as frequency-to-place mismatch) between the array and the natural cochlear tonotopy. The primary aim of our study was to evaluate changes in hearing performance in nine patients with SSD after cochlear implantation (CI) using both objective and subjective measures. The secondary aim was to measure the association of audiological outcomes with the FS between the stimulated center frequency for each electrode in the default map and the characteristic frequency stimulated by the electrode as estimated by the pre-operative planning software. Collected data included: pure-tone audiometry (PTA), speech reception thresholds in noise (SRT), spatial release from masking, sound localization tests, the Arabic version of the Hearing Implant Sound Quality Index (HISQUI), and the Speech, Spatial and Qualities of Hearing Scale (SSQ). FS was calculated based on the readings of four experts using radiological images and OTOPLAN software.

Results: (1) PTA Pure-tone average (PTA4) at 500, 1000, 2000, and 4000 Hz decreased from a mean of 113.9 dB to 37.2 dB. (2) HISQUI scores were significantly better post CI ($t = 6.07$, $df = 7$, $p < 0.0005$). (3) The post-CI SSQ Speech and Spatial subscales' scores were significantly better ($t = 7.24$, $df = 7$, $p < 0.0005$ and $t = 2.75$, $df = 7$, $p<0.05$ respectively) but not the qualities subscale. (4) SRT was significantly better when all conditions were pooled ($t = 2.66$, $df = 17$, $p < 0.05$). (5) Localization was significantly better post-CI ($t = 2.74$, $df = 5$, $p < 0.05$). (6) The absolute frequency shift for all frequencies ranged from 0.08 to 40 semitones with an average of 11.1x (±7.47) semitones. (7) The average frequency shift per participant for frequencies ≤ 1500 Hz ranged from 6.97 to 20.4x semitones with an average of 14.56 (± 6.67) semitones. (8) The shift in the lower frequency range (≤ 1500 Hz) had a significant association with the improvement in sound localization ($r(6) = -0.86$, $p < 0.05$) but not with speech perception.

In summary, CI improved sound localization, speech perception in noise, and self-perceived everyday auditory performance in adults with SSD. Association between localization benefits and the frequency shift lends support to anatomy-based fitting and efforts to minimize tonotopic-mismatch.

M33: A COMPUTIONAL MODELING FRAMEWORK FOR ASSESSING INFORMATION TRANSMISSION WITH COCHLEAR IMPLANTS

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Computational models are useful tools to investigate scientific questions that would be complicated to address using an experimental approach. In the context of cochlear-implants (CIs), being able to simulate the neural activity evoked by these devices could help in understanding their limitations to provide natural hearing. Here, we present a computational modelling framework to quantify the transmission of information from sound to spikes in the auditory nerve of a CI user. The framework includes a model to simulate the electrical current waveform sensed by each auditory nerve fiber (electrode-neuron interface), followed by an existing model to simulate the timing at which a nerve fiber spikes in response to a current waveform (auditory nerve fiber model). Information theory is then applied to determine the amount of information transmitted from a suitable reference signal (e.g., the acoustic stimulus) to a simulated population of auditory nerve fibers. As a use case example, the framework is applied to simulate published data on modulation detection by CI users obtained using direct stimulation via a single electrode. Current spread as well as the number of fibers were varied independently to illustrate the framework capabilities. Simulations reasonably matched experimental data and suggested that the encoded modulation information is proportional to the total neural response. They also suggested that amplitude modulation is well encoded in the auditory nerve for modulation rates up to 1000 Hz and that the variability in modulation sensitivity across CI users is partly because different CI users use different reference signals for detecting modulation.

M34: AUTOMATIC LANDMARK LOCALIZATION IN CT IMAGES USING DEEP LEARNING

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Cochlear implantation benefits from an in-depth understanding of the exact localization of a patient's individual anatomical landmarks, which can be ascertained by the otologist through computed tomography (CT) imaging of the temporal bone. Nevertheless, the manual localization of pertinent anatomical structures within the temporal bone presents a considerable challenge, consuming a substantial amount of time and effort for both surgeons and radiologists.

Consequently, our work aims to develop an automatic localization pipeline using a 2D CNN-based object detection deep learning algorithm, in both Pytorch and Keras framework, specifically designed to identify and distinguish anatomical structures of interest in 3D volumetric CT scans. For training on clinical data we use manually localized landmarks at the cochlear (modiolus axis in basal turn, round window center, and apex) as input for the model, serving as a "ground truth" also for evaluating the model's performance. The result shows our approach is able to detect the cochlea's presence (over 90% accuracy) and robustly localize landmarks at the cochlea fully automatically on CT scans from different manufacturers with an isometric image spacing of 0.3 mm. For a volume size of 812x812x460 voxels, the inference time is around 21s (Apple MacBook Pro, M1, mPS enabled), or 6s on Nvidia GPU (4* TeslaV100). Compared to manually defined ground truth, we attain an average accuracy of 0.71 mm on cochlea's basal point (Euclidean distance).

The benefits of this landmark localization approach is that it can be trained with little examples (around 40 CT scans) and it does not require manual segmentations for training but just clicking at landmarks, which is less labor intensive. Still an automatic segmentation is possible by using the landmarks as control points to construct 3D models.

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M35: A COMPUTATIONAL MODEL OF THE ELECTRICALLY AND ACOUSTICALLY EVOKED COMPOUND ACTION POTENTIAL IN HYBRID COCHLEAR IMPLANT USERS

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The compound action potential (CAP) is a response generated by auditory nerve fibers in response to a brief stimulus. In hybrid cochlear implant (CI) users with residual hearing, CAPs can be elicited via either acoustic stimulation (aCAP) or electric pulses delivered through the CI (eCAP). This provides a unique opportunity to explore the interaction between electric and acoustic stimuli at the peripheral level in humans. Computational models can support the design, evaluation and interpretation of CAP measurements.

We propose a novel computational model to simulate eCAPs and aCAPs. The model consists of three components: 1) a 3D finite element method model of an implanted cochlea to predict voltage spread between CI electrodes and auditory nerve fibers (Nogueira et al., 2016, 2017), 2) a recently published phenomenological model of a single auditory nerve fiber for electric-acoustic stimulation (Kipping and Nogueira, 2022), and 3) a physiological cable model to simulate patterns of each fiber's contribution to the measured CAP (Kalkman et al., 2014).

Previous models estimated eCAPs by convolving peri-stimulus time histograms (PSTHs) with a "unitary" response waveform and combining contributions from all auditory nerve fibers. This approach assumes that action potentials in each ANF contribute equally to the CAP response. Our model indicates that this is not the case if the CAP is recorded through electrodes of the CI. Moreover, “unitary” responses cannot account for different CAPs being recorded when the recording electrode along the CI array is changed.

The proposed model overcomes these limitations by using individual "single-fiber CAP contributions" (SFCCs) instead of a unitary response. For each recording electrode, a set of SFCCs is computed using the cable model embedded in the 3D FEM model of the cochlea. The actual PSTH for a given electric or acoustic stimulus is computed using the phenomenological single-ANF model. We compare predicted eCAPs and aCAPs as well as CAPs masked by the other stimulation modality to published data.

Potential applications for the model are broad, including the objective assessment of hearing thresholds through eCAPs/eCAPs, or testing methods to determine the neural health status (PECAP; IPG-effect). Moreover, the model will help to improve our understanding of interaction between electric and acoustic stimuli, with possible implications for the clinical fitting of EAS patients or the surgical procedure.

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M36: MULTIPOLAR VS. MONOPOLAR STIMULATION IN A COCHLEAR IMPLANT: A SIMULATION STUDY

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A limitation of cochlear implant stimulation is the wide spread of electric currents in the cochlea. To overcome this limitation, multipolar stimulation was introduced. Multipolar stimulation uses intracochlear stimulation and return electrodes, whereas monopolar stimulation uses intracochlear stimulation electrodes and one extracochlear return electrode. Due to stimulation and return electrodes being closer to each other in multipolar stimulation, a more focused stimulation of neurons can be achieved. However, studies did not find an improvement in speech understanding for multipolar stimulation. Our recent simulation study may help explain why multipolar stimulation is not an improvement to monopolar stimulation.

We developed a finite element (FE) model based on high-definition µCT scans (6 µm voxel size) of a human cochlea, implanted with a twelve-electrode MED-EL Standard array. Current spread was simulated for a monopolar (MP), a bipolar+1 (BP1) (stimulation and return electrodes separated by one electrode), a bipolar+0 (BP0) (stimulation and return electrodes as neighbors) and a tripolar+0 (TP0) (one stimulation electrode surrounded by two adjacent return electrodes) configuration, for all stimulation electrodes. FE simulation provided electric potential values along 400 reconstructed auditory nerve fiber paths along the cochlear length. Electric potential values were employed to simulate 400 biophysical multi-compartment neuron models, both for an intact dendrite and a degenerated dendrite state (dendrite removed), resulting in several excitation profiles. Based on the obtained excitation profiles, we found the following:

(I) For intact dendrites, thresholds (minimum current necessary to excite one fiber in the neuron population) averaged over all electrodes were -7.15, -4.91, -3.41, and -1.86 dB re 1 mA, for MP, BP1, BP0, and TP0, respectively. For degenerated dendrites, thresholds averaged over all electrodes were -7.20, 0.99, 6.81, and 14.23 dB re 1 mA, for MP, BP1, BP0, and TP0, respectively.

(II) On average, multipolar thresholds increased with degeneration, especially TP0 (+ 16.09 dB), while monopolar thresholds stayed similar (- 0.05 dB). This resulted in a difference of average threshold between TP0 and MP for intact dendrites of 5.29 dB, and for degenerated dendrites of 21.43 dB, i.e. the threshold difference between TP0 and MP increased approximately by a factor of 6 when dendrites degenerated.

(III) For intact dendrites, bipolar and tripolar stimulations showed “localized” excitation of neurons near return and stimulation electrodes, while neurons in between stimulation and return electrodes were largely silent. Bipolar stimulation generally excited neurons to a similar degree near both electrodes involved, while tripolar stimulation showed preferred excitation near the stimulation electrode. In addition, multipolar stimulation configurations were more likely to excite neurons in the peripheral part of the dendrite (near the inner hair cells), compared to monopolar stimulation.

Our simulations show that instead of focused excitation, multipolar stimulations are more likely to cause “localized” neuronal excitation near both stimulation and return electrodes. In addition, dendritic degeneration may have a stronger impact on multipolar configurations, as they tend to excite the peripheral part of the dendrite in intact neurons, which also explains the increase in thresholds for degenerated neurons. Our data suggests that the dendritic state of auditory nerve fibers in an implanted ear could be inferred by comparing the ratio between monopolar and tripolar thresholds.

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M37: MODELLING OF ELECTROPHYSIOLOGICAL ASSESSMENT OF AUDITORY NERVE FIBRE DAMAGE

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The efficacy of a cochlear implant is known to be affected by the survival and health of the cochlear nerve which impacts the conduction of electrically excited neural activity to the brain. In order to evaluate the survival rate and health of the auditory nerve (AN) in vivo, the plausibility of using electrophysiological measurements, such as electrically evoked compound action potential (eCAP) and electrically evoked auditory brainstem response (eABR) measurements as reported in literature, was examined. In addition, the projected effect of a broad spectrum of hearing loss aetiologies on eCAPs and eABRs was also investigated. Based on these findings, damage to the AN was divided into three separate mechanisms: degeneration, demyelination and fibre loss. Varying degrees of these damage mechanisms were implemented within an elementary curved, computational AN population model in an infinite homogeneous medium in MATLAB to predict eCAP responses. The modelled damage mechanisms were validated by comparing the predicted eCAP responses to measured responses in literature. The model also allows investigation into the effect of various other factors, such as electrode placement and stimulus levels, on the eCAP responses. Findings from preliminary experimental work to explore the identification and classification of neural damage in CI users is reported. This study may support more accurate predictive modelling, simplify in vivo auditory neural health diagnoses and enable better interpretation of measured eCAPs and eABRs.

M38: WATCHING HEARING WITH A NEURO-IMPLANT: ULTRA-HIGH-RESOLUTION MODELS OF NEURAL ACTIVITY IN THE HUMAN INNER EAR

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It is commonly known that there is wide variability in speech perception across cochlear implant (CI) users. Such high inter-individual variability is not only found in speech intelligibility, but also in detection thresholds as well as in pitch perception. A number of factors that may influence the CI performance, including the anatomical differences in the cochlea, can only be evaluated with the help of computational models. Nevertheless, those are mostly smooth parametric models that may not necessarily capture all anatomical variations of the cochleae. During the last years, we have acquired eight high-resolution μ-CT scans of human temporal bone specimens contrast enhanced with osmium tetroxide, and reconstructed anatomically realistic models. After careful segmentation and virtual insertion of an electrode array, we calculated the current spread in the inner ear using the finite element (FE) method. We then created a set of 500 spiral ganglion neurons for each of the eight inner ears and modeled their excitation with a biophysically motivated multi-compartment model. We examined threshold, excitation pattern and place pitch for each model for monopolar stimulation with biphasic current pulses. By animating the results, we finally were able to visualize the generation and propagation of action potentials in the nerve with unprecedented detail.

Quantitative analysis of the excitation patterns revealed that apical electrode stimulation is easily confused, especially if the dendrites of the nerve fibers were degenerated, which we have also observed in pitch ranking studies with CI users. We measured the detection threshold (DT) and maximum comfortable level (MCL) in eight CI users under the same stimulation scheme. We found the average stimulation thresholds for 5% neuronal excitation in the models were comparable to the measured DT, and those for 20% neuronal excitation were comparable to the measured MCL, but the modelled variance was smaller than the measured variance. “Ectopic activations”, referring to the excitation of a group of neurons distant to the stimulating electrode, were found in all models especially at higher stimulus amplitudes, and they did not necessarily occur at the same location across different models. As a result, the reconstructed place pitches were not at or close to the electrode characteristic frequencies in a number of simulations. The reconstructed pitches then shifted as the stimulus amplitude was increased, but with different trends across different models, and pitch reversals were also found in some models. In conclusion, our simulations suggest even without considering neuronal degeneration, fibrosis or other factors, the anatomical difference alone explains a large part of the variability observed in CI users. In addition, our spectacular animations rendered from our computer models provide a detailed insight into the function of the most delicate sensory organ.

M39: MODEL-BASED INFERENCE OF ELECTRODE POSITION AND NEURONAL DENSITY FROM MEASURED DETECTION THRESHOLDS IN COCHLEAR IMPLANT LISTENERS

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Introduction: Cochlear implants (CI) are a highly successful brain-computer interface that can restore hearing in individuals with sensorineural hearing loss. Nevertheless, the degree of successful hearing restoration varies widely. Two major variables are thought to contribute to poor performance: the distances between electrodes and surviving spiral ganglion neurons and the density of those neurons. If an electrode is too far away from the neurons, electrical stimulation is less effective (current levels required to reach perceptual threshold tends to be higher, e.g.). Similarly, threshold current levels are also higher if an electrode is located in a region with low density of spiral ganglion neurons. Effective reprogramming of the cochlear implant, for example using focused tripolar stimulation or remapping the electrodes, depends on which of these situations pertains.

Methods: Here we inverted a simplified cochlear model to infer electrode distance and neuronal density from monopolar and tripolar threshold values. To invert the model and infer electrode position and neuronal density values along the cochlea, the model takes monopolar and tripolar thresholds for each electrode and varies the electrode position and neuronal density using a least-squares minimization algorithm to match the threshold values provided. Assessment of threshold fit uses mean absolute threshold difference across all electrodes. Assessment of electrode-SGN distance fit uses mean absolute difference between inferred and measured distance. Pearson's correlation coefficient of inferred v. measured distance assesses the degree to which the inferred distances capture the spatial profile of distance. We validated this inverted model by accurately inferring electrode distance and neuronal density for example scenarios in which these values were known. We then applied the inverted model to 18 CI users for whom electrode distances were estimated from CT imaging.

Results: For most subjects the inverted model was able to reproduce threshold profiles very well along the length of the electrode array. For about ⅓ of subjects, the inference of electrode position was excellent. In other cases, significant errors remained. Nonetheless, even in some of these cases with poorer fits, qualitative profiles of electrode distances were captured.

Conclusions: This inverted model thus shows promise as a simple, practical tool that could be useful in clinical settings to assess the electrode-neuron interface. Accuracy in estimating electrode distance may benefit from using additional clinical measures.

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M40: THE POTENTIAL OF ADVANCED DEEP LEARNING MODELS TO EVALUATE SPEECH INFORMATION IN VOCODER SIMULATIONS

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Vocoder simulations have greatly contributed to the development of sound coding and speech processing techniques for auditory implants. These simulations model the signal processing used in implant devices and have been extensively used to study the effects of implant signal processing on speech perception, as well as to model individual anatomy and physiology of implant users. Example uses of vocoders in the auditory implant field include, for example, evaluating the effects of number of electrodes, envelope processing, frequency-to-place mapping, channel interactions.

Vocoder simulation studies have traditionally been performed on human subjects, and therefore suffer from several practical limitations. Studies involving human subjects are time consuming and costly, both in terms of subject recruitment and testing. In addition, perception of vocoded speech varies significantly across individuals, and can be significantly affected by small amount of familiarization or exposure to vocoded sounds.

Here, we propose and validate the potential of employing advanced publicly available speech recognition models in implant research as an alternative to human subjects. We used the OpenAI Whisper model, a recently developed open-source speech recognition model, to evaluate the effects of vocoder parameters on speech understanding. The model's performance was evaluated on words and sentences in both quiet and noisy conditions with respect to several vocoder parameters such as number of spectral bands, input frequency range, envelope cut-off frequency, envelope dynamic range, and number of discriminable envelope steps. The proposed method, in addition to being less expensive and quicker than human vocoder studies, is not biased by individual learning abilities and cognitive factors, the order of stimulus presentation, listener's attentional state or fatigue during a testing session.

Our results show that the Whisper model exhibits remarkably similar results and patterns to those reported in human studies and has human-like robustness to vocoder simulations. Model performance closely mirrored human results in response to modification of the number of bands, envelope cut-off frequency, dynamic range and number of discriminable steps. This was achieved at negligible cost and time compared to a similar study performed with human subjects.

This study demonstrates the potential of employing advanced machine learning models of speech recognition in auditory prosthesis research. These models can provide unique opportunities to assess or optimize large-scale parameter spaces with high precision that is practically impossible to do with human subjects. Future directions of this project will involve modifying and extending the Whisper model to build a biophysical model of auditory implants. This advancement will enable more realistic and personalized simulations of speech perception with an auditory implant that can be used to further improve implant device outcomes.

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M41: GSP COCHLEA: A GRAPH SIGNAL PROCESSING MODEL OF THE COCHLEA WITH APPLICATION TO COCHLEAR IMPLANTS

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While cochlear implant (CI) signal processing is optimized for speech, it is limited in processing complex auditory signals, such as music, and individual differences in hearing performance are not well understood but are thought to be related to neural health. Sound encoding in the cochlea has traditionally been understood to be the product of individual cells being excited at characteristic frequencies. This representation of cochlear function as an individual cell-driven process releasing neurotransmitters to individual auditory nerve fibers has been the inspiration for CI design: the hardware reduces the excitation of about 4,000 tonotopic cells to 12-22 frequency channels that stimulate tonotopic electrodes. However, this representation does not take advantage of the relationships in the functional activity among all of these cells, which may be especially important while they are encoding music with many simultaneous pitches and timbre mixtures. Here, we introduce GSP Cochlea: a novel framework of studying the cochlea as a graph, i.e., looking at how the signals of individual cells are coordinated at the level of the whole-cochlea to pass complex information to the auditory nerve fibers.

We construct cochlea graphs using clinical data from patients with normal hearing and diagnosed hearing loss in the AudGenDB database (Children's Hospital of Philadelphia). Patient audiograms are used in a simulation of the inner ear (UR EAR 2020b) to generate voltage responses, i.e., graph signals, of inner hair cells, i.e., graph nodes, for various stimuli. The Graph Signal Processing Toolbox (GSP BOX) is used to learn the graph links between hair cells from smoothness in their voltage signals and determine a cochlea graph for each patient. Using graph theory and complex systems theory, we found quantifiable differences in the graph structure of patients with different levels of hearing loss severity, where more severe hearing loss led to graphs with more links, lower link weights, and less modular organization. Additionally, we find that the cochlea graph topology is an important factor in de-noising signals.

The GSP Cochlea model provides a mechanism for constructing a patient's individual cochlea graph from their personal hearing health data. The cochlea graph will be input into a graph deep learning model to determine the optimal allocation of frequencies to be filtered into each CI channel for music processing, to ensure that melody and harmony information are not lost between channels. The long-term goal is to have a music signal processing algorithm that CI device companies would be able to implement as a personalized setting that users could turn on when listening to music for improved listening.

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M42: PARAMETERISATION AND PREDICTION OF INTRA-COCHLEAR STRUCTURES

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The functioning of cochlear implants (CI) is dependent on the biophysical interface between the electrode array and the surrounding cochlear tissues. Computational models provide a mechanism to probe the complexities of this interface. These models rely on a three-dimensional (3D) description of the relationship between the electrode array, through which electrical stimulation is applied, and the surrounding tissue, which provides a medium for current conduction and contains the target neural elements.

This study aims to provide a parametric model of the internal structure of the cochlea through reference to measurable landmarks. Because these landmarks form the basis for the prediction of the geometry of the internal structures, the resulting model should be a more accurate representation of a CI recipient's cochlea. The construction of the parametric model involves the definition of a reference geometry, including a description of relevant parameters, selecting appropriate source data and quantifying the parameters using the source data. This paper describes (i) the parameters that were chosen to define the mathematical description of the internal structures of the cochlea, (ii) the quantification of these parameters from mid-modiolar histologic sections of the human cochlea, and (iii) the equations that were derived to predict these parameters from only a few landmarks that are generally visible on clinical images of the cochlea.

M43: NEURAL NETWORK MODELS CLARIFY THE ROLE OF PLASTICITY IN COCHLEAR IMPLANT OUTCOMES

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Background:
Cochlear implants (CIs) are one of the great success stories in biomedical engineering, but nonetheless fail to restore fully normal hearing in individuals with sensorineural deafness. One plausible limitation on current CIs is suboptimal algorithms for converting sound into electrical stimulation. Models that can predict what a person hears with CI input could help develop better stimulation strategies for CIs. Here, we investigate models of CI-mediated hearing based on deep artificial neural networks, which have recently been shown to reproduce aspects of normal hearing behavior and replicate hierarchical organization in the auditory system.

Method:
We modeled normal hearing by training a deep artificial neural network to recognize speech using simulated auditory nerve input from an intact cochlea. We modeled CI hearing by testing this same trained network on simulated auditory nerve input from a CI. To simulate possible consequences of learning to hear through a CI, we retrained this network on CI input. Further, to model the possibility that only part of the auditory system exhibits this plasticity, in some models we retrained only the late stages of the network.

Results:
When the entire network was reoptimized for CI input, the model exhibited near-normal speech intelligibility scores. Performance on par with CI users was achieved only when just the late stages of the models were reoptimized (keeping the weights of the early stages unmodified).

Conclusion:
Our results are consistent with the possibility that limitations on CI-mediated speech perception relate to incomplete plasticity that prevents the rest of the auditory system from optimally decoding CI input. Overall, our work validates deep neural networks with altered peripheral input as a candidate model of auditory perception in CI users and suggests that the difficulties of CI users could partly reflect plasticity limitations in the human brain, rather than being entirely due to impoverished auditory nerve representations from CI stimulation.

M44: TOWARDS NEXT-GENERATION SCALABLE COCHLEAR IMPLANTS

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Despite the growing interest in cochlear implant (CI) research, clinical progress in improving sentence recognition scores has stalled for more than 2 decades. Significant efforts have developed novel audio encoding strategies. In contrast, there has been little innovation in the neural interface. Electrodes in intracochlear arrays are typically large and distant from their neural targets, which results in current spread, limiting the perceived spectral resolution. Although simply adding more channels to the CI will not solve this problem, novel electrode architectures and supporting electronics could improve the precision of stimulus targeting by controlling the current spread. This in turn could lead to new clinical experiments and enable more auditory coding methods. Hardware improvements, unlike coding and digital signal processing, have a higher barrier to entry including large costs and regulatory burden. In addition, many alternative, user-developed, and research-grade algorithms and coding schemes are currently impossible to implement due to the proprietary nature of existing systems further hindering CI research.

Here we present Open-CI, an open-source cochlear implant with the aim to advance the CI field with improvements including: 1) A precision semi-automated manufacturable high channel count electrode array, 2) An open-source custom integrated circuit, and 3) An open and standard expandable protocol for CI communication.

The proposed microfabricated intracochlear electrode array is composed of a flexible polyimide substrate and 32 platinum-iridium electrode rings subdivided into 4 arc-segments. Each electrode segment measures 0.45mm by 0.3mm. The assembled array substrate tapers from a diameter of 0.8mm at the base to 0.45mm at the tip. The expanded number of reconfigurable channel-segments enables a unique way to correct for surgical placement variability and apply strategies to reduce the spread of stimulation current. The array has been prototyped at the Lawrence Livermore National Laboratory Biomedical Foundry, a human-grade microfabrication facility. The proposed Open-CI integrated circuit contains a neural stimulator as well as biopotential recording, wireless power, and bidirectional data communication modules. The multichannel neural stimulator is designed to work in conjunction with the expanded segmented electrode array to implement arbitrary multipolar stimulation configurations with increased spatial targeting of the stimulation current or map local tissue impedance to the anatomical environment. Designed for scalability, the stimulator implements an active charge balancing strategy, in situ verification, and closed-loop calibration functions. In addition to the intracochlear array and custom electronics, we propose a generalized and expandable data communication protocol for CIs to increase compatibility with future external modules and facilitate a variety of preclinical experiments currently constrained to using clinically widespread hardware.

The Open-CI project will publish all design schematics, manufacturing techniques, firmware, software, and test data to encourage open collaboration, rapid implementation of advanced features, and reduced economic and regulatory barriers. Moreover, we expect contributions from the CI research community to improve future versions and to be able to use this platform for their own experimental studies. With improved collaboration, the benefits to industrial and academic participants should propel material innovations in hearing restoration hardware.

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M45: SIGNAL PROCESSING STRATEGY FOR COCHLEAR IMPLANT BASED ON FEATURE EXTRACTION

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CI signal processing performs time-frequency analysis of acoustic sound and encodes it into a series of information to be conveyed though electrical impulses directly in the cochlea so that hearing sensations are partly recovered. Modern CIs thus only require simple signal processing, mostly able to extract envelope information from finite frequency bands (12 to 22, depending on the manufacturer), of which the most energetic will convey information to auditory nerve fibers though intracochlear electrodes. CI users usually benefit from medium to good speech understanding. It is however well known that these performances suffer from high variability among subject and drop when CI users are placed in more complex (e.g., noisy) environment. Their perception and enjoyment of musical sounds remains poor. Furthermore, because the CI provides degraded sound information, listening requires explicit and maintained cognitive resources allocation (high listening effort) that leads to mental fatigue after daily use of the device. These limitations are closely related with the core design of CI signal processing, affected by poor frequency selectivity due to the spectral smearing on the signal processing, and poor pitch transmission.

This paper aims to present CueTracker strategy a feature extraction based signal processing. Most modern CI stimulation strategies are derived from the Continuous Interleaved Sampling (CIS), which avoid undesired channel interactions from simultaneous stimulations. The standard procedure spectrally decomposes the acoustic sounds by bandpass filtering the input signals, each band representing the theoretical frequency coded by intra-cochlear electrodes. The bands are usually full-wave rectified, low-pass filtered and used as patterns to amplitude-modulated and fixed-rate pulse trains. Each pulse train is stimulating the cochlea following the tonotopic axis. The CIS is part of a wider group of strategy (the Waveform group), which code information present in the temporal waveform of the acoustic input signal. Older stimulation protocols used another group of strategy based on the extraction of signal's feature where one or more speech characteristics are extracted from the acoustic signal (eg. F0, F1, F2). Then the feature(s) is(are) used either to modulate the stimulation frequency or to choose which electrode will stimulate. Improving on the two types of signal processing strategies, The CueTracker is a feature-oriented signal processing strategy that could be included either in a waveform, a feature or a hybrid encoding.

CueTracker aims to select the most salient signal features avoiding the spread of information observed on the bandpass filtering approaches. Spectrally accurate signal processing is expected to improve phoneme discrimination, speech understanding and reduce cognitive load.

CueTracker allows full frequency allocation flexibility, and allow the electrode contacts to match the cochlear tonotopy using standard theoretical frequency allocation maps (e.g. Greewood). It has already been proven that a reduced frequency mismatch provides better pitch perception and slightly increased speech performance on monaural CI hearing. Correcting frequency allocations may provide even more benefits in bimodal or binaural situations, in which patients suffer from medium to poor lateralization capabilities.

M46: AN APPROACH FOR DETERMINING INDIVIDUAL FREQUENCY ALLOCATION MAP IN COCHLEAR IMPLANT USERS USING COCHLEA CT-SCANS

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Background: It is well known that cochlear implants (CI) have a good track record in restoring hearing functions. However, the perception with state-of-the-art CI systems is significantly distorted in acoustic situations containing multiple talkers and music. Previous studies have shown the importance of the frequency allocation map (FAM) for better sound perception with CI stimulation. Finding an optimum FAM may be even more crucial for bimodal CI patients where acoustic- and electric-frequency information should be ideally tonotopically aligned between the two ears.

Goal: We have designed an approach in which we generate several individualized CT-scan-based FAMs. For each FAM some acceptance criteria are calculated based on Lambiks et al. (2020) and DiMarco et al. (2022) to see if enough electrodes are assigned to some pre-defined frequency regions. Our approach presents theFAMs to expert audiologists and researchers, who can then use the acceptance criteria to choose the most appropriate FAM for their patient, for both clinical and research purposes.

Methodology: Our method generates five different CT-based FAMs from the tonotopic map of the patient. Additionally, the default FAM proposed by Oticon Medical GMCI fitting software (non-CT-based) is proposed as the sixth FAM. Experts may calculate the tonotopic maps manually or automatically (e.g., with Oticon Medical Nautilus software) from the individualized CT scans. The first FAM (FAM1) fully matches the tonotopic map of the inserted electrodes in the cochleaFAM1 may not include some low frequency bands if the insertion of the electrode array is not deep. Additionally, a few basal electrodes may need to be deactivated if their tonotopic frequency pass over the Nyquist frequency derived from the sampling frequency of the microphone’s sound processor. The FAM2 introduces a low-frequency cutoff frequency below which the center frequencies of the electrodes linearly deviate from the tonotopic map to approach the GMCI map. The FAM3 does the same but based on a high-frequency deviation. The FAM4 combines FAM2 and FAM3 methods to compensate for the limitations of FAM1, but at the expense of more deviation from the tonotopic map at low and high frequencies. The FAM5 is designed to have a quasi-constant shift from the tonotopic map, and therefore preserves the slope or curvature of the tonotopic map. In this method, the expert may either fix the shift between tonotopic and FAM maps or let it be determined by an optimization method, where a cost function penalizes any curvature dissimilarity between the two maps when putting the lower/upper frequency boundaries of FAM and GMCI at the same level.

Results: We applied our FAM design approach to 10 bimodal CI patients. Tonotopic frequencies derived from CT-scans were provided by the Hannover Medical School (MHH) under framework of BiMoFuse project funded by the Demant Foundation. The lowest and highest tonotopic frequencies measured were 560±170 and 14900±890 Hz, respectively. These values are equivalent to 250 and 7312 Hz, respectively, in GMCI, indicating that FAM1 and FAM3 do not include apical frequencies below 560 Hz (in average). On the other hand, 2 to 3 basal electrodes had to be deactivated in the FAM1 and FAM2. The Hybrid FAM (i.e., FAM3) introduced an average deviation of 1.16 and 1.03 octaves between tonotopic and FAM frequencies at the lowest and highest GMCI frequencies, respectively. In FAM5, the average optimum shift was determined to be ~ -0.7 octave. Setting this to -1 (maintains harmonic relationships in both ears) required deactivation of 1-2 apical electrodes.

M47: TURNING ON THE COCHLEAR IMPLANT: ANATOMY-BASED FITTING VERSUS STANDARD FREQUENCY MAP

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Background: Patients suffering from deafness achieve promising results with cochlear implants (CI). However, the sound quality of CI-hearing is described as rather moderate. In real-life situations with background noise, the hearing performance decreases considerably. CI users often state that the sound of music is unbearable. A potential reason for poor sound quality is the current "one size fits all" allocation of frequency bands to electrode contacts. In some cases the location of the electrical stimulation differs from the normal neural mapping by more than two musical octaves. Therefore, a customized mapping of frequency bands, which depends on the determination of the exact electrode position by digital imaging and reconstruction has been developed (anatomy-based fitting, ABF). It is frequently hypothesized that patients perform better using ABF based mapping compared to standard mapping. However, due to habituation effects, interpretation of results obtained by acute comparison of different filter bank mappings is difficult. To exclude these habituation effects, a prospective study with randomized cross-over design was initiated in January 2022.

Material & Methods: Study participants are randomly assigned to two study arms. One group is initially fitted with the manufacturer's standard map (SMP) and the other group with an ABF approach. After 3 months of experience, a change is made to either the standard or ABF map for a further period of 3 months. After 6 months, all participants receive programming with both mapping alternatives for another period of three months. During this time, patients are allowed to switch between the two mappings to determine their preferred setting. At the different test intervals, speech perception in quiet (Freiburg Monosyllables, FMS) and with background noise (Matrix Sentence Test, MST) are performed to evaluate the individual benefit with both maps. In addition, subjective hearing quality is evaluated with the SSQ questionnaire. All participants were implanted with Synchrony 2 implant devices (MED-EL, Innsbruck, Austria) and used either the Sonnet 2 or Rondo III processor. As of the end of March 2023, 3 Flex26, 22 Flex28 and 11 FlexSoft cases have been recruited. In nine cases, the implants were placed in bilateral simultaneous surgery. According to the study protocol, 76 cases should be recruited by the end of the current study.

Preliminary results and observations: Of the 37 subjects currently recruited, 6 patients have been marked as dropouts to date. Two of them complained about the sound of the standard map after using ABF mapping. Two other patients complained vice versa about sound quality after conversion from standard to ABF mapping. In one case, the subject's cognitive competence was too low to determine reliable results. One patient was lost during follow-up. At the 3 months test interval, median FMS of the remaining subjects was 55% and 47,5%, median MST SRT 2,0 dB SNR and 1,6 dB SNR in the SMP-group (N = 12) and ABF-group (N = 10) respectively. Average SSQ total score was 3,92 (SMP) and 5,41 (ABF), thus, considerably higher in the ABF-group. After 6 months, median FMS was equal 65% in both groups, median MST SRT was 1,95 dB SNR and -0,6 dB SNR in the SMP- (N = 6) and ABF-group (N = 6). Results of the 9-month endpoint of the study will be presented and discussed at the meeting.

Preliminary Conclusion: With the results collected so far, no clear advantage of the ABF in speech perception scores could be observed after 3 months of experience. A tendency towards better quality scores in the ABF group was observed.

M48: ACUTE EFFECTS OF A LOMBARD EFFECT-BASED SOUND CODING STRATEGY FOR COCHLEAR IMPLANT LISTENERS

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Pre-emphasis and front-end processes combined with current sound coding strategies have been shown to improve speech understanding for cochlear implant (CI) users in challenging listening situations (e.g., speech-in-noise). In an earlier study, a proposed acoustic Lombard Effect (LE) perturbation approach demonstrated significant improvements in speech intelligibility in 10 and 5 dB SNR large crowd noise, where incoming speech was modified to mimic acoustic changes observed in natural Lombard speech production in response to the speaker's surrounding environment (Lombard, 1911; Saba and Hansen, 2022a).

In order to ensure perturbed acoustic characteristics are effectively perceived by CI listeners, a LE-based sound coding strategy, LACES (Lombard ACE and Separation) is proposed to incorporate acoustic perturbation in the electric domain (i.e., CI signal processing pipeline) within a common 'n'-of-'m' strategy for Cochlear speech processors, the Advanced Combination Encoder (ACE). Three distinct signal processing stages were designed to: (1) enhance formant structure (Saba et al., 2018) and consonant energy (Saba and Hansen, 2022b), (2) manipulate channel selection to prioritize information-rich channels (of both low-level consonant structure and mid-frequency transitions), and (3) introduce inhibition/recovery observed in neuronal physiology. Acute speech intelligibility was evaluated with 4 CI users using IEEE sentences in quiet and at 10 dB SNR large crowd noise using the CCi-MOBILE Research Platform (Ghosh et al., 2022).

Preliminary results using the sound coding strategy (LACES) with front-end perturbation indicated improved speech intelligibility for low-performing CI subjects (baseline performance with clinical processor between 50-80% in quiet). Electrodograms show pronounced consonant and consonant-vowel transition structure and an increase in selection of channels within the second and third formant region at the expense of noise-dominant, high-frequency channels during vocalic speech segments. The sigmoid-based inhibition function used in the separation algorithm reduced the total number of stimulated pulses on average of 40-50% and reduced speech intelligibility by ~12% points; however, average decrement in performance was not found to be significantly different than ACE. Future advancements of the separation algorithm will explore additional channel selection or loudness balancing/energy reallocation to compensate for the reduced number of stimulated channels. Results will be provided for the remaining 13 conditions consisting of performance with each individual processing stage, as well combinational stages with and without two variations of front-end, acoustic LE perturbation (Saba et al., 2022a). Implications of acoustic and electric signal processing stages as a sound coding strategy will be discussed.

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M49: PHONEME-BASED REVERBERANT SPEECH ENHANCEMENT FOR COCHLEAR IMPLANT USERS

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Cochlear implants (CIs) restore hearing to individuals with severe hearing loss by converting sounds to electrical pulses to directly stimulate the cochlea. Most CI users have good speech understanding in quiet conditions; however, they struggle to understand speech in challenging listening environments with noise and reverberation. While commercially available CIs have incorporated various technical solutions, such as beamforming and single-channel noise reduction, to reduce background noise, there are currently no solutions available in current CIs that directly address reverberation (Carlyon and Goehring 2021).

The main challenge with developing a solution to mitigate reverberation is the task of distinguishing wanted speech from unwanted speech with very similar characteristics: reverberant speech reflections are echoes - attenuated and delayed copies - of the target speech that a listener is trying to understand. Nonetheless, since speech structure is generally highly predictable, we hypothesise that this predictability can be exploited to improve the performance of novel speech enhancement algorithms. For example, vowels are primarily dominated by low-frequency information and the presence of high-frequency energy during a vowel utterance is likely indicative of either noise or reverberant acoustic artifact. Thus, our overall strategy for improving speech enhancement algorithms in CIs is based on the premise that if we can recognise reverberant speech, then we can clean reverberant speech.

Recent years has seen successful applications of artificial intelligence/machine learning for smart voice assistants that rely on the predictability of speech for automatic speech recognition of words to execute voice commands. Based on a similar concept of a “smart” CI, we leverage real-time automatic recognition of phonemes - the smallest unit of speech - to improve reverberant speech enhancement in CI users. We have developed a real-time feasible phoneme-based speech enhancement algorithm that relies on causal features extracted from the CI signal processing framework to: i) predict the phoneme within the current CI time frame; and ii) estimate a time-frequency mask to suppress reverberant acoustic artifacts based on a probabilistic weighting of the phoneme prediction. In a study simulating CI use with vocoded speech in individuals with normal hearing, we demonstrated the potential to significantly improve speech intelligibility in reverberant environments with phoneme-based speech enhancement when compared to the conventional phoneme-independent approach (Chu, Collins, and Mainsah 2022). We will present results from a listening study to test our phoneme-based speech enhancement algorithm with CI users in various simulated reverberant environments.

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M50: COMPARISON OF PERFORMANCE FOR COCHLEAR-IMPLANT USERS WITH AUDIO PROCESSING STRATEGIES BASED ON SHORT-TIME FFT OR SPECTRAL FEATURE EXTRACTION

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Background. We investigated if and to what extent a spectral feature extraction (SFE) audio processing strategy for cochlear implants (CIs) improves hearing performance and comfort compared to Crystalis, a short-time FFT based strategy currently implemented in Oticon Medical CIs. In the SFE strategy, acoustic events (or spectral peaks) were extracted using a synthetic feature extractor and mapped into the 20 CI stimulation channels. SFE was hypothesized to reduce frequency smearing and improve frequency resolution because spectral peaks are detected and narrower filter spacing can be achieved without the constrains of the FFT bin width.

Methods. For six users of Oticon Medical Digisonic CIs, we compared performance with the SFE and Crystalis strategies on various aspects: word recognition in quiet, sentence reception threshold in noise (SRT), consonant discrimination in quiet, listening effort, melody contour identification (MCI), and subjective sound quality. Word recognition and SRTs tests were conducted on the first and last day of testing to assess potential learning and/or accustomization effects. Listening effort was assessed in quiet and in a low-noise condition (individual SRT+15 dB) by measuring pupil dilation. MCI involved identifying a pattern of five tones among five possible patterns that formed either a constant, rising, falling, rising-falling, or falling-rising melody. MCI was measured for tone distances of two and four semitones and for fundamental frequencies of 131 and 262 Hz. Subjective sound quality was assessed using the multiple stimulus with hidden reference and anchor (MUSHRA) paradigm for three groups of sounds: sentences, music, and ambient sounds.

Results. Word recognition was similar for the two strategies on the first day testing, while it became (unexpectedly) better for Crystalis than the SFE strategy on the last day of testing. SRTs were worse with the SFE strategy than Crystalis on the first day of testing but became comparable for the two strategies on the last day of testing. Consonant discrimination scores were higher for Crystalis than for the SFE strategy. MCI scores were similar for the two strategies in all test conditions. Subjective sound quality scores tended to be lower for the SFE strategy than for Crystalis. Listening effort was not substantially different across strategies.

Conclusions. We conclude that CI-user performance is similar with SFE as with a more standard short-time FFT based approach. However, longer accustomization times may be required to reveal the full potential of feature extraction.

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M51: NEURAL MODEL-BASED FINE STRUCTURE CODING FOR COCHLEAR IMPLANTS

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Sound coding strategies for cochlear implants translate the incoming sound signal into parameters for the electrical pulse pattern to be delivered by the implant. Commonly, channel envelopes are computed and mapped to the current of fixed, high-rate pulse trains. This leaves aside the coding of temporal fine structure (TFS) in the temporal placement of the electrical pulses – one reason for problems with sound localization and listening in situations with noise and reverberation. Attempts to code TFS into the timing of the electrical pulses have yielded limited success, partially due to interaction between stimulation pulses at the electrode-nerve interface.

The S-BLIF model (Takanen and Seeber, 2022, DOI:10.5281/zenodo.4674564) predicts the nerve's response to sequential electrical pulsatile stimulation including the non-linear interactions between stimulation pulses due to adaptation, facilitation and refractoriness. These interactions need to be taken into account when coding TFS. I will report on a novel approach for a stimulation strategy, which considers the nerve's non-linear response and hence deviates from classical deterministic sound coding. The processing order is inverse – it does not start from the sound, but from the nerve's spiking response, which is taken as the target. Using the nerve model, the electrodogram's pulse timings and amplitudes required to evoke the target spike pattern are found. The efficiency and convergence of three approaches for creating the electrodogram will be discussed: 1) Inverting the model's monotonous computation functions efficiently leads to a suggestion for pulse timings and amplitudes, which can then be fine-tuned; 2) Using the neural model in the loop of a constrained (by prohibiting simultaneous pulses, C-levels) optimization process, the electrical pulse parameters can be found which minimize the neural distance between the evoked and the target spike train; 3) A genetic algorithm makes suggestions for pulse timings whose amplitudes are optimized with the help of the neural model. The inverse-model approach 1) is shown to be most efficient, but failing to compute accurate electrodograms when more complex, non-linear across-electrode interactions occur. These can be resolved in combination with the blind inversion approach 2), which considers the model's non-monotonous predictions. These approaches generate electrodograms that evoke – in the model – a particular temporal response on the auditory nerve. Psychophysical studies will show if this targeted TFS coding in the nerve will allow improving perception.

M52: CCI-CLOUD: A FRAMEWORK FOR COMMUNITY BASED REMOTE COCHLEAR IMPLANT USER EXPERIMENTS BASED ON THE CCI-MOBILE RESEARCH PLATFORM

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The speech processing field for hearing assessment has recently developed a critical need for conducting listener experiments remotely versus traditional in-person/laboratory methods due to social distancing measures enforced by COVID-19 pandemic, as well as increasing test subject opportunities for CI users not local. CCi-MOBILE is our current hardware research platform created to support the Cochlear Implant research community, facilitating the development of new strategies & algorithms for improving sound quality and scientific investigation for CI users/systems. In this study, CCi-CLOUD, a virtual platform, is proposed and developed to expand the functionality of CCi-MOBILE to allow for both subject testing and scientific studies to be performed remotely. The CCi-CLOUD portal is established with three strategic categories: (i) Remote Desktop: allows for direct connect support for CI user remote experimentation; (ii) Cloud Data Storage: allows for data sharing among researchers & subjects; and (iii) Online Web App: serves as a portal which connects CI subjects with those in the CI research community. Three multimodal sound experiments are considered in this study to demonstrate the effectiveness of the proposed Cloud infrastructure based on a virtual experimental framework including speech recognition, speaker identification, and sound type classification for both CI and normal hearing (NH) users. Experimental evaluations are performed for both In-Lab and Remote/Online scenarios to benchmark experimental protocols and demonstrate infrastructure validity for CI/NH subjects. Results on consistency between the two modalities will be presented and discussed. Results from 4 CI subjects will be included.

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M53: INTELLIGIBILITY AND SPEECH INFORMATION OF A TALKING AGENT FOR CI USERS

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There is a consensus in the field of speech science that part of the information obtainable from speech lies in the visual cues of the speaker. That is, the audio portion of speech, while generally sufficient for communication is incomplete without a visible representation of the speaker. The McGurk Effect is an auditory illusion that occurs when a voice producing one sound is presented with a face articulating another. Previous research suggests visual cues become more important in difficult listening situations or complex acoustic environments. Benoit et al. explored aspects of visual speech (synthetic lips, synthetic face, and natural face) and measured their utility when faced with speech degradation and noise. The conclusion was that synthetically produced visual cues from lips or lipreading can restore one-third of speech content, whereas a synthetic face could restore half of the speech content and a natural face (face of the actual speaker) could restore two-thirds of the speech content. As CIs do not return normal hearing to their users, one can model the use of a CI as speech degradation or noise. We will refer to this as the CI noise model. The proposed experiment will be carried out to determine the baseline speech recognition performance of audio and audio-visual speech with cochlear implant (CI) listeners. These scores will be evaluated for a significant difference between the conditions. It is hypothesized that the added effects of visual speech, in the form of facial cues, will restore some of the speech information that is lost due to sound degradation that results from the CI noise model. The experiment will be carried out using 60 sentences obtained from the AzBio dataset. The synthetic face used in the experiment will be generated using a lip-sync generator called Crazy Talk 8. The results of 4 CI users will be discussed.

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M54: CCI-MOBILE: VALIDATION OF A RESEARCH PLATFORM FOR WIRELESS DATA COMMUNICATION AND TRANSMISSION.

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The CCi-MOBILE Research Platform is a flexible, open-source cochlear implant (CI) research platform developed and maintained by the UT-Dallas CRSS-CILab. The main goal of CCi-MOBILE is to enable researchers in different areas of speech science to carry out CI-specific experiments in multiple modalities for in-field, in-lab, and psychophysical studies. This platform has the ability to test different CI MAP configurations, front-end/pre-processing algorithms, and signal-processing strategies in real-time, without having to design, develop, test, and manufacture new cochlear implant clinical processors, a feat that could span many months or even years. It is able to achieve this goal by replacing these clinical processors with a personal computer that serves as a processing device. We currently have the option of a Windows PC or an Android device. To perform processing tasks on these devices, CCi-MOBILE needs to communicate with them. Currently, CCi-MOBILE utilizes a wired(USB) method for communication and transmission. While this modality provides a faster and more stable connection, it limits the mobility of the CI user and makes it more difficult to perform in-field experiments in naturalistic environments. Therefore, the goal of this study is to design, verify and validate a wireless mode of communication and transmission (Wi-Fi) such that the same level of integrity and speech recognition is achieved as with the USB method. To test the Wi-Fi mode two experiments are proposed, one to collect objective measures of quality for verification purposes and the other to perform validation tests with CI users. The first makes use of a corpus of 1500 sentences obtained from the TIMIT, AzBio, and IEEE speech datasets. CCi-Mobile is run in Wi-Fi mode for seven hours on the data above. Quality is measured by computing the Wi-Fi data drop rate, CI frame error rate, and a speech correlation between input and transmitted speech. This gives a measure of the reliability of the transmission method. The second experiment makes use of 60 sentences obtained from the AzBio and IEEE datasets. The Wi-Fi mode is tested on CI users and their speech recognition scores are measured and stored. These scores are compared with those obtained from using the currently available USB mode. This experiment aims to validate the Wi-Fi method and ensure there is no significant difference in performance when compared to the USB method . Due to the nature of Wi-Fi transmission, we expect a minuscule level of data loss due to packet dropping. However, this is not expected to influence the speech recognition of CI subjects significantly. So far, verification tasks performed show a 5% data drop rate. There is also a 0.006% frame error rate at the point of stimulation. Further verification results as well as results obtained from 4 CI users will be discussed.

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M55: NON-LINGUISTIC SOUND SOURCE IDENTIFCATION AND LOCALIZATION FOR COCHLEAR IMPLANT USERS WITH ECOLOGICAL MOMENTARY ASSESSMENT

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Sound source localization involves the encoding of interaural time and level differences (ITDs and ILDs) and corresponding decoding of neurological responses, which enable the listener to locate their spatial placement. Historically, sound source localization has focused on speech, and it represents a cumbersome task for cochlear implant (CI) users. Previous studies indicate that CI users are particularly prone to poor source localization performance, due to ITD and ILD distortion and ITD reduced sensitivity. It is hypothesized that non-linguistic sound source localization (in tandem with sound source identification) will be especially challenging for CI users during spontaneous conversation. This study evaluates the CI listener accuracy and timed response delays for nonlinguistic sound identification and source localization in CI users within a natural conversational environment. The target sound identities come from three different non-speech sound classifications: animal, non-linguistic human, and interior. The target source locations emanate from speakers within a 3D Audio Sound Booth (at UT-Dallas Callier Center). In this experiment, the CI user engages in conversation with a normal hearing (NH) subject, while performing the listener task. The listener task includes identifying direction and interfering sound-type via an original Android application interface, “Emaging.” The application enables the user to perform visual real-time tagging of source and direction with replicated images of the potential nonlinguistic sounds and direction of emission along a 360° pictured speaker array. “Emaging” aims to provide the user with an experience akin to ecological momentary assessment (EMA), which can be taken outside of a synthetic setting and into a natural environment for the CI user to “tag” organic sounds as they occur and are observed naturalistically in real time. The anticipated results of this study indicate lower accuracy scores for sound source localization, relative to sound source identification. Likewise, the response delay times for directional analysis are anticipated to be higher than response delay times for sound classification. Results will be discussed and implications for CI development will be provided. Complete CI listener evaluations will be presented. Because the overwhelming majority of CI test measures are based on speech processing, it is the intent that EMA and our “Emaging” application can potentially motivate CI sound processing strategies for non-linguistic sounds, as well as further advance corresponding technological applications and interfaces for CI users.

M56: CCI-MOBILE: DEEP SOURCE SEPARATION AND NON-LINGUISTIC SOUND ENHANCEMENT IN COMPETING SCENARIOS: ADVANCEMENTS FOR COCHLEAR IMPLANT RECIPIENTS

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Non-linguistic sound (NLS) perception is essential for contextual awareness, daily engagement, safety, and autonomy. However, sensorineural hearing loss caused by the dysfunction of the cochlea, auditory nerve, or central auditory pathways reduces NLS perception. Cochlear implants (CIs) contribute to restoring auditory function and research platforms can enable customized CI processing and psychophysical studies. Several CI studies suggest no overall improvement in perception following implantation, though this is subjected to individual variability and other limitations in research methodology. In naturalistic environments, it is critical to identify, track, and separate specific sources of NLS from a mixed stream of sounds. Although convolutional neural network (CNNs) architectures have achieved state-of-the-art performance in sound classification, event detection, and source separation, there are limited studies on applying such advanced deep learning techniques for NLS identification and source separation among CI listeners. Our previous work involved a comparative analysis of NLS classification with NH and CI listeners,and proposed an NLS enhancement algorithm to improve NLS identification and perception in CI listeners (Shekar and Hansen, 2022). In this current study, an experimental framework is developed to study the perception of competing NLS sounds among CI and NH listeners. The competing NLS problem is modeled by considering a mixture of two distinct situational location sound sources, with one sound source assigned as "Target" and the other as "Interference." Additionally, SuDoRM-RF, a deep source separation network is proposed to recover the desired "Target" NLS source from the mixture (Tzinis et al. 2020), along with NLS enhancement applied as a post-filter (Shekar and Hansen, 2022) to benchmark improvement in "Target" sound perception among CI and NH listeners. CI and NH listener evaluations are carried out for the following perceptual measures, namely: (i) interference, (ii) audio quality, and (iii) distortion. Subjective ratings and forced choice pairwise preferences are comparatively assessed for audio tokens (i) ‘Target’ and ‘Interference’ mixed-baseline (ii) ‘Target’ source separated (SS) and (iii) ‘Target’ source separated and enhanced (SSE) conditions. Furthermore, statistical analyses are performed to assess the effect of applying deep NLS source separation and NLS enhancement algorithm. This proposed study is the first to consider modeling multi-source non-linguistic sound tasks among CI listeners, comparing NLS sound perception among CI and NH listeners, and applying NLS enhancement in a multi-source NLS scenario. The study aims to contribute towards modeling the cocktail party effect for CI and offers a potential effective simulation for realistic listening CI/NH test scenarios.

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M57: A COCHLEAR IMPLANT SPEECH CODING STRATEGY INTEGRATING TEMPORAL MASKING EFFECTS: EXTENSION TO REALISTIC LISTENING CONDITIONS AND CLINICALLY USED DEVICES

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Speech perception remains challenging for cochlear-implant (CI) recipients in conditions containing background noise, such as at work, school or in social settings. During the transmission of acoustic information to the central auditory system via the CI, a major bottleneck occurs at the electrode-nerve interface (ENI) (Brochier et al., 2022). Modifications to the speech coding strategy could improve the efficiency of information transmission across the ENI, alleviating speech perception difficulties in noise. One such modification, the temporal integrator processing strategy (TIPS), significantly improved the perception of CIS-processed speech in the presence of speech-shaped noise (Lamping et al. 2020). TIPS leverages a model of temporal masking to identify and remove stimulation pulses that are unlikely to be perceived. For TIPS to benefit CI listeners in their daily lives, further efficacy must be demonstrated, including an adaptation of the algorithm for real-time processing (a key constraint of CI devices) and additional testing of speech perception outcomes in everyday listening conditions. Here, we investigate the performance of TIPS in conjunction with both CIS and ACE processing and in conditions reflecting everyday listening, and demonstrate initial steps towards implementing the algorithm in real time.

First, TIPS was objectively evaluated in a range of acoustic conditions using computational comparisons. The computational analysis revealed that the pulse-removal behaviour of TIPS is invariant to the sentence material, speaker, and use of the pre-emphasis filter (applied in most clinically-available processing strategies). When stimulation patterns were sparser than those formed by clinical CIS strategies, such as with ACE or when the pulse rate was reduced, TIPS tended to remove fewer pulses. In all scenarios, TIPS could considerably reduce the power required for stimulation, addressing a major limitation of current devices. A low-latency causal version of TIPS was developed and validated in simulation, demonstrating the feasibility of applying TIPS in clinically-used devices. For speech-in-noise conditions, TIPS removed speech and noise pulses in equal proportion regardless of noise type and signal-to-noise ratio. These results suggest that TIPS functions equivalently in a variety of everyday listening conditions and could therefore benefit speech perception in those conditions. Further, the results suggest that the intelligibility benefit of TIPS did not arise from a reduction in noise pulses or low-amplitude pulses but rather from a reduction in detrimental pulse interactions across electrode channels. That is, although the removed pulses in each channel were predicted to be undetectable in isolation, interactions between multiple pulses across channels can distort the representation of speech (Boulet et al., 2016) and lead to difficulties in background noise.

Second, the speech recognition performance of CI listeners was measured in a double-blind within-subject experiment before and after TIPS processing, for both the CIS and ACE strategies. Prior to testing, participants were acclimatised for 10 minutes to the respective condition. Speech outcome measures include the percent of correct words identified in quiet and the speech reception threshold in the presence of speech-shaped noise and multi-talker noise. We will discuss results from the ongoing listening test, revealing whether additional speech perception benefits noted in the computational analysis occur in everyday listening scenarios.

M58: THE IMPACT OF ELECTRODE-SPECIFIC COMPRESSION FUNCTIONS ON OUTCOMES WITH A COCHLEAR IMPLANT

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Background and Significance
Cochlear implant strategies universally employ an instantaneous compression curve to map bandpass amplitudes to currents within the electrical dynamic range. However, these strategies utilize the same compression curve for all electrode contacts, disregarding potential disparities in loudness growth functions (LGF) across distinct cochlear regions. Our previous work [1] revealed a correlation between electrode contact location and LGF steepness in a cohort of cochlear implant recipients. Additionally, we observed a relationship between subjectively perceived LGF and the evoked compound action potential amplitude growth function (ECAP AGF). The primary aim of this study is to implement channel-specific mapping laws in a practical setting and assess speech comprehension in noise using individually customized compression curves. We will compare three conditions: an ECAP AGF-based compression curve (ECAPMap), a psychophysically determined LGF-based compression curve (LOUDMap), and the clinical routine map featuring the standard compression curve on all channels (BASEMap).

Materials and Methods
We are recruiting 20 cochlear implant recipients with MedEl implants and fully inserted long electrode arrays (either standard 31mm or Flex 28) for the study. One-third of the participants will have single-sided deafness (SSD) with near-normal contralateral hearing. The study comprises three visits and two take-home phases. During the initial visit, we will determine ECAP AGFs and loudness growth functions across all electrodes. We will measure ECAPs using the AutoART function within the clinical fitting software Maestro, while assessing LGFs with the psychophysical software suite PsyWorks through a loudness scaling procedure. Participants will rate the perceived loudness of each stimulus on a scale ranging from "inaudible" to "too loud" [1]. Based on these measurements, we will generate and store the two new maps (ECAPMap & LOUDMap) in the subjects' processors. We will then evaluate the hearing performance of the BASEMap and the two new maps with individualized compression curves using the adaptive matrix test and ling sounds, complemented by aided thresholds and a sound quality assessment. We will randomly assign one of the new maps to participants for a four-week take-home experience, with performance evaluation occurring during the second appointment, repeating the previously mentioned measures. Subsequently, participants will spend another four weeks using the second new map, culminating in a third appointment at the study's conclusion. During the final appointment, we will evaluate all three maps (BaseMap, LOUDMap, and ECAPMap) one last time for a direct comparison.

Preliminary Results
We currently have data sets from the first appointment for three subjects. As observed in [1], the slope of the ECAP AGF and the subjective LGF appear to be subject- and electrode-specific, with ECAP curves becoming shallower toward the base of the cochlea, indicating a place dependency. Participants tolerated the new maps well during the acute comparison in the first appointment, and no performance differences were observed between the maps at that stage.

Conclusion
Subjects readily accepted the new maps and were willing to adopt them as their exclusive hearing program during the take-home phase of the study. Comprehensive data from the long-term utilization of these personalized compression curves will be presented at the conference.

M59: DEVELOPMENT OF A MACHINE LEARNING SYSTEM FOR PREDICTING COCHLEAR IMPLANT PERFORMANCE: ANALYSIS OF A LARGE RETROSPECTIVE DATASET

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Introduction and Study Goal
Hearing loss affects over 17% of the population and can significantly impact daily activities and quality of life. Cochlear implantation is a promising solution to restore hearing ability, but predicting its efficacy for individual patients is challenging. To address this, we developed a machine learning system using a large dataset of approximately 2000 adult patients who had post-lingual onset of hearing loss and underwent cochlear implantation. The dataset included epidemiological factors and clinical information, such as age and deafness duration at the time of implantation, preoperative pure tone audiometry results and word recognition scores. The target variable to predict was the average postoperative monosyllabic score one year after implantation.

Methods
Our system involved iterative stages, starting with exploratory data analyses to select appropriate features, build a data pre-processing pipeline, and train and evaluate decision tree models using k-fold cross-validation. The best-performing models were finally tested on a hold-out dataset, resulting in a mean absolute error of 20.5% with a standard deviation of 15.6%. The decision tree visualization graphs provided interpretable paths for the predictions, aiding clinicians in understanding the rationale and potential error of a prediction.

Results
Our system's predictive capabilities were evaluated on the recent implantation data from 2020-2021 period, resulting in a mean absolute error of 18% with a standard deviation of 13.1%. The results demonstrate the potential of machine learning methods in predicting cochlear implant outcomes and improving patient care. Further research is needed to investigate the generalizability of our system and the effect of additional clinical and demographic factors on prediction performance.

Conclusion
In summary, our machine learning system for predicting postoperative performance of cochlear implantation utilized a large dataset and involved exploratory data analysis, data pre-processing, decision tree models, and decision tree visualization graphs. The system achieved a mean absolute error of 18% with a standard deviation of 13.1%, demonstrating promising potential for improving patient care.

M61: COCHLEAR IMPLANT ELECTRODE IMPEDANCE SUBCOMPONENTS AS BIOMARKER FOR RESIDUAL HEARING

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Introduction: Maintaining the cochlea's structural integrity and preserving residual hearing are crucial for patients, especially those receiving electric acoustic stimulation. Electrode array insertion trauma may be reflected in impedances, which could serve as a biomarker for tissue health and residual hearing. This study aims to evaluate the association between residual hearing and estimated impedance subcomponents in a known collective from an exploratory study.

Methods: The study included 42 patients with lateral wall electrode arrays from the same manufacturer. Residual hearing was calculated using audiological measurements, impedance telemetry recordings were used to estimate near and far-field impedances using an approximation model, and anatomical information about the cochlea was obtained using computed tomography scans. We used linear mixed-effects models to evaluate the association between residual hearing and impedance subcomponent data.

Results: The progression of impedance subcomponents showed that far-field impedance was stable over time compared to near-field impedance. Low-frequency residual hearing demonstrated the progressive nature of hearing loss, with 48% of patients showing full or partial hearing preservation after 6 months of follow-up. Analysis revealed a statistically significant negative effect of near-field impedance on residual hearing (-3.81 dB HL per kΩ; $p < .001$), but no significant effect of far-field impedance.

Conclusion: Our findings suggest that near-field impedance offers higher specificity for residual hearing monitoring, while far-field impedance was not significantly associated with residual hearing. These results emphasize the potential of impedance subcomponents as objective biomarkers for outcome monitoring in cochlear implantation.

M62: REAL-TIME ANALYSIS OF INTRAOPERATIVE ELECTROCOCHLEOGRAPHY WITH SIMULTANEOUS IMPEDANCE MEASUREMENTS USING LINEAR STATE-SPACE MODELS

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Electrocochleography (ECochG) is increasingly used to monitor the inner ear function during cochlear implantation. The goal is to detect and avert detrimental effects during electrode insertion. Currently, ECochG-based trauma detection typically relies on an expert's visual analysis of the amplitude obtained from the fast Fourier transform (FFT). However, this approach shows low sensitivity and specificity. Therefore, we suggest to combine automated ECochG feature analysis with real-time impedance recordings.

In this study, we propose a framework for automated real-time analysis of intraoperative ECochG signals with simultaneous impedance measurements using computationally efficient Autonomous Linear State-Space Models (ALSSMs). We developed ALSSM based algorithms for noise reduction, impedance artifact elimination, and feature extraction. The feature extraction includes local amplitude estimation and a confidence metric over the presence of a physiological response in a recording. We tested the algorithms in simulations and validated them on actual patient data recorded during cochlear implantation.

The simulations show that the ALSSM method provides improved accuracy in the amplitude estimation (error decreased by 14% at 0dB SNR) together with a more robust confidence metric of ECochG signals compared to the state-of-the-art methods based on the FFT. Tests with patient data were encouraging in terms of clinical applicability and consistency with the findings from the simulations.

We showed that ALSSMs are a valid tool for real-time analysis of intraoperative ECochG. Elimination of artifacts using ALSSMs enables simultaneous recording of ECochG and impedance data. The proposed methods provide the means to automate the assessment of ECochG.

M63: VOCODERS AND OBJECTIVE MEASURES: HOW MUCH TO TRUST FOR DESIGNING NEW SOUND CODING STRATEGIES IN COCHLEAR IMPLANTS?

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Background: Cochlear implants (CI) have shown to have a good hearing restoring performance for speech in silent environments. However, the perception is significantly distorted in challenging environments like multi-talkers and music. One of the methods to solve these limitations is through the design of new coding strategies. However, validation of the performance of a new designed strategy and the underlying hypothesis behind it is costly and time consuming through clinical validations. Therefore, the use of vocoders (VOCs) and mathematical objective measures (MOMs), such as STOI and NCM among others, have been considered more than before.

Goal: As a CI manufacturer we have recently used vocoders and objective measures to assess the performance of a newly designed coding strategy. We think that there are some fundamental limitations in this approach that should be discussed with the CI field experts for hopefully finding better and more practical solutions.

Method: We designed a new CIS-based coding strategy and sent its output pulses to three different VOCs (Sine (Luo et al 2007), Noise (Shannon et al 1995), and Spiral (Grange et al 2017)). We used two widely accepted MOMs, NCM and STOI, to estimate the speech intelligibility of the vocoded sound where the input sounds include speech, music, POP music sounds that included lyrics , extracted from different database. The assessment was performed at different SNRs.

Results: Results varied depending on the different VOCs, music stimuli and MOMs. There was significantly higher STOI scores for Sine vocoded speech compared to using Noise ($\beta=1.17$, SE=0.11, $p<0.05$) and Spiral vocoders ($\beta=1.01$, SE=0.11, $p<0.05$) and only significantly lower NCM scores for Spiral vocoder compared to using Sine ($\beta=0.64$, SE=0.11, $p<0.05$) and Noise vocoders ($\beta=0.53$, SE=0.11, $p<0.05$). The difference also depended on the acoustic inputs: speech and music with lyrics showed similar order of difference but music inputs showed that sine vocoded speech having the highest STOI ($\beta=0.55$, SE=0.09, $p<0.05$; $\beta=0.47$, SE=0.03, $p<0.05$) and NCM scores ($\beta=0.14$, SE=0.03, $p<0.05$; $\beta=0.39$, SE=0.01, $p<0.05$).

Discussions: Our results indicate that one may get quite different interpretations when comparing different CI strategies using this methodology, depending on the chosen VOC or MOM and their combination. We are wondering if using the VOC-MOM method might even mislead the researchers towards wrong design paths. The main issue is that the potential benefits of a CI strategy should be verified by a compound method that has two levels of uncertainty (i.e., VOC and MOM) that need to be validated individually. VOC evaluations by CI patients with single-sided deafness have shown that the preference of VOC is very subjective. However, each VOC's functionality is based on various assumptions that differ from one another. As a result, VOCs cannot guarantee that they accurately present all aspects of the benefits and improvements of newly developed coding strategies in their vocoded sounds. Although designing a strategy-specific vocoder is beneficial, it must undergo validation first. Thus, different VOCs must undergo statistical examination (e.g., sensitivity measurement, test-retest reliability, dropout testing). The second level of ambiguity is generated at the MOM level. Current MOMs assume similarity to unprocessed speech audio wave as a measure of the information transfer in the CI device. This is not so reliable to quantify the differences between coding strategies. Accentuating certain aspects of the original signals could be helpful to CI patient, and different physical features have different perceptual importance. Therefore, the CI community need to work on the definition of what is a better information transfer for CI In addition to the abovementioned ambiguities, we should add the mismatched outcomes between an acute testing clinical protocol and the VOC-MOM method due to acclimatization of the strategy. MOMs assume an ideal outcome, which will not appear in acute clinical testing. A predicted acute testing outcome that includes margin of error in acclimatization and evolution in time would be useful for estimating the realistic strategy effectiveness.

M64: DEVELOPING A NEW TEST-BENCH FOR SCREENING EFFECTIVE NEXT-GENERATION SPEECH PROCESSING ALGORITHMS FOR COCHLEAR IMPLANTS

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Improving cochlear implant (CI) user's speech performance with new signal processing algorithms is a significant challenge faced by CI manufacturers. Clinical studies are used to test new proposals and determine whether they should be integrated into products. However, conducting such studies for every new proposal is not feasible due to time and cost constraints.

To address this issue, we propose another approach featuring an evaluation test-bench that helps to select a new CI signal processing design by predicting patient performance improvements using mathematical models. Our approach focuses on selecting denoising algorithms but can be adapted for other signal processing algorithms.

Speech understanding can be particularly challenging for CI users in noisy environments, such as multi-talker noise (also known as babble noise, cocktail party noise), road traffic noise and static noise. To improve intelligibility in such conditions, denoising algorithms have been added to CI sound processors. Our evaluation test-bench aims to have a first set of metrics that may reflect the performance of CI users for speech in noise. To predict speech intelligibility, we used the extended short-time objective intelligibility (eSTOI) and normalized covariance metric (NCM) objective measures.

Factors such as the denoising algorithm, background noise type, signal-to-noise ratio (SNR), and distortion are considered in the evaluation. To cover all factors, we created our own sound bank, which contains 19 tracks of clean speech mixed with three different background noises (babble, traffic, and white noise) at different SNRs. Those sound files were duplicated to create versions with speech reverberation as well. In addition, the ability to preserve a non-speech sound of interest is also considered, by mixing target sounds such as a car horn and siren with background noise as part of our sound bank. Each sound file was processed by four different denoising algorithms, such as novel deep learning-based and classical signal-processing based algorithms.

The evaluation test-bench contains three steps. In the first step, we compute the eSTOI and NCM values for each file processed by a denoising algorithm. In the second step, each file is passed through both the denoising algorithm and a simulation model that executes the CI signal processing. The electrodogram output of the simulation model is then recomposed into a time-domain signal with a vocoder. eSTOI and NCM are computed again considering the clean speech passed through the same simulation chain as reference. For both steps, a baseline value is computed by considering the speech in noise file with no denoising processing, in order to set the performance of algorithms into context. Finally, a subjective evaluation with Normal Hearing is conducted to determine if the denoising algorithm effectively removes noise while preserving important sound information.

We will show the results of the first execution of this evaluation test-bench. Next steps will be to better understand the result variability and increase the number of sound files. Then, the results of this test-bench will be compared with results from listening tests on CI users to validate the approach.

M65: STREAMLINED COCHLEAR IMAGE ANALYSIS: ENHANCING AN AI-POWERED TOOL FOR LARGE-SCALE POPULATION STATISTICS AND ACCURATE 3D MODELLING

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Accurate modelling of cochlear anatomy and electrode placement is crucial for successful cochlear implant therapy. In this work, we will describe our latest advancements and applications of Nautilus [1], a web-based imaging pipeline for the field of otology and cochlear implantation designed at Oticon Medical. This tool automatically extracts 3D cochlear models from CT (Computed Tomography) images, computes the relevant cochlear measurements, detects the electrode array within the cochlea, and offers tonotopy mapping.

Although the core processing of Nautilus is automated, it still requires initial human interaction such as scrolling through the CT image slices and manually locating and annotating the centre of the region of interest, assigning the left or right side to it, and whether the image comes from a pre- or a post-operative image sequence. In this work, we show how, with the help of artificial intelligence and deep learning techniques, we have removed some of the last remaining manual steps and fully automated the entire pipeline. This new streamlined process eliminates the need for manual steps, saving time and reducing the potential for human error. Moreover, this opens the tool to a much wider audience, possibly with less experience with reading radiological images. As a result, the 3D modelling of the cochlea and the electrode array including the relevant measurements can be automatically performed after a simple drag and drop of the image files onto the web browser window.

We validated our tool on a dataset of more than 1000 cochleae and demonstrate its effectiveness in processing large datasets. To enhance research applications, our tool automatically generates comparison of the new cochleae with population statistics and allows for quick export of relevant metrics for future statistical analysis.

Our work shows the power of artificial intelligence techniques in advancing cochlear image analysis and implant therapy. We show their capabilities to reduce time and effort needed for manual data pre-processing and why they belong to an important set of tools for the otology and cochlear implantation community.

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M66: WAVEFORM MORPHOLOGY OF INTRAOPERATIVE ELECTROCOCHLEOGRAPHY

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Cochlear implant (CI) candidates increasingly have residual acoustic hearing, which should be preserved despite the surgery. Therefore, it is important to monitor the health of the inner ear during implantation, e.g., with electrocochleography (ECochG). Intracochlear CI electrodes can record hair cell potentials and early nerve responses intraoperatively. The present work examines how the morphology of these ECochG signals differs between individuals and how it may change during electrode insertion.

In this prospective study, we recorded real-time ECochG using pure-tone stimulation during electrode insertion in 50 CI recipients. We used autonomous linear state-space models (ALSSMs) to robustly parameterize the morphology of individual ECochG responses. The applied ALSSMs separately reproduced the signal onset as well as the sinusoid reflecting the acoustic stimulus in the physiological response. The extracted features were the amplitude, phase, latency, and envelope shape. We compared the features between individuals and examined their temporal variation during electrode insertion.

The ECochG signals had an average peak amplitude of 15uV, a latency of 1.76ms, and a rise time of 2.75ms, measured from signal onset to the beginning of the ongoing portion. The data showed that similar ECochG morphologies occurred in several individuals. In addition, we observed an intra-individual variation in ECochG morphology during electrode insertion. In many examples, single features changed coherently at different stages of the insertion process.

We have shown that intraoperative ECochG morphology depends on the progression of the implantation phase and local intracochlear conditions. Therefore, morphology may provide information about inner ear function and electrode location. These findings will support intraoperative ECochG analysis and could help to differentiate between traumatic and atraumatic signal changes. In a further step, the relationship between the extracted features and residual hearing must be investigated.

M67: PRINCIPAL COMPONENTS ANALYSIS OF AMPLITUDE ENVELOPES FROM SPECTRAL CHANNELS: COMPARISON BETWEEN MUSIC AND SPEECH

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Introduction: The efficient coding approach (Smith & Lewicki, 2006) predicts that perceptual systems are optimally adapted to natural signal statistics. According to this view, sensory systems evolved to encode environmental signals in order to represent the greatest amount of information at the lowest possible resource cost. Previous studies applied Factor Analysis (FA) on amplitude modulations channels from natural speech signals in order to estimate optimal frequency boundaries between channels. While some authors argued that 4 channels would be sufficient to represent the main contrastive segmental information in natural clean speech (Ueda & Nakajima, 2017), comparison of speech statistics with perceptual performance led to suggest that 6 to 7 frequency bands would be required to optimally represent vocoded speech (Grange & Culling, 2018). However, research on music perception in cochlear implanted listeners sheds light on potential limits associated with this hypothesis. Indeed, performance observed on vocoded signal material in normal-hearing listeners as well as in cochlear implant users is systematically better for speech signals than for music (Galvin et al.,2009; Crew et al., 2015). It is therefore crucial to compare statistical properties of music and speech in order to reach a better understanding of the relation between characteristics of various auditory communication signals and their possible optimal coding in auditory perception. We applied the same FA method on 2 different sets of data: (1) a database of free music recordings (Free Music Archive, https://github.com/mdeff/fma), (2) a free corpus of speech signals (Clarity Speech,https://doi.org/10.17866/rd.salford.16918180).

Method: Analyses were carried out using the Matlab environment and mirrored previous studies. Sample signals were passed through a gammatone filterbank (1/4th ERB bandwidth, approx. 100-120 channels depending on the higher-frequency limit) and their energy envelope was extracted. This amplitude modulation matrix was then run through FA, and Principal Components (PCs) were independently rotated. Channels that covary in amplitude envelope should be grouped as a single Principal Component. As our aim was to compare speech and music, for which typical signal bandwidths differ, two higher-frequency limits were compared (8000 Hz vs. 16000 Hz).

Results: Contrastive analyses of music and speech data exhibit the same amount of variance explained in relation to the number of PCs, e.g. 95% for 32 PCs and 75% for 16 PCs. Focusing on a reduced number of PC combinations that would compare to previous conclusions on speech according to which 4 to 7 PCs would be optimal, we find that cumulative explained variance is similarly located between 35% and 50% for music and between 39% and 52% for speech. Looking at factor loading curves however, obvious differences occur in music and speech in the distribution of factor loadings among the frequency channel boundaries. We are finalizing the automation of the frequency boundary computation. Perceptual studies are in preparation that will help assess the validity of these boundaries for the recognition of melodies and the perception of f0 in speech.

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M68: ESTIMATION OF INTRACOCHLEAR ELECTRODE POSITION FROM COCHLEAR IMPLANT IMPEDANCE TELEMETRY

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Previous studies have demonstrated a significant role of cochlear implant electrode position on hearing outcomes. Although certain electrode arrays are specifically designed for close placement to both the modiolar wall and the target neural elements, individual differences in cochlear geometry and surgical technique, in combination with a lack of visibility by the surgeon, may lead to undesired variability in final electrode position. Intra-operative radiographic imaging shows promise for enabling surgeons to further optimise electrode position and demonstrates the utility of surgical feedback; however, this adds expense and exposure to radiation to the procedure. Here we investigate the feasibility of intraoperative transimpedance matrix (TIM) measurements, in combination with statistical simulations, to estimate intracochlear electrode position of Slim Modiolar electrode arrays (Cochlear Limited: CI532, CI632). Models for estimating 2-dimensional projections of the lateral wall and modiolar wall spirals, from linear measures of cochlear size, were made from micro-CTs from cadaveric temporal bones. An algorithm was then designed and trained on a large dataset (84 patients) of intraoperative TIMs and intracochlear electrode positions, as derived from post-op CT. This algorithm was then validated with an independent dataset of 19 patients. The validation shows a positional root mean square error (RMSE) for individual electrode contacts of 0.28 mm for distance to the mid-modiolar axis and 14.7° for angular depth. Such an algorithm may be valuable to surgeons at the point of electrode insertion by providing timely feedback for optimising electrode position and ultimately outcomes.

M69: AUTOMATIC CLASSIFICATION OF CONGENITAL INNER EAR MALFORMATIONS FROM CT IMAGES USING UNSUPERVISED DEEP METRIC LEARNING FOR 3D SHAPES

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Congenital hearing loss in children is often caused by inner ear malformations, which can be challenging to detect and classify using standard imaging techniques. Radiological examination is crucial for an early diagnosis of these malformations, especially when cochlear implant therapy is planned, as it is prescribed to about 80,000 infants and toddlers globally each year. However, traditional classification methods based on explicit measurements and visual analysis of CT scans are time-consuming and subject to clinician subjectivity. Thus, automated classification methods are needed to aid in the diagnosis and treatment of inner ear malformations.

In this study, we present the first automated method for classifying congenital inner ear malformations. We generate 3D cochlear surfaces of the cochlear structure from 364 normative and 107 abnormal anatomies using the Nautilus pipeline in CT images. The pipeline was trained exclusively on normative anatomies and produces only rough yet consistent segmentations of the abnormal anatomies. To find a representation of the 3D shapes that can be used for classification we use a machine learning technique that can handle sparse and unbalanced datasets, we use the DeepDiffusion algorithm. In this approach, we use the PointNet neural network architecture for network-based unsupervised feature learning and combine it with the diffusion distance on a feature manifold. The manifold results in a representation where similar shapes are closer together and the less similar ones are further away. This unsupervised approach captures the variability of the different cochlear shapes and generates clusters in the latent space that faithfully represent the anatomical variability. A model based on shape characterization allows us to bypass the processing challenges intrinsic to a heterogeneous dataset that consists of images from different sources. We evaluate our method with the professional diagnosis of an ENT surgeon specialized in congenital inner ear malformations. We report a mean average precision of 77% over the seven main pathological subgroups present in our dataset: cochlear aplasia, common cavity, incomplete partitioning type I, II, and III, cochlear hypoplasia, and healthy anatomy. These results are very promising considering the challenges involved in this task.

In conclusion, we propose the first approach for the automatic classification of congenital inner ear malformations with promising results for clinical support in the detection and identification of congenital inner ear malformations. Our method uses state-of-the-art image processing software using artificial intelligence and computer vision to identify the type of malformation based on the anatomical 3D structure of the cochlea.

M70: A NOVEL, VALIDATED CI ELECTRODE LOCATION PREDICTION METHOD FOR IMPROVED PREOPERATIVE PLANNING

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In cochlear implantation, current preoperative planning procedures allow for estimating how far a specific implant will reach into the inner ear of the patient, which is important to optimize hearing preservation and speech perception outcomes. Here we report on the development of a methodology that goes beyond current planning approaches: the proposed model does not only estimate specific outcome parameters but allows for entire, three-dimensional virtual implantations of patient-specific cochlear anatomies with different types of electrode arrays. The model was trained based on imaging datasets of 186 human cochleae, which contained 171 clinical computer tomographies (CTs) of actual cochlear implant patients as well as 15 high-resolution micro-CTs of cadaver cochleae to also reconstruct the refined intracochlear structures not visible in clinical imaging. The model was validated on an independent dataset of 141 preoperative and postoperative clinical CTs of cochlear implant recipients and outperformed all currently available planning approaches, not only in terms of accuracy but also regarding the amount of information that is available prior to the actual implantation.

TUESDAY POSTER ABSTRACTS

T1: DETERMINATION AND COMPARISON OF TWO MEASUREMENT PARADIGMS OF ELECTRICALLY EVOKED COCHLEAR NERVE RESPONSES AND THEIR CORRELATION TO COCHLEAR NERVE CROSS-SECTION IN INFANTS WITH COCHLEAR IMPLANT

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Introduction: Electrically compound action potentials (ECAPs) are used for intra-/ postoperative monitoring with intracochlear stimulation of cochlear implants (CI). ECAPs are recorded in MED-EL implants using auditory nerve telemetry (ART), which has been further developed with automatic threshold determination as AutoART. The success of an ECAP-measurement also depends on the number of available spiral ganglion cells (SGC), the bipolar neurons of the cochlear nerve (CN). It is assumed that a higher population of SGC implies a larger CN-cross-sectional area (CSA), which consequently affects ECAP measurements.

Methods: Retrospective intraoperative ECAP-measurements from 19 implanted ears of children aged 8-18 months were evaluated. A comparison and correlation of ECAP-thresholds and -slopes (ART and AutoART) at electrodes E2 (apical), E6 (medial), E10 (basal), and averaged E1 to E12 with CN-CSA on MRI was performed.

Results: A Pearson correlation of the ECAP-thresholds and -slopes for E2, E6, E10, and the averaged electrodes E1 to E12 for ART and AutoART showed a significant correlation. The CN-CSA did not correlate significantly with the averaged ECAP-thresholds and -slopes for ART and AutoART across all twelve electrodes.

Summary: AutoART provides reliable measurements and is therefore a good alternative to ART. A significant influence of CN-CSA on ECAP-thresholds or -slopes was not observed. A predictive evaluation of the success of ECAP-measurements based on CN-CSA for a clinical setting cannot be made according to the present data.

T2: DEVELOPING COCHLEA-ON-A-CHIP MODEL FOR ADVANCING COCHLEAR IMPLANT PERFORMANCE AND ELECTRODE-NERVE INTERFACE STUDY

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Introduction:
Cochlear implants (CIs) are a type of medical device that can restore hearing in individuals with hearing loss by providing electrical stimulation to spiral ganglion neurons (SGNs)/ primary auditory neurons (PANs). However, the success of CIs depends on the quality of the electrical interface with SGNs, which is a major limitation of CI performance. Currently, there is a lack of reliable in vitro models for testing strategies for the electrical stimulation of SGNs. Clinical measures are limited, and animal models do not replicate human cochlear anatomy or physiology.

Methods:
To address this gap, we have been developing an in-vitro Cochlea-on-a-Chip model that replicates the current spread in the human cochlea caused by CIs and embeds SGNs and multielectrode arrays (MEAs) to record neural responses. The Cochlea-on-a-Chip model includes rat SGNs or human induced pluripotent stem cell (hiPSC)-derived SGNs, custom microelectrode arrays (MEAs) to measure electrical activity, and custom-designed 3D printed microfluidic chips to replicate the current spread of the human cochlea. Our microfluidic device design has been optimized to accurately represent the scala tympani (where CIs sit in the cochlea) and ensure reproducible 3D printing and casting of the features of the PDMS cast model. We have tested the chips with rat SGNs and hiPSC-derived SGNs and have measured their firing activities in response to varying electrical stimuli. We also use the simulation software COMSOL to validate the voltage spread of chips.

Results:
Our Cochlea-on-a-Chip model has demonstrated successful casting of microfeatures and survival of rat SGNs and glial cells for over a month. SGNs have extended neurites towards the CI channel, and hiPSC-derived SGNs have displayed similar morphology to rat SGNs and expressed a neuronal marker TUJ1. We have also measured the action potential profiles of both rat SGNs and hiPSC-derived SGNs on commercial MEAs. These neurons were cultured onto commercial MEAs and measured for their ability to develop spontaneous action potentials and their response to electrical stimulation. We showed that the action potential profiles of stem cell-derived SGNs are very similar to rat SGNs also grown on MEAs. On COMSOL, we validated that the voltage spread on our model fits the patient data from a CI.

Conclusion:
Our Cochlea-on-a-Chip model enables the rapid evaluation of existing technologies and the development of new CIs and hearing loss treatment strategies. By testing the relationship between SGN behaviour and varying electrical stimulation parameters such as pulse shape, amplitude, and duration, we hope to advance cochlear implant performance and study the electrode-nerve interface. The model is very important for modelling current spread and obtaining realistic measurements, which will help to improve CIs and understand the electrode-nerve interface.

T3: INVESTIGATING THE ELECTRODE-ELECTROLYTE INTERFACE MODELLING IN COCHLEAR IMPLANTS

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Objective: Cochlear implants (CIs) aim to restore hearing through electrical stimulation of specific auditory nerve fibers. The auditory neural response to the stimulation pulses is dependent on the electrode-electrolyte interface (EEI). Therefore, proposing a good EEI model and properly identifying relevant parameters are crucial for CI stimulation and recording optimization. However, the state-of-the-art and related literature exhibit large variability among EEI model parameter values. We aim to explain some root causes of this variability using the Cole model and its simpler form, the Basic RC model.

Method: We use temporal and frequency methods and fit the models to both chronopotentiometry voltage response (CVR) and electrochemical impedance spectroscopy (EIS) data. Oticon Medical CI electrodes (Pt:90%, Ir:10%, Area: 0.46 mm2) were used in this study. CVR and EIS data were gathered on 10 electrodes inserted in artificial perilymph. CVR measurements were obtained using anodic-first rectangular stimulation pulses of 180 µs/phase. We used 10 different current amplitudes ranging from 100 to 2000 µA. EIS data was obtained using 10 mV sinusoidal signals and frequency variation from 0.05 Hz to 1 MHz.

Results: The results of the temporal fitting show that there are multiple sets of model parameters that provide a good fit to the CVR data. Therefore, small methodological differences in literature may result in different model fits. The models share similar characteristics at high frequencies, greater than ~500 Hz. However, the CVR fitting method is blind to low frequencies, thus it cannot correctly estimate the Faradaic resistor (reported values vary from a few kΩ to several MΩ). Similarly, estimation of the fractional order n and the capacitance are not robust due to limited observation of mid-range frequencies. Consequently, the fractional order may vary from 0.6 to 1, and the capacitor value may vary from the nano- to microfarad range, as it changes exponentially with the fractional order.

EIS frequency analysis provides a good single-component Cole model fit over a wide range of frequencies down to ~3Hz. At lower frequencies, charge mechanisms may modify the EEI, requiring multi-compartment Cole model fitting to EIS to improve the estimation of Faradaic characteristics. Our EIS data measurements down to 0.05Hz show that a single-compartment Cole model cannot explain the measured data properly, whereas a two-compartment Cole model is sufficient to fit the data.

Conclusion and Significance: Our study describes the scope and limitation of CVR and EIS fitting methods, explaining literature variability among CI EEI models. Caution should be used when making statements about physical interpretations of a CI EEI based on the outcome of a model. The estimation of mid-to-low-frequency characteristics of the CI EEI is not in the scope of the CVR method. EIS provides a better fit; however, its results should not be extrapolated to unobserved frequencies where new charge transfer mechanisms may emerge at the EEI.

T4: RESPONSIVENESS OF THE ELECTRICALLY STIMULATED COCHLEAR NERVE IN CHILDREN WITH INCOMPLETE PARTITION TYPE 2

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Background: The auditory function of patients with inner ear malformation (IEM) is not well understood, making their clinical management challenging. Previously, we showed that children with cochlear nerve deficiency (CND) have significantly poorer cochlear nerve (CN) function than children with normal-sized CNs (He et al. 2018). This study expanded this line of research by including implanted patients with incomplete partition type 2 (IP2). IP2 is characterized by a normal-sized cochlea and basal turn but the absence of the apical part of the modiolus and corresponding interscalar septa (Sennaroğlu & Bajin 2017; Brotto et al. 2021). We evaluated the responsiveness of the CN to a single biphasic-electrical pulse in implanted children with IP2 and compared their results to those of implanted children with CND and normal-size CNs. We hypothesized that the functional status of the CN in children with IP2 would be (1) better than in children with CND and (2) worse than in children with normal-size CNs.

Methods: To date, sixteen children with IP2, seventeen children with CND, and eighteen children 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 electrically evoked compound action potential (eCAP) amplitude growth function (AGF) and eCAP refractory recovery function (RRF) were measured at seven electrode locations across the electrode array. Both functions were measured with a charge-balanced, cathodic leading, biphasic electrical pulse. The eCAP parameters used in this study included the refractory recovery time estimated based on the eCAP RRF, the eCAP threshold, the maximum eCAP amplitude, the slope of the eCAP AGF, the negative-peak (i.e., N1) latency, and the electrode-neuron interface (ENI) index. The effects of subject group and electrode location on each eCAP parameter were assessed using linear mixed-effect models (LMMs).

Results: Children with IP2 had significantly shorter absolute refractory recovery times, lower eCAP thresholds, shorter N1 latencies, and higher ENI indices than children with CND. No statistically significant difference was observed in the slope of the eCAP AGF and the maximum eCAP amplitude between these two groups. Meanwhile, children with IP2 had significantly higher eCAP thresholds and smaller maximum eCAP amplitudes than children with normal-sized CNs. No statistically significant group difference was observed in the absolute recovery time, the slope of the AGF, the N1 latency, or the ENI index. Electrode location did not significantly affect any eCAP parameter for the IP2 group or the normal-sized CN group but was a significant factor for the CND group.

Conclusion: Electrically stimulated CNs in children with IP2 show better responsiveness than those in children with CND. As indicated by the results of some eCAP testing paradigms, children with IP2 appear to have worse responsiveness of their CNs to electrical stimulation than children with normal-sized CNs. Electrode location is not a major factor affecting the quality of the ENI in children with IP2, which is different from the electrode location effect observed in children with CND.

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T5: UTILITY OF THE PITCH RANKING PROCEDURE IN THE INDIVIDUALIZED MAPPING OF COCHLEAR IMPLANT RECIPIENTS

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Objectives
Cochlear implant (CI) recipients vary widely in speech recognition outcomes. One source of this variability could be poor spectral resolution due to an inability to discriminate pitch differences between stimulation from adjacent electrode contacts (non-discrimination) or a perception of a reversal in pitch relative to normal cochlear tonotopicity (pitch reversal). There is a pitch ranking procedure that assesses the perceived pitch between stimulation of adjacent electrode contacts and determines whether stimulation results in discrete differences, non-discrimination, or pitch reversals. This information could be useful in the mapping of CI and electric-acoustic stimulation (EAS) devices. The present report evaluated the incidence of pitch reversals and non-discriminations for CI and EAS users, and whether modifications to the map to create discrete pitch perceptions across active channels resulted in improved sound quality and/or speech recognition for the patient.

Design
Adult CI and EAS users completed a pitch ranking procedure at the 3- or 6-month post-activation interval. Participants were recipients of either a 24- (n=12), 28- (n=11), or 31.5-mm (n=39) lateral wall electrode array. The pitch ranking procedure was a two-alternative forced-choice task. Participants were presented with stimulation from two adjacent electrode contacts sequentially following a randomized presentation pattern and instructed to indicate which stimulus was higher in pitch. A minimum of 7 trials were completed for each contact pair comparison to determine whether stimulation followed cochlear tonotopicity, were reversed, or were non-discriminable. For cases of pitch reversals or non-discrimination, mapping adjustments, such as adjusting the filter frequencies or deactivating channels were completed in attempt to improve the sound quality and provide discrete pitch percepts across all active channels. Speech recognition was evaluated with CNC words in quiet and AzBio sentences in a 10-talker masker in 3 target-to-masker conditions.

Results
Of the 62 participants at the time of data review, 18 individuals demonstrated pitch reversals (n=5), non-discrimination (n=8), or both (n=5). The effected electrode contacts were noted across the electrode array. For these cases, better sound quality was reported and/or speech recognition improved after mapping adjustments to create discrete pitch perceptions across the active channels.

Conclusions
Pitch reversals or non-discrimination between adjacent electrode contacts was observed in approximately 29% of CI and EAS users. Including the pitch ranking procedure in the mapping of CI and EAS devices can identify pitch reversals or non-discrimination between adjacent electrode contacts that may negatively influence outcomes with the device. Mapping manipulations to potentially improve discrete pitch perception may results in better outcomes with the CI or EAS device.

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T6: THE ASSESSMENT OF ELECTRODE-NEURON INTERFACE IN CHILDREN AND ADULTS WITH COCHLEAR IMPLANTS

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Despite the fact that cochlear implants (CIs) have been very successful in restoration of hearing ability to many people with severe to profound hearing loss, there are some CI users who cannot take enough benefits from them. The quality of the interface between CI electrodes and spiral ganglion neurons may influence CI outcome. Poor electrode-neuron interface could reduce optimal signal delivery or create interactions between the electrical fields or overlap between excited neurons. In addition, the size and density of the spiral ganglion neurons might be influential factors for signal transmission to the central and cortical auditory system for perception. Electrical compound action potentials (eCAPs) have been suggested for the assessment of the electrode-neuron interface and spiral ganglion density assessment. Animal and computational modelling studies have shown changes in eCAPs measures (e.g., threshold, amplitude-growth function, and amplitude) could reveal changes in electrode-neuron interface and spiral ganglion density. However, the results in human CI population need more clarification as the etiology, electrode impedance, electrode position inside cochlea and distance to neurons and pattern of neural degeneration are different from those in animals.

In this study, eCAPs were recorded while the gap length between the negative and positive phases of CI biphasic signals were changed (inter-phase gap or IPG effect). Since previous studies showed children and adult had different amount of the spiral ganglion density, two groups of CI users (children and adults) participated in this study. They had at least one year of experience with their CIs. They all had perimodiolar electrode arrays. Mixed model analysis was used to assess between- and within-group differences on IPG effect. Due to the spread of neural excitation in monopolar mode of stimulation, IPG effect was assessed after compensation for spread of neural excitation. In addition, electrode impedance was entered into analysis as covariate. The analyses were done for electrodes in three locations inside the cochlea (base, middle, apex). The correlation between electrode discrimination and spread of excitation was also assessed.

The preliminary data analysis showed that some of the eCAPs measures like threshold of eCAPs were influenced with spread of neural excitation while none of the measures changed with physical impedance. Slope of the amplitude-growth was not influenced by spread of excitation. Therefore, the measures influenced with spread of excitation could not exclusively inform about spiral ganglion density.

T7: INVESTIGATING ELECTROCHEMICAL SAFETY LIMITS OF NEURAL STIMULATING ELECTRODES

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Background: The neurons are electrically stimulated by applying charged pulses from a stimulating electrode, thereby creating an ionic gradient in the local environment of the neuron. This rearrangement of ions at the neuronal membrane and extracellular matrix, creates an action potential. Stimulation of neurons were used to provide sensory input, as successfully demonstrated by cochlear implant devices. For efficient stimulation, electrode-neuron interface, biocompatibility and biosafety are the most crucial part in mediating the stimulation from the electrode to extracellular space to target neurons. In this work, we have studied the electrochemical properties of nano/microscopic topographic structure of stimulating electrode and their influence on the safe stimulation strategies.

Methods: For this study, Oticon Medical EVO electrodes were used. The electrodes were characterised for both physical and electrochemical properties using SEM (Sorbonne University) and AFM (Faculty of Medicine, University of Cote D'Azur), whereas Princeton Applied Research Parstat MC potentiostat with a three-electrode system in Artificial Perilymph (AP) electrolyte set-up for electrochemical characterisation and stimulation safety investigations. Electrode corrosion was evaluated by employing ICP.

Results: In this work, we have studied the electrochemical properties of nano/microscopic topographic structure of EVO electrode and their influence on the safe stimulation strategies. The influence of topographic variation was studied by understanding the electrochemical surface properties. The charge injection and storage capacity, and charge density were calculated for geometric and electrochemical surface area of the electrodes. The evaluation of the biosafety was explored by calculating the concentration: of the Pt corrosion, with respect to stimulation pulse.

Conclusion These analyses offer better understanding of the electrochemical safe limits of the electrode in terms of deliverable current, safe window potential and electrode properties. It is also substantiating the discrepancies in determining the safe limit depending on the outlook of the surface property and electrode area. This information is vital to build on novel stimulation strategies and electrodes for better, safe and efficient neuronal activation.

T8: GETTING MORE AUDITORY-NERVE BANG FOR YOUR FACIAL-NERVE BUCK: EFFECTS OF PULSE SHAPE ON LOUDNESS AND FACIAL-NERVE ACTIVATION IN COCHLEAR-IMPLANT LISTENERS

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Facial-nerve (FN) activation by cochlear-implant (CI) electrodes can require those electrodes to be re-programmed or turned off. We investigated the effects of two manipulations – increasing phase duration and using asymmetric pulses – that have been proposed to reduce FN effects. Both implicitly assume that the proposed manipulation reduces the current needed for the so-called Most Comfortable Loudness level (MCL), but produces a smaller or no reduction in the FN threshold ("FNT"), thereby increasing the Facial-Auditory Nerve Gap ("FANG" = FNT-MCL). Method 1 involved 8 patients undergoing implantation of an Advanced Bionics (AB) CI. FNTs were estimated intra-operatively for single pulses using the clinical FN monitor; MCLs were obtained post-operatively using loudness scaling and 500-pps or 70-pps pulse trains. Intra-operative stimuli were single symmetric cathodic-leading biphasic pulses with phase durations of 32 and 150 µs ("SYMC32" and "SYMC150"), pseudomonophasic pulses with 1st/2nd phase durations of 32/256 µs and with the first phase either anodic or cathodic ("PSA", "PSC"), and triphasic pulses with a 150-µs central phase flanked by two 75-µs flanking phases and with an anodic or cathodic central phase ("TPA", "TPC"). No FN response was observed for the SYMC32, PSA, or PSC pulses at safe stimulus levels. For 4 patients FN stimulation was observed for the TPC pulses and with the FNT for TPA pulses between 0 and 3.5 dB higher, supporting the clinical use of anodic-dominant asymmetric pulses to minimise FN effects.

Method 2 measured MCLs with three awake patients known to experience FN activation, and measured behavioural FNTs and electrophysiological growth functions. Stimuli for both measures were 40-pps pulse trains using the same pulse shapes as in Method 1 plus symmetric pulse shapes with the anodic phase leading (SYMA32, SYMA150). For one patient, who had a Cochlear CI, the TPA and TPC pulses were approximated using quadraphasic pulses (QPA, QPC). For all patients FNTs were lower for "cathodic-dominant" than for "anodic dominant" pulse shapes, both for symmetric (SYMC32 < SYMA32) and asymmetric (TPC)

Method 3 simulated MCLs by passing stimuli through a finite-element cochlear model combined with 1500 AN neurons based on Rattay's multi-compartment cable model (Brochier et al, 2021). The FNT was estimated using a multi-compartment cable model of a single FN neuron; input to this FN model was obtained from facial-nerve-canal recordings in cadaver heads. The model successfully predicted both the effect of polarity on MCLs and the fact that this effect was larger than that observed at detection threshold. The predicted effect of polarity on FNTs depended on which cadaver-head recording formed the input to the model, with a mean value close to zero. The model is undergoing further development. Overall, the study provides evidence that supports the use of anodic-dominant pulse shapes to increase FANG but only mixed evidence to support the clinically used method of increasing phase duration.

T9: EFFECTS OF STIMULUS POLARITY ON LATENCY OF THE EVOKED POTENTIAL IN PATIENTS WITH AN AUDITORY BRAINSTEM IMPLANT

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The measurement of the electrically evoked compound action potential (ECAP) is widely used in cochlear implant (CI) patients to provide evidence of a functioning electrode-nerve interface, to confirm proper location of the electrode array and to program the sound processor. In patients with an auditory brainstem implant (ABI), a likewise versatile measure would be desirable. Recent studies on evoked potentials (EPs), recorded with ABI electrode arrays placed on the cochlear nucleus [1], showed presence of EP responses being similarly predictive (compared to CI [2]) of auditory perception. Nevertheless, evaluation of placement of the array on the cochlear nucleus and/or indications for programming of the sound processor based on EPs requires detailed knowledge about the electric field propagation respectively nerve excitation processes.

Here, basic excitation properties were investigated in eight subjects (four subjects <15 years, one subject 33.8 years, and three subjects >58 years) implanted with an ABI from MED-EL (Innsbruck, Austria). Amplitude growth functions (AGFs) of the EPs were measured using symmetric charge-balanced biphasic pulses, separately in cathodic-anodic (CA) and anodic-cathodic (AC) arrangement, using the revised forward-masking paradigm [3] for artefact reduction. A default phase duration of 40 µs was used and, only in case the desired intensity of 35 qu could not be reached due to higher electrode impedance, it was prolonged to 60 or even 100 µs. The inter-phase gap was fixed at 2.1 µs, and the EPs were recorded always at four contacts for each electrode of the array.

While AGF parameters (threshold and slope) did not show significant differences between AC and CA pulses, the latency of the dominant positive peak in the EP trace differed between AC and CA pulses, and the latency difference between AC and CA pulses matched well with the chosen phase duration.

These results indicate a dominant excitation via the cathodic phase and only minor influences of the anodic phase on the excitation process of electric stimuli at the cochlear nucleus.

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T10: CI STIMULATION PARAMETERS PLAY A KEY ROLE IN REDUCING FACIAL NERVE STIMULATION

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The proportion of CI users affected by unwanted facial nerve stimulation (FNS) is estimated to be >5%. For some sufferers, the effort to control this problem involves changing stimulation parameters, thereby reducing CI performance. For others, using their CI becomes impossible. A growing body of case studies suggests that unwanted FNS can be treated by re-implantation with an Oticon Medical (OM) Neuro-Zti implant [1][2][3][4]. But why? Does the benefit arise from surgical adjustments—e.g., different array geometries and positioning—or from different stimulation parameters and/or grounding [5]? Indeed, the OM device has both: (1) atypical stimulation parameters, including anodic leading pulses and loudness controlled by pulse duration instead of amplitude—leading to pulses with generally lower current amplitudes and (2) atypical grounding, utilizing a distributed grounding scheme—one that is neither monopolar nor bipolar/tripolar—and passive (capacitive) discharge that affects the pulse shape. Case studies alone cannot disentangle surgical factors from these implant-related factors.

Here we present a follow-up study involving two CI subjects who previously suffered from FNS prior to reimplantation with Neuro-Zti implants [1]. Using the Oticon Medical Research Platform (OMRP) we stimulated a single electrode for each subject in two ways: (1) with traditional monopolar biphasic cathodic first pulses or (2) with the very different OM-style stimulation. In each case, FNS could be elicited with the traditional stimulation but not with the OM-style stimulation. This provides the first direct evidence that these implant-related factors were the key factors in reducing FNS for these subjects.

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T11: IMPACT OF AGING AND THE ELECTRODE-TO-NEURAL INTERFACE ON TEMPORAL PROCESSING ABILITY IN COCHLEAR-IMPLANT USERS

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Cochlear-implant (CI) performance outcomes are variable. Part of this variability may be a result of age-related temporal processing deficits, which can be assessed by recovery from forward masking (RFM). Older CI participants demonstrate longer RFM functions in regions of a poor electrode-to-neural interface (ENI), a combination of the peripheral neural and non-neural factors that affect the effectiveness of electrical stimulation. Additionally, temporal processing deficits appear to be exacerbated with increasing stimulation levels of speech stimuli, which may be a result of an additional central processing deficit. However, such level-dependent temporal-processing deficits have not been established using highly controlled direct stimulation experiments. Therefore, this study investigates the effects of level on RFM measured on electrodes of varying ENI. We hypothesized that older CI participants would have a longer RFM than younger participants, especially at higher stimulation levels and in regions of poor ENI.

CI participants were recruited across the lifespan (35-85 yrs). For each participant, the ENI was assessed across the entire array using the slope of the evoked compound action potential (ECAP) amplitude growth function or the slope of multipulse integration (MPI). Electrodes with the best, median, and worst ENI were selected. Following electrode selection, the participant's dynamic ranges (DR) were measured for the masker (200 ms) and a target (20 ms) stimuli on individual electrodes. The RFM thresholds were measured with varying masker levels (40, 65, 90%DR) and masker-target intervals (MTI: 0,100, 150, 200, 250, 300 ms).

Preliminary data in 8 (currently 55-83 yrs) participants showed variability in RFM across participants and electrode locations, as expected. RFM was longer at higher masker levels. Critically, the current results suggest a possible interaction between age, level, and ENI on RFM in older CI participants, consistent with our hypothesis.

Delineating the role of peripheral vs. central factors that contribute to temporal processing deficits could help understand speech perception abilities in CI users. Furthermore, it could provide individualized and age-specific programming guidance to clinicians.

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T12: ASSESSING THE NEURAL INTERFACE AND AUDITORY FUNCTIONALITY OF ABI ELECTRODES TO INFORM ELECTRODE SELECTION FOR SPEECH PROCESSING

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Auditory brainstem implants (ABI) are used to treat deaf individuals who cannot benefit from cochlear implants due to damaged or abnormal cochleas or auditory nerves. ABIs use the same sound coding strategy, software and processor hardware as cochlear implants. However, speech perception outcomes with ABIs are typically much poorer than with cochlear implants. This discrepancy may be due to the complex electrode-neuron interface of ABIs. The cochlear nucleus, which is the target site of ABI stimulation, contains many different neuron types with diverse biophysical properties. Some of these neuron types may not be suitable for conveying speech information.

This study aimed to evaluate whether ABI outcomes can be improved by selecting a subset of electrodes based on electrode-neural interface and perceptual auditory processing measures. It was hypothesized that ABI electrodes that are most effective in transmitting speech cues are those that elicit neural and perceptual responses that closely resemble those elicited by CI stimulation. We evaluated neural responses by recording ECAP (electrically-evoked compound action potential) using the voltage recording capability of the implant device. ECAPs were used to quantify several electrode-neural interface properties, including neural recovery from refractoriness and adaptation, and channel interactions. Perceptual auditory processing measures included gap and amplitude modulation detection thresholds obtained from single electrodes as well as pitch relations across the electrode array.

Results show that ECAP measures can vary significantly across ABI users and also across different electrodes within each ABI user. The observed diversity in ECAP measures is consistent with the expected diversity of the cochlear nucleus neurons. The morphology of ABI ECAPs often differed from the negative peak-positive peak morphology that is typically observed in cochlear implants. ECAP recovery times were sometimes an order of magnitude longer than the typical recovery times of cochlear implant patients. Channel interaction patterns generally agreed with what is typically observed in cochlear implants, in that interaction was significantly reduced by increased distance between electrodes. Consistent with ECAP results, perceptual measures also varied significantly between and within patients and were sometimes an order of magnitude worse than those typically observed in cochlear implant patients. ABI electrodes whose stimulation resulted in abnormal neural or perceptual responses tended to cluster together within the ABI array.

The preliminary speech perception results suggest that selecting a subset of electrodes based on ECAP and perceptual measures can result in better ABI outcomes. These findings support the potential of ECAP and auditory processing measures to reveal the functionality of ABI electrodes and inform electrode selection for speech processing. Overall, the results highlight the role of electrode functionality in ABI outcomes and provide a potential pathway to improve ABIs.

This study was supported by NIH R21DC020305, Cochlear Ltd., and Action on Hearing Loss (Azadpour)

T13: A NOVEL TOOL FOR FASTER PSYCHOPHYSICAL TUNING CURVE MEASUREMENT IN COCHLEAR IMPLANT LISTENERS: DATA FROM LISTENERS WITH NORMAL HEARING

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Introduction. Cochlear implants (CIs) provide significant speech perception benefits in quiet environments, but poor performance in noise and music appreciation remains a significant challenge due to the poor electrode-neuron interface (ENI) in many CI listeners. The quality of ENI determines how effectively individual CI electrodes stimulate the targeted auditory nerves, which can be impacted by factors such as the electrode-neuron distance, neural health, and tissue growth and fibrosis. Poor ENI can lead to elevated current levels, channel interaction, and reduced spectral resolution, potentially resulting in poorer speech perception. Accurate and fast assessment of the spectral resolution of individual electrodes could, therefore, be essential for identifying electrodes with poor ENI. Speech perception can then be improved by applying effective CI programming strategies or/and signal processing algorithms on channels with poor ENI to minimize channel interaction. The psychophysical tuning curve (PTC) is a standard tool for assessing frequency selectivity, but traditional PTC measurement methods are time-consuming. To address this, we are developing a faster approach using a 5-point PTC measurement procedure and Bluetooth-enabled acoustic stimulation via CI listeners' speech processors. This study presents PTC data from normal hearing (NH) listeners using this novel tool, to examine its feasibility and provide a baseline for comparison with adult CI listeners of various ages.

Methods. We developed a fast, 5-point PTC measurement tool that is based on an earlier 3-point method initially developed for testing children. For CI listeners with Advanced Bionics device, acoustic pure tones are presented via wireless Bluetooth connection. The pure tones used for masker and probe signals matched the corner frequencies of the analysis filter bands in the processor settings such that mainly one electrode is stimulated with each signal (75% or 100% to the target electrode for Optima strategies). The experiment was controlled through custom software (MATLAB 2022b). Each PTC required four steps: (1) measure the absolute detection thresholds for a probe tone (probe duration = 20 ms) using a two-interval two-alternative forced-choice (2-IFC) task, (2) measure on-frequency probe thresholds for a fixed masker level of 40 dB SPL (masker duration of 200 ms, masker-probe gap=10 ms) using a 3-IFC task, (3) measure four masker frequencies (two apical and two basal) through 3-IFC adaptive frequency sweep procedures (step size =1 electrode) at two fixed masker levels + 6 and +10 dB SPL relative to the fixed masker level of 40 dB SPL. The measured masker frequencies and two fixed masker levels were used to create 5-point PTCs. PTC data was collected from 11 NH listeners (hearing threshold ≤ 20 dB HL at 0.25, 0.5, 1, 4, and 8 kHz; Mean age (SD) = 41.43 (19.2)) for frequencies corresponding to probe electrodes of E4 (646 Hz), E8 (1257 Hz), and E12 (2549 Hz). The stimuli were presented via Sennheiser HD 265 headphones in the sound booth. The measured pairs of frequency-masker level data were used to calculate two best-fit lines on the apical and basal side of each probe electrode to quantify the sharpness of tuning.

Results. Consistent with prior studies, the results obtained from this novel tool indicate that the slopes of the PTCs were steeper for probe electrodes with higher frequencies ($F(1, 54)=3.49$, $p=.03$). Notably, the PTC slopes were significantly greater for frequencies corresponding to stimulation by middle and basal electrodes E8 and E12 compared to apical electrode E4 (E12 vs. E4: $F(1, 54)=10.17$, $p=.002$; E8 vs. E4: $F(1, 54)=4.76$, $p=.03$).

Conclusions. Data collected from using this fast tool for PTC measurement with NH listeners has provided insights into the potential of using this method to assess frequency selectivity in CI listeners. The consistency of these results with prior findings on sharper tuning for the more basal (high frequency) probes provides evidence for the validity of this novel technique. Future studies with larger sample sizes will use PTCs from NH as a baseline for comparison with those from CI users to optimize CI programming and ultimately enhance speech perception.

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T14: RELATING ELECTROPHYSIOLOGICAL (AUDITORY CHANCE COMPLEX) AND BEHAVIORAL MEASURES OF AMPLITUDE MODULATION RATE DISCRIMINATION TO SPEECH IN NOISE PERCEPTION IN COCHLEAR IMPLANT USERS

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Background: For cochlear implant (CI) users' speech information transmission is reliant upon the ability to detect, track, discriminate and process the amplitude-modulated (AM) envelope of speech sounds independently in different channels and make comparisons across channels. Information transmission can be hindered at many stages in the auditory pathway due to, for example, spread of electrical current, survival of inner-ear neurons and the neural representation of dynamic spectro-temporal cues. It is known that for CI users that there is a relationship between speech perception abilities and the ability to use AM cues. For individuals with poorer perception of AM cues re-mapping approaches could potentially improve AM delivery and in turn improve speech perception. In this work we have refined our psychophysical and electrophysiological measures of AM rate discrimination and relate them to speech in noise perception.

Methods: A group of adult listeners with CIs (Nucleus) participated in this experiment. The objective measure that we use captures the neural response to a perceived change in an auditory stimulus, in this case a change in the AM rate (the so-called auditory change complex (ACC)). The ACC is a transient N1-P2 response, the amplitude of which is related to the size of the perceived change in the stimulus. We used direct stimulation via the NIC4 research interface. The two stimuli in each cycle were fully modulated and AM rate changed between 13 and 40 Hz with a 400pps stimulation rate. Stimuli were 4 seconds long with an onset, a change at 2 seconds and an offset at the end with a 2 second inter-stimulus-interval. We measured the ACC on 5 different channels. In addition, we extracted the auditory steady-state responses. Participants passively listened while the electroencephalology (EEG) responses were measured with a 64 channel Biosemi (16 kHz) Active Two system. Artefacts caused by CI processing were attenuated using interpolation and spatial filtering. The psychoacoustic task to explore AM processing is called the AMCI. This task involves acoustic presentation of sinusoids at two different rates (13 versus 40 Hz) discriminated in a three-interval two-alternative forced choice task, where the modulation depth of both modulated sinusoids was adjusted adaptively to derive an AM discrimination threshold. Testing was conducted without interferers and in the presence of speech envelope interferers on adjacent +1 channels. Carrier frequencies were set to the center frequency of the same five channels as used in the ACC task. Stimuli were delivered through headphones (HD600s) placed over the sound processor of the CIs. All front-end noise reduction features were de-activated during the experiment. Speech-in-noise perception was measured using an adapted version of the coordinated response measure with multi-talker-babble as masker. It is hypothesized, that CI listeners with higher N1-P2 amplitudes across the electrode channels are better able to behaviorally discriminate between different AM rates and that this is related to better speech perception abilities.

Results and Conclusions: This work is ongoing, preliminary results confirm our previous findings that the ACC paradigm for changes in AM rate provides an objective measure of AM discrimination that is related to the behavioral discrimination of the same stimuli. Early findings for the AMCI indicate that the AM depth at threshold was larger in the presence of the interferers. We observed differences in performance on different channels for different participants. We speculate that the performance without interferers may relate to the neural processing abilities and that performance in the presence of the interferers relates more to the blurring between channels.

The goal of developing the AMCI & the ACC to AM rate change was to determine if we can identify poor functioning channels for consideration for re-mapping. Our ongoing work on measuring responses on different channels and analyses of the relationship with speech in noise perception will be presented. This research will help us to understand how these AM processing skills vary across CI listeners and how they relate to speech perception.

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T15: ELECTROPHYSIOLOGICAL AND PSYCHOPHYSICAL TUNING COMPARISONS IN ADULT COCHLEAR IMPLANT LISTENERS

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Introduction: Cochlear implant (CI) outcomes vary significantly among individuals; the electrode-neuron interface (ENI) is a likely contributing factor. ENI is the individual electrode's effectiveness in stimulating the target spiral ganglion neurons. It can vary across electrodes within individuals and is affected by the electrode position, bone and tissue fibrosis, and neural health. In cases where the ENI is poor, higher levels of electrical stimulation may be required to evoke auditory excitation, leading to higher thresholds, broader tuning, and more channel interaction. Channel interaction occurring at the level of the cochlea is indicated by the spread of excitation (SOE) measured with the electrically evoked compound action potentials (ECAPs). Psychophysical tuning curves (PTC) also quantify frequency selectivity, or channel interaction, in CI users – albeit further downstream along the auditory processing pathway. Some studies have shown broad PTCs for channels with high behavioral thresholds, with the thought that poor frequency selectivity at a specific channel reflects poor neural health or a considerable electrode-neural distance. The extent to which behavioral PTCs reflect channel interaction at the cochlea and auditory nerve levels has not been well studied. Therefore, the present study aims to characterize the relationship between ECAP SOE and PTC sharpness for two test electrodes with differing focused stimulation thresholds.

Methods: In this study, we compare two measures of spectral resolution for channels with low and high focused stimulation thresholds. Ten ears were tested (5 bilateral CI listeners) with the Advanced Bionics HiRes 90k CI. The two measures were: 1) ECAP SOEs and 2) PTC thresholds. ECAP SOEs were obtained using a forward masking paradigm for every masker and probe electrode combination. We quantified the selectivity by converting amplitude to a percentage of the maximum voltage and calculating the slope of the best-fit lines on the apical and basal sides of the SOEs. The absolute values of the apical and basal slopes were averaged to determine the mean slope for each channel. Behavioral thresholds and PTCs were collected for all available electrodes using steered quadrupolar (sQP) configuration and a modified threshold sweep procedure. For PTCs, we similarly used a forward masking paradigm. We quantified the selectivity by calculating the slope of the apical and basal sides of the PTCs in units of percent of the masker dynamic range. A sign test was used to determine if there was a significant interaction effect between high versus low threshold electrodes. We ran a Pearson's product-moment correlation to assess the relationship between SOE slopes and PTC selectivity.

Results: The average SOE slope for the high and low threshold electrodes was 10.9±3.76 (range: 8.87-17.4) and 10.5±2.92 (range: 6.17-13.68), respectively. The PTC slopes were broader for the high threshold channels (28.1±18.1, range 9.05-49.0) compared to the low threshold channels (44.0±18.8, range 17.5-69.1). Overall, there was no statistically significant correlation between the slopes of SOEs and PTCs, $r(8) = .14$, $p=.71$.

Conclusions: We did not observe a consistent relationship between SOE and PTC slopes within this small subject cohort. These findings suggest that SOEs and PTC may be measuring different aspects of spectral resolution.

T16: A LARGE-SCALE ANALYSIS OF SPEECH RECOGNITION, AGING, ELECTRODE LOCATION, AND ESTIMATES OF NEURAL HEALTH IN ADULT COCHLEAR IMPLANT RECIPIENTS

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Introduction: Speech recognition outcomes vary widely among CI recipients. Prior studies using more limited populations of CI recipients have shown that outcomes depend on several factors such as recipient age, electrode location, and neural health. Although these factors are often independent, studies have also shown them to be correlated, which complicates efforts to understand and improve CI outcomes. For example, estimates of neural health in the cochlear implanted ear are correlated with aging in some studies; yet both of these factors are independently related to speech recognition in CI users. Furthermore, there is a limited understanding of how neural health measures vary along the length of the array. This study uses a multimetric approach to examine covarying factors related to speech recognition scores in a large cohort of cochlear implanted ears.

Methods: 70 adult, peri- or post-lingually deafened CI ears were included in the analysis. All participants were implanted with Cochlear™ devices. Data were collected at two different institutions but using the same protocols. The electrically-evoked compound action potential (ECAP) amplitude growth function (AGF) was measured on each electrode, for each ear. ECAP metrics of interest included those previously shown to represent neural health characteristics in human and animal models, such as the peak amplitude, linear slope, N1 latency, and N1 half-width latency. Post-operative CT analyses were performed in a subset of ears, and measures of insertion angle and medial-lateral distance were examined. A 2 down, 1 up adaptive task was used to speech perception using CUNY sentences and speech-shaped noise; speech in noise data was available in a subset of ears.

Results: Preliminary analysis suggests poorer speech-in-noise performance in older compared to younger listeners. Age alone is not strongly associated with suprathreshold ECAP measures. Timing characteristics of the ECAP response, which include the N1 peak latency and the half-width latency of the N1 response, are associated with speech-in-noise performance; both latency values are greater among recipients with better speech-in-noise performance. N1 latency decreases with increasing insertion angle, whereas the N1P2 peak amplitude and N1 half-width-latency increase with increasing insertion angle of the electrode array.

Conclusion: Preliminary results suggest that temporal response properties of the auditory nerve are related to speech recognition outcomes. Furthermore, several ECAP measures varied from base to apex and are hypothesized to represent neural health and population diversity along the length of the electrode array. Poorer speech recognition performance was observed in older listeners, but ECAPs were not strongly associated with aging. These results have important implications for understanding underlying factors of speech understanding in CI recipients.

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T17: AN INVESTIGATION OF THE EFFECT OF CHANGES IN IPG ON THE AMPLITUDE GROWTH FUNCTION IN COCHLEAR IMPLANT RECIPIENTS

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Objectives: Intraoperative electrophysiological measurements provide insight into the neural interface for implanted neuromodulation devices and may provide guidance to the eventual therapeutic effectiveness. Changes to the gradient of the evoked compound action potential (eCAP) amplitude growth function (AGF) have been reported to correlate with surviving spiral ganglion cell density for cochlear implants. The present study investigated AGF Growth, the change in the AGF gradient in response to changes to the stimulation inter-phase gap (IPG). The effectiveness of machine learning techniques in identifying and removing invalid and sub-threshold eCAP waveforms from a clinical data set was also investigated. It was hypothesized that machine learning would be an effective mechanism to remove invalid eCAP waveforms, and that AGF growth would correlate more strongly with age and duration of deafness at implantation (DDI) than AGF gradient.

Design: eCAP waveforms were recorded intraoperatively, under general anesthetic, for basal, mid-turn, and apical electrodes for 89 new cochlear implant recipients. Data were recorded for stimulation currents from 200 to 1400 microamps, and IPGs from 10 to 50 microseconds. A Random Forests model and two different feature extraction functions (Gaussian and CDLD) were used to identify and remove sub-threshold and invalid eCAP. AGF gradients were calculated using linear, window and sigmoid methods. Knowledge that AGF gradient correlates with age at implantation was used to identify the most effective machine learning feature extraction function. The three gradient calculation methods were compared and the method which showed the largest response to changes in IPG was identified. AGF growth was calculated for participant in the filtered dataset using the selected method, and Pearson correlations of AGF growth and gradient with participant age and DDI were calculated and compared.

Results: The Random Forests classifier using CDLD extracted features was effective in identifying and removing sub-threshold and invalid eCAP waveforms. The sigmoid gradient calculation method was most responsive to changes in the IPG. The known sensitivity of the sigmoid method to the eCAP maximum amplitude appears not to have been an issue in the present study likely due to data being recorded under general anesthetic. AGF growth had a stronger negative correlation with age than AGF gradient across all ages and DDI. The correlation was weaker for older participants and those with longer DDI. Negative correlation of growth with DDI was generally stronger than the gradient correlation. Exceptionally there was a weak positive correlation with DDI for growth and gradient, potentially indicating age is the dominant factor.

Conclusions: Varying the IPG in the biphasic stimulus has been an under-utilised technique in cochlear implantation. The present study showed a substantial change in the electrophysiological response as IPG varied from 10 to 50 microseconds. AGF growth showed a stronger correlation with age in younger participants than AGF gradient. The machine learning method was shown to be an effective approach for identifying and removing both sub-threshold and invalid eCAP waveforms. The model trained in the present study has potential application in other studies with similar data sets. The study provides an evidence base for clinicians aiming to prognosticate long term outcomes based on on-table electrophysiological measurements immediately following cochlear implantation.

T18: ELECTRICAL STIMULATION OF COCHLEAR IMPLANT PROMOTES ACTIVATION OF MACROPHAGES AND FIBROBLASTS UNDER INFLAMMATION

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The implanted electrodes deliver electric signals to spiral ganglion neurons, conferring restored hearing of cochlear implantation (CI) recipients. Post-implantation intracochlear fibrosis, which is observed in most CI recipients, disturbs the electric signals and impairs the long-term outcome of CI. The activation of macrophages and fibroblasts is critical for the development of intracochlear fibrosis. However, the effect of electric stimulation of cochlear implant (ESCI) on the activity of macrophages and fibroblasts was unclear.

In the present study, a human cochlear implant was modified to stimulate cultured macrophages and fibroblasts. By measuring cellular marker and the expression level of cytokine production, the polarization and activity of macrophages and fibroblasts were examined with or without ESCI. Our data showed that ESCI had little effects on the morphology, density, and distribution of culturing macrophages and fibroblasts. Furthermore, ESCI alone did not affect the polarization of macrophages or the function of fibroblasts without the treatment of inflammatory factors. However, in the presence of LPS or IL-4, ESCI further promoted the polarization of macrophages, and increased the expression of pro-inflammatory or antiinflammatory factors, respectively. For fibroblasts, ESCI further increased the collagen I synthesis induced by TGF-β1 treatment. Nifedipine inhibited ESCI induced calcium influx, and hereby abolished the promoted polarization and activation of macrophages and fibroblasts.

Our results suggest that acute inflammation should be well inhibited before the activation of cochlear implants to control the postoperative intracochlear fibrosis. The voltage-gated calcium channels could be considered as the targets for reducing post-implantation inflammation and fibrosis.

T19: REACTION TIMES CAPTURE TEMPORAL INTERACTIONS IN ELECTRICAL HEARING

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Cochlear implants enable people experiencing severe to profound sensorineural hearing loss recover hearing sensations by directly stimulating the auditory nerve using electric pulses. These pulses are typically presented using an interleaved sampling paradigm. However, temporal integration at the auditory nerve creates interactions between consecutive pulses, affecting temporal resolution and potentially affecting recipients' abilities to recognize sounds. Temporal interactions are typically tested in subjective and/or discrimination paradigms, which can be hard for some recipients and tend to inefficiently dichotomize responses.

We evaluated temporal interactions by objectively and continuously measuring the reaction times of 14 cochlear implant recipients to pairs of biphasic pulses when varying the interval separating them (59 – 350 µs). The order of the anodic and cathodic phase of each pulse was varied to create two different configurations: one in which the last phase of the leading pulse and the first phase of the lagging pulse were anodic, and another one in which they were cathodic. We tested at sub- to supra-threshold stimulus amplitudes. Our results show that decreasing the interval between pulses led to faster responses, indicating greater pulse integration at intervals below 150 µs. Additionally, pulses with an anodic centre phase led to faster responses than their cathodic counterpart, suggesting greater integration for the former.

Our study indicates that reaction times are a valid tool to evaluate peripheral temporal interactions in electric hearing, allowing for a continuum between threshold and supra-threshold evaluations. We also present a model based on leaky integration of the stimuli by the auditory nerve, combined with a decision time model, that can describe the observed reaction times precisely. Ongoing research is exploring whether the individual time constants fitted for this model can predict speech outcomes for cochlear implant recipients with varying levels of performance.

T20: MODELLING SGN RESPONSES TO NON-RECTANGULAR STIMULI BASED IN PATCH CLAMP EXPERIMENTS OF INTRACELLULAR AND EXTRACELLULAR STIMULATION

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While cochlear implants can provide speech perception for hearing-impaired individuals in low-noise environments, they may not offer satisfactory frequency resolution for music perception. Recent research suggests that the rectangular pulse current waveform used by cochlear implant devices to stimulate auditory nerve fibers in the cochlea may not be optimal. To explore this issue, we conducted patch current clamp experiments on rat SGNs (Type I and Type II), comparing equal-charge, non-rectangular monophasic pulse shapes such as ramp, exponential, and Gaussian, with the typical rectangular shape, using pulse widths ranging from 25 us to 1 ms.

Our initial results indicate that the direction of the non-rectangular pulse has a significant impact on subthreshold integration, affecting the mechanism of action potential initiation and thereby the spike latency and charge-duration curve. To model these findings, we used an integrate-and-fire neuron, fitting subthreshold membrane voltage traces and comparing model parameters, such as membrane time constant, with calculations based on voltage clamp. We also developed an apparatus for extracellular stimulation using the same pulse shapes, including biphasic shapes, and recorded intracellular membrane voltage while parameterizing the distance from the neuron.

Our ongoing experiments suggest that the spatial topology of extracellular stimulation affects the threshold and latency of neural responses. We anticipate that our research will help bridge the gap between intracellular and extracellular stimulation, leading to a better understanding of SGN encoding and optimizing cochlear implant design.

T21: THE EFFECTS OF MULTI-MODE MONOPHASIC STIMULATION WITH CAPACITIVE DISCHARGE ON THE FACIAL NERVE STIMULATION REDUCTION IN YOUNG CHILDREN WITH COCHLEAR IMPLANTS: INTRAOPERATIVE RECORDINGS

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Facial nerve stimulation (FNS) is a potential complication which may affect the auditory performance of children with cochlear implants (CIs). We carried out an exploratory prospective observational study to investigate the effects of the electrical stimulation pattern on FNS reduction in young children with CI. Ten ears of seven prelingually deafened children with ages up to 6 years old who underwent a unilateral or bilateral CI surgery were included in this study.

Electromyographic (EMG) action potentials from orbicularis oculi muscle were recorded using monopolar biphasic stimulation (ST1) and multi-mode monophasic stimulation with capacitive discharge (ST2). Presence of EMG responses, facial nerve stimulation thresholds (T-FNS) and EMG amplitudes were compared between ST1 and ST2. Intra-cochlear placement of the electrodes, cochlea-nerve and electrode-nerve distances were also estimated using Nautilus software (Oticon Medical, France) to investigate their effects on EMG responses. The use of ST2 significantly reduced the presence of intraoperative EMG responses compared to ST1. Higher stimulation levels were required to elicit FNS with ST2, with smaller amplitudes, compared to ST1. The EMG responses did not show any significant correlations with cochlea-nerve nor electrode-nerve distances. ST2 may reduce FNS in young children with CI. Differently from the electrical stimulation pattern, the cochlea-nerve and electrode-nerve distances seem to have limited effects on FNS in this population.

T22: INTERRELATIONSHIPS AMONG ECAP REFRACTORY RECOVERY, MAXIMUM AMPLITUDE, AND AGF SLOPE

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Several outcome measures obtained with electrical stimulation through a CI have been correlated with aspects of neural health in animal models. Specifically, larger maximum eCAP amplitudes have been shown to correlate with greater spiral ganglion cell counts, size, or density (Hall, 1990; Shepherd & Javel, 1997; Ramekers et al., 2014, 2015). Steeper slopes of the amplitude growth function (AGF) have also been correlated with better spiral ganglion cell survival (e.g., Smith & Simmons, 1983; Hall, 1990; Zhou et al., 1995; Ramekers et al. 2014). Results for refractory-recovery times, however, are inconsistent. Botros and Psarros (2010) reported longer refractory-recovery times for a larger population of modeled fibers and shorter recovery times for a smaller population of fibers. In contrast, Zhou et al. (1995) and Shepherd et al. (2004) found prolonged refractory recovery was associated with greater degrees of neural degeneration. The purpose of this study was to examine the relation between eCAP refractory-recovery time and (a) maximum amplitude and (b) AGF slope to determine whether eCAP refractory recovery in human CI recipients aligns with the cat-based model of Botros and Psarros (2010) or the rodent models reported by Zhou et al. (1995) and Shepherd et al. (2004). If longer refractory-recovery times reflect better neural survival (Botros & Psarros, 2010), then we would expect longer recovery times to be associated with larger eCAP amplitudes and steeper slopes (positive correlations). However, if refractory recovery in CI recipients aligns with the rodent-based models of Zhou et al. (1995) and Shepherd et al. (2004), we would expect shorter recovery times to be correlated with larger eCAP amplitudes and steeper slopes (negative correlations). ECAP AGF (providing amplitude and slope data) and refractory-recovery functions were obtained from all available electrodes in 22 ears implanted with Cochlear devices. There was a significant negative correlation between recovery time and maximum eCAP amplitude, which aligns with the rodent-based models of Zhou et al. (1995) and Shepherd et al. (2004). Specifically, larger maximum amplitudes were associated with shorter recovery time. However, there was a significant positive correlation between recovery time and AGF slope, which aligns with the cat-based model of Botros and Psarros (2010). Specifically, longer recovery time was significantly correlated with steeper slopes. These conflicting findings were due to a negative correlation between maximum amplitude and AGF slope, which suggests that these outcome measures in human CI recipients are likely sensitive to different aspects of neural health than what has been suggested by animal work.

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T23: ESCUDE AND AVCI ET. AL. REVISITED. COCHLEAR MICROANATOMY FROM A DATABASE OF 1100 EARS

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As well detailed by Escudé 2006 and further explored by Avci 2014, understanding cochlear microanatomy is crucial for performing less traumatic cochlear implant insertions, developing less traumatic electrode arrays and insertion guidance systems for cochlear implantation. The human cochlea shows considerable variability in size and morphology. This study analyses 1100+ clinical temporal bone CT images using Oticon Medical's Nautilus tool. Cochlear size and shape parameters were obtained to determine population statistics and perform regression and correlation analysis.

As expected, the analysis revealed that cochlear morphology follows Gaussian distribution in all parameters. However, some counter intuitive results were observed, such as a lack of correlation between cochlear dimensions A and B, as well as a lack of strong correlation of A to any other obtained. Dimension B, on the other hand, was seen to be well correlated to duct lengths, cochlear wrapping factor and volume. Additionally, when comparing the subset of data where both cochlear were imaged, inter-individual variability was four times that of intra-individual variation. On average, the dimensions of both ears are similar. However, statistically significant differences in clinical dimensions were observed between ears of the same patient, suggesting that size and shape are not the same.

Finally, a comparison between the height and largest circle (electrode) possible in the scala tymapani is explored as a possible guide to improving surgical outcomes. Preliminary data suggest a correlation between B and the scala tympani largest circle that may prove insightful to the preoperative planning of electrode selection.

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T24: PULSE TIMING INTERVAL SENSITIVITY IN THE INFERIOR COLLICULUS OF COCHLEAR IMPLANTED RATS

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In normal hearing, the neural processing of temporal fine structure information provides valuable pitch cues which help the perception of speech prosody, tonal language reception, musical melody appreciation and acoustic scene analysis. However, cochlear implant (CI) processors in current clinical use provide only limited amounts of fine structure in their electrical pulse trains, and the perceptual sensitivity of CI users is usually very poor compared to that of normal hearing individuals.

To understand this deficit, several researchers have probed the sensitivity of CI patients to changes in the timing of pulses delivered via experimental processors. When investigating this phenomenon, one needs to control for confounds that can arise when changes in stimulus pulse rate also imply a change in stimulus intensity and therefore perceived loudness. One recent study controlled for this by delivering CI pulses in pairs and changing the interval in each pair while keeping the rate at which pairs were delivered constant. They observed a psychoacoustic interpulse interval discrimination threshold of 3 ms for pulse pairs delivered at a rate of 100 pairs per second in CI users. We suspect that CI patients who spend many months listening to stimuli with entirely fixed pulse rates over their clinical processors may become desensitized to small pulse interval changes, and that CI supplied, neonatally deafened rats which have not been similarly desensitized might exhibit lower inter-pulse interval detection thresholds. We therefore used a multichannel probe to record neural responses in the inferior colliculus (IC) of anesthetized, deafened rats to continuous trains of electrical pulse pulse pairs with inter-pair intervals that changed once per second from 1 ms to 1.04, 1.08, 1.12, 1.16, 1.2, 2, 3, 4, or 5 ms. We analyzed the recorded multiunit responses by computing their spectral power at 100 Hz. Using paired-sign rank tests we compared the power of the neural response during the stimulus periods where the interval in each pair was 1 ms against each of the other intervals. We found significant differences in the neural responses for interpulse interval changes as small as 1 ms to 1.04 ms in as many as 48 out of 606 IC multiunits.

Our findings suggest that the IC of neonatally deafened rats is sensitive to much smaller changes in inter-pulse intervals than those previously reported in a psychoacoustic study of human CI users, which suggests the intriguing possibility that much better temporal fine structure sensitivity might be achievable in CI patients with better signal processing and treatment strategies.

T25: OPTIMIZING EEG PREPROCESSING PIPELINES FOR COCHLEAR IMPLANT ARTIFACT REMOVAL: CHALLENGES AND SOLUTIONS

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Introduction: Cochlear implants (CI) pose a challenge in recording neural activity from scalp electroencephalography (EEG), given the immense number of artifacts produced by CI devices during auditory stimulation. To support neuroscientific investigations of the CI population there is a need to optimize preprocessing pipelines of EEG data that can efficiently detect and remove CI-related artifacts while preserving the neural activity of interest. Although several methods have been previously developed to extract CI artifacts from EEG data, they were limited by the duration of the stimuli used in the experimental paradigms, such that shorter stimulus durations would generally generate fewer artifacts. However, using brief auditory stimuli might not always be feasible, especially when implementing speech-in-noise paradigms that often use prolonged duration auditory stimuli. Here, we developed a preprocessing pipeline that can efficiently remove CI artifacts produced by long duration auditory stimuli (4 seconds) from EEG data.

Methods: A stochastic figure-ground (SFG) stimulus was used in the experiment. The length of the SFG stimuli were 4 seconds. A total of 46 CI subjects (23 bilateral CI and 23 bimodal CI) and 21 normal hearing subjects performed the experiment while EEG was recorded, wherein they had to indicate whether there was a transition to regularity within a background of noise. To remove CI artifacts from the EEG, we preprocessed the data in the following sequence. First, data were downsampled from 2024 Hz to 512 Hz. A bandpass filter with three different cut-off frequencies was applied to explore which parameters most effectively reduced CI-related artifacts. These filter parameters were either 1-57 Hz (filter 1), 2-45 Hz (filter 2), and 2-35 Hz (filter). Subsequently, data were epoched from -1 second to 5 seconds relative to the stimulus onset, having a total length of 6 seconds per epoch. Bad trials and channels with high voltages (>200 uv) were removed, and ICA comparing two different algorithms was performed on the remaining trials. ICA components were manually inspected, and the components that showed CI artifacts and eye movement were rejected. Finally, a second round of bad trial removal was done, and evoked responses were plotted. Results: The number of ICA components rejected using the three filters was variable: with filter 1, the number of ICA components removed was in the range of 30 to 40 components in both CI groups, and the resultant evoked waveforms either contained residual CI artifacts or showed no neural responses. Filters 2 and 3 produced fewer rejected ICA components than filter 1, with filter 2 having an average of 23.33 ± 3.4 and 20 ± 5.88 of removed ICA components in the bilateral and bimodal CI groups, respectively. Using filter 3, the number of rejected ICA components was 20.33 ± 2.49 for the bilateral CI group and 20.33 ± 3.29 for the bimodal CI group. Evoked responses were seen using either filter 2 or 3, with no residual CI artifact.

Conclusions: The developed pipeline showed promising results in removing CI artifacts using more stringent filtering parameters. Choice of ICA algorithm did have an effect on the ability to capture the CI artifact. Filtering the EEG data with a larger bandwidth can be influenced by DC offsets if a high-pass filter of <2 Hz is used, and more CI-related high-frequency energy can leak into EEG data with low-pass filters of >45 Hz. Also, the developed pipeline showed the feasibility of removing CI artifacts produced by prolonged auditory stimuli, and it can be implemented on CI subjects with different auditory configurations.

T26: COMPARISON OF SPEECH IN NOISE PROCESSING IN HEARING IMPAIRED POPULATIONS USING O-15 WATER PET

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One of the most important issues in hearing impairment (HI) is difficulty with speech in noisy real-world environments. Research in normal hearing listeners indicates that auditory cortex is active while abstracting speech objects from noise and provides input to fronto-temporal networks for further perceptual, attentional, and semantic analysis. We want to understand whether these are the same neural mechanisms across hearing impaired listeners with different devices (CI and hearing aid) and configurations, and how these mechanisms relate to successful hearing outcomes.

Previously we demonstrated in a proof-of-concept study that we could robustly and reliably measure brain [15O]Water positron emission tomography (PET) blood flow activity to speech in noise in cochlear implant users at a single subject level. We observed activity in a fronto-temporal network to speech in noise in each single subject. Here we expand our investigation to include a broad range of hearing impairment (CI and hearing aid users) and device configurations to capture variability that may be different to that of a matched control population.

We measured PET blood flow in a group of 38 cochlear implant subjects, 11 hearing aid users, and 20 age-matched normal hearing controls while they performed a word-in-noise identification or noise-control task (matched on RMS sound level). Six runs were performed for each condition. On a given 3-min run for speech in noise (+15 dB SNR), word tokens were presented in multi-talker babble, and at random intervals subjects were prompted to perform a 4-alternative forced choice task. The control condition was a noise level detection task matched for response demands. PET data were analyzed in SPM12 using a flexible factorial model.

We found robust activations in single subjects for the contrast speech in noise vs control noise in auditory cortex and inferior frontal cortex. Group level activation regions of interest in auditory cortex and inferior frontal cortex were significant, along with activations across a network of areas involved in language processing ($p<0.05$, corrected). Group comparisons highlighted differences in the involvement of frontal cortex which may relate to the existence of acoustic hearing. A regression analysis including speech in noise task performance indicated the involvement of brain regions for attention and object analysis.

Our results show that speech in noise processing in different hearing impaired populations may depend on the availability of residual acoustic hearing, and the use of brain networks for language more similar to that of the normal hearing population.

T27: THE EFFECT OF PULSE SHAPE ON PITCH SENSITIVITY OF COCHLEAR IMPLANT USERS

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Current cochlear implant (CI) devices use cathodic-leading symmetric biphasic (BP) electrical pulses to convey acoustic information to profoundly deaf people. However, research indicates that asymmetric charge-balanced pseudo-monophasic pulses may reduce spread of excitation as compared to BP pulses, resulting in improved spectral resolution (e.g., Frijns et al., 1996). In addition, anodic-centered quadra-phasic pulses appear more effective in stimulating auditory nerve fibers with lower most comfortable levels than cathodic-centered quadra-phasic pulses (e.g., Macherey et al., 2017), while the polarity effect on threshold level may depend on auditory neural health (e.g., Rattay, 1999). To date, the effect of pulse shape on pitch sensitivity is largely unknown, except that anodic-centered quadra-phasic pulses have been reported to yield higher percent correct scores for discrimination of 20- and 35-Hz amplitude modulation frequencies than cathodic-centered quadra-phasic pulses (Undurraga et al., 2021).

This research examined if anodic-centered triphasic (A-TP) pulses could enhance CI users' place and temporal pitch sensitivity as compared to cathodic-centered triphasic (C-TP) and BP pulses. Eight post-lingually deaf adult CI users with a total of 12 implanted ears participated in this study. Experiment 1 measured virtual channel ranking (VCR) thresholds using BP, A-TP, and C-TP pulses on apical, middle, and basal electrodes at a low pulse rate (99 pulses per second; pps), which may enhance the polarity effect on auditory nerve stimulation (Undurraga et al., 2021). The VCR thresholds were significantly higher (i.e., worse) on basal electrodes than on middle electrodes. However, the effect of pulse shape on VCR thresholds was not significant, possibly due to the interference of a fixed 99-Hz temporal pitch.

Experiment 2 used a 1000-pps pulse rate to measure VCR thresholds as well as amplitude modulation frequency ranking (AMFR) thresholds with a 100-Hz base AM frequency. Both the VCR and AMFR thresholds were significantly higher (i.e., worse) on basal electrodes than on apical and middle electrodes. Moreover, the VCR thresholds with A-TP pulses were significantly lower (i.e., better) than those with C-TP pulses, and were nearly significantly better than those with BP pulses. In contrast, no significant effect of pulse shape was found on AMFR thresholds. The results revealed a polarity effect on supra-threshold place-pitch perception with CIs and suggest that A-TP pulses may more selectively stimulate auditory nerve fibers and potentially enable CI users to more accurately discriminate place pitches.

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T28: ASSESSING THE ELECTRODE-NEURAL INTERFACE USING FOCUSED STIMULATION AND SPATIAL TUNING CURVES IN COCHLEAR-IMPLANT USERS

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In cochlear implant (CI) users, the quality of the electrode-neural interface (ENI) is determined by the health and quantity of the surviving neural structures, as well as the proximity of the electrodes to those neural structures. Absolute thresholds, measured in CI users via focused stimulation, have been used as an estimate of the ENI quality at individual electrodes sites. Our objective was to test two hypotheses related to the ENI: 1) Good ENI should be reflected not only by low absolute thresholds with focused stimulation, but also by narrow forward-masked psychophysical tuning curves, indicating better spatial selectivity; 2) Focused stimulation should lead to narrower psychophysical tuning curves than monopolar (MP) stimulation, at least for locations with a good ENI.

Users of the Advanced Bionics CI system were recruited to participate in this direct-stimulation study. A total of 13 participants (20 ears) were enrolled. Absolute thresholds across each electrode array were measured for each listener using focused stimulation (0.9-steered quadrupolar, sQP) via a sweep method. The two electrodes between 4 and 13 with the highest and lowest focused thresholds were selected as target electrodes for a forward-masking spatial tuning task. Both monopolar (MP) and 0.5-sQP stimulation modes for both masker and probe were used, with the test order of stimulation mode (MP or sQP) and electrode (low- or high-threshold) pseudorandomized. The forward-masking paradigm used a 200-ms masker with a 20-ms gap and a fixed low-level 20-ms probe. Thresholds and maximum acceptable loudness levels were determined for all stimuli in both stimulation modes. Forward-masked thresholds were measured for spatial tuning curves using a 2-interval, 2-alternative forced-choice procedure with a fixed probe level and adaptively varying masker level.

The variability of the thresholds (defined as the mean of the unsigned differences between adjacent electrodes) across the array was found to be significantly smaller for the MP compared to the more focused 0.9 sQP stimulation mode, as predicted. For each array, the electrodes with the lowest and highest sQP thresholds were denoted the LOW and HIGH electrodes, respectively. The dynamic range (DR) was significantly different between LOW and HIGH electrodes, but not between the two stimulation modes. The spatial tuning curves were defined in terms of bandwidth, tip shift, and slopes. To address the first hypothesis, spatial tuning curve slopes and bandwidths were compared for LOW and HIGH electrodes in each ear. No significant or systematic differences were observed between the LOW and HIGH tuning-curve parameters, although individual differences were large. To address the second hypothesis, tuning-curve bandwidths were treated as the dependent variable in a within-subjects repeated-measures ANOVA, with factors of stimulation mode (MP/sQP) and focused threshold (LOW/HIGH). Although individually, 18 of the 20 ears tested showed the same or wider bandwidths for MP than for sQP stimulation for the LOW electrode, compared to 14 of the 20 ears for the HIGH electrodes, neither the main effects nor their interaction reached statistical significance.

Inconsistent with our two hypotheses, the results so far suggest no robust relationship between focused threshold and tuning-curve bandwidth, or between bandwidth and stimulation mode. Further work is being undertaken to develop more sophisticated methods of characterizing spatial resolution from tuning curves.

T29: HOW DO LISTENERS WITH MISMATCHED EAR QUALITY LATERALIZE ITDS AND ILDS FOR COMPLEX SOUNDS?

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Listeners with bilateral cochlear implants (BiCIs) struggle to accurately identify the location of a sound source. This might be due to an inability to access precise binaural cues such as interaural time differences (ITD) and interaural level differences (ILD). The complexity of the stimulus across ears plays a major role in the ability to locate sounds in a real-world environment. Typical hearing (TH) listeners are most sensitive to ITDs below 1000 Hz and ILDs above the 1500 Hz range. Both cues are most effective when a sound contains a broadband signal; broadband sounds are a more realistic representation of everyday stimuli. However, there is limited knowledge on how BiCI listeners weight binaural cues of broadband sounds. Prior work in listeners with TH shows that the weighting of ITDs and ILDs can vary based on the stimulus type, hence we emphasized the use of real-world environmental sounds in the present study. The aim of this study was to investigate how TH listeners weight ITDs and ILDs when they have mismatched quality across ears, in controlled-laboratory settings as well as remotely in everyday environments. The motivation behind using mismatch across the ears was to assess its relevance in TH listeners and understand how this might impact BiCI listeners who might have mismatch sound quality across the ears. We hypothesized that when ITDs and ILDs are combined, the weight of cues will shift in a lateralization task when one ear is presented with lower quality sound.

Here, TH listeners participated in a lateralization task; a subset of the listeners were tested in a controlled laboratory setting with audiometric screening (Group 1) and the remaining listeners completed the task remotely (Group 2) using an online platform, Gorilla. Both groups of participants were asked to report environmental parameters such as the loudness of the room and how easy it was to focus. However, Group 2 completed an additional online hearing and headphone screening in order to begin the task. All listeners were presented with a 300-ms token of speech-shaped noise with a combination of ITDs and ILDs, where one cue was held constant and the second cue was systematically manipulated, with a total of 18 cue combinations. Listeners were given response options on the lateral azimuth ranging from -90 degrees to 90 degrees on a computer screen, with 10-degree intervals. Listeners were permitted to repeat the stimulus as many times as they desired. Across-ear sound quality was manipulated by changing the vocoding parameters in three different conditions: (1) matched across-ear sound quality, (2) left-degraded and (3) right-degraded. This was done in order to reproduce similar listening conditions as commonly observed in BiCI listeners. Each ITD and ILD were randomly selected, combined and presented to the listener. Listeners were asked to report the lateral location of the perceived sound.

Preliminary data show that even with mismatched and degraded sounds, participants localize the sound towards the ILD rather than the ITDs. This suggests that the impact of mismatched sound quality across the ears might play a role not only in summation of broadband sounds for speech understanding but for localization and lateralization in listeners with BiCIs.

T30: TEMPORAL PITCH PERCEPTION IN CI USERS: CHANNEL INDEPENDENCE IN APICAL COCHLEAR REGIONS

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In modern cochlear-implant (CI) systems, sound information is encoded in spatial and temporal electrical stimulation patterns along the cochlea. While CI users can discriminate well between the place of stimulation of adjacent electrodes for middle and basal stimulation sites, discrimination of pitch based on purely place cues can be poor on apical electrodes. It has also been shown that apical pitch is dominated by temporal and not place information, and that tonotopic pitch perception can be fully restored by providing place-dependent temporal cues on apical electrodes.

Two-electrode stimuli presented on adjacent mid-array contacts in cochlear-implant (CI) users elicit pitch percepts that are not consistent with a summation of the two temporal patterns. This indicates that low-rate temporal rate codes can be applied with considerable independence on adjacent mid-array electrodes. In this presentation we investigate whether a similar independence of temporal pitch cues can also be observed for more apical sites of stimulation, where temporal cues have been shown to be more reliable than place cues, in contrast to middle and basal sites.

In CI recipients with single-sided deafness (SSD) implanted with long lateral-wall electrode arrays, pitch percepts were assessed by matching the pitch of dual-electrode stimuli with pure tones presented to the contralateral normal-hearing ear. The results were supported with an additional pitch-ranking experiment, in a different subject population with bilateral deafness.

Unmodulated pulse trains with 100, 200 and 400 pulses per second were presented on three pairs of adjacent electrodes. Pulses were separated by the minimal inter-channel delay (1.7 µs) in a short-delay configuration and by half the pulse period in a long-delay configuration. The hypothesis was that subjects would perceive a pitch corresponding to the doubled temporal pattern for the long-delay stimuli due to the summation of excitation patterns from adjacent apical electrodes, if those electrodes were to activate largely overlapping neural populations. However, we found that the mean matched acoustic pitch of the long-delay pulses was not significantly different from that of the short-delay pulses.

These findings suggest that also in the apical region in long-array CI recipients, temporal cues can be transmitted largely independently on adjacent electrodes.

T31: PITCH AND QUALITY OF SOUND PERCEPTION OF MODULATED AND UNMODULATED PULSES AS A FUNCTION OF PLACE AND RATE OF STIMULATION

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In a previous study on pitch perception with amplitude modulated pulse trains, McKay et al. compared pitch percepts of AM and FM pulse trains as a function of modulation frequency and carrier rates for a fixed electrode (Nucleus system, subject-specific electrode number) [1]. They found that subjects could consistently rank AM stimuli only for carrier rates that were high enough to avoid aliasing effects in the sampling of AM envelopes. Vandali et al. studied pitch and loudness of AM vs. FM stimuli as a function of modulation depth, rate, shape and presentation level at a single electrode and a high carrier rate [2]. They found that the perceived pitch of AM pulses generally decreases with increasing modulation depth and that it was difficult for subjects to consistently rank AM stimuli for shallow modulation depths of about 12.5%. Both studies found that generally the perceived pitch of AM stimuli is higher than the pitch associated with unmodulated pulse trains presented at a rate corresponding to the modulation frequency of an AM stimulus.

In this presentation, we investigate pitch perception for rate (FM) and amplitude modulated (AM) stimuli in MED-EL CI users, both as a function of stimulation rate and place. This especially includes pulse trains presented on electrode contacts in the very apex of long MED-EL electrodes. A pitch scaling procedure is used to compare the pitch of unmodulated pulse trains presented at different stimulation rates to that of amplitude modulated pulse trains presented at different carrier rates and at a fixed modulation frequency and depth, on an apical, middle, and basal electrode each. In addition to single electrode pulse trains, pitch percepts are also be investigated for multi-electrode stimuli.

In addition to pitch perception, we assessed the tone quality of the unmodulated and modulated pulse trains in a visual-analog scaling (VAS) task. We found that the perceived pitch depends on both place and rate. As expected, pitch depends on the place of stimulation for all rates in a tonotopical way, while for low rates under 400pps, pitch also depends on the rate of stimulation. The lowest perceived pitch values appear only for a low stimulation rate on the apical electrode. The same rate applied to a middle or basal electrode produces significantly higher pitch for most subjects.

In the assessment of how clean and how uncomfortable stimuli sounded to a subject, in general, stimuli with high rates on average sounded more comfortable and cleaner. However, for low rates, stimuli applied to the apical electrode were identified as cleaner and more comfortable that stimuli applied to either the middle or basal electrodes. When comparing the influence of pitch modulation, the perceived pitch of a pulse train with a pulse rate of 400pps or more that was modulated with 100Hz was found to be always higher than an unmodulated 100pps pulse train. Modulated higher rate stimuli were also perceived as less clean than unmodulated pulses.

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T32: THE UPPER LIMIT OF TEMPORAL PITCH PERCEPTION FOR APICAL STIMULATION IN COCHLEAR IMPLANT RECIPIENTS

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Cochlear implant (CI) recipients typically have poor temporal pitch perception, as revealed by a low upper limit measured on a single electrode. The upper limit is generally in the range 200-400 pulses per second (pps) and is considerably lower than the 700 pps observed in normal-hearing listeners. Based on recordings from the cat inferior colliculus, Middlebrooks and Snyder (2010, J. Neurosci. Res. 30(5): 1937-1946) argue that there might be a specialised brainstem pathway that supports precise temporal pitch processing and is activated by selective stimulation of the apex. Here, the upper limit of temporal pitch perception was studied in three experimental conditions that would be expected to affect either the place of stimulation or the spread of excitation. Specifically, single-electrode apical stimulation of the Med-El CI was compared to single-electrode stimulation of a mid-array electrode and blurred apical stimulation. We expected to find superior temporal processing for single-electrode apical stimulation. Eight experienced CI recipients performed a range of pitch ranking tasks using the optimally efficient MidPoint Comparison (MPC) procedure. First, participants did a place-pitch ranking task for an 80-pps pulse train presented at the four most apical (e1 to e4) electrodes to verify monotonically increasing pitch across electrodes. Second, rate-pitch ranking of pulse-train stimuli between 80-981 pps was done for the following three conditions: (1) single-electrode apical stimulation on e1, (2) single-electrode mid-array stimulation on e7 or e8, and (3) multi-electrode simultaneous apical stimulation on e1-e4. Upper limit values were compared across these conditions. Finally, detection thresholds were measured for 99-pps trains of triphasic pulses where the central high-amplitude phase was either anodic (TP-A) or cathodic (TP-C). The difference between TP-C and TP-A thresholds (i.e., polarity effect, PE) was measured at the most apical (e1) and the mid-array (e7 or e8) electrode. In all participants, e1 was either ranked as having the lowest pitch or was indiscriminable from its neighbour e2. For this reason, e1 was used as the most apical electrode in the single-electrode apical condition in all participants. For rate-pitch ranking, Wilcoxon signed-rank tests revealed no significant difference in the upper limit between single-electrode apical stimulation on the one hand, and single-electrode mid-array ($T = 22$, $p = .575$) or multi-electrode apical stimulation ($T = 24$, $p = .401$) on the other hand. The polarity effect varied considerably across participants. In about half of them, sensitivity to TP-C was higher than TP-A pulse trains. We also replicated the positive correlation between the normalised PE and the normalised average threshold ((TP-C+TP-A)/2) (Pearson's $r = .791$, $p < .001$), which has previously been interpreted as evidence that the PE can be used to estimate survival of auditory-nerve peripheral processes. This correlation occurred in the absence of an effect of electrode location on PE ($T = 19$, $p = .398$), inconsistent with the predictions of a computational model that proposed an alternative explanation for this correlation (Kalkman et al., 2021, Hear. Res. 415).

To conclude, we found no consistent evidence for superior temporal processing for single-electrode apical stimulation in this group of CI recipients. The PE correlated positively with absolute thresholds and was independent of electrode position.

T33: FAST, CONTINUOUS ESTIMATION OF SPECTROTEMPORAL MODULATION SENSITIVITY

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Introduction: Spectrotemporal modulations are changes in the frequency and amplitude of sound over time that are vital to perceiving complex sounds, including speech. Despite their importance, assessments of spectrotemporal modulation sensitivity are not widely used in clinical hearing assessments due to factors such as ease of administration, interpretation, equipment availability, and clinical relevance.

Objectives: This study aimed to develop a more efficient method for estimating continuous spectrotemporal modulation sensitivity using moving ripples stimuli, reaction time measures, and Bayesian estimation. We compared the accuracy, reliability, and speed of this new method to a reaction time measurement technique with a discrete grid of spectrotemporal modulations of the ripples.

Design: We recruited 10 participants between the ages of 18 and 35 years with normal hearing as determined by pure-tone audiometry. We measured spectrotemporal modulation sensitivity using a reaction time task, acquiring two repetitions of automated machine learning estimation and one repetition of conventional reaction time measurement. We compared the estimated spectrotemporal modulation sensitivities of these two techniques at a discrete set of modulation velocities and densities.

Results: The two estimation methods produced similar estimates at standard modulation velocities and densities. The Bayesian method generated estimates using fewer samples than the conventional procedure while providing a continuous estimate as a function of modulation velocity and density.

Conclusions: Our novel method for estimating spectrotemporal modulation sensitivity accurately, reliably, and efficiently produces continuous estimates, making it an excellent candidate for widespread application in clinical and research auditory processing assessments. The use of this method could improve the assessment of auditory processing abilities, leading to a better understanding of hearing impairments and targeted interventions.

Keywords: Audiogram | Audiology | Audiometry | Reaction Times | Estimation | Machine learning | Gaussian Processes | Psychoacoustics | Psychophysics | Humans | Adult

T34: EFFECTS OF RATE TRAINING ON PITCH DISCRIMINATION AND MODULATION DETECTION THRESHOLDS

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The human auditory nerve can phase lock to sounds at very high rates and this neural synchrony can extend up to 3 kHz when electrically stimulated. Even with the robust synchrony, pulse rate-based pitch discrimination in cochlear implant users greatly diminish above about 300 Hz. However, this may be because stimulation rate pitch cues are not given to cochlear implant users in their current processor. Research in our lab has shown that stimulation rate sensitivity can improve with psychophysical training. The present study explores whether an increase in stimulation rate sensitivity through daily training, including stimulation rates above 300 Hz, can be useful for cochlear implant users' pitch perception. Preliminary results will be reported from an ongoing experiment that considers the extent to which pitch ranking based on stimulation rate can be improved through training and how this effects place pitch discrimination, place-rate pitch discrimination, and modulation detection thresholds.

T35: CHARACTERIZATION OF A PSYCHOPHYSICAL TEST BATTERY FOR THE EVALUATION OF NOVEL SPEECH CODING STRATEGIES IN COCHLEAR IMPLANTS

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Introduction: The objective of this study is to evaluate the capability of a psychophysical test battery to identify and further characterize challenging aspects of hearing for CI users. It is part of the TEMPORAL project. The TEMPORAL project aims to develop a novel speech coding strategy to improve performance in challenging situations such as speech in noise, music perception, and tonal languages by applying machine learning and computational models on the neural responses of normal hearing ears and ones stimulated with a cochlear implant.

Methods: Seven psychophysical tests were selected for this study. The standard Dutch monosyllabic (CVC) word test (Bosman & Smoorenburg, 1995, Audiology, 34(5)) served as a reference point for speech perception. Digits in noise (DIN) test (Smits et al., 2013, JASA, 133(3)) is a fast adaptive closed set speech in noise test. The spectral-temporally modulated ripple test (SMRT) (Aronoff & Landsberger, 2013, JASA 134(2)) was included to measure spectral performance. Suggestions by Resnick et al. (JASA 2020, 147(2)) were added to accurately measure thresholds for NH subjects. A modified version of SMRT that varies ripple repetition rate (RR) instead of ripples per octave (RPO) was included together with the Modulation Detection Threshold (MDT) (Landsberger & Stupak, 2022, Ear and Hearing, 43(2)) and Temporal Fine Structure Test 1 (TFS1) (Moore & Sek, 2009, Int J Audiol, 48(4)) to measure temporal resolution. Finally, an in-house developed Glide Tone test was included as a measure of music perception. The CVC test was administered to all participants in quiet and speech shaped noise at SNR+5. All other tests were administered following the protocol described by the original authors. Exception is the TFS1 test, where the fundamental frequency was increased to 200 Hz, to allow for a frequency shift (ΔF) of 100 Hz. All tests were repeated twice in random order to assess test-retest reliability. Twenty-five adult CI users and twenty-five adult NH subjects will be included in this study.

Results: So far, 9 CI users were included, 44% female and 56% male. Mean age of the participants was 69±10 (53-87) years and the average experience with CIs was 85±63 (17-192) months. Average word score (%correct) for the Dutch CVC word test was 66±18 (27-88) at 65 dB quiet and 36±10 (21-49) in noise (SNR+5). DIN scores were 1.3±3.8 (9.8--3.9) dB SNR. Spectral resolution results measured by SMRT were 2.3±1.4 (1.0-5.8) RPO. Scores for temporal resolution tests were 1.0±0.7 (0.2-2.4) RR for the modified SMRT, MDT scores were -9.0±4.6 (-3.4--16.9) dB re 100% AM and TFS1 scores were 58.7±24.8 (19.8-86.1) ΔF. Music perception scores measured by the Glide Tone test were 2.3±1.0 (4.4-1.3) slope. Test-retest correlations indicate good reliability of all tests.

Discussion and Conclusion: The diverse test battery used in this study provides insights in temporal and spectral processing in CI users. It measures temporal processing in novel ways by using the TFS1 test and a modified version of the SMRT on CI users. This study introduces the Glide Tone test as a new measure of music performance. We expect to be able to present the full outcomes during the CIAP conference.

T36: SPECTRAL RESOLUTION AND ITS EFFECTS ON SPECTRAL RIPPLE DISCRIMINATION AND SPEECH UNDERSTANDING IN A VOCODER

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Cochlear implant (CI) speech outcomes are highly variable across patients. We hypothesize that this is due in part to degraded spectral representation of input sounds at the auditory nerve. Various psychophysical tests employing spectral ripple stimuli have been proposed to measure spectral resolution with a CI. However, few studies have evaluated the relationship between manipulated spectral resolution and spectral ripple discrimination. The goal of this study was to examine the effects of varying spectral resolution on spectral ripple discrimination and speech understanding in noise using a vocoder model of CI listening. Two methods for imposing changes in spectral resolution in a CI were explored: (1) changing the “input resolution” of the CI coding strategy by altering the filterbank sharpness and (2) changing the “output resolution” by modeling different degrees of current spread in the vocoder.

Eleven normal-hearing listeners aged 20-46 years completed a spectral ripple phase discrimination task and speech-in-noise testing. Ripple phase discrimination thresholds were measured using a two-down, one-up procedure adapting on modulation depth. Spectral ripple stimuli were generated by sinusoidally modulating the spectrum of band-limited noise (187.5-1187 Hz) with a density of 667 Hz/cycle. Ripple stimuli were presented at 50 dB SPL ±3 dB rove. Speech stimuli were five-word Boston University matrix sentences presented at 60 dB(A). Noise was 10-talker babble presented at 0 dB SNR. All testing was completed in the free field. A 22-channel, tone-excited vocoder and fast-Fourier transform (FFT) approximating the Advanced Combination Encoder filterbank was used. Filterbank sharpness was altered by changing the FFT size (128- or 512-pt). Current spread was modeled by convolving channel envelopes with neighboring channels and varying channel roll-off (-6 or -12 dB/channel).

Results from the spectral ripple test indicated that performance was affected by channel roll-off but not FFT size. In contrast, speech understanding in noise was affected by both channel roll-off and FFT size. Simulated CI output measured using a Simulink implementation of the CP910 (Nucleus 6) processor as well as the Nucleus MATLAB Toolbox (NMT) revealed that the difference between 0- and 180-degree phase shifted stimuli was less pronounced, but still present, for the 128- versus the 512-pt FFT. Results suggest that the correlation between spectral ripple and speech-in-noise performance was weaker than that observed in previous CI studies.

This study implies that the spectral ripple test used in the present experiment might be sensitive to some changes in spectral resolution (e.g., spectro-temporal smearing of output) but not others (e.g., smaller FFT sizes), despite their effect on simulated CI output. In contrast, speech understanding was sensitive to all changes in spectral resolution, with the poorest spectral resolution conditions yielding the poorest speech understanding performance.

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T37: CHARACTERIZING THE EFFECT OF PHASE DURATION ON PITCH: IS IT PLACE-PITCH?

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It is well-established that the spiral ganglion (SG) extends into the second turn of the cochlea, and place-pitch confusions are more prevalent in the apex of the cochlea for deeply inserted electrodes, presumably due to the clustering of cell bodies in the terminal bulb of the SG. In typical acoustic hearing, peripheral axons at the SG terminal bulb extend from the cell bodies to connect to more apical hair cells, thereby preserving tonotopic coding at low frequencies. While it is generally accepted that cochlear implants stimulate the SG cell bodies, it may be possible to preferentially excite SG via the smaller peripheral axons by using relatively long duration, low amplitude stimulation pulses. Using the midpoint comparison procedure for pitch ranking, a systematic decrease in the mean rank (i.e., pitch) was previously observed with a progressive increase in phase duration (PD) on apical electrodes, and an inconsistent effect of PD on pitch was observed for middle and basal electrodes (Stohl et al., poster at CIAP, 2013). Stimuli were 1000 pulses/s pulse trains delivered to single electrodes. This pattern of results matches the radial projection of SG fibers in the middle and basal regions of the cochlea and the projections of the peripheral processes of apical SG cells from the terminal bulb toward the helicotrema. If indeed changes in apical pitch are the result of shifting excitation from central cell bodies or axons to peripheral axons, such changes would be expected to be along the same perceptual dimension as a change in electrode location, or place-pitch. If instead, earlier pitch ranking results reflected changes in another perceptual dimension, this might be revealed through a multi-dimensional scaling procedure, such as is the case for a change in pulse rate for a given electrode.

In this study, multi-dimensional scaling was used to determine if perceptual changes attributable to an increase in PD could be described as a change in place-pitch. Stimuli consisted of single-electrode, fixed-amplitude pulse trains on 6 different electrodes at a short (usually 25 µs) or long (usually 200 µs) PD. The data was analyzed using ALSCAL. If the perceptual changes due to changes in PD at a fixed electrode were along the same dimension as the changes in electrode, then we could conclude that changes in PD resulted in changes in place-pitch. Additionally, a single-dimensional pitch scaling task was conducted to determine the size of the effect of a PD change for each participant.

It was expected that perceptual differences between the short and long PD would be place-pitch differences and that the size and magnitude of the shift would be greater in cochlear apical regions than other regions. Preliminary data with the first three subjects suggested that perceptual changes with PD indeed corresponded with changes in place-pitch. However, for some participants, little effect of PD was observed, possibly due to variations in electrode insertion depth.

T38: PSYCHOPHYSICAL TUNING CURVES IN COCHLEAR IMPLANT LISTENERS: COMPARING A FAST, NOVEL METHOD TO A TRADITIONAL APPROACH

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Objectives: Psychophysical tuning curves (PTCs) provide a measure of spectral resolution that is thought to be sensitive to the quality of the electrode-neuron interface (ENI) in cochlear implants (CIs). The quality of the ENI is primarily related to the health and density of the target auditory neurons and the distance between the electrodes and the neurons. Differences between the sharpness of PTCs are often observed for different electrodes, even within the same CI listener. The time-consuming nature of obtaining traditional PTCs has led us to develop a new, potentially faster, method. The goals of this study are to test the new method for reliability and speed, and to explore the relationship between sharpness of PTCs and focused stimulation thresholds.

Design: Adult CI users with the Advanced Bionics CI system were recruited to participate (N=9 ears, 2 bilateral participants, Age (years): M = 59.7, SD = 8.1). The traditional method of measuring forward-masked PTCs uses direct stimulation, while the new approach uses audio-stimulation through the speech processor via a Bluetooth connection. Absolute thresholds across each electrode array were measured for each listener using focused stimulation (0.9-steered quadrupolar, sQP) via a sweep method. The electrodes between 3 and 13 with the highest and lowest focused thresholds were selected as probe electrodes for PTC measurements to maximize the difference between electrodes. The forward-masking paradigm used a 200-ms masker with a 10-ms gap and a fixed low-level 20-ms probe. For the direct stimulation method, the sQP mode with a 0.5-sQP focusing coefficient was used for both masker and probe. Measurement of max comfort level and threshold was required for every electrode using the direct method. Forward-masked thresholds were measured for PTCs using a 3-interval 3-alternative forced-choice procedure with a fixed probe level and varying masker level. For the audio-stimulation method, all the same temporal parameters were used for the pure-tone masker and probe, with the exception of a 5-ms gap instead of a 10-ms gap. No measurements of masker thresholds or comfort levels were needed because signals were presented through the CI listeners' speech processors. The pure-tone frequencies were selected to stimulate the main and flanking electrodes at 75% and 25% respectively through the listeners' speech processor. The forward masker was presented at a fixed level above that needed to mask the fixed-level probe when the masker and probe were at the same frequency. The masker frequency was then adaptively varied to directly find the 6- and 10- or 12-dB slopes of the PTC.

Results: Mean threshold differences between the two selected channels with the highest and lowest 0.9-sQP thresholds were 7.12 dB (ranging from 2.40 - 12.69 dB re.1uA). PTCs were quantified in terms of the slopes of the best-fit line of each side of the PTCs from the probe electrode. Preliminary trends suggest that results from the two methods match, but more data is needed for statistical analysis. We observed steeper electric PTC slopes for the probe channels with lower absolute 0.9-sQP thresholds (mean = 33.8% masker dynamic range/electrode, ranging from 12.5 to 69.1) than high threshold channels (22.7% masker dynamic range/electrode ranging from 3.17 to 49.0). A similar trend was observed for low (10.4 dB/electrode from 1.6 to 23.0) and high (6.2 dB/electrode from 1.9 to 13.4) threshold channels using the Bluetooth audio stimulation approach. Focused thresholds were a significant predictor of tuning curve slopes from the audio-stimulation method but not the direct-stimulation method.

Conclusions: In this small sample of adult CI listeners, our new audio-stimulation PTC method appears to match results from a traditional PTC method, but further testing required. Sharper tuning was observed for lower focused-threshold channels with both methods of PTCs measurement. These pilot data support the further exploration and validation of this more efficient way to measure PTCs via Bluetooth stimulation.

T39: DEVELOPING PERSONALISED INTERVENTION INFORMED BY THE VIABILITY OF THE ELECTRODE-NEURAL INTERFACE

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Purpose: There is a wide range of hearing outcomes for people using Cochlear implants (CIs). The Electrode-Neural Interface (ENI) could be a bottleneck for sound delivery. Different re-mapping techniques intended to improve speech outcomes for damaged ENI have been suggested by researchers, but it isn't clear which approaches should be used clinically. This project starts with a systematic review to compare interventions and identify the applicable clinical scenario of the intervention. The next step aims to determine if electrically evoked compound action potential (ECAP) could be used to inform interventions.

PART I: Cochlear Implant Re-Mapping Informed by Measures of viability of the Electrode-Neural Interface: A Systematic Review Method A systematic review registered with PROSPERO (CRD42021292483) was performed according to PRISMA 2020 statements. Six electronic databases were searched. The risk of bias (ROB) of the publications was independently assessed by three reviewers. The effectiveness of each intervention was analysed focusing on the speech in noise performance. The probability of an individual benefiting from an intervention was estimated. Findings The statistical powers of the included articles are generally low and hence some false negatives are expected. Channel deactivation was more successful while being informed by low-rate thresholds and imaging tools. Frequency re-allocation intended to reduce the frequency-to-place mismatch did not show a significant improvement at the group level.

PART II: Does temporal responsiveness of human spiral ganglion cells change tonotopically? A computational study supported by human data Method The computational model consists of a CI processing front-end, a finite element voltage model of the inserted cochlea, and the auditory nerve model. Human ECAP data and refractoriness measures were collected from several published studies. For each data set, the model is configured as close as possible to the original conditions at data collection and under two different assumptions, with or without tonotopically changing temporal responsiveness. The similarity between the predictions and the data is assessed.

Expected Results: The data collection and model configuration are currently in progress. It is expected the similarity between the prediction and data will be higher when the assumption approaches reality closer. If the temporal responsiveness of human SGCs changes tonotopically, normative data could be established to predict the characteristic frequency of the stimulated SGCs and hence to guide interventions in re-mapping and innovative coding strategies.

Conclusion: Researchers agree that a poor ENI could cause a bottleneck to good information transmission in cochlear implant users but the optimal approach for characterising and intervening remains unclear. A computational model is being developed to explore characteristics of neural refractoriness and whether this can help to guide the appropriate interventions, to include re-mapping or even different approaches to signal processing.

T40: SPATIAL RELEASE FROM MASKING FOR SMALL SPATIAL SEPARATIONS BETWEEN THE TARGET AND THE MASKERS FOR SIMULATED COCHLEAR IMPLANT PROCESSED SPEECH

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Background: Spatial release from masking (SRM) is the improvement in speech intelligibility when the masking signals are spatially separated from the target signal and the amount of improvement is based on the individual’s age and hearing ability. Previous research investigating SRM on cochlear implant (CI) users has used big spatial separations (≥ 45°) between the target and the maskers. However, in realistic conversational settings, the spatial separation could be far less than that. Here, we present SRM data using simulated CI speech from young, normal hearing listeners for smaller, yet realistic, spatial separations between the target and the maskers.

Methods: Twenty-five young normal hearing adults (age range: 19-23 years) participated in the experiment. Coordinate Response Measure sentences were used for the target and the maskers. Eight spatial configurations were used: (colocated (target and the two maskers presented from 0° azimuth) and one of seven spatially separated conditions (target at 0°, symmetrical maskers at ±2°, ±4°, ±6°, ±8°, ±10°, ±15°, or ±30°). Head related impulse responses (HRIRs) were generated and the speech stimuli were convolved with the appropriate HRIRs for their appropriate locations. An eight-channel noise-excited vocoder was used to simulate the cochlear implant processed speech.

Results: Initial analysis of the data revealed that the listeners had significantly poorer speech identification thresholds (as measured by the target-to-masker ratio required to identify 50% of the target words correctly) for the simulated cochlear implant processed speech when compared to natural speech. Also, the amount of release of masking (defined as the difference in speech identification thresholds between the separated conditions and the colocated conditions) was higher for the natural speech compared to the simulated cochlear implant processed speech.

Conclusion: The data presented here suggests that the listeners can use the level difference cues in the simulated cochlear implant processed signal to obtain release from masking at smaller separations.

T41: THE IMPACT OF PULSE RATE, ELECTRODE LOCATION AND CROSS-CHANNEL INTERACTION ON PITCH PERCEPTION AND FREQUENCY DISCRIMINATION IN CI USERS

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Currently, most commercial cochlear implants (CI) use the continuous interleaved sampling (CIS) strategies to transduce acoustic inputs into electric stimulation to convey sound to CI users. Typically, CIS strategy divides the input sound signal into a set of frequency bands and the envelope variations within the different bands are extracted. The envelopes are then used to modulate trains of electric pulses that are presented at a fixed rate and in a non-overlapping sequence. The electric pulses proceed to stimulate different electrodes in the cochlea, following the tonotopic pattern in the auditory nerve. Although this envelope-based approach can transmit temporal pitch, this approach could not deliver well the fundamental frequency of speech and other low-frequency components to provide salient pitch sensation and sensitive frequency discrimination. we propose series of clinical studies to investigate how to improve pitch perception and frequency discrimination by manipulating pulse rate (either single or a few adjacent electrodes) and its relationship with electrode location and cross-channel interaction.

The first set of studies will focus on pitch perception and sensitivity elicited by varying pulse rates via single electrode. Past studies have shown that combining place and rate of stimulation could deliver more differences in sensations to CI users, therefore, we will firstly replicate the perception map of pitch by varying orthogonally pulse rate and electrode location (similar to Landsberger et al., 2015). However, it is unclear from previous studies whether all dissimilarities in behavioral responses are attributable to improvement in pitch sensitivity. Therefore, we will improve on the previous design by implementing multi-dimensional scaling and an adaptive track to find the just-noticeable-difference in pitch delivered by the combination of place and rate cue. We will also investigate how the configuration of the pulse rate cue affects pitch sensation and discrimination, by manipulating the inter-pulse duration via jittering the stimulations onset stochastically.

The second set of studies will focus on pitch perception and frequency modulation detection when multiple electrodes are engaged. CI users experience significant channel interactions due to technical constraints of CI and neural health in electrode-neural interface. It is unclear to what degree the saliency of pitch and the sensitivity of frequency modulation are affected by channel interaction. In traditional CIS, spectral temporal modulation detection is strongly limited by cross-channel interaction because frequency modulation is transmitted via cross-channel difference in temporal modulation. Whether the same constraint remains when delivering frequency modulation with rate and place cue remains unclear. Therefore, we will present different pulse rates at two electrodes, either one or two electrodes away, and examine the degree of masking between electrodes by changing the duration/amplitude of the masker electrode and fixing the level of the target electrode. To quantify the spectro-temporal sensitivity required to perceive frequency modulation, we will run an adaptive procedure to find the number of electrodes needed to discriminate between upward and downward sweeps. Different pulse rates will be delivered to corresponding electrodes consecutively to elicit a sweep. The number of electrodes used will increase until participants can successfully discriminate the sweep direction.

Results in this set of experiments will show how channel interaction affects the efficiency of frequency information transmission. We aim to recruit 10 CI participants for the four experiments mentioned above. All stimuli will be delivered through the Oticon Medical Research Platform (OMRP) via direct stimulation, and the experiments will run on Oticon Medical Experiment Platform (OMEXP) that allows for custom psychoacoustic experiments. Data collection aims to start in April 2023.

To summarize, our experiments will bring new understanding to the pitch sensation and sensitivity by combining place and rate cues. Our results will bring the research and development closer to designing a new stimulation strategy that can fully utilize the place and rate cues to deliver better pitch sensation in complex and realistic acoustic signals.

T42: SHOULD COCHLEAR IMPLANT LOUDNESS BE MORE LIKE A HEARING AID?

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Cochlear implants (CIs) encode acoustic information into electrical stimulation to elicit a percept of hearing. The conversion from acoustic sound pressure level (SPL) to electrical current level is typically handled by an instantaneous mapping function with limited input dynamic range (IDR), 40 dB for example. To access SPLs in the environment not within the IDR, automatic gain control (AGC) is commonly utilised to adjust the signal level appropriately. Acoustic hearing aids (HAs) also utilise AGCs to provide gain and adjust the signal appropriately for the limited dynamic range of acoustic hearing it is aiding. When a CI and HA are used together in a bimodal system, the AGCs influence the perceived loudness balance across the two ears.

The aim of this study was to investigate AGC configurations for a CI that would lead to more natural loudness perception and would ultimately achieve matched loudness behaviour across the ears in a bimodal system.

The AGCs were categorised as broadband or channelised, slow or fast, and compressive or limiting. Three AGC configurations were evaluated in CI listening experiments:

The Baseline condition, typical of CI sound processing, was dominated by broadband limiting controls. The Emulator condition was designed as a multi-channel AGC and configured to mimic the Baseline condition for speech-based inputs. Finally, the multi-channel WDRC condition was designed to act closer to a typical hearing aid AGC configuration.

All three AGC configurations were evaluated in acute listening experiments in a group of 13 adults with CIs. Evaluation was performed unilaterally at two presentation levels, 65 and 80 dB SPL. Intelligibility was measured with speech reception thresholds (SRTs) of sentences presented in 4-talker babble noise. Sound quality ratings were obtained using Multiple Stimulus with Hidden Reference and Anchor (MUSHRA) procedure for speech in quiet, speech in babble noise, and two music excerpts (jazz and classical). Loudness scaling and loudness equalisation tasks were also performed for different stimuli.

Analysis of the group's SRTs indicated Baseline and Emulator were not significantly different from each other, while WDRC produced significantly poorer intelligibility (1.2 dB SRT). Presentation level had no significant effect on intelligibility. MUSHRA ratings indicated Emulator was slightly but significantly worse than Baseline (4.4 rating points), and WDRC was significantly worse than both Baseline and Emulator (by 14.8 and 10.4 points respectively). Analysis revealed that stimulus type, presentation level, and overall loudness did not have a significant effect on sound quality ratings. Loudness scaling and loudness equalisation tasks indicated minor differences between Baseline and Emulator, while WDRC showed a different pattern of loudness growth as expected.

In conclusion, a multi-channel AGC (Emulator) was configured to accurately emulate the broadband AGC condition (Baseline), notwithstanding a small but statistically significant drop in sound quality ratings. The multi-channel fast WDRC configuration provided an alternative loudness growth profile, like what might be expected in a hearing aid, but produced lower intelligibility and sound quality when acutely evaluated in unilateral CI users. Further work is required to investigate the potential benefit of WDRC processing for CI in a bimodal context.

T43: TRANSFORMER-BASED MONAURAL SPEECH ENHANCEMENT FOR COCHLEAR IMPLANT (CI) USERS VIA COMPLEX SPECTRAL MAPPING

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In daily life, cochlear implant users face challenges in understanding speech due to background sounds or competing talkers that distort the magnitude and phase spectrum of speech. While most speech enhancement (SE) systems only enhance the magnitude response, recent studies have shown that phase is also essential for perceptual quality of speech.

To address this, this study proposes a deep complex convolution transformer network for complex spectral mapping that simultaneously enhances both the magnitude and phase responses of speech. The proposed network leverages a complex-valued U-Net structure with a transformer in the bottleneck layer to capture low-level details of contextual information in the time-frequency domain. Additionally, the proposed network integrates a frequency transformation block to capture harmonic correlation in the speech. This system learns a complex transformation matrix to accurately recover speech from a noisy spectrogram. A large training set is used to train the U-Net architecture, ensuring a powerful model capable of estimating the nonlinear mapping between noisy and clean speech via supervised learning. To validate the proposed system, speech intelligibility and quality of speech were evaluated for 5 CI listeners with a total of 200 sentences in naturalistic environment.

Evaluation using subjective and objective measures suggest that the proposed network substantially outperforms an existing convolutional recurrent network (CRN), deep complex convolutional recurrent network (DCCRN), and a gated convolutional recurrent network (GCRN) in both seen and unseen noise in terms of both subjective and objective speech intelligibility and quality. Furthermore, the proposed network can suppress highly non-stationary noise without creating musical artifacts commonly observed in conventional enhancement methods.

Keywords: Cochlear Implants, Speech Enhancement, Transformer, U-Net, Complex-Valued Network. This work was supported by Grant No. R01 DC016839-02 from the National Institute on Deafness and Other Communication Disorders, National Institutes of Health.

T44: CURRENT SPREAD AND CHANNEL NUMBERS LIMIT DISYLLABIC WORD AND TONAL RECOGNITION IN SIMULATED AUDITORY BRAINSTEM IMPLANTS

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Introduction: For deaf patients with contraindication to cochlear implant (CI), such as children who have cochlea or cochlear nerve aplasia, auditory brainstem implant (ABI) is the only way to restore hearing. However, the performance of ABI users is far from satisfactory, with only 30% of users achieving open-sentence recognition. Current spread and limited channel numbers are thought to worsen speech recognition in CI, but little is known about the effects of those factors on speech performance in ABI. In this study, we aim to develop an ABI simulation model based on paddle geometry and investigate the effects of current spread and channel numbers on the recognition of disyllabic words and tonal languages based on that model.

Methods: ABI simulation model was created by MATLAB, and was based on the electrode paddle geometry data of a custom ABI to imitate current spread between electrodes. The number of channels used ranged from 8 to 16 channels. To simulate different degrees of channel interaction, the calculation of envelope on each spectral band was weighted. The coefficient was set at 0.2, 1, and 2, to simulate 'narrow,' 'moderate,' and 'broad' current spread, respectively. Five individuals with normal hearing (aged 22-35 years) participated in the study. Disyllabic word and Mandarin tone perception was measured with close-set test of simulations words on ‘Angel Sound Test’. The overall input frequency of simulation ranged from 153to 7769 Hz, which corresponds to the default of Nurotron Corp.'s WH-01 ABI device. All participants were tested in a quiet environment and completed an 8AFC and 4AFC test for disyllabic word and tone perception. The scores from all trials were averaged for analysis.

Results: All participants scored above 90% in disyllabic word performance when channel interaction was set at 0.2, but performance declined as channel interaction increased. A two-way repeated measures analysis of variance indicated significant main effects for channel interaction ($F=53.3$, $p=0.000$) and number of channels ($F=12.9$, $p=0.000$), as well as a significant interaction effect ($F=4.1$, $p=0.003$). Post-hoc Bonferroni comparisons showed significant differences between all channel interaction conditions ($p<0.05$ in all cases), as well as between data from 16 channels and other channels ($p<0.05$). In terms of tonal recognition, most participants scored below 50% in the tonal recognition test. A two-way repeated measures analysis of variance indicated a significant main effect for channel interaction ($F=5.1$, $p=0.03$), but not for number of channels ($F=0.1$, $p=0.96$). Post-hoc Bonferroni comparisons revealed that scores significantly declined when channel interaction increased from 0.2 to 1 ($p=0.04$).

Conclusion: The results partially align with previous research on ABI studies, which indicate that patients with ABIs tend to have poorer performance in limited channels. Our findings suggest that channel interaction may more significantly impact their performance than that of CI users, highlighting the importance of promoting independence among spectral channels when developing new stimulation strategies.

T45: DESIGN AND OPTIMIZATION OF AN END-TO-END DEEP LEARNING SOUND CODING STRATEGY FOR COCHLEAR IMPLANTS THROUGH A COMPUTATIONAL MODEL AND PERCEPTUAL TESTS

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Cochlear implants (CIs) can successfully restore hearing to people with profound sensorineural hearing loss. Although CI recipients generally achieve good speech understanding in favorable acoustic environments, their hearing performance deteriorates drastically in noisy environments. Front-end speech enhancement algorithms have been proposed as a solution. However, these algorithms only work well in certain acoustic situations and noisy environments.

We have proposed a Deep Neural Network (DNN) that replaces the entire CI sound coding strategy with end-to-end processing. The DNN is trained to predict the denoised electrodogram, i.e., predict the electrical stimulation patterns applied to the electrodes over time from the raw audio input and remove unwanted background noise. We specifically design the DNN to emulate a common CI sound coding strategy; the Advanced Combination Encoder (ACE), which we refer to as Deep ACE, but we also show how this concept can be extended to FS4, which we refer to as Deep FS4. The DNN was designed to not only faithfully emulate the encoding of acoustic signals that the sound coding strategy would perform, but also to remove unwanted noise, if present, without sacrificing processing latency. In general, DNN models are extremely flexible in their configuration: the architecture, parameterization, and cost function must be defined. Furthermore, the optimization of these models is challenging, and obviously, clinical trials on CI users for this purpose would be prohibitively expensive and time consuming. For this reason, we created a computational model that consists of a processing stage with i) the sound coding strategy module, including de baseline and the end-to-end DNN-based sound coding strategies; (ii) a three-dimensional electrode-nerve interface that accounts for auditory nerve fiber (ANF) degeneration; (iii) a population of phenomenological ANF single fiber models; and (iv) a feature extractor algorithm to obtain the internal representation (IR) of the neural activity. As the back-end, the simulation framework for auditory discrimination experiments (FADE) was chosen. The model predicts speech understanding with each sound coding strategy. The DNN-based sound coding strategies were optimized using CI-specific loss functions and evaluated through speech performance tests with the computational model and with real CI participants.

Results show that the proposed computational model achieves worse speech reception thresholds when compared to real CI data. Furthermore, the computational model predicted a consistent SRT improvement for Deep ACE which is consistent with speech intelligibility scores observed in eight CI users.

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T46: EFFECT OF MICROPHONE DIRECTIONALITY SETTING ON SPEECH UNDERSTANDING IN NOISE IN BILATERAL CI RECIPIENTS

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Directional microphones have been shown to improve speech understanding for frontal speech in noise in unilateral and bilateral CI recipients with severe to profound hearing loss. However, due to the narrow focus of directional microphones to the front, their application might compromise understanding of speech presented at the recipients' side, or behind them. For these speaker positions, the application of less focused microphone directionalities or omnidirectional microphones might be beneficial. This study aims to assess the effect of the microphone directionality setting used with two Nucleus 7 sound processors CP1000 on speech understanding in noise in bilateral CI (BiCI) recipients. Until now, 11 adult BiCI CI recipients have been included. Speech understanding was assessed as speech reception threshold (SRT) in ICRA5-250 noise (ICRA), a single-talker, male speaker babble fluctuating masker (Wagener et al. 2006), and in a road traffic noise (TRAFF). Speech and noise were presented in four spatial configurations using four loudpeakers at 0°, 90°, 180°, and 270°: speech from front, from left side, from right side or from behind, and noise simultaneously from the three remaining loudspeakers, respectively. With regard to the sides of the 1st and 2nd CI, the configurations are referred to as S0N3, Sci1N3, S180N3, and Sci2N3. In ICRA and all configurations, and in TRAFF and the two configurations Sci1N3 and Sci2N3, four microphone directionality settings were investigated: the standard fixed moderate directional microphone (Standard) used with both CIs (Std/Std), the fixed directional microphone Zoom with both CI (Zoom/Zoom), Standard with 1st CI and Zoom with 2nd CI (1Std/2Zoom), and Zoom with 1st CI and Standard with 2nd CI (1Zoom/2Std). In S0N3 and ICRA, the BiCI recipients showed lowest SRT for Zoom/Zoom (-4.5 dB), and poorest performance for Std/Std (0.6 dB). In S180N3 and ICRA, there was no effect of microphone directionality setting on SRT. In Sci1N3 and both noises, SRTs were lower with 1Std/2Zoom (ICRA: -4.1 dB, TRAFF: -8.5 dB) and Std/Std (ICRA: -2.9 dB, TRAFF: -8.3 dB) compared to 1Zoom/2Std (ICRA: -1.3 dB, TRAFF: -4.7 dB) and Zoom/Zoom (ICRA: -0.5 dB, TRAFF: -4.2 dB). In Sci2N3 and both noises, BiCI recpients yielded lower SRTs with 1Zoom/2Std (ICRA: -3.0 dB, TRAFF: -7.2 dB) and Std/Std (ICRA: -3.5 dB, TRAFF: -7.3 dB) compared to 1Std/2Zoom (ICRA: 0.3 dB, TRAFF: -4.7 dB) and Zoom/Zoom (ICRA: -1.9 dB, TRAFF: -4.7 dB). For presentation of speech from front, BiCI recipients using two CP1000 gain better speech understanding in noise with bilateral application of the directional microphone Zoom compared to using Zoom with only one CI and the standard moderate directional microphone with the contralateral CI, or bilateral use of Standard. However, for presentation of speech from the side, using the standard directionality with the CI at the speech side and the standard directionality or Zoom with the contralateral CI, enables better speech in noise performance compared to Zoom with the CI at the speech side and Standard with the contralateral CI, or bilateral use of Zoom.

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T47: A GENERIC SIGNAL PROCESSING FRAMEWORK FOR SPEECH REDUNDANCY MANIPULATION ALGORITHMS IN SPEECH PERCEPTION STUDIES

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Speech signals are highly efficient in facilitating interpersonal communication, but their acoustic variability and degradation in noisy environments pose a considerable challenge for both contemporary machine learning algorithms and hearing-impaired individuals. To better understand the cues underlying speech perception, various synthesis approaches have been employed, such as resynthesized acoustic stimuli based on degraded speech, reconstructed stimuli from simplified hand-drawn spectrograms, and stimuli from sinusoidal waves or temporal envelopes of limited channels.

In this study, we propose a unified signal processing framework based on Gaussian-enveloped atoms to unify several existing speech manipulation algorithms, such as channel vocoders, mosaic speech, chimaeric speech, and pulsatile Gaussian-enveloped tones. The algorithms were independently studied, but using this framework they could be treated as special cases of the framework. This framework not only can unify existing algorithms but also have to ability to generate new models. We further demonstrate the promise of this framework by proposing an "atomic speech" model, in which continuous sound is treated as a combination of discrete atoms. The model showed high sparsity in both spectral and temporal domains, and the intelligible degraded patterns of the atomic speech have not been reported in existing literature.

To investigate the perception with the atomic speech, we conducted a speech-reception-threshold (SRT) experiment. Ten normal-hearing college students were tested in a soundproof room using the Mandarin Hearing in Noise Test corpus. SRT was measured using a 1-down 1-up adaptive procedure, and three conditions for the number of spectral maxima (in the same manner as the n-of-m cochlear implant strategies) were tested for each participant. The study found that a total atom rate of 72.7 pps on average was sufficient for understanding sentences, even though the speech was highly sparse in both spectral and temporal domains. Time-frequency trade-off effects on intelligibility were also demonstrated between the results with 1 and 8 maxima. The SRT for total-rate (=maxima number × rate per channel) with 4 spectral maxima was lower than those with 1 and 8 maxima.

In summary, this study proposes a unified signal processing framework based on Gaussian-enveloped atoms to unify existing speech manipulation algorithms and presents an "atomic speech" model to investigate speech redundancy. The proposed model showed novel observations in the SRT experiment, and we suggest that the framework can serve as the foundation for the development of new algorithms and new advances in the field of speech redundancy study. The proposed signal processing framework and the "atomic speech" algorithm may have significant implications for cochlear implant simulation and speech intelligibility in noisy environments.

T48: PITCH AND LEXICAL TONE PERCEPTION IN QUIET AND NOISE USING F0-RATE CODING STRATEGIES

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Temporal pitch information can be conveyed by electrical pulse-rate or amplitude modulation (AM) rate in cochlear implant (CI) systems up to rates of approximately 300 Hz beyond which the salience of the percept diminishes. In most clinical sound coding strategies AM rate encodes information pertaining to the fundamental frequency (F0) of the incoming sound. For example, band-pass filter envelope signals in channels of the clinical ACE (Advanced Combination Encoder) and CIS (Continuous Interleaved Sampling) strategies carry AM information related to F0 which is sampled at a fixed higher-rate to generate electrical stimulation pulse-trains.

For experimental strategies, such as OPAL (Optimised Pitch and Language), F0 is explicitly estimated from the signal and used to control AM rate coded by fixed-rate electrical pulse-trains in each stimulation channel. In contrast, the experimental FAST strategy extracts peak-timing information from the channel envelopes to derive pulse-timing/rate in each stimulation channel. The performance of such strategies in pitch related tasks can differ, particularly as a function of F0 range, and/or the presence of other cues, such as confounding place cues, or the addition of background noise. Presented here are results of two studies exploring the salience of such pitch percepts for tones presented in quiet and noise. Study 1: Pitch ranking by eight experienced adult CI recipients was measured using experimental versions of the OPAL and FAST strategies, OPAL+ and FAST-EQ, respectively. A 2AFC procedure was used with synthetic harmonic tone and natural sung-vowel stimuli, the latter containing stronger confounding effects of place. The tests were conducted in quiet and in speech-weighted noise (SNR +15, +10, or +5dB). Results in quiet were not significantly different between strategies indicating that the salience of pitch information derived from both strategies (i.e., via F0 pulse rate versus F0 AM rate) was comparable. However, in noise a significant benefit of OPAL+ (10 and 20% points for synthetic and sung-vowel stimuli, respectively) was observed compared to FAST-EQ. This outcome was attributed to the adverse effect of noise on the accuracy of coded rate-pitch information derived from temporal peak timing in channel envelopes of FAST, in contrast to the greater accuracy of F0 estimation and explicit F0 AM-rate coding of OPAL; and greater difficulty in perceptual separation (auditory streaming) of the target stimulus from the noise when using FAST. Study 2: Mandarin lexical tone discrimination was measured in thirty-one experienced adolescent and adult CI recipients when using the clinical ACE strategy and the experimental OPAL strategy. A 4AFC discrimination test was employed using naturally produced Mandarin lexical tones, and duration/intensity normalised versions of the natural tones. The tests were conducted in quiet conditions and in speech-weighted noise (SNR +5dB). Significant benefits of OPAL compared to ACE were observed in all conditions. For both the natural and normalised tones in quiet, an average benefit of 2.8% points was observed while in noise it increased to 7.3% points. For normalised tones in quiet, perception of tone 3 (dipping) and tone 4 (falling) (which are the longest and shortest tones, respectively), was most degraded compared to the natural tones. However, their perception was also most improved using OPAL suggesting greater use of F0 contour as a cue to lexical tone for OPAL. In noise, benefits of OPAL were observed for all tones suggesting greater salience/accuracy of F0 AM rate information in noise, and/or greater perceptual segregation of target and noise coded by OPAL compared to ACE.

T49: DEEP NEURAL NETWORK-BASED NOISE REDUCTION FOR COCHLEAR IMPLANTS

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Noisy conditions make understanding speech with a cochlear implant difficult. Speech enhancement algorithms that reduce noise based on estimates of signal statistics are beneficial in stationary noise but not in modulated babble noise. Deep neural networks (DNNs) rely on a data-driven approach for training and, when applied to noise reduction, promise improvements over a wide variety of conditions, although network size can limit deployment in low-power wearable solutions.

In this study multiple DNN-based noise reduction algorithms were evaluated. Algorithm performance was first predicted with a range of standard and novel objective metrics and then measured through listening experiments, where sounds were pre-processed by the algorithms and played back to research participants through their commercial CI. Objective metrics generally predicted good speech intelligibility and sound quality improvements for the algorithms, especially for positive signal-to-noise ratios (SNRs) also in the range that are challenging for CI listeners (e.g., +5 dB SNR). A double-blinded acute evaluation of the algorithms was conducted with 10 adult cochlear implant users. Speech understanding and sound quality measures were made for sentences embedded in multiple different noise types, including stationary speech-weighted noise, 4- and 20- talker babble, and recordings of a cafeteria, a cocktail-party, and street-side city noise. None of the speech or noise materials used in testing were used to train the network.

Two of the DNN-based noise reduction algorithms provided statistically significant benefits in speech intelligibility and all three algorithms improved sound quality for cochlear implants listeners across all noise types evaluated in the study. Speech reception thresholds, the SNR required to understand 50% of the speech material, improved up to 1.8 to 3.5 dB depending on algorithm and noise type. Benefits also varied with the SNR of the input signal. While substantial benefit was observed over most SNRs tested, the DNNs generally produced lower quality and intelligibility improvements at low SNRs.

These results suggest that DNN-based noise reduction has good potential for improving CI hearing performance over a large range of noisy conditions.

T50: SOUND OF METAL: A REAL-TIME VOCODER AUDIO PLUGIN FOR COCHLEAR IMPLANT SIMULATIONS

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This poster presentation will explore the development of a real-time VST software plugin based on a vocoder simulation of cochlear implant (CI) processing using the JUCE C++ framework. These types of tools have great value in aiding in artistic and scientific explorations by the broader public in understanding how different types of music may sound like to a cochlear implant user. Such tools can also be used for sound design and music production.

This presentation will cover the development process of this audio plugin from its inception in the Matlab scripting environment, to a real-time prototype in MaxMSP, and finally to a VST plugin written in C++ using the JUCE framework. This work will explore the effect of using different carrier waveforms as well as IIR and FFT based filterbanks on subjective and objective assessments of sound quality.

The relative advantages and disadvantages of such design choices will be evaluated in terms of computational complexity and spectrotemporal fidelity. Code excerpts and DSP block diagrams will be shared which detail the underlying signal processing of CI devices. Approaches to simulating different aspects of CI stimulation such as current focusing/steering and frequency shifting (to simulate electrode array mismatch with place of stimulation) will be explored. Consideration will be given to using CI processing for sound design for artistic purposes.

T51: A COMPARATIVE STUDY OF MUSIC PREPROCESSING STRATEGIES FOR COCHLEAR IMPLANT LISTENERS

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The access to music and thus the enjoyment thereof is limited for CI listeners due to several physiological and technological constraints. These include the limited number of frequency channels and the current spread inside the cochlea. Most of these constraints are caused by the currently available CI technology, so they are unlikely to be overcome in the short term. Therefore, a number of music preprocessing strategies have been proposed, which emphasize essential elements such as the main melody and rhythmic cues and attenuate the accompaniment. Previous studies have shown that music perception of CI listeners can be improved by this approach.

In a recent study, four algorithmic preprocessing methods based on different musical source separation and spectral dimensionality reduction approaches, and manually generated baseline remixes were evaluated (Gauer et al., 2023). In a listening experiment, 15 CI users indicated their preference for signals processed with the respective methods over an unprocessed reference. Additionally, NH listeners assessed signal quality criteria and we determined instrumental measures and signal-level features for the stimuli presented to the CI listeners. Three of the four tested methods and the baseline remix were significantly preferred over the unprocessed reference by the CI listeners with average preference rates between 59% and 69%. Thereof, the highest preference scores were obtained for remixes generated with deep neural networks, capable of processing harmonic and percussive components of the sources “vocals”, “bass”, “drums”, and “other accompaniment” separately. Besides the accompaniment, this method attenuates the harmonic components of the “drums” source. It was preferred more often than a related remix containing the full drum signals, supporting earlier findings from an experiment with NH listeners using a vocoder-based CI simulation (Gauer et al., 2022). By contrast, remixes emphasizing only the melody and emphasizing drums, bass, and all other accompaniment were only rarely preferred by the CI listeners. Further, the particular music piece and genre also had an impact on the preference scores. Correlation analyses between the CI preference scores and both the NH signal quality ratings and the instrumental measures identified an increased distinctness of the rhythm, increased spectral sparseness and a shift in spectral distribution towards low-frequency content as factors which might explain the CI preference ratings.

The results of the listening experiment with CI listeners indicate a preference for music preprocessing methods, which emphasize both the main melody and rhythmic cues in favor of the accompaniment and thus reduce the spectral complexity. The studied strategies provide a number of techniques to develop individual preprocessing methods. Moreover, the explanatory factors identified by the instrumental and perceptual signal assessments may further support the development of new algorithms and remixing presets.

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T52: FREQUENCY DISCRIMINATION AND MUSIC ENJOYMENT IN ADULT COCHLEAR IMPLANT USERS

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The effectiveness of CIs can vary depending on a person's unique hearing and music-related experiences. Despite the significant advances in speech perception with the use of CIs, CI listeners who have little to no residual hearing can still encounter difficulties in perceiving music and speech-in-noise environments. This is partly due to the limited access to low-frequency information that is crucial for music and speech perception.

In a previous study, Lam et al. (2022) found that CI users were better able to discriminate chords when the second note (out of three) was lowered than when the third note was raised (Lam et al., 2022). We hypothesize that this effect could reflect the use of within-channel temporal interactions between tones in the form of beats. Beats are more salient when the fundamental frequencies of the constituent tones are close together. The detection and discrimination of beats may play a strong role in speech and music perception for individuals listening with CIs, given that CIs mainly provide information about temporal envelope fluctuations in different frequency regions (Spitzer et al., 2019). This study examines how CI users discriminate between tones for which the frequency components may fall into one channel (giving rise to beats) or multiple channels (reducing the salience of beats), to clarify the extent to which they use beat cues.

We also aim to assess whether the ability to use within-channel beats is related to to speech-in-noise perception and music enjoyment. The study is ongoing, and we aim to test 24 CI users. The study involves completing a hearing- and music-related questionnaire, undertaking frequency discrimination and direction identification psychoacoustic tasks for pure and complex tones, measuring speech-in-noise perception and performing a melodic contour identification task. Preliminary results suggest that some CI listeners are able to use beat cues to discriminate frequency, but not necessarily in all channels and frequency ranges.

Overall, this study should improve our understanding of the cues that CI users use for music and speech perception and should provide insights into how CI processing strategies can be modified to improve music and speech perception.

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T53: EXPLORING RATE-CODED PITCH PERCEPTION IN CI USERS VS. A WAVELET VOCODER USING THE OTICON MEDICAL RESEARCH PLATFORM

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Pitch can be transmitted to CI users by varying stimulation rate as well as by changing the stimulating electrode [1]. However, the commercial rollout of such variable rate strategies has not yet capitalized on this opportunity [2]. This is partially due implant limitations and partially due to the lack of development tools with which to realistically evaluate rate-coding ideas. Traditionally, vocoders are used give normal hearing people an idea of what listening through a CI is like. They come in many types: sine, noise, wavelet, spiral [3], etc. While all types have been used to guide CI development, only spiral and wavelet types can represent rate-coding. To be useful for CI development, the performance (and experiences) of a CI user vs. someone listening through a vocoder must first be aligned—this is particularly difficult for rate-coding vocoders due to the complex action of the basilar membrane and the resulting resolved vs. unresolved harmonics [4]. Here we compare CI vs. vocoder experiences in a rate-coded pitch experiment by using the Oticon Medical Research Platform (OMRP). The platform can (1) directly stimulate a CI user with a novel rate-coded pitch (via a MIDI keyboard) and (2) present a wavelet vocoded version (like the Bräcker vocoder [5]) of those electrograms to a normal listener. The vocoder listener displayed much better pitch discrimination then the CI user indicating that more information remained in the wavelet vocoder than was used by the CI user. The vocoder should be adapted to better mimic the CI user experience before using it for rate-coding CI development. One way to do this is to introduce jitter into the electrogram prior to vocoding to 'blur' the temporal information. These techniques (or other ones in the case of the spiral vocoder [3]) may enable vocoders to be useful for CI rate-coding development—but no vocoder, however clever, can eliminate the effect of the basilar membrane.

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T54: INDIVIDUALIZED OPTIMIZATION OF A MUSIC REMIXING METHOD FOR COCHLEAR IMPLANT USERS

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Although many users of cochlear implants (CI) typically achieve a high degree of speech understanding, music perception is severely impaired in general. Among other factors, this can be attributed to a spread of excitation in the cochlea and a poor encoding and transmission of temporal fine structure, leading to strong degradations of pitch and timbre cues. At the same time, rhythmic information is recognized by CI users almost as good as by normal-hearing (NH) listeners. To improve music perception in CI users, different music preprocessing algorithms have been proposed, which emphasize mainly vocals and rhythmic contributions in popular music (e.g., Buyens al., IEEE TBME, 2015; Gajecki & Nogueira, JASA, 2018; Gauer et al., JASA, 2022) or reduce the spectral complexity of classical music (e.g., Nagathil et al., JASA, 2017). While these processing methods generally facilitate the access to music in CI users, the need for an individualized tuning of algorithmic parameters was also recognized. However, depending on the number of tuning parameters, the determination of individual parameter settings can be a tedious and strenuous procedure for CI users.

In this work we present and evaluate an optimization procedure for a recently proposed parametric music source mixture model, which first separates individual music sources (vocals, bass, drums, other accompaniment) into harmonic and percussive contributions and then provides a customizable remix based on eight weighting parameters (Gauer et at., JASA, 2022; 2023). To this end, we applied a model-based optimization (MBO) technique which iteratively fits and refines a tractable surrogate model based on user feedback.

The procedure is divided into an initialization stage and an optimization stage. During the initialization stage users have to evaluate a small set of parameter settings which are randomly selected. Based on this initial user feedback the MBO iteratively proposes optimized parameter settings and ultimately finds a suitable user-dependent setting. We investigated this approach with NH listeners using a vocoder-based CI simuluation. The MBO procedure delivered individually optimized parameter settings: in general, harmonic contributions were more strongly attenuated than percussive components, while drums and vocals (especially their percussive contributions) were widely preserved. These tendencies are in line with remixing preferences found in previous studies with CI users. In an additional listening experiment seven NH listeners compared their individually optimized settings either with the unprocessed case or a general reference setting, which had been significantly preferred by CI users in a recent study (Gauer et al., JASA, 2023). This experiment was implemented as a two-alternative forced choice test, where 20 vocoded music pieces were considered. All participants significantly preferred their individual parameter setting over the unprocessed case (individual binomial tests, $p < 0.003$) with an average preference score of 94.3%. Two participants preferred their individual parameter settings over the reference parameter settings ($p < 0.042$) and one participant preferred the reference setting ($p = 0.041$). For the remaining participants no significant differences were found.

In conclusion, the MBO approach delivered reasonable individual settings for the given mixing model, which compare well with a previously chosen reference setting. At the same time, it operates in a time-efficient fashion and avoids an exhaustive search within the whole parameter space. Hence, it can be applied for the optimization of future remixing models with even more parameters for which optimal settings might not be obvious. In view of fitting procedures with CI users, strenuous tuning cycles can be avoided by involving CI users only in the optimization stage of the MBO procedure. This will be investigated in future work.

T55: MELODIC CONTOUR IDENTIFICATION THROUGH CI SIMULATIONS USING EFFICIENT CODING FILTERBANKS.

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Introduction: According to the efficient coding approach (Smith & Lewicki, 2006), perception should be optimally adapted to the statistics of natural signals such that they carry the most information at the least possible cost. Therefore, perceptual performance should be best when sensory codes match the statistics of environmental stimuli. Previous studies applied Factor Analysis (FA) on amplitude modulations over spectral channels from natural speech signals. While some authors argued that 4 channels would be sufficient to represent the main contrastive segmental information in natural clean speech (Ueda & Nakajima, 2017), comparison of speech statistics with perceptual performance led to suggest that 6 to 7 frequency bands would be required to optimally represent vocoded speech signals (Grange & Culling, 2018). However, research on music perception in cochlear implanted deaf listeners sheds light on potential limits associated with music perception. Thus, performance observed on vocoded signal material in normal-hearing listeners as well as in deaf CI users is systematically better for speech signal than for music and prosodic components of speech (e.g. pitch recognition; Galvin et al., 2009; Crew et al., 2015). Speech and music would therefore seem to require very different levels of spectral resolution. Duniec et al. (2023) compared statistical properties of music and speech signals in order to evaluate their respective contributions to the efficient coding theoretical proposal. Our aim in this presentation is to evaluate our previous results, that are based on natural signal statistics, through perceptual evaluation. A series of experiments will evaluate music and speech intonation perception through CI simulations using efficient coding filterbanks via identification and discrimination tests. In this study, we present our first experiment in which it is planned to evaluate recognition accuracy for vocoded music signals created using efficient coding filterbanks deriving spectral boundaries from the statistical regularities of music signals. This experiment is based on the melodic contour identification task (MCI; Galvin et al., 2007).

Method: Our study is still in progress. 10 Normal-Hearing young adults without advanced musical training, will be recruited among students at Nantes University. The stimuli have been synthesized using Matlab and consist of nine melodic contours, each contour being built from five notes: (1) simple pitch contours: flat, rising and falling and (2) changes in pitch contour: Flat-Rising, Falling-Rising, Rising-Flat, Falling-Flat, Rising-Falling and Flat-Falling. Three overall frequency ranges are compared that relate to a reference tone: A3 (220 Hz), A4 (440 Hz), A5 (880 Hz). The spacing between pitches in the contour is manipulated (from 1 to 5 semitones between notes). The stimulus set consists of 135 different melodic contours. For each randomly selected melodic contour, participants are instructed to choose the corresponding one from 9 pictograms on a computer screen. All stimuli are passed through CI simulations based on channel boundaries vocoding that either fit conventional logarithmic CI boundaries or the efficient-coding based organization derived from previous FA analyses. All stimuli are presented via headphones in a sound-treated booth.

Results: Data collection is still in preparation. Our hypothesis is that, based on the assumption that statistical properties of natural signals would at least partially govern perceptual analysis, (1) melodic contours would be easier to identify when using efficient-coding based boundaries than when using conventional CI boundaries, (2) this difference would depend on specific stimulus properties (number of semitones, reference note) depending on how reference pitch and pitch spacing within a contour relate to the generated spectral boundaries.

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T56: EFFECTS OF MANIPULATING CHANNEL INTERACTION ON MUSIC PERCEPTION IN ADULTS WITH COCHLEAR IMPLANTS

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Background: Cochlear implants (CIs) enable sound awareness and spoken communication to recipients. However, outcomes that rely on high-fidelity spectral encoding, such as music perception, remain challenging for CI recipients (e.g., Dornhoffer et al., 2021). Channel interaction contributes to CI outcome variability by interfering with electrode discrimination, tonotopicity, and independence (e.g., Oxenham, 2008). Unfortunately, channel interaction is unavoidable in CIs because the electrodes rest in a highly conductive fluid and are relatively far from the neural interface (e.g., Jones et al., 2013; Won et al., 2014). Spectral blurring is a recently developed method of measuring channel interaction in CI recipients by manipulating the excitation patterns of stimulation. Spectral blurring experiments have shown a clear, inverse relationship between channel interaction and speech recognition (Goehring et al., 2020; 2021). However, the relationship between channel interaction and music perception is untested. Image-based electrode selection (IGES) is a CT-guided approach aimed at promoting channel independence by identifying electrodes causing extensive overlapping stimulation based on electrode-to-modiolus distance and selectivity deactivating said electrodes (i.e., Noble et al., 2014, 2016). Previous work has demonstrated the benefits of IGES for speech understanding, but the impact of IGES on music perception is unexplored. Therefore, the current study had two aims. Aim 1 characterized the effects of channel interaction on music perception using spectral blurring, hypothesizing that performance would decline as the amount of spectral blurring increased. Aim 2 measured the degree of IGES benefit on music perception tasks, hypothesizing that performance will improve if a reduction in channel interaction is achieved.

Methods: Participants included three (anticipated N = 12) adults with at least one MED-EL CI. Performance was compared between six conditions, 1) baseline (no blurring), 2) all blurred, 3) apical blurred, 4) middle blurred, 5) basal blurred, and 6) IGES. Electrode placement information (electrode-to-modiolus distance, angle of insertion depth, and scalar location) was calculated from post-insertion CT imaging (Noble et al., 2014). Music perception tasks included pure tone frequency discrimination, tone in noise discrimination, and melodic contour identification (MCI) using several base frequencies across the electrode array (196 Hz, 262 Hz, 1176 Hz, and 3136 Hz).

Results: At present, Aim 1 preliminary results showed no differences in performance for pure tone frequency discrimination, tone in noise discrimination, or MCI between the spectral blurring conditions. Aim 2 preliminary results also showed no differences in performance between the IGES program and baseline for any task. While these preliminary results suggest neither spectral blurring nor IGES meaningfully impacted music perception performance with the CI in our current sample, these analyses will be re-run, and individual differences analyses will be completed once our full sample is recruited and data collection is complete.

Conclusions: Channel interaction may impact music and speech perception differently, suggesting that potential programming strategies aiming to reduce channel interaction may need to differ for each domain to maximize performance.

T57: FEATURE INFORMATION TRANSMISSION ANALYSIS OF MUSICAL TIMBRE PERCEPTION

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Difficulty to detect the timbre of musical sounds (reflected in difficulty to distinguish instruments) probably reflects inadequate encoding of elements of music into CI electrical stimuli. The present study considered data from a timbre perception study that measured just-noticeable differences (jnds) of the primary acoustic properties that underlie timbre perception: brightness and irregularity (spectral properties) and attack and decay (temporal properties). Multidimensional scaling has often been used as an analysis tool in timbre perception studies to investigate the timbre properties that cause two musical instrument tones to sound dissimilar. This approach provides information on how timbre properties are perceived by noting the relative importance of a spectral or temporal property, but does not explicitly measure the fidelity of the reception of individual timbre properties by the listener. To achieve this, feature information transmission analysis (FITA) is required. FITA estimates information transmitted by an acoustic property by assigning tokens to categories according to the feature under investigation and comparing within-category to between-category confusions. The original FITA method (or MN-FITA) was developed by Miller and Nicely (1955) for categorical features (e.g. voicing) for which category assignments arise from the feature definition. Oosthuizen and Hanekom (2015, 2016) developed the MN-FITA approach to include continuous features, resulting in continuous FITA (C-FITA). This expanded its application to detection, discrimination, estimation and ranking experiments. C-FITA was applied to the data from the timbre perception study to estimate the amount of information transmitted on the musical timbre properties. The timbre property jnds of NH and CI listeners were measured using synthetic instrument tones that allowed independent adjustment of timbre properties. These jnds were used to predict a musical instrument confusion matrix for the two listener groups which in turn allowed estimation of the percentage of transmitted information through a C-FITA analysis.

As expected, feature information received by NH listeners was high for all the timbre properties. Brightness feature information transmission was particularly poor in CI listeners. While CI perception of temporal characteristics of speech is usually assumed to be better than that of spectral characteristics, the C-FITA analysis showed poor transmission of both of the temporal timbre properties. This may reflect an inability to track intensity changes in the temporal envelope. Interestingly, irregularity was the property of which most feature information was transferred to CI listeners.

T58: EXPLORING MELODIC CONTOUR IDENTIFICATION WITH SPECTRALLY REDUCED STIMULI FOR IMPROVED COCHLEAR IMPLANT MUSIC PERCEPTION

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Recently, techniques such as spectral complexity reduction have been used to improve music enjoyment for cochlear implant (CI) users. While many studies have shown improvement in CI users' subjective preference ratings, it is important to note the distinction between music enjoyment and perception. Thus, in this study we examine if spectral complexity reduction can also be used to improve pitch perception for monophonic stimuli. A corpus of five-note melodic contours is established which consists of rising, falling, rising-falling, falling-rising, and flat contours. The melodies are synthesized using MuseScore 4 software for three instruments of varying timbres: piano, violin, and clarinet. In addition, the semitone spacing between notes is varied between 1, 3, and 5 semitones, resulting in pitches from 440 Hz to approximately 1.4 kHz. To generate spectrally reduced versions of the melodies, principal component analysis (PCA) is performed on spectra obtained using the constant-Q transform. The number of retained principal components is varied to produce alternate spectral complexity conditions. The melodic contour identification task is conducted using an online listener assessment. All CI users were screened and used their clinical processors with their own MAPs. In addition, to benchmark differences for CI subjects, normal hearing (NH) subjects were also evaluated. The melodic contour identification results from CI users and NH users will be discussed. Differences across spectral complexity conditions, instruments, and semitone spacing are explored in the analysis, as well as between individual CI listeners. This work was supported by Grant No. R01 DC016839-02 from the National Institute on Deafness and Other Communication Disorders, National Institutes of Health.

T59: MUSIC EMOTION PERCEPTION WITH COCHLEAR IMPLANTS

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Although some cochlear implant (CI) listeners enjoy music, for others, music appreciation remains limited. Numerous studies reported perceiving emotions depicted by musical excerpts to be impaired by electric hearing. Using acoustic vocoders to simulate CI hearing, we have previously shown that information related to arousal (e.g., joy vs. serenity) was well transmitted whereas valence (e.g., sadness vs. serenity) was only poorly transmitted. The aim of the present study was to expand from acoustic simulations to CI users. Specifically, we assessed music emotion perception in actual CI listeners, from arousal and valence perspectives, and further, to what degree individual results could be explained by performance in psychophysical tasks related to rhythm and pitch perception. Preliminary results suggest that CI listeners' performance was very similar to that of normal-hearing participants with vocoder stimulation. Variability in arousal perception did not correlate with performance in a beat-alignment task, which evaluates rhythm perception. Similarly, variability in valence perception did not correlate with performance in an instrument identification and classification task. However, valence perception weakly correlated with voice-pitch discrimination thresholds. These results suggest new perspectives about how improving fundamental frequency perception — for example via musical training — might improve valence transmission for CI users during music listening.

T61: OPTICAL COHERENCE TOMOGRAPHY FOR IMAGE-GUIDED COCHLEAR IMPLANTATION AND DIAGNOSTICS: A NEAR FUTURE?

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Advancements in intracochlear diagnostics, as well as prosthetic and regenerative inner ear therapies, rely on a good understanding of cochlear microanatomy. The human cochlea is very small and deeply embedded within the densest skull bone, making nondestructive visualization of its internal microstructures extremely challenging. Current imaging techniques used in clinical practice, such as MRI and CT, fall short in their resolution to visualize important intracochlear landmarks, and histological analysis of the cochlea cannot be performed on living patients without compromising their hearing. Recently, optical coherence tomography (OCT) has been shown to be a promising tool for nondestructive micrometer resolution imaging of the mammalian inner ear. First, we present an atlas of intracochlear OCT images, which were acquired in a series of 7 fresh and 10 fresh-frozen human cadaveric cochleae through the round window membrane and describe the qualitative characteristics of visualized intracochlear structures. Likewise, in this work in progress, we will try to describe several intracochlear abnormalities, which could be detected with OCT and are relevant for clinical practice. Finally, OCT was used to steer the insertion of cochlear implant electrode arrays and verification experiments with micro-CT imaging have been performed. This resulted in a correct insertion technique.

T62: IMPACT TRIAL: A MULTICENTRE RANDOMISED CONTROLLED TRIAL EVALUATING THE EFFICACY OF A PARENT-IMPLEMENTED THERAPY ON LANGUAGE DEVELOPMENT IN CHILDREN WITH COCHLEAR IMPLANTS

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Background: Speech and language outcomes in deaf children that receive cochlear implants are variable, with some children struggling to develop language. Parents significantly influence language development but are often overlooked in existing CI rehabilitation models. Evidence supports the use of parent-implemented therapy, to improve language development in normally-hearing children. Neuroimaging research suggests that interbrain synchrony during parent-child interactions might be the mechanism driving the effectiveness of parent-implemented therapies.

Aim: We have designed a randomised controlled clinical trial that will evaluate the efficacy of parent-implemented therapies as an adjunctive therapy to standard care on language development in children with CIs. Interbrain synchrony between mothers and children with CIs will be compared in two groups who receive parent -implemented therapy vs a control group that does not, to assess whether interbrain synchrony is an underlying mechanism that mediates parent-implemented therapy effects.

Methods: Approximately 160 children newly implanted <5 years old and their families will be recruited from cochlear implant centres across the UK. Families will be randomised to either receive i) standard NHS care in addition to participating in the parent-implemented therapy program, or ii) standard care alone. Children will be assessed at baseline, 6 and 12 months after randomisation, with the primary outcome being receptive language development at 12 months measured using the PLS-5 UK. We hypothesise that children of families who receive parent-implemented therapy will have better language skills than those who do not. Since little is known about ways in which parent-implemented therapy might benefit language development, a mechanistic sub study will measure interbrain synchrony between children and parents using functional near infrared spectroscopy, with the hypothesis that interbrain synchrony will be stronger between those who receive parent-implemented therapy, compared with those who do not. We will also assess whether parent-implemented therapy influences a child’s interactions with their parents, their behavioral, emotional and social growth, and their developmental milestones.

Anticipated impact and dissemination: Results from this trial will be shared via scientific conferences, high-impact peer-review publications, newsletters, and the media. Robust evidence that parent-implemented therapy benefits language development in children with CIs, will lead to a future trial to assess the longer-term effectiveness and cost-effectiveness of this therapy. Since this result may impact on the future support needs and educational outcomes of these children, it could lead to significant cost savings for the NHS and educators.

T63: PERSONALIZED COCHLEAR IMPLANTATION USING REAL-TIME FLUOROSCOPY AND INTRAOPERATIVE ECAP MEASUREMENTS

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Introduction Fluoroscopy is a medical imaging technique that uses X-rays to capture real-time images. It is used to visualize the placement of the electrode array inside the cochlea during the surgical procedure. This enables the surgeon to adjust the position of the electrode array in real-time, to ensure that it is optimally placed. Combining fluoroscopy with other intraoperative measurements, such as evoked compound action potential (ECAP), can provide surgeons with feedback on the cochlear health and position of the electrode array during insertion. This information helps optimize and personalize the implantation for the patient. Methods The surgical setup was optimized by combining fluoroscopy with intraoperative electrophysiological measurements, including trans-impedance matrix and ECAP. During insertion, electrophysiological measurements were performed at the maximal insertion depth, and then the electrode array was slightly pulled back to position it near the modiolus and the measurements were repeated. This procedure was applied to fifteen adult CI patients, and a retrospective evaluation was conducted using registered preoperative and postoperative CT images as well as intraoperative fluoroscopic images. The insertion angle and distance from the modiolar axis for individual electrode contacts were measured for both maximal insertion and pull-back positions, and the final electrode position was related to the patient's clinical performance, as measured by the word recognition score (WRS) six months after implantation. Results The mean insertion angle achieved was 399° ± 52° (SD). After a pull-back, most electrode contacts were moved closer to the modiolus by an average of 0.09 ± 0.17 mm. The average decrease in ECAP thresholds was 6 ± 7 CL, and this decrease was correlated with the movement towards the modiolus (average change of 17 CL/mm, $R^2 = 0.4$, $p < 0.001$). The final electrode array position was evaluated, and a closer distance of electrode contacts to the modiolus was found to correlate with better WRS ($R^2 = 0.3$, $p = 0.04$). When combining ECAP thresholds and electrode contact distance from the modiolus, there was an even higher correlation, explaining up to 41% of the variation in postoperative speech performance ($p = 0.013$). Discussion Direct control of the electrode array pull-back enables personalized implantation by achieving a high insertion angle and minimizing the distance between the electrode contacts and modiolus for each patient. This approach improves speech intelligibility for CI patients. Combining imaging and intraoperative measurements can provide additional insight into the neural health of the cochlea and help explain the variability of CI outcomes.

T64: FEASIBILITY OF EXTRACOCHLEAR STIMULATION TO INDUCE HEARING AND REDUCE TINNITUS

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Introduction: While previous studies have demonstrated positive effects of stimulation via a cochlear implant (CI) on tinnitus, the underlying mechanisms how electrical stimulation can relieve tinnitus remain unclear. In this study, we aimed to investigate the feasibility of extracochlear stimulation as a potential treatment for tinnitus. Additionally, we examined if extracochlear electrical stimulation can lead to hearing, so that hearing impaired persons could benefit from combined electric and acoustic hearing. The objective of this study was to develop a method to produce a hearing perception and alleviate tinnitus in patients with normal cochlear function by utilizing extracochlear electrical stimulation of the cochlea and the auditory nerve.

Methods: Six patients who underwent standard ear surgery were temporarily implanted with extracochlear electrodes at various locations in the middle ear. Electrophysiological recordings and subjective feedback were collected to assess the impact of extracochlear stimulation on hearing perception. The effect of extracochlear stimulation on tinnitus before and during stimulus was evaluated through standardized tinnitus questionnaires.

Results: Subjective feedback on hearing impressions during extracochlear stimulation was collected in four out of six patients. Extracochlear stimulation successfully induced a hearing perception in all four patients, although these impressions were not loud enough to be detected as electrically evoked auditory brainstem responses (eABR). Additionally, two patients suffering with tinnitus sensed decreased perceived tinnitus loudness from the extracochlear stimulation.

Conclusion: These preliminary results suggest that extracochlear stimulation may has the potential as a treatment option for hearing loss and tinnitus. The results also provide a foundation for further investigation of stimulation parameters best suited for extracochlear stimulation.

T65: AUDITORY DIAGNOSTICS AND ERROR-BASED TREATMENT: WORKING TOWARDS A PERFORMANCE-DRIVEN FITTING PARADIGM

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Variability in outcomes is a well-known problem in the field of Cochlear Implants (CIs). It is hard to predict how well a CI candidate will recognize speech after their implantation, and it is also difficult to maximize their outcomes after the implantation. Each user's poor outcomes need to be addressed post-implantation, by either programming the sound processor (known as "fitting") or by auditory training. However, there are no generally agreed, standardized current clinical practices for post-implantation follow-up, which are instead dependent on clinicians' knowledge and experience: fitting usually focuses on delivering uniform levels of stimulation across the full range of frequencies covered by a CI and training is left to the discretion of audiologists and speech-language therapists.

The AuDiET (Auditory Diagnostics and Error-based Treatment) clinical trial has been designed to investigate whether a guided fitting paradigm would be possible: one in which the treatment is performance-driven and patient-centered. The main assumption driving the study is that intervention, whether focused on fitting or training, should be targeted at those phonemes where each subject is experiencing the greatest difficulties. This means, for instance, that subjects who have issues especially at recognizing or discriminating high-frequency phonemes will receive a fitting intervention aimed at making high-frequency sounds clearer and more distinct; subsequently, they will train on recognizing and discriminating those same phonemes. A sample of 25 experienced CI users with a postlingual onset of hearing loss whose native language is Dutch makes up the study population for AuDiET. A battery of tests assessing both phoneme and word recognition has been developed in order to assess each subject's error pattern. After undergoing these tests, each subject is given personalized fitting and training interventions based on their individual error patterns. The results of tests after each intervention are then compared to the baseline and previous interventions.

Early results already show that fitting interventions can have a noticeable effect, both positive and negative, on the recognition of vowels and consonants. More complete and detailed early data will be shown and explained at the conference via a visualization tool developed specifically for this study: this tool is called TRAIT (Test Results Analysis and Investigation Tool) and it allows the investigators to easily visualize each subject's error patterns and the effects of interventions.

The gathering of data detailing how fitting and training interventions are linked to phonemes recognition might be valuable for future studies: for instance, the AuDiET framework and tools could be easily adapted to support larger studies involving multiple centers and subjects speaking multiple languages; additionally, the vast amount of data collected could help with developing future fitting and training solutions based on Machine Learning and Artificial Intelligence, reducing the workload of clinicians and allowing each CI user to benefit from the unique opportunities of the digital era. MOSAICS is a European Industrial Doctorate project funded by the European Union's Horizon 2020 framework programme for research and innovation under the Marie Sklodowska-Curie grant agreement No 860718.

T66: EXPLORING THE EFFECT OF CHANGE TO ELECTRICAL THRESHOLD SETTING AND RATE OF STIMULATION TO THE PERCEPTION OF SOFT INTENSITY SPEECH CUES AND SPEECH IN EXPERIENCED ADULT COCHLEAR IMPLANT USERS.

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Background and aims
A study was conducted to evaluate the influence of electrical stimulation rate and the setting of electrical threshold (T) level on the discrimination of soft intensity spectral temporally modulated ripples (SMRs), intensity difference limens (IDLs), amplitude modulated sinusoids (AM), monosyllables in quiet and co-ordinate response measures in noise.

Methods
Participants were twenty-four adult experienced adult users of the Advanced Bionics cochlear implant. Nine experimental maps were created with T levels at: 10% of the level perceived 'most comfortable'; the threshold of audibility and a level perceived 'very soft'. Rates of electrical stimulation were approximately 900, 1800 and 2700 pulses-per-second (pps). Stimuli were presented through the direct input of a PSP speech processor at approximately 54 dBSPL. Adaptive 2I-2AFC IDLs and AM were presented on electrode 7 and 3I-3AFC SMRs and speech perception were presented with all active electrodes. Speech perception tests followed 5 minutes of live voice speech tracking.

Results
T Level has a significant effect on SMRT (spectral discrimination) [$F(2,34) = 13.652$, $p = 0.001$, partial $\eta 2=0.445$] and CAPT (monosyllables in quiet) [$F(2,46) = 6.085$, $p = 0.005$, partial $\eta 2=0.209$] with a medium and small effect size respectively. Stimulation rate has a significant effect on AM (temporal discrimination) [$F(2,36) = 3.384$, $p = 0.045$, partial $\eta 2=0.125$] with a small effect size. A significant interaction between Stimulation Rate and T level setting exists for both speech tracking rate TR and CAPT (monosyllables in quiet).

Conclusions
Electrical T level has a significant effect upon both spectral discrimination and monosyllables in quiet presented at soft intensity and a bespoke implementation should be considered during clinical programming. Stimulation rate has a significant effect on temporal discrimination, where applying a slower rate may be a consideration to improve discrimination.

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T68: AN ALTERNATIVE METHOD FOR DRUG-COATING PREPARATION ON ELECTRODE ARRAY OF COCHLEAR IMPLANT PORTABLE ELECTROSPINNING OF PCL/PEO

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Background: Cochlear implantation is the primary method of hearing rehabilitation for patients with severe to profound hearing loss. Reducing inflammation in the inner ear or enhancing the function of spiral ganglion cells could improve the effectiveness of cochlear implants. Drug coating techniques have been an important component of local delivery. Therefore, the purpose of this study is to explore a feasible and alternative method for preparing a drug-coated electrode array using a portable electrospinning instrument, taking into consideration the clinical application scene.

Method: A mixture of PCL (with a molecular weight of 80,000 g/mol) and PEO (with a molecular weight of 10,000 g/mol) was prepared at a mass ratio of 5:1. The mixture was then dissolved in HIFP at room temperature for 4 hours with stirring at 600 beats per minute, resulting in a 5% PCL/PEO solution. To coat the electrode arrays, a portable electrospinning instrument (TTE-1, JUNADA, Qingdao, China) was used. During the electrospinning process, the solution was sprayed at a rate of 30 μL/min through a 5 mL syringe with a 20G needle, and charged with a positive potential of 15 kV to form a solution jet. The electrode arrays were rotated at a speed of 12 turns per minute, and were sprayed for 10 seconds, 30 seconds, and 1 minute, respectively. The resistances of the coated electrodes were tested before and after electrospinning. The coated electrodes were then soaked in PBS solution for up to 7 days to observe the adhesion of the coating, and the morphology of the coating was observed using an optical microscope.

Results: A uniform filamentous coating was observed on the surface of the electrode arrays. The resistance values were 6.16±1.56 kΩ before coating, and changed to 4.85±0.84 kΩ, 14.6±11.6 kΩ, and 27.4±11.8 kΩ, respectively. As the soaking time was extended, the coated fibers gradually deformed but did not detach.

Conclusion: Portable electrospinning appears to be a feasible and alternative method for rapidly coating the electrode arrays of cochlear implants without significantly affecting the physical properties of the electrode within short electrospinning time.

T69: TRANSLATIONAL ANATOMY IN COCHLEAR IMPLANT RESEARCH

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Variation in human cochlear anatomy is well documented. Few studies have quantified the anatomy of the cochlea using landmark-based methods. Quantification of anatomical landmarks within a standardised cochlear coordinate system is necessary for the accurate construction of person-specific, three-dimensional computational models of the cochlea. Defining landmarks to describe structures surrounding the cochlea that may be affected by intracochlear electrical stimulation, for example, the facial nerve, is also important in the quest to develop comprehensive computational models of intracochlear stimulation. A comprehensive cochlear landmark framework, for the purpose of person-specific modelling, will be presented. This includes landmarks that define selected surrounding structures.

A closely related issue is the optimization of scanning device settings for obtaining images from which cochlear and surrounding structure landmarks may be derived. High-quality imaging is important for improving the accuracy of landmark placement to describe the macro-anatomy of the cochlea. The error of measurement for a selection of landmarks measured on clinical images of the cochlea compared to measurements of the same landmarks on high-resolution scans (microCT) of the cochlea provides insight into the error that may be expected when using measurements on clinical scans as the basis for the construction of person-specific models.

T70: DEVELOPING AND VALIDATING VIRTUAL-AUDIO CLINICAL TOOLS FOR ASSESSING SPATIAL-LISTENING SKILLS FOR CHILDREN WITH BILATERAL COCHLEAR IMPLANTS

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Background: Clinical tests for the assessment of spatial listening require multi-speaker arrays rarely available in clinical settings. A virtual-audio version of the Spatial Speech in Noise Test (SSiN; Bizley et al, 2015) leads to similar performance across spatial locations for loudspeaker arrays with normal-hearing listeners (Salorio-Corbetto et al, 2022). The aim of this work is to determine whether the virtual-audio versions of the SSiN and the Adaptive Sentence List (ASL; (MacLeod & Summerfield, 1990) using a spatial release from masking test configuration test yield comparable results than their loudspeaker versions for children with bilateral cochlear implants. Additionally, the efficacy of a centralisation app to identify the degree of balance between the ears was explored together with the findings from the virtual speech tests. The purpose of this work is to validate virtual assessments for use in a clinical trial with virtual reality spatial training games.

Method: A participatory-design approach was used to develop and finalise the virtual-audio implementations of the tests (Vickers et al, 2021). Ten children and young adults who wear bilateral cochlear implants and ten age-matched normal-hearing participants, will perform each test (SSiN and Spatial ASLs) in each implementation (virtual-audio or loudspeaker). The order of the tests and implementations were counterbalanced across participants. The participants also completed the centralisation task (i-balance app) using narrow-band noise and wide-band stimuli consisting of speech-shaped noise and a non-language specific speech-like stimulus (Holube et al, 2010). The interaural level differences for these stimuli were varied by the children using a visual/tactile interface so that the sound was perceived in the midline. Children were asked to show where they located or heard the sound relative to their head by colouring a drawing.

Results: So far, the virtual-audio applications were finalised. Two participants with cochlear implants have completed the tests. Our outcomes will allow us to determine whether the virtual-audio versions of the tests have potential for clinical use, provide the validation for use in the clinical trial and determine whether the results from the centralisation task used in the i-balance app are informative in terms of spatial hearing abilities for children with bilateral cochlear implants.

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WEDNESDAY POSTER ABSTRACTS

W1: LOUDNESS ENHANCEMENT FOR COCHLEAR IMPLANT USERS WITH TACTILE STIMULATION

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Tactile stimulation can increase the perceived loudness of auditory tones. This audio-tactile loudness bias could be employed to enhance loudness for listeners with reduced dynamic range, such as cochlear implant users. However, it is not known if the audio-tactile loudness bias occurs in cochlear implant users to the same extent as normal-hearing listeners. An initial loudness-matching experiment was performed with 12 normal hearing listeners. Listeners were instructed to match the loudness of a monaural auditory reference and comparison stimulus with a virtual knob, which controlled the intensity of the comparison stimulus. In half the trials, fixed-level vibrotactile stimulation was applied to the wrist during the comparison stimulus. Listeners matched the comparison stimulus lower than the reference, implying an increase in perceived auditory loudness when tactile stimulation was presented. A pilot experiment with 2 cochlear implant users was then performed- and both cochlear implant users also showed signs of the audio-tactile loudness bias. Results are promising for the future of using audio-tactile crossmodal biases to enhance music or other sounds for cochlear implant users.

This work was supported by the William Demant Foundation and the Innovation Fund Denmark.

W2: VISUAL PLASTICITY THROUGHOUT REHABILITATION WITH A COCHLEAR IMPLANT

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While the cochlear implant (CI) is the most successful neuroprosthetic device, the degree of benefit remains highly variable. The variance could be accounted for, at least in part, by how the brain processes sensory signals. Following the onset of hearing loss, there is evidence for neural recruitment of auditory areas by the visual cortex (e.g., Finney et al., 2001). Although this phenomenon, known as cross-modal plasticity, has been well documented in CI users (e.g., Sharma et al., 2015), relatively little is known about the impact of plasticity on the amount of benefit a patient receives from a CI. Furthermore, the extent to which this plasticity occurs and potentially changes following implantation is also unknown. This study aims to characterize visual plasticity in post-lingually deafened adult CI candidates both pre- and post-operatively and to examine the role this plasticity plays, if any, in post-operative CI-aided speech recognition.

In order to assess sensory reorganization throughout the CI process, all measures were completed both prior to receiving a CI and again three to nine months post-implantation. A series of visual and audiovisual (AV) behavioral measures were used to characterize visual performance and AV integration. To further index the neural basis of sensory reorganization in CI candidates, functional-near-infrared-spectroscopy (fNIRS) was used to localize and quantify cross-modal plasticity. To examine the degree to which these behavioral and neural indices of visual plasticity explained heterogeneity in CI outcomes, we completed correlation analyses between pre-implantation measures and post-activation clinical measures of speech recognition performance (CNC scores). At this point, 23 post-lingually deafened adults with symmetric bilateral hearing loss who met CI candidacy criteria have completed pre-operative testing and clinical outcome measures at least three months post-activation. Eight of these 23 have completed the full test battery, including fNIRS pre- and post-operatively.

Preliminary results suggest that CNC word recognition at three months post-implantation is significantly related to pre-operative visual word ($r = .454$ $p = .044$) and phoneme recognition ($r = .583$, $p = .007$) as well as AV phoneme recognition ($r = .494$, $p = .027$). Additional findings from the fNIRS data suggest that visually evoked activity measured in the temporal lobe pre-operatively, suggestive of hearing loss-induced cross-modal reorganization, is also significantly correlated with post-operative CNC word recognition at three months ($r = .728$, $p = .040$). Together these results provide preliminary empirical support that better visual-only and AV speech recognition performance, as well as underlying levels of cross-modal plasticity, may predict better CI outcomes. In addition, early analyses of fNIRS data collected post-operatively indicate that cross-modal reorganization seen pre-operatively may reorganize again following rehabilitation with a CI. If these preliminary patterns persist, these findings may suggest a need for CI candidacy criteria to be expanded to include multisensory metrics to identify underlying cross-modal reorganization and its malleability post-implantation.

W3: INVESTIGATING CROSS-MODAL PLASTICITY AND SPEECH OUTCOMES IN CI USERS USING EEG

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Neuroimaging studies suggest that cochlear implant (CI) users exhibit cross-modal plasticity, where neurons that typically respond to auditory input are repurposed to serve visual functions following auditory deprivation. Visual reorganization of auditory regions is believed to be responsible for certain improvements in visual perception commonly observed in congenitally deafness. In CI users, cross-modal plasticity can emerge prior to implantation, but also appears post-implantation. Research designs that measure cross-modal plasticity in humans typically present visual or audiovisual stimuli and then estimate the degree of activation in auditory brain areas. Within these studies, there is debate whether cross-modal plasticity 1) depends on the stimulus and its relevance for language and communication and 2) predicts or directly affects auditory-only speech outcome measures post-implantation. We will address these questions and present three main findings from multiple studies using electroencephalography (EEG) in human CI users. First, we found that CI users have larger cross-modal activation to orthographic words and faces compared to typical hearing controls, but only the degree of activation to face stimuli predicted speech ability in CI users. Second, we find that the relationship between speech outcomes and cross-modal activation depends on whether EEG measures were taken prior to or after implantation: large cross-modal activations during the pre-CI period relate to lower outcomes, and large activations measured post-CI relate to better outcomes. Third, a novel finding was that cross-modal changes in 8 to 12 Hz (alpha) oscillations localized to temporal cortex also relate to speech performance, such that better outcomes occurred with stronger desynchronization of alpha power during visual stimulus processing.

The results overall suggest that the link between speech outcomes and cross-modal plasticity depends on stimuli used to evoke visual responses. In addition, individual differences in cross-modal activity measured before or after implantation may reflect variability in ways that (pre-)CI users leverage visual cues.

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W4: EFFECT OF AUDIOVISUAL ASYNCHRONY ON SPEECH INTELLIGIBILITY IN CI USERS AND TYPICAL HEARING CONTROLS

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Spoken language is a fundamentally multisensory phenomenon. Integration of the auditory signal provided by the voice and complementary visual signals arising from mouth and face movements gives rise to a highly salient, information-rich audiovisual signal. Audiovisual integration is generally strongest when underlying unisensory components are poorly resolved (Sumby & Pollack, 1954). Because the representation of speech provided by a cochlear implant (CI) contains fewer spectrotemporal cues than that provided by the typically developed cochlea, CI users rely on visual speech cues and the perceptual gain associated with multisensory integration to a greater extent than those with typical hearing. In addition to signal resolution, the temporal alignment of unisensory signals is an important factor in the likelihood of their integration (Stein & Meredith, 2008). When communicating in person, auditory and visual speech cues are perceived to occur in near perfect synchrony. However, when transmitted digitally (e.g., via online video calls) there is potential for significant temporal asynchrony. Accordingly, this work examined the extent to which audiovisual asynchrony affects multisensory integration and subsequent speech intelligibility in CI users compared to typical hearing controls. Participants were presented with a series of spoken sentences in audio-only, visual-only, and audiovisual conditions. In the audiovisual condition, the auditory and visual speech streams were presented synchronously, or at one of eight audiovisual asynchronies. After each trial, participants typed the sentence as completely and accurately as possible, and intelligibility was quantified as proportion of keywords correctly reported. Finally, indices of multisensory gain were computed by comparing performance in unisensory conditions with the audiovisual condition at each offset. Analysis of intelligibility scores and measures of multisensory integration showed that gains were strongest for both groups near the point of synchrony and tapered off as audiovisual asynchrony increased. Interestingly, CI users showed larger decrements in performance with increasing offset than typically-hearing controls. Most notably, at the largest audio-leading offset, we observed a marked difference in accuracy between the groups, with CI users continuing to show impaired performance while typical hearing participants showed improvements relative to smaller offsets. We interpret this “rebound effect” as a behaviourally advantageous release from integration, whereby typically hearing listeners disregard delayed visual cues and process stimuli as though they were unisensory auditory signals. Moreover, typical hearing listeners may be able to selectively attend to the lagging visual cues to resolve previously-perceived ambiguity in the auditory stream. That a visual release was not seen in CI users suggests that efforts to attend to and integrate visual speech cues continue even when integration is not possible. These findings align with existing literature on visual bias in CI users (Butera et al., 2021) and raises questions for future research regarding possible compensatory roles of attention and other cognitive mechanisms.

W5: ASSESSING THE RELATIVE BENEFIT OF REAL TIME CAPTIONING FOR SPEECH IN NOISE BENEFIT

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Captioning has been shown to be beneficial to listeners using high quality transcripts. Automated speech recognition (ASR) programs have the potential to create convenient real-time captioning; however, ASR is known to perform poorly in the kinds of noisy settings that listeners are faced with in the real-world. It is unknown how well listeners combine auditory information with text generated from an ASR in background noise. It is also unknown how hearing loss interacts with a listener's use of these captions. We aim to evaluate the benefit for normal hearing (NH) listeners and those with hearing loss (HL) from text generated from an ASR in the listener's background noise. Speech perception was evaluated based on auditory information, text information that was derived from an ASR, and on both auditory and text information combined at three levels of background noise (+6, +4 and +2 dB SNR). Ten NH and 15 adults with HL were evaluated. Both NH listeners and listeners with HL achieved lower speech perception as the background noise increased within each condition (auditory, text and combined auditory and text). The addition of text to auditory information was only beneficial to NH listeners in the +6 dB SNR condition (where the captioning was the most accurate), whereas it was beneficial in all levels of background noise to those with hearing loss. Listeners, especially those with HL, may benefit from the addition of partially correct text to the auditory information when the text is generated from an ASR.

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W6: THE USE OF FREQUENCY IMPORTANCE FUNCTIONS IN PREDICTING SPEECH PERCEPTION IN ADULT COCHLEAR IMPLANT AND NORMAL HEARING LISTENERS

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Objectives: The purpose of this study was to measure determine if there was a correlation between frequency importance functions (FIFs) and conventional speech perception (i.e., CNC words and AzBio sentences) among adult cochlear implant (CI) listeners. Design: A total of seven adults with CIs participated, along with and nine adults with normal hearing (NH) as a control group. Each participant completed speech perception measures (CNC words and AzBio sentences) and FIF testing using filtered monosyllabic words.

Results: The FIFs of NH and CI participants showed higher relative importance of the mid frequency bands. The FIFs for NH participants were consistent across all participants with a peak at band four (1414-2828 Hz). The FIFs for CI participants were highly variable across the frequency spectrum with no discernable peak at a particular frequency band.

Conclusions: Results of this study suggest that adults with CIs have more variable FIFs compared to adults with NH, and adults with NH consistently place greater weight on band four. Additionally, both groups had the least frequency importance at band six (5660Hz-11314Hz).

W7: BILATERAL COCHLEAR IMPLANT USERS HAVE MORE DIFFICULTY CONTROLLING VOCAL INTENSITY WHEN USING BOTH DEVICES

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Using bilateral cochlear implants (BiCIs) can result in significant improvements over unilateral implantation in many perceptual tasks, including speech perception and localization. However, evidence suggests that BiCI users may perform worse when using both devices than when they use their better ear alone on some vocal tasks such as F0 production. Although some studies have demonstrated that BiCI users struggle with controlling long-term variations in vocal intensity (vAm), there is insufficient evidence comparing their performance to that of using their better ear alone. The link between speech perception and production suggests that the difficulties experienced by BiCI users to control vocal intensity variations may stem from perceiving inconsistent and varying relative loudness cues across two ears due to mismatched loudness growth.

This study aims to investigate how differences in loudness growth across ears contribute to poor vocal intensity control. Experiment 1 tested 13 BiCI users with sustained vowel vocalization using both cochlear implant devices together and each one separately to measure their ability to control long-term vocal intensity variation (vAm). To determine if deficits in vAm when using both ears reflected mismatched loudness growth perception across ears, Experiment 2 examined loudness growth from each ear. A subset of 8 BiCI users from the first experiment participated in Experiment 2, in which loudness scaling was measured while using their clinical devices to obtain the loudness growth perception separately for the left and right ears. To determine the extent to which loudness growth affected vAm, Experiment 3 manipulated the amount of amplitude compression through the processor to change the shape of the loudness growth function while measuring vAm for 7 BiCI users. Experiment 1 found that BiCI devices significantly decreased the ability to control vAm compared to unilateral CIs. Experiment 2 revealed that most BiCI users perceived different loudness growth between their left and right CI, potentially explaining their poor vAm when using both devices together. Experiment 3 demonstrated that increasing the compression reduced the ability to control vAm, indicating that changes in loudness growth affect vAm.

These findings suggest that unmatched loudness growth perception between ears likely contributes to poor vocal intensity control in BiCI users.

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W8: EFFECTS OF TALKER VARIABILITY AND LINGUISTIC CONTENT ON SPEECH-PERCEPTION SCORES

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The AzBio Sentences and Hearing in Noise Test (HINT) are commonly used sentence recognition tests for assessing speech perception for cochlear-implant (CI) users. These tests differ in the number of talkers and linguistic content. Clinically, CI listeners typically perform more poorly on AzBio sentences than on HINT sentences. It is unclear whether these differences are due to differences in talker variability used in the recordings or differences in linguistic content.

The primary purpose of this study was to examine the relative contributions of talker variability and linguistic content to speech-perception performance. The role of talker variability was assessed by comparing performance in noise for normal-hearing (NH) and CI listeners with the original recordings and re-recorded sentences using diverse talkers that included children, adults, native- and non-native-English speaking talkers, and various U.S. dialects. The role of linguistic content was evaluated by comparing scores in noise for NH and CI listeners for the diverse-talker AzBio and diverse-talker HINT sentence tests, where both tests were comprised of the same talkers. This study was conducted in three phases: Phase I involved re-recording the AzBio and HINT sentences using diverse talkers. Five AzBio lists (20 sentences/list = 100 sentences) and 10 HINT lists (10 sentences/list = 100 sentences) were re-recorded using a diverse set of 20 talkers that encompassed different U.S. dialects, foreign accents, adults, and children. Each talker contributed one sentence per each AzBio list and each pair of HINT lists so that no single talker was repeated within a list (AzBio) or pair of lists (HINT). Phase II involved piloting performance to determine the optimal number of background talkers (20-talker vs. 4-talker babble) and signal-to-noise ratio (–3 dB vs. –1 dB) for the background noise for NH listeners (n = 16). Phase III evaluated performance in the presence of 20-talker babble using diverse and original AzBio and HINT sentences for NH and CI listeners.

Preliminary results show that the diverse recordings yielded significantly poorer average performance than the original recordings for NH and CI listeners, which suggests that increasing talker variability reduces speech-perception performance in noise among NH and CI listeners. However, when the diverse talkers were used for both tests, performance was not significantly different between diverse HINT and diverse AzBio for both NH and CI listeners, which suggests that differences in linguistic content between the two tests does not account for the performance differences observed clinically in CI users between tests. These results have implications for increasing talker diversity in standardized tests to better reflect the potential range of conversation partners in everyday life. Future studies are needed to empirically study the effect of talker variability and linguistic content on speech perception among individuals with hearing loss who use amplification.

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W9: LINKS BETWEEN PERCEPTION AND PRODUCTION OF EMOTIONAL PROSODY BY PRELINGUALLY DEAF CHILDREN WITH COCHLEAR IMPLANTS

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Compared to normally hearing peers, prelingually deaf children with cochlear implants (CCI) show deficits in their perception of complex harmonic pitch, such as vocal pitch. Voice pitch and its changes constitute a dominant cue to a talker's emotion. Not surprisingly, CCI also show deficits in their identification of emotional prosody. In a previous study (Chatterjee et al., 2019), we reported that school-age CCI produced smaller acoustic contrasts between their productions of happy and sad emotional prosody compared to their normally hearing counterparts. However, the links between the perception of emotional prosody and the acoustic cues in emotional prosody production by CCI remain unknown.

The goal of the present study was to test the hypothesis that CCI performance in an emotional prosody perception task is linked to the acoustic features of their emotional speech productions. We recorded 21 school-age CCI reading 20 simple, emotion-neutral sentences (e.g., This is it; Time to go; The bus is here) aloud in a happy way and a sad way. Acoustic analyses were performed on these recordings, focusing on mean fundamental frequency (F0), F0 standard deviation (an indicator of voice pitch modulation during production), duration cues, and intensity cues. The same participants completed an emotion identification study on the same day. Participants listened to 12 sentences in 5 emotions (angry, happy, neutral, sad, scared), each produced by two talkers in a child directed manner and by two talkers in an adult directed manner. For each talker, the CCI completed a single-interval, five-alternative forced-choice task in which they heard each of the 60 stimuli and indicated which emotion it was associated with. Accuracy in the emotion identification task was compared to the acoustic contrasts between happy and sad productions by the same participants.

Results showed that the happy-sad contrasts for three acoustic features in the productions– the happy-sad ratio of the standard deviation of voice pitch and overall duration, and the happy-sad difference in mean intensity – were linked significantly with the CCI's emotion identification accuracy for both child-directed and adult-directed emotional speech. Multiple linear regression analysis showed that a combined model including the happy-sad production contrasts for F0 standard deviation and duration cues in the explained 43% and 49% of the variance in the emotion identification accuracy scores obtained with child-directed and adult-directed emotional speech, respectively.

These results suggest that the perception and production of emotional prosody are significantly linked in CCI.

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W10: HOW CHILDREN AND ADULTS WITH NORMAL HEARING OR COCHLEAR IMPLANTS USE VOICE PITCH AND DURATION CUES FOR EMOTIONAL PROSODY IDENTIFICATION

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To convey and contrast happy vs. sad emotions via the same speech carrier words, we use voice pitch cues primarily, with other cues such as duration and intensity as secondary cues. However, little is known about how cochlear implant patients utilize these cues to decipher emotions. Little is also known about how children with typical hearing develop the ability to perceive emotional contrasts with these cues, and how children with cochlear implants who are prelingually deaf differ from typically hearing counterparts in their cue-utilization for emotional contrast perception.

We conducted a cue-weighting study to quantify the utilization of these cues by systematically and orthogonally varying the voice pitch contour cues, duration cues, and mean intensity cues associated with a single utterance “Time to go”, creating a corpus of 125 samples of the same utterance with 5 voice pitch contours (happy to sad in 5 steps), 5 durations (short/fast (happy) to long/slow (sad), and 5 intensities (louder (happy) to softer (sad)). Listeners heard each version in random order and indicated whether it sounded happy or sad in a single-interval, 2 alternative forced choice task. Participants were normally hearing adults, normally hearing school-age children (6-18 years old), postlingually deaf cochlear implanted adults, and prelingually deaf cochlear implanted school-age children.

Results showed that normally hearing adults used both the voice pitch and duration cues strongly. Children with normal hearing used each of these cues significantly but less than adults with normal hearing. Adults and children with cochlear implants used the voice pitch contour cue significantly but dramatically less than normally hearing counterparts. Postlingually deaf adults used the duration cue strongly, but prelingually deaf children used the cue significantly less than other groups.

These results indicate that i) while cochlear implanted listeners show reduced ability to utilize the F0 contour cues for emotional contrast perception compared to hearing peers, they can still glean some F0 contour information from the degraded input; ii) prelingually deaf children do not use duration cues as effectively as postlingually deaf adults; iii) normally hearing children show reduced ability to use voice pitch contour cues and duration cues relative to normally hearing adults, suggesting a developmental trajectory.

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W11: DOES SPEECH PRODUCTION RELATE TO SPEECH PERCEPTION IN ADULT COCHLEAR IMPLANT USERS?

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Adult cochlear implant (CI) users exhibit substantial variability in speech perception in high-variability, challenging listening environments. Due to the well-established link between speech perception and speech production in normal-hearing individuals, examining acoustic properties of the speech productions of adult CI users may be informative in predicting some of the variability observed in high-variability sentence recognition. This relation between perception and production may occur because speech production taps into aspects of phonological processing, which is known to facilitate speech recognition. For example, previous research has demonstrated that word reading efficiency is associated with high-variability sentence recognition in post-lingually deafened adult CI users, suggesting that efficient phonological processing enhances speech recognition. Additionally, cochlear implantation and subsequent restoration of auditory feedback may modify speech acoustics and increase intelligibility of speech in adult CI users, but the degraded signal delivered by the CI may attenuate this benefit by reducing access to auditory feedback. In particular, the degraded auditory feedback that CI users receive can lead to compression of vowels in the first by second formant (F1 x F2) vowel space, which results in vowels being produced closer together in the vowel space. This compression makes vowels more ambiguous and confusable with one another, which may lead to decrements in speech intelligibility.

Accordingly, the current study had two primary goals. First, we sought to determine whether a measure of vowel space compression relates to sentence recognition in adult CI users. Second, we aimed to determine whether vowel space compression is related to a measure of phonological processing to further understand the relationship between speech perception and production in adult CI users. Twelve adult CI users read out loud a series of 250 monosyllabic consonant-vowel-consonant words. For each participant, mean vowel dispersion (i.e., degree of vowel space compression) was calculated as the mean Euclidian distance from the center of their acoustic-phonetic vowel space to the F1 x F2 point of each of their vowel utterances. Participants also completed a high-variability auditory sentence recognition task and the nonauditory Test of Word Reading Efficiency (second edition; TOWRE-2). Demographic variables, including age, duration of deafness, and sex were also considered. We predicted that participants with less compressed (more dispersed) vowel spaces would demonstrate higher sentence recognition accuracy than participants with more compressed vowel spaces. We further predicted that participants with less compressed vowel spaces would perform higher on TOWRE-2, as word reading efficiency should tap into phonological processing skills.

Supporting our prediction, results suggest that adult CI users with less compressed vowel spaces show higher sentence recognition accuracy than those with more compressed vowel spaces. CI users with less compressed vowel spaces also demonstrate better phonological processing skills, as assessed by word reading efficiency. These results suggest that acoustic properties of CI speech production, such as degree of vowel dispersion, and potentially the intelligibility of speech produced by a CI user, may be used to predict high-variability speech recognition performance. Further, our findings on the relation between vowel dispersion and word reading efficiency suggest that this relation may be due, at least in part, to individual differences in phonological processing that are manifested in vowel production.

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W12: SPEECH-IN-NOISE ABILITY IS DIFFERENTIALLY PREDICTED BY NEURAL RESPONSES IN AUDITORY AND PREFRONTAL CORTEX OF COCHLEAR IMPLANTEES

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Cochlear implants have proven to be an invaluable technology in restoring hearing for moderately-to-severely deafened individuals. Despite their success, there is still considerable variability in outcomes following surgery, particularly in the perception of speech in a noisy environment. Indeed, this is the most common complaint across the hearing-impaired population and can lead to social withdrawal due to avoidance of difficult hearing situations.

We sought to understand the neural mechanisms underlying this variability, towards a greater aim of accounting for other factors that act as covariates. We used O-15-water positron emission tomography in 33 cochlear implantees to examine neural activity whilst subjects performed either a speech-in-noise task (+ 20dB signal-to-noise ratio; SNR) or a level detection task (also +20dB SNR, on average), designed to control for the effects of attention. Contrasts between the two conditions across subjects showed greater activity across auditory cortex for the speech-in-noise task, the peak of which was frequently localized towards the lateral temporal convexity on an individual subject basis. Across hemispheres, linear regression analyses demonstrated that peak beta values in auditory cortices of individual subjects were strongly predictive of behavioral scores on the speech-in-noise task ($r = 0.51$, $p = 0.003$). Inferior frontal gyrus (IFG) activity was inversely correlated with speech behavioral scores ($r = 0.41$, $p = 0.021$), wherein better performance was associated with less of a difference between the two conditions. Separating data according to hemisphere, we found that the auditory cortex effect was mediated almost entirely by the left hemisphere, whilst the IFG effects were bilateral.

Overall, these results highlight robust neural correlates of variability in speech-in-noise performance in cochlear implantees. The effects in lateral auditory cortex suggest a better representation of the speech signal being extracted from noise, whilst the IFG results may reflect the novelty of the level detection control task, suggesting that better performers are more adept to deal with novel situations and thus require less recruitment of frontal cortex, which could be indicative of less effort.

W13: AGE-RELATED TEMPORAL PROCESSING DEFICITS IN COCHLEAR-IMPLANT LISTENERS INTERACT WITH PRESENTATION LEVEL TO ALTER PERCEPTION OF SPEECH CONTRASTS

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Poor temporal processing can have a profound effect on a listener's ability to understand cochlear-implant processed speech. In listeners with acoustic hearing, auditory temporal processing ability decreases with advancing age, which results in poorer accuracy when trying to differentiate certain speech sounds, especially at high presentation levels. It is unknown how the perception of different temporal speech cues is affected by presentation level in CI listeners, who may also be experiencing age-related temporal processing deficits.

We hypothesized that CI listeners would demonstrate age-related temporal processing deficits that would interact with presentation level, resulting in older listeners showing decreased ability to distinguish temporal speech contrasts at high presentation levels. Post-lingually deafened CI listeners across a range of adult ages (50-85 years) were presented four acoustic continua, each transitioning along a single temporal dimension between two words. Two word-initial contrasts were chosen: one that was distinguished by voice-onset time (beak/peak) and one by formant transition duration (beat/wheat). Two word-medial contrasts were chosen: one that was distinguished by silence duration (dish/ditch) and one by vowel duration (wheat/weed). The effect of presentation level was hypothesized to differ by the position of the temporal contrast in the word, with the largest effects seen in the word-medial contrasts. Listeners were asked to categorize words along each continuum as one of the two endpoint words at presentation levels between 45-85 dB SPL in 10-dB steps. The resulting psychometric functions were analyzed to determine the effects of presentation level and temporal contrast location as a function of the age of the listener.

Results show steeper psychometric function slopes with increased presentation level for beak/peak and dish/ditch (both $p < .001$) indicating a sharper category boundary perception with increased levels. The psychometric function slopes for beat/wheat and wheat/weed appear to increase initially and then decrease, indicating poorer discriminability at higher presentation levels. A model of reduced temporal precision is presented as a potential explanation for the differences in performance across temporal contrasts. The age and baseline speech understanding abilities of the participants were also analyzed as predictors of performance.

These findings demonstrate the detrimental effects of age-related temporal processing deficits on a range of temporal speech cues and may help explain some of the variability in speech perception accuracy among CI listeners.

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W14: PERCEPTION OF PROSODIC CUES FOR CONTRASTIVE FOCUS IN SENTENCES

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Prosody is used to mark important information in speech, yet despite this important role in everyday communication it is not a customary part of speech recognition testing for people with cochlear implants. Listeners might fail to perceive meaningful emphasis on a specific words signaled by prosodic cues despite repeating the words correctly. Cochlear implant listeners have notorious difficulty perceiving pitch, putting them at risk for impaired prosody perception that goes unnoticed if we only track repetition of the word as if it were text. This study introduces a new paradigm for assessing perception of prosodic cues that are used to signify new/corrective information in a sentence. Stimuli consisted of spoken sentences where one word (in various sentence positions) was emphasized in a manner that indicated that a prior statement was incorrect. Participants used a visual analog scale to mark the timing and degree of emphasis aligned with the target words. Responses from listeners with normal hearing verified that the prosodic focus was perceptible and ranked consistent with the talker's intention. However, listeners with cochlear implants indicated weaker perception of prosodic focus, as well as outright mistakes on prosody perception. For example, they reported some or all emphasis on words other than the one intended by the talker. Perceptual data in this study are linked with acoustic measures of voice pitch contour, intensity, and duration to characterize how contrastive stress cues are recovered by listeners with and without cochlear implants.

W15: INCREASED LEXICAL COMPETITION DURING SPOKEN WORD RECOGNITION BY CHILDREN WITH COCHLEAR IMPLANTS

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Children with cochlear implants (CIs) lag behind their peers with typical hearing (TH) in speech, language, and literacy. These outcomes are not fully explained by early auditory deprivation; language abilities of children with CIs don't mirror performance of younger children with TH with similar amounts of hearing experience. The spectrally degraded CI signal also influences spoken language performance. Specifically, phonemic contrasts relying on perception of spectral acoustic features (place of articulation) are less reliably discriminated by children with CIs relative to contrasts discriminated by temporal cues (voicing).

The present study examines how speech perception difficulties contribute to observed delays in spoken word recognition by children with CIs. Specifically, we investigate the dynamics of lexical competition across spoken words relying on various phonemic contrasts, including place (/t/ vs. /k/ or /s/ vs. /ʃ/) and voicing (/k/ vs. /g/ or /p/ vs. /b/). Twelve 8- to 13-year-old children with CIs were compared to two control groups of children with TH: one was matched by hearing age and another by chronological age. There was also a group of children with TH matched by chronological age that completed an identical experiment with 8-channel noise-band vocoded speech to simulate the spectral degradation of the CI signal. Participants listened to spoken words and then selected the target from a set of four pictures on a computer while their eye gaze was recorded. Each of the 96 target words (e.g., saddle) appeared in three conditions: 1) No-Competitor trials with no phonologically similar words, 2) Cohort trials with one cohort competitor (sandwich) and two unrelated distractors, and 3) Contrast-cohort trials in which the competitor word had an initial consonant differing by a single phonetic feature, followed by a shared vowel (shadow). Contrast-cohort competitors differed by place (curtains-turkey) or voicing (carpet-garbage). If children have difficulty distinguishing phonemes differing by either place or voicing, we might expect these items to compete with the target in the same way that a cohort competitor competes. Data collection is ongoing.

Preliminary analyses calculated the average proportion of looking to referents on the screen during perception of the spoken word. Proportion of looks was compared across groups and conditions using a linear mixed effects model. More sophisticated statistical methods analyzing the dynamics of looking behavior over time will be carried out when data collection is complete. Analysis of target looks showed that all groups of children looked less to the target when presented with a Cohort competitor. There was a trend towards an effect of Contrast-cohort appearing for Place contrasts, but not Voicing contrasts. This analysis did not detect any group differences in target word access. However, the competitor analysis showed that children with CIs demonstrated more lexical competition than same-age peers and hearing-age peers with TH listening to clear speech, and this did not differ across contrasts or trial types. The children with TH listening to vocoded speech demonstrated similar levels of lexical competition to the children with CIs. All groups demonstrated an effect of Cohort and Contrast-Cohort for Place contrasts. For Voicing contrasts, a lesser effect of Cohort was present, but no effect of Contrast-Cohort appears. In general, we did not find that listening to a spectrally degraded signal differentially impacted recognition of spoken words relying on place vs. voicing contrasts. Interestingly, we found that even children with TH will consider words that are not true cohorts during recognition of words relying on place contrasts (e.g., considering turkey while hearing the word curtains). This was unexpected and warrants future research. We did find that children listening to a spectrally degraded signal experience more lexical competition during spoken word recognition, including children with CIs and children with TH listening to vocoded speech. More sophisticated analyses will reveal whether there are any group differences in the dynamics of lexical competition across time, as this comparison can investigate the effects of learning spoken language via the degraded CI signal, over and above the effect of listening to a degraded signal in the moment of speech recognition.

W16: ATTRIBUTES OF VOCAL EMOTION PERCEIVED THROUGH A COCHLEAR IMPLANT

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Cochlear implant (CI) users have difficulty perceiving the emotion encoded in speech. Vocal emotion perception is typically measured by playing a speech sample and asking a listener with a CI to identify the emotion conveyed. While such experiments may describe CI users' ability to label perceived emotional intent, they do not describe how sound attributes relevant to vocal emotion perception (e.g., absolute pitch, pitch contours, changes in intensity, and other elements of timbre) are conveyed or distorted.

In this experiment, we used a vocal mimicry technique with single sided deaf (SSD) CI users to better understand how these attributes are conveyed through a CI. Stimuli consisted of sentences produced in a happy, sad, angry, scared, or neutral manner. Stimuli included both adult-directed and child-directed speech (exaggerated prosody) produced by male and female talkers. In the vocal mimicry task, a single sentence was played directly to either the acoustic hearing (AH) ear via headphone or to the CI ear via direct audio input to the processor. Participants were asked to repeat the sentence while mimicking the timing, pitch, intonation, sound quality, and any other attribute of the stimulus. In both the AH and CI conditions, participants could hear their vocalizations only with their AH ear. Vocalizations were recorded and analyzed for multiple attributes, including fundamental frequency (F0), amplitude, and intensity. After finishing the mimicry experiment, vocal emotion identification was measured using the using the same stimuli. In each trial, a sentence was presented to the CI ear or the AH ear, and participants were asked to identify whether the sentence conveyed a happy, sad, angry, scared, or neutral emotion. Vocal reproductions were consistent across multiple trials, suggesting that responses were reliable and accurate. When listening with the AH ear, SSD CI users were able to accurately mimic the vocal emotion stimuli. However, the vocal reproductions when listening with the CI ear were quite different from those when listening with the AH ear. Relative to the AH reproductions, CI reproductions were often pitch-shifted. When the F0 of the stimulus was <300 Hz, F0 contours were well-preserved for both the CI and AH reproductions. When the F0 of the stimulus was >300 Hz, F0 contours for the CI reproductions were often highly compressed. It is possible that these high-frequency pitch contours may be driven by perception of intensity and not pitch. Unsurprisingly, the duration of the reproductions was similar for stimuli presented to the AH or CI ear. Recordings of the vocalizations will be presented. Audition of these recordings reveal many of the distortions of pitch, tone, intensity, emphasis, and sound quality associated with vocal emotion perception through a CI.

W17: SPECTRAL RESOLUTION AND SPEECH PRODUCTION IN PEDIATRIC COCHLEAR IMPLANTS USERS

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Objectives: Performance outcomes with cochlear implants (CIs) are limited by channel interaction or considerable spread of intracochlear electrical excitation. One way to reduce channel interaction through CI programming is to improve spatial selectivity of electrode contacts by deactivating electrodes most likely to illicit the greatest channel interaction. In previous studies with adult CI recipients, CT image-guided maps for electrode deactivation were associated with improved spectral resolution, among other performance improvements. The present study examines pediatric CI users recruited for a 2-year, randomized controlled trial of CT image-guided cochlear implant programming in which we administer various tasks of auditory perception, speech production, language, and literacy. Auditory input is foundational for speech and language development and this study provides a unique opportunity to examine the relationship between auditory ability and speech production. As channel interaction can affect the spectral resolution and quality of auditory information that children with CIs receive, it is possible that channel interaction plays a role in speech- articulation ability. In this complementary exploratory study, we are investigating whether changes in spectral resolution were accompanied by changes in consonant production accuracy at seven time points across the study.

Design: Currently, 47 participants have been recruited for this study. Participant speech samples included a list of 27 words from a single-word picture elicitation task (cf. Sosa & Bunta, 2019) designed to assess phonological variability in young children with hearing loss and their peers with normal hearing. Each item was prompted three times to test the consistency of phonological productions. Recorded speech samples were transcribed in PRAAT. Spectral resolution was measured using a spectral modulation detection (SMD) task at 0.5 and 1.0 cyc/oct administered in the sound field at 65 dB SPL.

Results: Preliminary data for 13 children with bilateral CIs (mean age = 8.92 years) show a non-significant, but trending, positive correlation between changes in SMD threshold (∆ SMD) and consonant production accuracy (∆ consonant accuracy) controlling for chronological age in the analysis. That is, SMD threshold improvements were associated with consonant accuracy improvements over the first year of study enrollment.

Conclusions: Preliminary evidence suggests a trending relationship between improvements in spectral resolution and consonant production accuracy for children with CIs. Thus, it is possible that implementation of a programming approach aimed at limiting current interaction and improving electrode spatial selectivity could yield improvements in speech production, namely consonant accuracy. At the time of poster presentation, we intend to have data coded for additional participants up to both the 12- and 24-month points for an updated analysis.

Reference

Sosa, A., & Bunta, F. (2019). Speech production variability in monolingual and bilingual children with cochlear implants: A comparison to their peers with normal hearing. Journal of Speech, Language, and Hearing Research, 62, 2601-2616. https://doi.org/10.1044/2019; JSLHR-S-18-0263

W18: TRANSMISSION OF ACOUSTIC CUES IN CONSONANT CONFUSIONS AND ITS RELATIONSHIP TO SPECTRAL RESOLUTION IN LISTENERS WITH COCHLEAR IMPLANTS

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Though early implanted infants with cochlear implants (CIs) can develop good speech understanding, speech discrimination outcomes are highly variable and difficult to predict until after several years of device use. Non-linguistic measures of auditory acuity, such as spectral and temporal resolution, have been proposed as potential proxy measures of device efficacy for children too young for clinical open-set speech discrimination tests. Postlingually-implanted adult CI listeners' spectral resolution has been shown to predict performance on several speech perception tasks. Though similar relationships have been shown for prelingually-implanted children (Horn et al., JASA 2017; DiNino & Arenberg 2018; Noble et al., AAOHNS 2022), there is still question as to whether children who develop speech perception abilities with spectrally degraded input will demonstrate as much reliance on spectral processing as postlingually-deaf adults (Gifford et al 2018). In this study, we examined the relationship between spectral resolution and perception of voicing, manner and place of articulation cues during consonant identification in prelingually-implanted children and post-lingually implanted adults. Spectral resolution includes two factors, frequency resolution (FR) and spectral modulation sensitivity (SMS); both were measured using a spectral ripple discrimination (SRD) paradigm.

It was hypothesized that perception of place, but not voicing, will be positively correlated with FR in both children and adults. Participants included 15 children (5-16 years) implanted prior to age 2, and 12 post-lingually implanted adults; all participants had at least one CI. Children had no severe cochlear malformations or significant neurocognitive impairments that would preclude psychoacoustic testing. Participants were tested using their "preferred" CI side and with their other ear unaided and plugged if necessary. All testing was completed in a soundbooth with stimuli presented via a speaker at 0 degrees azimuth, and participants responded on a computer. SRD stimuli were spectrotemporally-modulated noise with fixed 5 Hz modulation rate and spectral modulation densities varying from 0.25 to 8 "ripples" per octave (RPO). Presentation level was 70 dBZ. A 3-afc 2-down 1-up adaptive method was used to find the highest ripple density a listener could discriminate from a highly-rippled referent. Listeners were tested at 4 modulation depths (3, 7, 10, 15dB) and each listeners' data were fit to a spectral modulation transfer function (SMTF), $y=B*\ln(x/A)$ where slope (B) represents FR and intercept (A) represents SMS (Horn et al., 2017). Listeners were also tested on their ability to identify target consonants. Stimuli were 14 consonants in aCa format spoken by a single male talker. Each consonant was presented 3 times in randomized order and scores were in % correct. Listeners who scored >= 80% in quiet completed the task with 4-talker babble at +10 dB signal-to-noise ratio. Target presentation level was 60 dBA. Consonant error patterns were analyzed using the sequential information transmission analysis (SINFA) on voicing, manner, and place (Miller & Nicely, 1955). SINFA was performed on individual and group average confusion matrices across the noise and quiet conditions.

Participant's performance on SRD, consonant identification, and acoustic cue transmission were examined for effects of age-group using independent t-tests. Correlations between SMTF coefficients and transmission of each acoustic cue were examined using 2-tailed bivariate correlations. Looking at consonant identification in quiet, analyses show a significant correlation of place with SMTF slope (FR) in both children and adults as anticipated; this correlation was stronger in adults than children. SMTF was borderline significantly correlated to manner, and there was no correlation with voicing. There were no significant differences in cue transmission between the children and adults, and all cues correlated to overall consonant identification for both groups. Preliminary analyses for consonant identification in noise show children have significantly better consonant identification and transmission of place cues when compared to adults. Additionally, voicing was not highly correlated with consonant identification in adults. More data is needed to further investigate the differences in acoustic cue transmission across groups and conditions.

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W19: RELATIONSHIPS BETWEEN PERCEPTION AND PRODUCTION ERRORS IN NORMAL HEARING CHILDREN, PEDIATRIC COCHLEAR IMPLANT USERS AND CHILDREN LISTENING TO VOCODER SIMULATIONS

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In children with hearing loss (HL) using cochlear implants (CIs), speech perception and production are influenced by natural developmental constraints, the amount and quality of acoustic information accessible through the CIs, as well as duration of device use. Previous research suggested that children with HL experience deprivation of auditory input, leading to fewer opportunities for using their articulators to produce sounds they hear. This may result in delayed development of oromotor coordination. To examine the link between perception and production, we asked: 1) are consonant errors in perception related to errors in production in children using CIs, normal hearing (NH) children, and NH children listening to vocoder simulations (NHV)? We hypothesized that significant relationships between perception and production would be evident in each group; 2) are there differences in error patterns across groups in production and perception? We hypothesized that children with CIs would make more errors in perception and production than children with NH, and that their perception outcomes would be similar to the NHV group since both received degraded signals. We did not expect a difference in production performance between NH and NHV groups. We expected some error patterns would be related to development (i.e., fewer errors among stop consonants compared to fricatives, since stop consonants develop earlier than fricatives) while others might be best explained by signal degradation in the CI and NHV groups. In addition, we evaluated the error patterns for individual consonants to determine if errors in perception were mirrored in speech production.

Participants: Three groups of children participated in this study. CI group included 20 children (5 - 9 years of age) implanted before age of three. NH and NHV groups included 20 NH hearing age-matched children in each group (4 - 7 years of age). NH group listened to the unprocessed signal and NHV listened to a 9-channel tone vocoder simulation. Procedure: A modified California Consonant Test (CCT) (Owens & Schubert, 1977) was used to evaluate speech perception and production skills. Twelve consonants (/f/, /v/, /θ/, /s/, /z/, /ʃ/, /p/, /b/, /t/, /d/, /k/, and /g/) were presented in consonant-vowel-consonant (CVC) words. For speech perception, participants viewed expanding pictures while hearing the corresponding CVC word in a carrier sentence ("Show me ____"). In the speech production task, participants saw a target picture and heard the instruction "Say the word ____." Each child produced word whose image was depicted on the screen. The stimuli were presented at 65dB SPL in a sound booth.

Results: The study revealed relationships between perception and production performance in all groups. The data did not confirm the difference in perception between CI and NH groups, and none of the three groups showed significantly different error rates in the production task. Predictions regarding the similarity of perception performance between CI and NHV groups also were not supported when we evaluated the overall error rates. Children in the NHV group perceived the consonants significantly poorer with more errors than both CI and NH groups. Poor perception in the NHV group could be attributed to insufficient opportunities for the NH children to adapt to the degraded signal presented through the vocoder. Different patterns of errors across consonant features were observed between the groups. In perception, the NH group had fewer errors in stops compared to fricatives. In production, all three groups produced stop consonants with fewer errors than fricatives. All three groups perceived and produced voiceless consonants with fewer errors than voiced consonants. The error patterns for individual consonants observed in perception were not necessarily evident for production performance. Overall, for individual consonants, perception error patterns did not resemble production error patterns within each group.

Conclusions: The data from this study support the need for further evaluation of mechanisms underlying the perception and production error patterns in children using CIs. Although the overall error rates were similar between CI and NH groups, the error patterns were often different. These error patterns suggest that therapy for CI participants should consider both perception and production abilities. Follow-up work is planned to examine how individual listeners' spectral and temporal resolution is related to perception and production error patterns.

W20: AMPLITUDE ENVELOPE CUES TO VOCAL EMOTION RECOGNITION WITH COCHLEAR IMPLANTS

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Cochlear implant (CI) users have poor recognition of vocal emotions because the degraded spectral and temporal resolution with CIs limits access to voice pitch cues. Although vocal emotions are primarily characterized by pitch variations, CI users have been shown to use secondary cues such as overall amplitude and duration to recognize vocal emotions. However, previous studies have not investigated amplitude envelope cues (i.e., slow variations in amplitude over time) to vocal emotions, which may be perceptually useful for CI users. Fundamental frequency (F0) generally co-varies with amplitude in speech. For example, the F0 contour and amplitude envelope are highly correlated in Mandarin tones, and CI listeners may use the F0-related amplitude envelope cues to compensate for limited pitch cues.

The present study investigated whether the amplitude envelope and F0 contour are correlated for emotional utterances and how amplitude envelope cues may contribute to vocal emotion recognition with CIs. Praat was used to extract the F0 in Hz and amplitude in Pascal every 10 ms from the House Ear Institute Emotional Speech Database, which includes 10 semantically neutral English sentences produced by a male and a female talker in five emotions (angry, happy, neutral, sad, and anxious). Errors in F0 extraction were manually corrected before calculating the correlation between the F0 contour and amplitude envelope for each emotional utterance. The mean amplitude-F0 correlation coefficients ranged from 0.53 to 0.67 across emotions for the female talker, and from 0.40 to 0.72 for the male talker, larger than those reported for Mandarin tones in previous studies. Statistical analyses showed a significant interaction between emotion and talker for the amplitude-F0 correlation coefficients. Correlation coefficients were significantly larger for the angry and neutral utterances than for the anxious utterances produced by the male talker. Correlation coefficients were significantly larger for the female than for the male talker only for the anxious utterances. The perceptual contribution of amplitude envelope cues to vocal emotion recognition was evaluated in normal-hearing participants listening to a 1-channel noise-band vocoder with 50-Hz temporal envelope. Overall amplitude and duration were normalized across stimuli. Thus, the only cue available was the amplitude envelope. This differed from our previous study, in which duration was not normalized across stimuli and a fixed-frequency sinewave carrier was used, both of which may have affected vocal emotion recognition. Pilot data showed that vocal emotion recognition performance was near chance level with amplitude envelope cues alone.

Compared to Mandarin tones, emotional utterances contain more complex F0 and amplitude variations over time. It is possible that training may be required to use the F0-related amplitude envelope cues for vocal emotion recognition.

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W21: THE EFFECT OF BIMODAL HEARING ON SPEECH INTONATION PRODUCTION OF ADULT COCHLEAR IMPLANT USERS

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Prosodic features such as fundamental frequency (F0), intensity, and duration convey important information of speech intonation (i.e., is it a statement or a question?). Because cochlear implants (CIs) do not adequately encode pitch-related F0 cues, pre-lingually deaf pediatric CI users have poorer speech intonation perception and production than age-matched normal-hearing children. In contrast, post-lingually deaf adult CI users have developed normal speech production skills before deafness and implantation. In our recent study, we temporarily turned on and off the CI and hearing aid (HA) of post-lingually deaf adult CI users, and found that such changes in auditory feedback via electric (CI), acoustic (HA), and bimodal (CI+HA) hearing significantly affected the participants' formant frequencies, overall durations, mean intensities, and mean F0s of vowel production.

The present study tested whether post-lingually deaf adult CI users have improved speech intonation production with auditory feedback via electric, acoustic, and bimodal hearing than without auditory feedback. Eight post-lingually deaf adult CI users who used an HA in the non-implanted ear participated in the present study. Four short-term hearing conditions were tested in random order: (1) both CI and HA were turned off (no-device; ND), (2) only HA was turned on (HA), (3) only CI was turned on (CI), and (4) both CI and HA were turned on (CI+HA). Ten question-and-answer dialogues with an experimenter were used to elicit ten pairs of syntactically matched questions and statements from each participant under each hearing condition. The F0 change in semitones, intensity change in dB, and duration ratio between the last two syllables of each utterance were analyzed using Praat to evaluate the quality of speech intonation production. There was a significant effect of hearing condition on the utterance-end F0 decreases of statements but not on the utterance-end F0 increases of questions.

Post-hoc analyses showed that the CI+HA condition led to significantly larger utterance-end F0 decreases of statements than the ND condition. Hearing condition did not significantly affect the utterance-end intensity changes of either questions or statements. Finally, the utterance-end duration ratios of both questions and statements were significantly affected by hearing condition. Post-hoc analyses showed that the ND condition led to significantly larger utterance-end duration ratios of both questions and statements than the CI and CI+HA conditions. These results suggest that post-lingually deaf adult CI users change the use of prosodic cues for speech intonation production under different hearing conditions, and that access to auditory feedback via bimodal hearing may improve their voice pitch control to produce more salient intonation contours of statements.

W22: THE CONTRIBUTIONS OF HARMONICITY IN SPEECH-ON-SPEECH RECOGNITION WITH COCHLEAR IMPLANTS

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Harmonicity is a sound characteristic that assists normal hearing (NH) listeners in separating multiple sounds with harmonic structure. However, cochlear implant (CI) users lack the ability to track individual harmonics due to their inherently limited spectral and temporal resolution. It is uncertain whether they benefit from the harmonicity of the target speech or the masking speech, particularly in scenarios where both sounds are a single-talker speech, as in speech-on-speech masking.

This study explores the role of harmonicity in speech perception for CI users by examining both harmonic and inharmonic speech. Harmonic speech is a naturally spoken sentence, while inharmonic speech is created by jittering the harmonic frequency relationships while maintaining the spectrotemporal envelope using the STRAIGHT with sinusoidal modeling algorithm provided by Popham et al. (2018). We conducted two subjective experiments to compare the speech reception threshold (SRT) in a speech-on-speech scenario. In experiment 1, we performed listening tests for both simulated and actual CI recipients. Participants listened to two concurrent Mandarin sentences that were either structured harmonically or inharmonically.

Results reveal that speech perception increased by 30% in the group with harmonic concurrent sentences compared to the inharmonic group. However, it was unclear whether the contribution was from the target or the masker since the concurrent sentences had the same jitter amount. To address this issue, in experiment 2, we fixed the target harmonicity and varied that of the masker, or fixed the masker harmonicity and varied that of the target. The results indicate that target harmonicity can result in a maximum masking release about 4 dB, but masker harmonicity did not significantly affect the results.

To summarize, these findings show that harmonicity has the potential to benefit speech perception in CI recipients. Target harmonicity has a small but significant contribution to speech-on-speech masking, but there is no evidence for significant contribution from masker harmonicity.

Index Terms— Harmonicity, speech perception, Mandarin, cochlear implant

W23: DEVELOPMENTAL EFFECTS OF CONCURRENT AUDITORY AND VESTIBULAR IMPAIRMENTS ON WORKING MEMORY, LANGUAGE, AND ACADEMIC ABILITIES IN CHILDREN WITH BILATERAL COCHLEAR IMPLANTS

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Background: The present study aims to determine the developmental effects of dual sensory impairments on working memory, language, and academic abilities in children with bilateral cochlear implants (BCI) and concurrent vestibular impairments. This study expands our previous findings of poor spatial perception, working memory, academics and learning in children with hearing loss (McSweeny et al., 2021). Vestibular impairments are common in these children (20-70%), potentially further impairing cognition and spatial perception across modalities. Our hypothesis is that working memory, language, and academic skills are compromised in children with bilateral cochlear implants and are further impaired in children with concurrent hearing and vestibular impairments.

Methods: Effects of vestibular impairment on measures auditory and visuospatial working memory, academics, and language were assessed in a group of 44 children (20 female, 24 male) who were divided into 3 groups: 1) typically developing [NH-NV] (n=13, average (SD) age = 12.09 years (3.39)), 2) sensorineural hearing loss [HL-NV] (n=12, average (SD) age = 12.16 years (2.80)), and 3) concurrent hearing loss and vestibular impairment [HL-VI] (n=19, average (SD) age = 10.85 years (4.15)). Spans of dot matrix and corsi blocks assess 2D and 3D visuospatial working memory, respectively. Digit spans assess auditory verbal working memory. The Weschler Individual Achievement Test 3rd Edition – reading & math subtests (WIAT) assess learning in the reading and mathematical domains and the Clinical Evaluation of Language Fundamentals 5th Edition (CELF) assesses language abilities. Group analyses of data were conducted using mixed model regressions which accounted for fixed effects of group, age, sex, and vestibular status. Post-hoc analyses on significant findings were conducted using least square means.

Results: Results show that bilateral CI users have poorer language ($F(1)=14.92$, $p<0.01$), academic skills (math: ($F(1)=5.96$, $p<0.02$), reading: ($F(1)=5.75$, $p<0.02$), and working memory scores (auditory: ($F(1)=9.94$, $p<0.01$); 2D visuo-spatial: ($F(1)=4.53$, $p<0.05$) compared to typically developing peers. Vestibular impairment may have further effects on math ($F(1)=4.40$, $p<0.05$), language ($F(1)=3.51$, $p=0.07$), and auditory working memory ($F(1)=4.34$, $p<0.05$).

Significance: Present data reveal a relationship between poor cognitive function and hearing loss which may be exacerbated by having concurrent vestibular impairments across academic and working memory domains.

W24: DEVELOPMENT OF FREQUENCY RESOLUTION AND SPECTRAL-MODULATION SENSITIVITY IN INFANTS WHO USE COCHLEAR IMPLANTS

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Development of non-linguistic tests of CI benefit in CI users too young for clinical speech perception testing could help improve precision of audiologic and habilitative care for implanted infants. With this goal, we have been studying how spectral ripple discrimination (SRD) develops in infants and young children who use a CI. SRD performance depends on two factors that mature at different rates: frequency resolution (FR) and spectral-modulation sensitivity (SMS). FR characterizes a listener's ability to perceive individual peaks of energy across the spectrum and is mature in 6-month-old normal hearing (NH) children. SMS characterizes a listener's ability to detect differences in intensity across the spectrum and remains immature in school-aged NH children. Previously, we have reported that FR is correlated with speech recognition in CI listeners (Horn et al., JASA 2017; Noble et al., AAOHNS 2022). Preliminary data from two longitudinal studies of children implanted prior to age 18-months are presented here. FR and SMS were measured in infants 3-months post-activation (study 1) and in 5–7-year-old children (study 2). It is hypothesized that FR will mature between 3-6 months after CI activation whereas SMS will mature between 5-7 years of age. Participants thus far include 5 CI infants, 8 CI children, and 8 CI adults. Infants and children all were implanted in 1 or both ears by 18 months old, and had consistent daily CI use, no severe cochlear dysplasia. Adults were all post-lingually implanted, auditory/oral language users, with over 1 year of CI experience. Stimuli were adapted from Aronoff & Landsberger (2013) where listeners are presented with spectrotemporally modulated sounds with fixed modulation rates and varied spectral modulation, or "ripple", densities (Noble et al., E&H 2022; Resnick et al., JASA 2020). Listeners were asked to discriminate stimuli of varying ripples-per-octave (RPO) from a highly-rippled referent (20 RPO). For infants, an observer-based, single-interval procedure was used (Noble et al., E&H 2022) and for older listeners, a 3-afc, 2-down 1-up, adaptive method was used (Noble et al., AAOHNS 2022). Listeners were tested in soundfield, at 70dBA, using their preferred clinical CI processor and setting. Participants used only one CI with the contralateral ear unaided and plugged if necessary. For each listener, two thresholds were obtained. First, the SMS threshold was obtained by finding the smallest modulation depth, in dB, the listener could perceive at fixed spectral modulation density of 0.5 RPO. Second, the FR threshold was obtained by finding the highest modulation density, in RPO, the listener could perceive at fixed modulation depth = 2 X SMS. Thresholds at both depths were obtained from 4/5 infants and all older listeners. One infant provided the SMS threshold only but became too fussy to test further. A clear age-related improvement in SMS is apparent from the preliminary data with adult thresholds between 2-7dB and infants from 4-16dB (with 4/5 infants 11-16dB) while 5–7-year-olds' and adults' SMS thresholds were 3-9dB and 2-7dB respectively. In contrast, preliminary data show FR ranges from 1 – 1.1 RPO, 0.92 to 2.3 RPO, and 0.92 to 1.6 RPO in infants, 5–7-year-olds, and adults, indicating that all 3 age groups have similar threshold ranges between 1 to 1.5 RPO.

These preliminary results demonstrate immature SMS in CI infants, consistent with immature SMS in NH infants (Noble et al., 2022). For FR, infants were within the range of performance relative to 5–7-year-olds and adults. Work is ongoing to measure SMS and FR longitudinally at 3-6 months post-activation and from 5-10 years of age in children who receive a CI prior to 18 months of age.

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W25: PHONOLOGICAL DISCRIMINATION FOR THE LEARNING OF NOVEL WORDS: A STUDY IN CHILDREN WITH COCHLEAR IMPLANTS

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Background: The learning of a novel word is dependent on the accurate categorization of its phonemes and the creation of a stable representation of the novel phonological sequence in the lexicon. The acoustic cues delivered by cochlear implants (CIs) may be distorted and suboptimal. This creates unstable word-forms in working memory during word learning, increases cognitive load, and results in slower learning.

Objective: This study aimed to investigate how phonological discrimination determines the speed of learning novel words in school-aged children who use CIs, under a quiet listening condition. Methods: The novel word learning task was designed based on the methods used by Pittman (2011). In this paired-associated learning task, four nonwords derived from the Danish phonology were used as novel word proxies and paired with four unknown-object illustrations. The task was conducted in a computer-based platform, in quiet, with stimuli presentation at 70 dB. Preliminary data from children who use CIs are compared to a cohort of 30 typical-hearing children (age range: 7-12 years, mean age: 9.1 years). The learning speed, specified by the time constant of the exponential growth curve at a criterium of 70% correct, is analyzed. Global phonological discrimination abilities, discrimination of the specific task targeted phonemes, phonological and general work memory capacity were assessed.

Results: The preliminary data comprehends a group of children who received early diagnosis of hearing impairment and early surgical and language intervention. The data suggest that, compared with children with typical hearing, children with cochlear implants have similar novel word learning speed, and comparable phonological and general working memory capacity, even when they perform below 1SD in the phonological discrimination assessment. These comparisons hold even when children are compared just with those in the same age.

Conclusion: The data reported here refers to children with CIs who received early intervention and extensive auditory verbal training. These might have accounted for good use of compensatory strategies that enabled the efficient encoding of novel words. These preliminary results call for research in a more diverse population to unravel possible constrains in their learning process.

W26: CHANGES IN INFANTS' AND TODDLERS' VOCAL ACTIVITY BEFORE AND IMMEDIATELY AFTER COCHLEAR IMPLANT ACTIVATION

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The minimum age of on-label cochlear implantation in the United States is 9 months (USFDA, 2020), but the average age of implantation is closer to two years (Fitzpatrick et al., 2015). Before this time, pediatric cochlear implant (CI) candidates receive little to no oral language input - either from caregivers in their environments or the sound of their own voices. However, before age two, infants and toddlers with typical hearing (TH) experience many critical components of speech, such as acoustic-auditory mappings from their own vocalizations (Vihman, 2014) and vocal feedback loops with caregivers (Warlaumont et al., 2014), that set the stage for later speech-language development. Prior work suggests that post-activation, infants and toddlers with CIs do rapidly advance through some early stages of speech development (Schauwers et al., 2008; Fagan, 2014). However, it is relatively unknown how these critical aspects of early vocal development change from a pre-activation baseline. Longitudinal trends, as children continue to employ the devices, are likewise unclear.

The goal of this study was to evaluate children's vocal activity in a naturalistic setting immediately prior to and following CI activation and compare this activity to a normative sample of children with TH. Twenty children with CIs (0-35 hearing months at initial observation) wore a lightweight recorder in a specialized shirt for an entire day as they went about their daily activities (appx. 16 hrs./recording). Children completed recordings semi-regularly for up to three years post-implantation (avg. # of observations/child=3.75; >2050 total hrs. of observation, or appx. 110 hrs./child). 65% of children completed recordings pre- and again post- implantation. Two key components of the children's vocal activity were estimated from each recording: (1) child vocal productivity (excluding crying and vegetative sounds) and (2) conversational turns between the child and key caregivers. We derived growth functions by age (separately for hearing and chronological age) for both of these components and compared their age-related growth to a normative sample of children with TH (N=329).

Results show, surprisingly, that children with CIs do vocalize and engage in speech-related vocal activity with caregivers pre-implantation. However, there are immediate, effects of CI activation upon both the quantity of children's vocalizations and the number of conversational turns with caregivers. Furthermore, both child vocalizations and conversational turns grow at faster rates for children with CIs than children with TH of the same chronological age.

Together these results suggest that pediatric CI recipients may use vocal feedback from caregivers to progress through critical stages in speech development and meet age-appropriate milestones.

W27: PEDIATRIC COCHLEAR IMPLANT USERS' SPEECH AND LANGUAGE PERFORMANCE: THE ROLE OF SOCIOECONOMIC FACTORS AND THIRD-PARTY SUPPORT

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Introduction: In children with severe to profound hearing loss, a cochlear implant (CI) is the best option for hearing rehabilitation. Although the degree of parental education and household income have been associated with performance after CI in some studies, there is no study examining if there is a significant difference even when support for language therapy is provided financially. We attempted to investigate how these familial factors affect speech and language performance after CI even when providing enough financial support.

Method: We retrospectively analyzed the pediatric patients who underwent CI between 2007 and 2020, and a total of 109 pediatric patients were assessed for eligibility. We collected information on the economic level (property, household income, parental occupation), parental education level, family type (single parent family or not), and location of residence of the family whose child underwent CI. All patients received full expenses for CI surgery costs and were granted five years of support for language therapy. CAP and K-Ling test scores before and after surgery were analyzed according to factors of family environment.

Results: Familial economic level and location of residence had no effect on speech and language performance after CI. However, there were statistically difference for perioperative language evaluation according to parental educational level (father and mother both) and family type (single parent family or not) even after adjusting for the age at CI and the modality of the hearing rehabilitation after CI. Additionally, we found a significant correlation between the child’s age at the first CI and the level of the maternal education.

Conclusion: Parental educational level and family type (single parent family or not) significantly affected the peri-operative language evaluation results, even when financial support for surgery and language therapy was provided. Furthermore, the earlier the child underwent CI, the higher the level of maternal education.

W28: MEASURING THE TIMING AND DURATION OF LISTENING EFFORT NEEDED TO MENTALLY REPAIR MISPERCEPTIONS IN COCHLEAR IMPLANT LISTENERS

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People who listen with a cochlear implant (CI) report listening effort as a barrier to successful social communication that negatively impacts their quality of life. One situation that is effortful for CI listeners is when they must mentally repair misperceived words. The current study attempts to elicit moments of increased effort used to repair misperceptions and then track how long those effortful moments last. We hypothesized that the effort needed to repair a missing word will emerge earlier and last longer when context is used to repair a word early in a sentence, compared to when a word is missing at the end of a sentence and was predicted by earlier context. CI and NH listeners heard sentences where a single word was masked by noise, either early or later in the sentence. Changes in pupil dilation were measured and analyzed using GAMMs to track differences in the timing and duration of effort elicited by these conditions. Results showed a brief increase of effort when the missing word followed context that enabled prediction, and a longer-lasting increase in effort when the misperceived word was earlier in the sentence. Both conditions elicited similar peak dilations, suggesting that timing analysis adds new information to our understanding of listening effort.

W29: COCHLEAR IMPLANT LISTENING EFFORT: A DIFFERENCE OF EFFICIENCY RATHER THAN MAGNITUDE

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Listening effort is a commonly reported difficulty among those who use cochlear implants. The goal of this study is to expand the concept of listening effort beyond a “more” or “less” framework, toward a framework of efficiency. This study measured the engagement or disengagement of mental resources at strategic times, which we hypothesize to be an important signature of a person’s ability to guard against wasted effort. Stimuli were designed to simulate the situation of seeking clarification of a misperceived word (which would ideally evoke effort aimed only at the target word) or conversely to ignore words that were already heard (which would ideally elicit reduced effort). Pupillometry was used as an index of moment-to-moment changes in listening effort. Data showed pupil dilations linked in time with critical target words, enabling precise measurements of the efficiency of effort. Listeners with normal hearing displayed the ability to plan and exert effort at specific times while also reducing effort in situations where it was unnecessary. However, listeners who wear cochlear implants generally did not display these efficient effort characteristics, instead showing signatures of effort that spread through the entire stimulus regardless of condition. These results suggest that the timing and efficiency of effort need to be examined as a possible source of the difficulties of understanding speech with a cochlear implant.

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W30: MEASURING THE TIMELINE OF RETROACTIVE SENTENCE REPAIR IN LISTENERS WITH COCHLEAR IMPLANTS

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If a listener is processing a previous sentence, they may miss the next sentence during regular conversation. This is a common struggle for individuals with cochlear implants, who are more likely to miss words during speech perception and need to repair these words. The timeline of this mental repair process has only been measured using pupillometry, which is not feasible for clinical practice. This study uses a clinically feasible dual-task paradigm that measures the timeline of this effortful repair process. Individuals with normal hearing (under unprocessed & vocoded conditions) and listeners with cochlear implants heard sentences that were fully intact, or which required retroactive repair. Concurrently, they completed a secondary case-judgement task requiring them to decide whether a visually presented letter was upper- or lower-case. The letter was presented either during the sentence, 0.5 sec after, or 2 sec after the sentence. Results indicate that response times were faster for intact sentences. Reaction times also generally improve as more time has passed after a repaired word. Our results suggest that the timeline of this effortful repair process can be understood using behavioral measures.

Financial support for this project was provided by the NIH-NIDCD F32DC019301 (Gianakas).

W31: WHEN DO COCHLEAR IMPLANT USERS "GIVE UP"?: THE IMPACT OF SNR, PERIPHERAL AUDITORY SENSITIVITY AND CENTRAL COGNITIVE PROFILE ON CI USERS' SPEECH RECOGNITION AND LISTENING EFFORT

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Introduction: Despite substantial technical advances and wider clinical use, cochlear implant (CI) users continue to report significant listening effort especially under challenging noisy conditions. Conventional metrics of CI performance such as speech recognition do not capture the effortful experience of CI users when they expend cognitive resources explicitly to achieve a certain level of speech performance. Among all the objective measures, pupillometry is one of the most widely used and robust physiological measures to quantify listening effort. Accordingly, much work has been done with normally hearing (NH) and hearing impaired (HI) listeners to understand the psychometric relation between task difficulty and pupillary response. Previous studies have shown that the relation between speech performance in noise and listening effort (as measured by peak pupil dilatation) is not linear and shows an inverted U-shape: listeners show bigger pupillary response until they eventually "give up" at a certain "tipping point "and disengage from the task as this gets more and more difficult (e.g., at lower SNRs). From there onwards, listeners show smaller pupillary responses. It is unclear whether the same psychometric relation exists in CI users, and whether individual differences in auditory sensitivity and central cognitive capacity affect this relation.

Methods: 17 post-lingually deaf CI adult participants performed a series of speech-in-noise tasks at 0dB, 4dB, 8dB, 12dB, 16dB and 20dB SNR, using Spanish HINT sentences embedded in speech-shaped noise. Simultaneously, their pupillary responses were recorded while they were listening to the sentences. At the end of each sentence, participants rated their subjective effort using NASA-TLX. Each SNR level was repeated twice, and all blocks were randomized. To analyze possible interindividual differences, a spectro-temporal modulation task (SMRT) and a set of cognitive tests (N-back, visual Stroop task, and Progressive Matrices) were measured. Individual word recognition in quiet and Quality of Life (QoL) were also collected.

Results: At a group level, an inverted-U shape relation between task difficulty and peak pupil dilation (PPD), as previously reported in NH and HI, was not observed in our data. Nevertheless, there were significant inverted-U shapes when dividing the sample into two subgroups of high and low CI performers. In the group of high performers, CI participants showed an increasing PPD from 20dB to 4dB SNR, when the pupillary response started to decrease. In the group of low performers, CI participants started to disengage earlier at 16dB SNR. Correlation analysis showed that CI participants with higher speech recognition presented a quadratic increase of PPD over SNR conditions, thus suggesting that this pattern was consistent at an individual level. In addition, we also found that better non-verbal intelligence (measured by Progressive Matrix test) was associated with smaller PPD and that higher QoL was associated with larger PPD. For high CI performers, better inhibition and working memory efficiency correlated with smaller PPD and concave shape of PPD across SNR conditions. No such correlation was found for low CI performers.

Conclusion: To summarize, the psychometric relation between task difficulty and pupillary response did not bear the same non-linear pattern in CI users compared to NH and HI listeners, possibly due to individual differences. Individual word recognition in quiet and cognitive profile had consistent effect on the 'tipping point' where listeners disengaged from the task and PPD was more dominated by the status of engagement rather than by listening effort. The results also highlighted the importance of considering individual differences when utilizing pupillometry to compare listening effort across individuals and scenarios.

W32: THE ROLE OF LISTENING EFFORT IN MITIGATING ROLLOVER EFFECTS OF SPEECH-IN-NOISE PERCEPTION IN COCHLEAR IMPLANT USERS

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The current best approach to treat severe to profound hearing loss in older individuals is cochlear implants (CIs), but they are not perfect solutions when considering challenging listening conditions such as speech in noise. Paradoxically, speech in noise presented at higher intensities may actually worsen behavioral performance, and this is known as the “Rollover” phenomenon. There is some evidence of rollover in CI users, but it is currently unknown how this phenomenon compares to individuals with acoustic hearing. Previous studies have hypothesized that rollover is a result of temporal processing deficits. Even when spectral information is severely degraded, such as in the case when listening through a cochlear implant (CI), temporal cues can provide relatively robust information to support a CI listeners’ ability to understand consonants, vowels, words, and even sentences. In addition, there is mounting evidence that listening effort plays an important role in challenging listening conditions, and this effort can be directly quantified with biophysical measures such as pupil dilation. However, there is a limited understanding of how CI listeners utilize listening effort to aid in speech understanding in challenging listening conditions. Therefore, we hypothesized that listening effort plays an essential role in mitigating rollover effects to differential extents across age and hearing status.

Pupillometry and behavioral measurements quantified the role of effort in mitigating challenging listening conditions as a result of rollover. We recruited across the adult lifespan normal-hearing individuals (NH), hearing-impaired individuals with mild-to-moderate hearing loss (HI), and individuals fitted with a cochlear implant (CI) to perform a speech discrimination two-alternative forced-choice task. Minimal word pairs were presented both in quiet and in six-talker babble noise (0 dB SNR), while varying across sound intensities ranging from 35-85 dB SPL. Pupil area was tracked across stimulus and response phases and quantified simultaneously with behavioral responses in percentage correct during the speech discrimination task. We expect rollover to affect NH listeners the least, HI listeners to a moderate degree, and CI listeners the most when speech is presented at high sound intensities, particularly in background noise. This is due to the prediction that the combination of speech in noise and high sound intensities induces temporal smearing of cues leading to poor speech understanding. However, we predict that effort plays an essential role in mitigating the effects of rollover, leading to potentially similar behavioral performance in CI listeners when compared to their HI counterparts, especially in older individuals with listening in noise. In contrast, we expect that NH listeners are fully able to utilize effort contributions to minimize rollover effects between in quiet and in noise conditions. Therefore, we expect a three-way interaction with age x hearing status x sound levels, and we will use this data to generate a linear mixed-effects model.

The results of this project will uncover the current unknown effects resulting from rollover, which will provide deeper insight into understanding age-related temporal processing deficits with the use of CIs to aid hearing in challenging listening conditions. Finally, the results of this project could broadly influence how to design future hearing devices and interventions that maximize hearing abilities for those affected by hearing loss.

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W33: REDUCING LISTENING EFFORT WITH COCHLEAR IMPLANT SIMULATION VIA AUDITORY TRAINING

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The limited spectral and temporal resolution of cochlear implants (CIs) negatively affects speech recognition of CI users in background noise and leads to increased listening effort. Studies have suggested that increased listening effort may result in mental fatigue, stress, withdrawal from social communication, and degraded quality of life. After speech recognition performance stabilizes after long-term CI use, auditory training can help CI users further improve their ability to recognize speech. However, it remains unclear whether listening effort with CIs may reduce with auditory training.

This study will investigate whether targeted phoneme-recognition training may improve sentence recognition in noise while reducing listening effort with CI simulation. Normal-hearing listeners will listen to 6-channel noise-vocoded speech that simulates CI processing. In the pre-test, the speech reception threshold (SRT) for AzBio sentence recognition in speech-babble noise will first be measured. Listening effort will then be measured in three different methods: (1) dual-task paradigm, (2) pupil dilation, and (3) self-report. For the dual-task paradigm, the primary task will be sentence recognition in noise at the SRT, and the secondary task will be a mental rotation task in response to visual stimuli. The response time of the secondary visual task will be measured to indicate the extent of change in listening effort in the primary listening task. In a single task of AzBio sentence recognition in noise at the SRT, pupil dilation will be measured as a physiological index of listening effort. Finally, subjective ratings of listening effort during the single task of sentence recognition in noise will also be collected. After the pre-test, half of the listeners (randomly selected) will receive vowel- and consonant-recognition training for five days, while the other half will serve as the control group without training. A week later, the post-test will be conducted in a similar way to the pre-test, except that listening effort will be measured at both SRTs in the pre- and post-tests.

Our hypothesis is that the SRT will decrease and listening effort will reduce (as indicated by shorter reaction time in the secondary visual task of the dual-task paradigm, less pupil dilation, and lower subjective rating) from pre- to post-test in the training group but not in the control group. With a focus on understanding the cognitive impact of auditory training on listening effort with CIs, the results will reveal how the improved bottom-up recognition of phonemes after targeted training may affect the demand for top-down cognitive processing in sentence recognition. By using behavioral, physiological, and subjective methods, this study aims to identify the most sensitive measure of listening effort that may be used to fully assess the outcome of aural rehabilitation.

Overall, the results will support evidence-based clinical practice in using auditory training to improve the mental health, ease of communication, and quality of life of CI users.

W34: OSCILLATORY ALPHA ACTIVITY AS A NEURONAL CORRELATE OF WORKING MEMORY, IN ADULT COCHLEAR IMPLANT RECIPIENTS WITH DIFFERENT DEGREES OF SPEECH PERCEPTION PERFORMANCE

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Introduction: Cochlear implants (CI) provide substantial hearing benefits to severely hearing-impaired adults. Nevertheless, speech perception remains challenging and performance outcomes differ across CI users. In challenging listening situations, top-down neurocognitive factors have been shown to be relevant for understanding speech in typical hearing listeners. This might also hold for CI listeners and potentially vary depending on bottom-up auditory processing skills. Therefore, we investigated both bottom-up and top-down auditory processing using objective measures based on electroencephalographic (EEG) recordings and behaviour.

Methods: Measuring EEG during an auditory-digit working-memory task in which memory load and intelligibility were manipulated revealed an effect in the alpha frequency band (Obleser et. al., 2012, J Neurosci; Petersen et. al., 2015, F. Psych.). We aimed to replicate these results in 26 CI listeners showing a range of speech recognition outcomes. Participants memorised a sequence of digits (2, 4 or 6 digits) presented with three levels of SNR (0, +5, +10 dB) and used a button press to report whether a later presented probe stimulus was included in the preceding sequence. Since alpha-band activity has been associated with working-memory load and attentional processes, it was expected that better-performing CI listeners would display higher alpha in centroparietal electrodes as memory load increased and SNR decreased. In poorer-performing CI listeners, this effect was expected to disappear in the most challenging conditions.

Results: Behavioural results across all participants, showed that both memory load and SNR had a main effect on accuracy (p=0.003, p=0.003). Furthermore, an interaction effect was found between memory load and SNR on promptness (1/RT) for correct trials (p=0.005), with an increase in memory load leading to a significant decrease in promptness. A decrease in SNR enhanced this effect for memory loads of 2 and 4 digits. These psychophysical results seem related to alpha power in EEG recordings. We further explore interindividual variability as well as different ways of quantification of EEG alpha power.

Conclusive remarks: The results show that response time in CI listeners is affected by both memory load and SNR. Further analysis will also provide insight into interindividual variability related to CI outcomes, which might help gain understanding of performance variability in CI listeners.

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W35: GATED WORD RECOGNITION: EFFECTS OF SPECTRAL RESOLUTION AND ELECTRO-ACOUSTIC STIMULATION

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Objectives: Although much is known about how normal-hearing listeners process spoken words under ideal listening conditions, little is known about how a degraded signal, such as speech transmitted via cochlear implants (CIs), affects the temporal dynamics of word recognition. In the experiments to be described, the gated word recognition paradigm was used with the goal of describing the time course of word recognition and lexical processing. In the first experiment, gated word recognition performance was measured using noise-band vocoder processed speech, where spectral resolution was altered by changing the number of spectral channels and the spread of excitation. The second experiment examined the advantages of providing acoustic information in conjunction with vocoder processed speech on gated word recognition performance.

Methods: In the gated word recognition task, listeners were presented with increasing amounts of word-onset information (i.e., a series of increasingly longer gates), and following each gate, they were asked to predict the target words. In the first experiment, spectral resolution of gated words was manipulated using a noise-band vocoder with a variable number of spectral channels (20, 16, 12 or 8) and carrier filter slopes (-24 dB or -48 dB/octave). In the second experiment, full spectrum speech was presented either ipsilaterally (electro-acoustic stimulation) or contralaterally (bimodal stimulation) in conjunction with vocoder processed speech.

Results: For full spectrum speech, listeners required just over half of the total duration of the target words for correct identification. Results from the first experiment suggested that: (A) gated word recognition performance decreased with each successive degradation in spectral resolution, and (B) listeners required as many as 16 independent channels to achieve comparable performance to full spectrum speech on the gated word recognition task. Initial results from the second experiment suggest that full spectrum speech (either presented ipsilaterally or contralaterally) in conjunction with vocoder processed speech can improve gated recognition performance. Within each condition, gated word recognition performance was not correlated with word intelligibility (percent correct) scores.

Conclusion: Overall, our results indicate that degradations in the signal acoustics can affect the temporal aspects of speech processing, which is not captured by speech intelligibility performance alone. These results may potentially reveal the benefits of various aspects of CI signal processing.

W36: DUAL-TASK PERFORMANCE OF NORMAL-HEARING ADULTS, COCHLEAR IMPLANT USERS, AND HEARING AID USERS IN A LISTENING EFFORT DUAL-TASK PARADIGM

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Introduction: Hearing loss can make listening an effortful activity, even when sounds are audible and words are recognized accurately. To measure listening effort, a dual-task paradigm can be used whereby a primary speech understanding task and a concurring secondary task are presented separately (i.e. baseline condition) and simultaneously (i.e. dual-task condition). Typically, the change in performance of the secondary task between the baseline and dual-task condition is considered a measure of listening effort, presuming similar performance in the primary task. However, recently it is suggested that it is important to evaluate changes between the dual-task and baseline condition (i.e. dual-task interference) for both the primary and the secondary task to identify the used listening strategy [1, 2]. Therefore, the purpose of the current study was to assess this dual-task interference. More specially, the patterns of dual-task interference were compared between normal-hearing (NH) adults, hearing aid (HA) users, and cochlear implant (CI) users.

Material and methods: Three matched groups of 31 participants were included: (1) NH adults, (2) adult HA users with a moderate to severe hearing loss, and (3) adult CI users with a severe to profound hearing loss. The dual-task paradigm consisted of a primary speech understanding task in different listening conditions (i.e. silence, favorable and unfavorable noise conditions), and a secondary visual memory task [3]. Then, dual-task interference was calculated for both the primary and secondary task, and participants were classified based on the different patterns of interference based on the framework presented by Plummer and Eskes [1]. Descriptive parameters were established for the primary and secondary task, as well as for the dual-task interference and the patterns of dual-task interference. Furthermore, differences between the three groups were examined using a one-way analysis of variance or Kruskal-Wallis test for scores for the primary and secondary task and for the dual-task interference, and a Fisher's exact test for the patterns of dual-task interference.

Results: NH adults scored significantly better than HA and CI users in the favorable and unfavorable noise conditions for the primary task, both in baseline and dual-task condition. No significant differences were found for the secondary task. Considering the patterns of dual-task interference, descriptive results showed that these patterns varied among the three listening conditions. Most participants showed visual memory interference (i.e. worse results for the secondary task in the dual-task condition, and no difference for the primary task) in the silent condition, but speech understanding priority trade-off (i.e. worse results for the secondary task in the dual-task condition, and better results for the primary task) in the unfavorable condition. Particularly in HA and CI users this shift was seen. However, preliminary analysis indicates that the patterns of dual-task interference are not statistically different between the three groups.

Conclusion: Results of this study may provide additional insight into the interpretation of dual-task paradigms for measuring listening effort in different groups of participants. It is suggested to consider both the primary and secondary task for accurate interpretation of the results.

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W37: DIFFERENCES IN NEURAL CORRELATES OF AUDITORY WORKING MEMORY BETWEEN COCHLEAR IMPLANT USERS AND NORMAL HEARING CONTROLS

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A common concern for individuals with severe-to-profound hearing loss fitted with cochlear implants (CIs) is difficulty following conversations in noisy environments. Previous literature has alluded to cognitive resources related to attention and working memory as a factor explaining some the variability associated with speech in noise perception. However, the neural basis for this relationship is not fully understood. In this study, we investigated behavioural and neural correlates of auditory working memory in 14 CI users and normal hearing (NH) controls using high-density electroencephalogram (EEG) while participants completed an N-back task consisting of two conditions, 0-back and 2-back. While 0-back measured speech perception ability, the 2-back measured cognitive ability through working memory and attention. The auditory stimuli presented for each condition and trial was ten double-digit numbers (DDN). Behavioural results suggest no differences between groups in both conditions but in both groups, participants performed better on the 0-back than the 2-back. Although no behavioural differences were found between groups, differences were observed in sensory and neural oscillatory activity. CI users, overall, showed decreased evoked responses (P1, N1, and P2) to digits compared to NH and showed differences in alpha/beta and beta activations throughout the encoding and retaining of digits into memory. Importantly, the degree of auditory evoked potentials and oscillatory power were significantly correlated to speech perception in noise in CI users and NH. These results show neural differences in both bottom-up (encoding) and top-down (attention and working memory) processes in CI users which may contribute to difficulties speech communication.

W38: NEURAL ENTRAINMENT OF A NATURALISTIC CONVERSATION IN VARYING WORKING MEMORY LOADS

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In a noisy environment with auditory and visual distractions, selective attention to target stimuli can be cognitively demanding especially in individuals with a hearing impairment or using a hearing protheses such as a cochlear implant (CI). CI users have been shown to rely more on visual input for the understanding of speech stimuli; this can result in an increased listening effort and therefore, more resources utilized from a limited cognitive load. The neural basis of this relationship between cognition and speech perception and understanding is not fully understood. In this study, using a high-density electroencephalogram (EEG) in normal hearing adults, we investigated the neural correlates of speech entrainment to two people having a conversation with background multitalker noise whilst visual digits appeared on the screen around them. The participant task was to answer conversation content questions and recall the digits that were presented. Three memory loads were assessed, no digits, three digits and seven digits. Behavioural results showed that as visual load increases, performance on recall for both the conversation and digits decrease. The degree of neural entrainment varied as a function of memory load such that larger memory load resulted in greater neural tracking. These data suggest that non-specific, cross-modality attention increases auditory-speech encoding. These data provide evidence that natural conversations be used as a stimulus when probing cognitive functions related to speech in noise listening and working memory.

W39: DIFFERENCES IN CORTICAL PROCESSING OF MEANINGFUL AND SEMANTICALLY ANOMALOUS SENTENCES IN ADULT CI USERS: THE EFFECTS OF "NEURAL CONTEXT GAIN" ON SENTENCE RECOGNITION SCORES

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Understanding the variability in speech recognition scores obtained by adult cochlear implant (CI) users remains a challenge. The perception of spoken language involves the integration of bottom-up sensory input and top-down cognitive-linguistic factors. Because sensory input delivered by a CI is often highly degraded, excellent speech recognition ability may heavily rely on neurocognitive functioning. Top-down factors that reflect cognitive-linguistic functioning, including the use of semantic context, are positively correlated with speech recognition scores in both adults and children with CIs. Previous studies that investigated cognition as it relates to CI speech recognition used a variety of behavioral measurements of cognitive ability, however, scores obtained from some behavioral tasks may be influenced by other factors unrelated to cognition.

The goal of this study is to further investigate the relationship between CI speech recognition and cognition using an objective measure of semantic processing. Neural activity in brain regions associated with semantic processing and executive function, including the premotor cortex and the middle frontal gyrus, was measured using functional near-infrared spectroscopy (fNIRS). The amount of neural engagement of semantic-processing regions was estimated by contrasting neural activity in response to meaningful speech vs anomalous speech, otherwise known as "context gain." Anomalous sentences block the use of semantic and contextual cues to sentence recognition by maintaining correct grammatical and syntactic structure while eliminating all semantic meaning. This experiment tested the hypothesis that individuals with stronger neural activity in response to meaningful speech (i.e., larger neural "context gain") will demonstrate better speech recognition outcomes with their CI. Cortical activation of the semantic-processing regions was measured using systemic-physiology augmented fNIRS. Twenty trials of both meaningful and anomalous sentences were presented in a standard block-design paradigm. Participants were instructed to actively listen to each stimulus presentation and to perform a word-monitoring task (select yes/no if the previous stimulus contained a particular word shown on a screen). The purpose of the word-monitoring task was not to measure speech recognition performance, but rather to keep participants oriented to the experimental task. Hemodynamic response amplitudes for oxygenated and deoxygenated hemoglobin in the cortical regions of interest were calculated using a block-averaging approach. Speech recognition scores were measured using standard clinical procedures for AzBio sentence scores in quiet and in noise at +5 dB SNR. Preliminary results from one adult CI user showed significant context gain, reflecting greater neural activity in the middle frontal gyrus in response to meaningful sentences as compared to anomalous sentences. AzBio sentence recognition scores from the same participant were 96% correct in quiet and 78% correct in noise.

Results suggest that this high-performing CI user showed stronger neural activity when contextual cues were available, potentially reflecting a high level of cognitive-linguistic functioning. Participants with a wide range of speech recognition ability will be recruited in order to further investigate the relationship between cognition and CI outcomes. This relationship may reflect individual differences in listeners' ability to take advantage of the available semantic and contextual cues in everyday speech, which may underlie some of the variability in CI outcomes.

W40: IDENTIFYING THE NEURAL RESPONSES TO AUDITORY AND AUDIOVISUAL SPEECH DURING MOVIE WATCHING USING OPTICAL NEUROIMAGING

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Visual speech information aids understanding, particularly under challenging listening conditions. Listeners who use a cochlear implant (CI) for listening frequently find auditory-only speech challenging to understand, and thus may rely on visual speech information to a greater degree than listeners with normal hearing. However, the brain mechanisms underlying audiovisual speech processing in listeners with cochlear implants are poorly understood. Compounding this issue is the challenge that everyday communication situations typically involve rich linguistic and environmental context not present in the majority of laboratory tests. To better understand how adult listeners with CIs comprehend speech in natural situations, we used a movie-viewing paradigm. Participants (n=20) viewed a 10-minute clip from The Good, The Bad, and The Ugly. We manually identified speech events and classified these as either auditory-only or audiovisual based on the amount of the speaker's mouth that was visible. We then convolved these onset times with a canonical hemodynamic response function to provide predictors for modeling the measured response. All participants were adults with a single right-sided implant who were at least 12 months post-implantation. We measured brain activity using high-density diffuse optical tomography (HD-DOT), a form of functional near infrared spectroscopy (fNIRS). HD-DOT provides even sensitivity and high spatial accuracy over a large portion of the superficial cortical surface, including large portions of the occipital, temporal, and frontal lobes, and permits localizing measurements to atlas space. Using this approach, we were able to identify responses in the temporal lobes related to auditory-only speech. Interestingly, we also found that dorsolateral prefrontal cortex, not active in controls, was engaged during auditory-only speech, consistent with our recent findings in a laboratory-based (non-movie) paradigm. Finally, we found that audiovisual speech recruited both auditory and visual cortices, and reduced the involvement of dorsolateral prefrontal cortex. Together these findings establish the feasibility of using movie-based paradigms for studying both auditory and audiovisual speech understanding in listeners with CIs, and lay the groundwork for better understanding individual differences in the brain networks supporting successful speech comprehension. They are consistent with the notion that auditory speech processing requires more cognitive effort on the part of listeners with CIs, and that this cost may be ameliorated in part by the availability of visual speech information.

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W41: COMPARING COGNITIVE PERFORMANCE BETWEEN INDIVIDUALS WITH COCHLEAR IMPLANTS AND ACOUSTIC HEARING ON A NEUROPSYCHOLOGICAL BATTERY WITH ACCOMMODATIONS FOR HEARING LOSS

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A relationship between hearing loss and cognitive decline has emerged across multiple studies. In fact, hearing loss is estimated to be the most significant modifiable risk factor associated with dementia. Individuals with sensory impairments often perform more poorly on cognitive tests across a variety of domains compared to their peers. Many cognitive tests assume individuals have near perfect sensory perception. Without accommodations for the effect of hearing impairment on cognitive testing, scores may be under-representative of an individual's true cognitive ability and may lead to inappropriate diagnoses and recommendations. Individuals with CIs, who make use of a degraded auditory signal, may have normal cognitive processing but perform more poorly on cognitive tests that have high auditory load. The goal of this study was to compare the cognitive abilities of older adults with cochlear implants and older adults with acoustic hearing using a test battery designed for individuals with CIs. Thirty-five older adult (>50 years) CI users with postlingual hearing loss as well as 20 older adults with acoustic hearing completed a neuropsychological test battery designed for individuals with hearing loss. Non-auditory cognitive tests and auditory tests with written instructions and stimuli were used. The neuropsychological battery assessed six cognitive domains including attention, language, memory, executive function, processing speed, and visuospatial ability. The Montreal Cognitive Assessment for the Hearing Impaired (MoCA-HI) was completed as a cognitive screening test. Functional speech perception was measured with AzBio sentences presented in quiet and in noise. Results suggest that there were no significant differences between cognitive scores in CI listeners and acoustic-hearing listeners across all domains. Performance on the MoCA-HI was moderately correlated with speech perception in noise across all listeners ($r=0.472$, $p=0.002$). Tests of immediate memory were also significantly correlated with speech perception ($r=0.506$, $p<0.001$). In conclusion, when a neuropsychological test battery has accommodations for hearing loss, individuals with CIs perform similarly to individuals with acoustic hearing. Nonetheless, performance on a common cognitive screening test was associated with speech perception scores. Together these findings suggest that cognitive screening tests in individuals with CIs should be interpreted with caution; individuals with CIs can perform similarly to acoustic-hearing individuals when auditory demands are decreased and a comprehensive battery is used.

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W42: NEURAL MECHANISMS OF SPATIAL RELEASE FROM MASKING IN VOCODED AND NON-VOCODED ENVIRONMENTS

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Spatial cues help listeners both segregate the sources in an auditory scene and focus attention on whichever source they wish to analyze. Cochlear implant listeners hear degraded spatial cues, which may contribute to their difficulties in performing this task. We are interested in the question of how the spectral sparsity introduced by vocoding affects the ability to use acoustic spatial cues, and how this may affect neural signatures of spatial release from masking. The current study compared behavioral and neural responses in a vocoded speech intelligibility paradigm (Zhang et al, 2021) and a similar non-vocoded paradigm, both of which controlled for energetic masking. Functional Near-Infrared Spectroscopy (fNIRS) was used to record hemodynamic responses in superior temporal gyrus (STG) and lateral prefrontal cortex (LPFC). 20 subjects participated in experiment 1 (14 females, 6 males, mean age 38 years), and 50 participated in experiment 2 (34 females, 15 males, 1 gender non-binary, mean age 51). All subjects were native English speakers and reported no hearing deficits. Subjects, seated in a sound-treated booth, heard target (spatialized left) and masker (spatialized right) sequences of object and color words. They pressed a button when they detected a color word in the target stream. In the first experiment, target and masker were vocoded into 16 log-spaced frequency bands, nine of which were randomly selected to represent the target and the remaining seven, the masker. In the second experiment, target and masker were not vocoded, but instead were staggered in time such that they had minimal temporal overlap. Seven spatial conditions were tested. Two replicated a previous study, using whole-waveform ITDs with either speech or noise maskers (ITDSpeech and ITDNoise, respectively). The remaining five used whole-waveform ILDs of different magnitudes (ILD0, ILD10, ILD20, ILD30, ILDinf) to spatially-separate target and masker streams. fNIRS was used to record hemodynamic activation over STG and lateral frontal cortex during completion of the task. The results of the ITD conditions replicate Zhang et. al. (2021): hemodynamic activation in STG is greater for a speech masker than a noise masker. Hemodynamic responses in STG did not significantly differ between experiment 1 and experiment 2. Responses in LPFC however, were greater for the vocoded experiment than the non-vocoded experiment. Behavioral sensitivity did not vary across conditions within either experiment. The replication of the results from Zhang et. al. 2021 suggests that hemodynamic activation in STG may be a proxy for release from masking when the competing talker is confusable with the target. Larger LPFC activation in the non-vocoded experiment appears to signify an increase in the magnitude of neural activity associated with parsing sounds in a vocoded environment as opposed to one where more spectral content is available. fNIRS in spatial release from masking experiments allows us to explore the neural mechanisms underlying SRM in environments where sounds are confusible, as well as form hypotheses about the effects of cochlear implantation on the brain.

W43: VARIABILITY IN CLINICIANS' PREDICTION ACCURACY FOR OUTCOMES OF ADULT COCHLEAR IMPLANT USERS

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Current literature still reports varying speech perception outcomes across adult cochlear implant (CI) users. The largest proportion of variability in post-implantation outcomes remains unexplained, making it challenging for clinicians to provide adult CI candidates with an accurate expected outcome with their CI. Outcome prediction in this field has been attempted using linear models and machine learning algorithms, which have yet to yield reliable and accurate predictions of CI performance. The predictive value for such models and algorithms in clinical practice also remains to be explored. Available literature does not explore whether clinicians appear to hold additional knowledge on outcome prediction when presented with clinical case studies, compared to the factors currently implemented in outcome prediction models. Knowledge in this area may shed light on current prediction strategies in the clinical context. Our study investigated how accurately clinicians can predict adult CI users' speech perception in quiet, one-year post-implantation. A survey of 10 clinical case studies of adult CI users was completed by 41 clinicians from around the world. Clinicians were provided with a comprehensive overview of pre-implantation, one-month post-implantation and 6 months post-implantation information for each case. The case studies ranged in one-year post-implantation performance in quiet, from low performers (5% monosyllabic word score) to high performers (82% monosyllabic word score). Our results revealed that low performance was significantly over-predicted. Instead, clinicians appear to predict average performance (49-54% monosyllabic word score) across all cases and not performance variability between cases. Overall, clinicians were confident in their predictions, regardless of their prediction accuracy. Our findings can serve the clinical field by bringing to light prediction bias towards average performance, even when risk of lower performance is suggested. We hope these findings inspire clinicians to continue to be critical thinkers in the pre-operative counselling and expectation management journey, to timeously identify candidates at risk of low performance, and to initiate early, individualized intervention when indicated. Further research into methods of accurate outcome prediction is important for expectation management and counselling (especially given expanded CI criteria for individuals with more residual hearing), increased CI uptake and to streamline clinical care for high and low performers.

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W44: USE OF MACHINE LEARNING TO PREDICT ADULT COCHLEAR IMPLANT BENEFIT USING RELIABLE CHANGE INDEX

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Postlingually deaf adults who receive cochlear implants (CIs) routinely display enormous unexplained variability in benefits to speech recognition performance and self-reported quality of life (QOL). Traditional clinical demographic, audiologic, and surgical factors together explain less than 40% of the variability in these outcomes, and our ability to prognosticate CI outcomes before surgery using pre-operative measures is even poorer. Additionally, most studies examining individual difference in CI outcomes focus on endpoint outcome scores, rather than considering the degree of benefit (i.e., improvement) each patient receives. Our limited ability to reliably prognosticate likely benefits for patients considering CIs creates a barrier to effectively counseling patients pre-operatively or identifying patients who are at risk for limited benefit after CI surgery. The objective of this study was to use a machine-learning approach for pre-operative prediction of adult CI benefits to speech recognition and quality of life outcomes after 6 months of CI use, using a battery of both traditional and research measures. A prospective, longitudinal study was performed in 32 adults undergoing CI surgery. A battery of predictor measures was collected prior to surgery, including traditional demographic and audiologic measures, but also assessments of spectrotemporal processing and environmental sound awareness, non-auditory neurocognitive functioning, linguistic skills, and pre-operative speech recognition and patient-reported QOL. All measures were scaled from 0 to 1. Missing values were imputed via KNN imputation (k=3). K-means clustering was leveraged to separate patients into 4 groups according to their demographic and pre-operative measures. Six months after CI activation, speech recognition (using auditory and audiovisual CUNY sentences, AzBio sentences in quiet, and AzBio sentences in +10 dB SNR babble) and QOL (using the Nijmegen Cochlear Implant Questionnaire, NCIQ) measures were repeated, and "reliable change index" (RCI) scores were computed for speech recognition and QOL measures. The RCI provides a metric of change from pre-op to 6 months post-CI, while accounting for variance in those measures among all participants. Kruskal-Wallis tests and analyses of variance were performed on the RCI scores to ascertain whether the four groups were associated with distinct amounts of CI benefit in speech recognition and QOL. Clustering based on demographic and pre-operative measures yielded four distinct groups with significant differences RCI for auditory ($p = .016$) and audiovisual CUNY sentence recognition ($p = .005$) as well as the Physical domain of the NCIQ ($p = .029$). These four groups represented two groups with relatively low pre-op performance and large RCI scores, one group with relatively high pre-op performance and small RCI scores, and a fourth group with relatively low pre-op performance and small RCI scores. This fourth group could be considered a "high-risk" group in that these participants demonstrated relatively poor speech recognition and QOL pre-op but did not demonstrate large improvements in speech recognition and QOL 6 months post-CI. Lastly, we explored which pre-operative measures were most defining of the high-risk group as compared with the other three: pre-op scores of verbal learning and memory on the California Verbal Learning Test (CVLT) were poorest in the high-risk group as compared with the other three groups. Findings suggest that a battery of pre-operative assessments can help prognosticate and distinguish four groups of CI recipients who will or will not experience favorable benefits to speech recognition and QOL at 6 months after implantation. Importantly, these participant groups were determined by measures beyond traditional demographic and audiologic measures currently used clinically to try to counsel patients regarding their likely outcomes. Specifically, some assessments of neurocognitive functioning and QOL may provide additional useful information in prognosticating CI outcomes. Lastly, clustering analysis provides a potential tool for identifying individuals who are at high risk of experiencing poor CI benefits, and potentially mechanisms that underlie those poor benefits, which may have ramifications for suggesting individuals for whom more intensive counseling or rehabilitation may be needed.

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W45: THE INFLUENCE OF STIMULUS POLARITY ON OUTCOME PREDICTION WITH MEASURES OF COCHLEAR NEURAL HEALTH AND THEIR RELATIONSHIP WITH AGE

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A better understanding of the variation in cochlear implant (CI) outcomes is crucial for effective development of individualized treatment strategies. Various factors, such as etiology, demographics, cognition, insertion angle and implant type can contribute. The status of the peripheral auditory system including number and status of spiral ganglion neurons (SGNs), i.e. cochlear neural health, can be assessed with the CI (Ramekers et al., 2014) and also contributes to the interindividual variance (Kamakura and Nadol, 2016). It is still a matter of ongoing debate how to reliably estimate cochlear health during a routine clinical visit. The goal of this study was to further investigate the potential of cochlear health measures for predicting CI outcomes and to explore their dependance on stimulus polarity using age as an indicator of neuronal degeneration. Speech intelligibility was assessed in 24 ears (13 bilateral CI users) by measuring speech reception thresholds (SRT) for the German matrix sentence test in stationary speech-shaped noise. ECAP amplitude growth functions (AGF) were measured twice on each electrode with forward masking artefact reduction using cathodic-first (FMC) pulses in the first condition and forward-masking with anodic-first pulses (FMA) in the second condition. The change in the slope of the AGF when the interphase gap (IPG) of the biphasic pulse was increased from 2.1 µs to 30 µs, which was defined as the IPG effect on slope (IPGEslope), was measured in both conditions. To consider the relative importance of each frequency for speech intelligibility, the measured IPGEslope of each electrode was weighted according to the band importance function (BIF) introduced by ANSI (1997). The across-site mean value of these weighted IPGEslope values were reported as the cochlear health measure for each ear and each condition when correlating with CI outcomes. The BIF weighting was not used when correlating with age. The FMC condition showed a mild but significant correlation ($R2=0.33^{**}$) between the weighted IPGEslope and SRT, while FMA resulted in a slightly lower determination ($R2=0.25^{*}$). Omitting the BIF weighting resulted in non-significant results for both conditions when correlating IPGEslope with SRTs. Furthermore, a significant correlation was observed between IPGEslope and age for FMC ($R2 = 0.54^{***}$), but the same analysis had non-significant results for FMA measurements ($R2 = 0.11$). These results suggest that IPGEslope has the potential to serve as a clinically feasible measure for cochlear neural health, especially when measured with cathodic-leading pulses. IPGEslope may contribute to outcome prediction when integrated with cognition and other factors when BIF weighting is applied. The reduction of IPGEslope with increasing age for FMC but not for FMA pulses suggests that cathodic-leading pulses are more sensitive to degeneration of SGNs, in agreement with previous modeling studies (Resnick et al. 2018).

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W46: COMPARISON OF TONOTOPIC MAPS FOR COCHLEAR IMPLANT FITTING: A STUDY ON 149 PATIENTS FROM MHH HOSPITAL

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Tonotopy refers to the mapping of different frequencies of sound onto specific locations in the cochlea, and tonotopic mapping involves identifying these locations and programming the implant accordingly. In recent years, researchers have suggested that fitting a cochlear implant based on tonotopic mapping can lead to better patient outcomes. Several tonotopic mapping methods have been proposed in the literature, including the Greenwood, Stakhovskaya, and Helpard. Their mapping approach differences may lead to variation in the way that the cochlear implant (CI) is programmed, and thus its performance. To assess the differences between these tonotopic maps, we conducted a retrospective study on 149 CI patients who received Oticon Medical Evo electrodes at Hannover Medical School (MHH) hospital. The insertion coverages and tonotopic frequencies associated with each electrode were obtained by automatically analysing the pre- and post-operative CT images using Nautilus software (Oticon Medical, France). We also examined the frequency mismatches between the abovementioned tonotopic maps and patient's preferred frequency maps and compared them with FBE (Freiburg Monosyllabic test) and HSM (Hochmair-Schulz-Moser sentence test) speech tests. Our results showed that on average electrodes 6-10 inhibit the lowest mismatch between the different tonotopic maps. The maps yielded sinusoidal-like frequency mismatch patterns (ranging from 0.4 - 1.2 octaves on average) when compared with patient’s frequency maps with the most apical and basal electrodes yielding the highest mismatch. There were very minimal changes between frequency maps at 6 and 12 months post-implantation. Additionally, the analysis showed that there are weak correlations (r = -0.202 to -0.296) between frequency mismatch and speech performance, indicating that other factors beyond tonotopy may also influence cochlear implant outcomes. These factors could include electrode positioning, trauma, patient's age, duration of deafness, or underlying cause of hearing loss. Our study offers valuable insights regarding the utilization of tonotopic maps in cochlear implant fitting, emphasizing the necessity for further research to recognize potential factors that might influence patient outcomes.

W47: INVESTIGATION OF THE AUDITORY, VISUAL, AND COGNITIVE ABILITIES: DIFFERENCES BETWEEN NORMAL-HEARING ADULTS, HEARING AID USERS, AND COCHLEAR IMPLANT USERS AND THE PROPOSITION OF AN AVC-PROFILE

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Investigation of the Auditory, Visual, and Cognitive Abilities: differences between normal-hearing adults, hearing aid users, and cochlear implant users and the proposition of an AVC-profile Dorien Ceuleers1 (presenting author), Hannah Keppler2,3, Sofie Degeest4, Nele Baudonck2, Freya Swinnen2, Katrien Kestens3, Ingeborg Dhooge1,2 1 Department of Head and Skin, Ghent University, Ghent, Belgium; 2 Department of Otorhinolaryngology, Ghent University Hospital, Ghent, Belgium; 3 Department of Rehabilitation Sciences, Ghent University, Ghent, Belgium; 4 Independent researcher Introduction and aim: Speech understanding is a bi-modal and bi-directional process, whereby also visual information (i.e. speechreading) and cognitive functions (i.e. top-down processes) are involved. Therefore, the aim of this study was twofold: (1) to investigate the Auditory (A), Visual (V), and Cognitive (C) abilities in normal-hearing individuals, hearing aid (HA) users, and cochlear implant (CI) users, and (2) to determine an AVC-profile providing a comprehensive overview of a person's speech processing abilities, containing a broader variety of factors involved in speech understanding. Material and methods: The study sample consisted of three matched groups of 31 participants: (1) normal-hearing (NH) adults, (2) adults with a moderate to severe hearing loss using HAs, (3) adults with a severe to profound hearing loss using a CI. The auditory assessments included pure-tone audiometry, speech audiometry in quiet and in noise. For evaluation of the (audio-)visual speech processing abilities, the Test for (Audio-)Visual Speech Perception was used [1]. The cognitive assessments included the Letter-number sequencing task [2], the Letter Detection Test [3], and an auditory Stroop test [4]. Differences between the groups were examined and a Principal Component Analysis was conducted to determine the AVC-profile. Results: NH individuals scored significantly better for both auditory and cognitive abilities than HA- and CI users, listening in a best-aided condition. No differences were found for speech understanding in a visual-only condition. Furthermore, an AVC-profile was proposed, allowing to compose one comprehensive score for auditory, visual, and cognitive functioning. Conclusions: It is suggested to evaluate individuals with hearing loss from a broader perspective, considering more than only the auditory abilities, when making decisions regarding hearing rehabilitation. In the future, the AVC-profile could be used to determine individual strengths and weaknesses for the different abilities related to the process of speech understanding, resulting in more person-centered care. Financial disclosures/conflicts of interest:

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W48: GATHERING ECOLOGICAL DATA TO ASSESS REAL-LIFE BENEFITS OF COCHLEAR IMPLANTS

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Cochlear implant (CI) can restore sensation of hearing and near perfect speech communication to many patients with severe-to-profound sensorineural hearing loss in quiet environments. However, many challenges remain. There are big individual variabilities observed in speech and quality of life outcomes following cochlear implantation. Specifically, most of the clinical assessments for patients are conducted in an isolated lab or clinic, using unrealistic sound stimuli, which are far from the real communication scenarios CI users face daily. Therefore, results generated from these tests cannot uncover fully the challenges and difficulties CI users are experiencing. This discrepancy might be able to explain the lack of association between real-life quality of life measurement and standard clinical assessment. Oticon Medical Field Research Platform (OMFRP) introduces a new way to investigate the realistic usage of medical devices for CI users. It is a standalone iPhone application connected with the hearing devices via Bluetooth connection to control device-related settings (e.g., programs, sound level, data logging, acoustic scene classification). The application interacts with the user by collecting ecological momentary assessment (EMA) questionnaires at certain intervals. The application is also extendable to other devices to collect simultaneous physiological signals (e.g., Apple Watch for heart rate variability data). To understand better the validity and sensitivity of this method in assessing CI users' device usage, we are designing a clinical protocol to compare the in-lab results and field data on two CI features: noise reduction and NofM. During the in-lab session, participants will perform a series of speech-in-noise tasks with simultaneous pupillometry and post-task subjective effort rating, to obtain CI users' speech recognition and listening effort. Then the participants will take OMFRP back to their daily life and fill out EMA assessment on self-rated communication success and effort/fatigue level. Different noise reduction and NofM settings will be coded as different programs in the users' CI device so we can pair accordingly the response and the experimental manipulation. Furthermore, we can also utilize the device's own data logging and OMFRP's automatic scene classification to understand how different communication scenarios affect users' speech recognition and perceived difficulty. We are aiming to recruit 20 CI users to finish both the in-lab and field data collection. During the conference, we will demonstrate 1) the full development pipeline of the field research application 2) the ios application connectivity and features 3) interactive data visualization portal 4) pilot data results from normal hearing and CI users. To summarize, OMFRP and the validation clinical experiment will serve as a next-generation tool for assessing realistic CI outcomes. The phone application will provide access to extend the in-lab knowledge to real life. The clinical experiment will assess the construct validity of this method and synthesize the information gathered in-lab and field.

W49: EFFECT OF FREQUENCY-TO-PLACE MISMATCH AND FREQUENCY WARP ON SPEECH AND MUSIC SOUND QUALITY IN ACOUSTIC COCHLEAR IMPLANT SIMULATION

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In more recent years a greater emphasis has been placed on improving the sound quality for individuals using cochlear implants (CIs). Indeed, many post-lingually deafened adults with CIs have speech recognition performance close to normal hearing (NH) listeners in quiet environments, but yet complain about poor sound quality, especially for music. The contribution of CI technology to the degradation of music quality has been well documented, but little is known about the relative importance of different aspects relating to the technology and how they interact with the personal preferences and hearing characteristics of the individual. One individual factor that is suspected to contribute largely to the sound quality degradation is the frequency-to-place mismatch (FTPM) induced by the incomplete insertion of the electrode array inside the cochlea. It is defined as a deviation between the characteristic frequency and the allocation frequency assigned during CI fitting. Whereas much of the speech perception improvement occurs during the first months after CI activation, recent studies have shown that a significant FTPM could negatively affect this adaptation process. Alongside the improvements in speech perception over time from device activation patients often also change their reports of sound quality, from “high pitched”, “screechy”, “dalek-like” to more “normal” or “natural” after extensive listening experience. However, the specific contribution of FTPM on sound quality isn’t clear. This research investigates the link between sound quality and FTPM in acute listening experiments with CI simulations with NH listeners situation and how pre-modifications of speech and music material can be used to explore and understand the impact of FTPM. Testing used the MUlti Stimulus test with Hidden Reference and Anchor (MUSHRA) paradigm for listening to different acoustic simulations of monaural CIs for different sound materials (speech, vocal music with instruments, and instrumental only). The first experiment explored the link between sound quality and FTPM, where participants had to assess the sound quality of different FTPM profiles relative to a non-shifted reference. The second experiment was a frequency shifting experiment, where NH listeners compared and rated their listening experiences for the speech and music stimuli previously shifted. Preliminary results from the first experiment indicate that FTPM degrades sound quality, with the level of degradation depending on the frequency content of the sound material and the frequency band in which the FTPM is simulated. However, for now no specific trend has been observed in the second experiment between the FTPM simulated and the degree of frequency that results in the best sound quality judgements. This work will be continued with CI listeners with the intention of quantifying the degree of FTPM and the importance with the intention of informing re-mapping.

W50: AN EXTRAORDINARY AUDITORY BRAINSTEM IMPLANT (ABI) USER: STRENGTHS, WEAKNESSES, AND MILESTONES

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Purpose: Variability and individual differences in speech recognition outcomes following auditory brainstem implantation (ABI) in patients with neurofibromatosis type 2 (NF2) is enormous with most patients achieving suboptimal open-set speech recognition outcomes. A case report of one individual with exceptionally good postoperative outcomes with an ABI is presented, allowing for examination of the information processing mechanisms underlying variability in outcomes.

Method: A case study is reported of one adult ABI recipient (ID-006) with postlingually acquired, NF2-related hearing loss who displayed exceptional postoperative speech recognition scores on conventional clinical outcome measures decades after activation. A novel battery of sensitive auditory, cognitive, and linguistic information processing tests as well as self-reported subjective questionnaires was used to assess his strengths, weaknesses, and milestones in each domain.

Results: Seventeen years following ABI activation, ID-006 scored 77.6% correct on the AZ Bio Sentences in quiet. On auditory processing tasks, ID-006 scored higher on tasks with meaningful sentences and much lower on tasks that relied exclusively on audibility. ID-006 also demonstrated exceptionally strong abilities on several cognitive and linguistic information processing tasks.

Conclusions: Results from a novel battery of information processing tests suggest that ID-006 relies extensively on top-down predictive processing and cognitive control strategies to efficiently encode and process auditory information provided by his ABI. Results suggest that current measures of outcomes and benefits should be expanded beyond clinical speech recognition measures to include more sensitive and robust measures of speech recognition as well as neurocognitive measures such as executive function, working memory, and lexical access.

W51: ON THE DEVELOPMENT OF A QUESTIONNAIRE TOWARDS UNDERSTANDING BARRIERS TO ADULT CI UPTAKE: A LITERATURE REVIEW

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Introduction: One known patient-related factor that contributes to cochlear implant (CI) performance is length of deafness: longer duration of hearing loss before implantation is associated with poorer outcomes. However, despite the urgency to decrease the duration of deafness before implantation, some individuals are still waiting or deciding against the CI. After becoming a candidate, many factors outside of severity and duration of hearing loss may determine a person's readiness and willingness to proceed with cochlear implantation. Defining these barriers may help in counseling, community outreach, and in improving overall patient performance and device satisfaction. The purpose of this scoping review is to identify and summarize the existing literature on barriers to CI uptake. This review will provide a basis for the development of a new questionnaire that can be given during CI initial evaluations to identify those who may need extra resources in making their CI decision.

Methods: The words uptake, barriers, and decision preceded by the words cochlear implant were used to search PubMed for relevant journal articles pertaining to CI uptake and barriers in adults. The search revealed 38 journal articles. All articles were screened for inclusion. Two articles were unrelated to the topic of cochlear implants. One article was related to osseointegrated devices, and one was related to barriers of speech processor usage rather than device implantation. Finally, 19 articles were related to pediatrics, and the remaining 15 journal articles pertaining to adults were summarized for this review.

Results: Our preliminary review revealed that several studies have compared differences between those being implanted and those deciding not to be implanted using questionnaires and interviews. Overall, there are obstacles in gaining access to the CI evaluation and recommendation, and there are obstacles to patient decision making after being considered a candidate for a CI with the latter being the focus of this review. Some main factors determining CI uptake relating to willingness and readiness after candidacy criteria have been met include knowing someone who already has a CI and how their experience (positive or negative) affects a candidate's decision, fear of losing residual hearing, and concerns about sound quality. Other barriers in the evaluation process that proceed readiness are lack of referral, lack of CI awareness from their main healthcare providers (non-hearing healthcare), and lack of receiving an accurate diagnosis to initiate the CI evaluation. Even after some or most of these barriers have been met some patients are often concerned with distance of travel for follow-up and monetary out-of-pocket expenses. Additional work is needed to uncover why some individuals are still waiting longer than needed to be implanted.

Conclusion: Barriers to CI uptake are barriers to good clinical care. The development of a preoperative or a widespread hearing-healthcare questionnaire could provide patients and their clinicians guidance to extra resources to decide towards or against getting a CI.

W52: DO SOCIAL NETWORKS RELATE TO SPEECH RECOGNITION AND REAL-WORLD FUNCTIONING IN ADULT COCHLEAR IMPLANT USERS?

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Cochlear implants (CIs) are an effective treatment for adults with severe-to-profound sensorineural hearing loss, and ideally lead to improved real-world communication skills and social engagement. However, we currently do not have a good understanding of relevant, modifiable factors that contribute to the enormous unexplained variability in speech recognition outcomes or in real-world benefits reported by adult CI users. Although not yet examined in adult CI users, there is evidence that the auditory and social environments in which individuals communicate influence both speech recognition ability and aspects of real-world functioning. In particular, larger and more diverse social networks are associated with better speech recognition accuracy and may support overall well-being, at least in normal-hearing individuals. However, for CI users, the spectro-temporal degradations in the transmitted signal may limit the beneficial effects of listening to diverse speech input (provided by larger or diverse social networks) on speech recognition outcomes. Regardless of any benefit on speech recognition, larger or more diverse social networks may still have a positive impact on CI users' real-world functioning.

The current study examined the relation between social network size and diversity and speech recognition outcomes and self-report measures of real-world functioning in adult CI users. Twenty-five adult CI users with more than one year of CI experience completed a detailed questionnaire regarding their communication practices and social networks. For this study, we specifically examined social network size (defined as number of regular communication partners) and social network diversity (defined as degree of age, education, and accent heterogeneity in their networks, using calculated age and accent diversity metrics). To assess speech recognition abilities, they completed vowel, word, and sentence recognition tasks in quiet and multi-talker babble (MTB). To assess their perceived real-world functioning, they completed self-report questionnaires of Speech, Spatial and Qualities of Hearing (SSQ) and the Cochlear Implant Quality of Life (CIQOL) questionnaires. All behavioral tasks and self-report questionnaires were completed remotely. We compared social network size and diversity metrics to 1) word and sentence recognition performance, controlling for vowel recognition (here, taken as a measure bottom-up signal quality) and 2) self-report real-world functioning. Adult CI users varied in their social network size and diversity. First, while social network size was not related to word and sentence recognition, social network age diversity showed a moderate positive correlation with word recognition in quiet and sentence recognition in quiet and MTB. Network education and accent diversity were only weakly correlated with word and sentence recognition. Second, social network age diversity showed a moderate positive correlation with SSQ and CIQOL scores. While network education and accent diversity were only weakly related to SSQ and CIQOL scores overall, they were both moderately correlated with scores specifically on the CIQOL Listening Effort domain. Social network size was not related to real-world functioning.

These preliminary results suggest that CI users' social network diversity impacts both their speech recognition abilities and their perceived real-world functioning. Adult CI users may benefit from listening to diverse speech input, similar to normal-hearing listeners, but the benefit may be moderated by bottom-up signal quality. Interestingly, adult CI users also appear to receive a broader benefit to perceived real-functioning from having a more diverse social network. More research is needed to establish the direction of the relation, i.e., if good outcomes lead to more diverse social networks or more diverse social networks lead to better outcomes. These preliminary findings suggest that characteristics of CI users' auditory and social environments may be useful for predicting or explaining individual differences in outcomes, and may inform our counseling and rehabilitation protocols to optimize speech recognition abilities and real-world functioning following implantation.

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W53: EFFECTS OF INTER-IMPLANT DELAY AND AUDITORY EXPERIENCE ON SPATIAL RELEASE FROM MASKING IN CHILDREN WITH BILATERAL COCHLEAR IMPLANTS

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Background: Multiple studies have shown the importance of using bilateral cochlear implants (BiCIs). While unilateral CIs provide access to language and environmental sounds, BiCIs are known to improve patients' ability to localise sounds and understand speech in noise. Studies have also shown that speech recognition in noise can be improved with spatial release from masking (SRM). Numerous questions remain about factors that contribute to emergence of SRM. In this study, we compare new data from a group of 12 children who received BiCIs at younger ages with previously published data from children who received their second CI at a later age.

Methodology: This study focused on 12 children with BiCIs who were tested when they were between the ages of 4–7 years. Speech understanding was assessed in quiet, and with interfering sentences that were either co-located or spatially separated. Target stimuli were spondaic words. Children engaged with a four-alternative-forced-choice task and speech reception thresholds (SRTs) were measured. The difference between studies was age at second CI which ranged from 14-43 months in the current study and 25-73 months in the previous study.

Results: Significant relationships were observed between the following factors and SRTs in quiet: (1) age, and (2) years of bilateral auditory experience. Preliminary findings demonstrate improvements in SRTs in co-located and asymmetric conditions with age and bilateral auditory experience even though the findings were not statistically significant. Furthermore, we are exploring SRM and other factors such as age and bilateral auditory experience and the interactive effect of both factors on SRTs and SRM.

Conclusion: This study focused on investigating effects of age at testing and bilateral auditory experience on SRTs and SRM. Preliminary findings suggest that effects are more prominent in quiet conditions than in conditions with interferers. This suggests that there may be associations with harnessing cognitive resources and language skills to solve the listening task. Those skills may also associate with speech understanding in noise, but factors such as the limitations of the device may make these effects less prominent.

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W54: A PROSPECTIVE, MULTI-CENTRE CASE-CONTROL TRIAL EXAMINING FACTORS THAT PREDICT VARIABLE CLINICAL PERFORMANCE IN POST LINGUAL ADULT CI RECIPIENTS (PREVA)

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Aim. The variability in speech perception outcomes for adult cochlear implant (CI) recipients has been attributed to a range of factors involving “bottom-up” auditory sensitivity and “top-down” linguistic knowledge and neurocognition (Moberley et al., 2016), although the relative importance of these factors is not clearly understood. The present study primarily aimed to investigate the relative contribution of a range of factors – mapping, anatomical placement, neural health, and conduction pathway – to predict word in quiet performance and auditory sensitivity outcomes. A secondary objective was to determine the influence of cognitive factors, in addition to the above factors, on sentence in noise performance.

Method. The study was conducted at two sites, HEARnet in Melbourne and Medizinische Hochschule Hannover (MHH). Enrolled were 120 experienced adult CI subjects with similar numbers of poorer and good performers defined by word recognition in quiet scores of < 35% and > 65% words respectively. Auditory sensitivity was measured using aided thresholds, phoneme discrimination, spectral resolution, and temporal resolution tests. Mapping variability was assessed firstly by creating a Measured MAP in a study visit using a systematic behavioural mapping procedure. This Measured MAP was then compared with the subject’s everyday Own MAP, and potential issues in the Own MAP were flagged, e.g. poorer audibility due to T-levels being mapped well below the true T-levels. Anatomical predictor variables included scalar translocation, modiolar distance, and electrode insertion depth. Neural health measures included two psychophysical measures - BP thresholds and polarity effect (PE) using asymmetrical pulses and four NRT measures -interphase gap (IPG) change, PE using biphasic pulses, refractory ability, and MediumCAP, a shortened version of the Panoramic ECAP (Garcia et al. 2021). Conduction pathway predictor variables included 4-point impedance and a trans-impedance matrix dependence measure. Finally, cognitive measures included a vocabulary test, the Victoria Stroop and the Symbol Digit Modality Test.

Results. Multiple linear regression model analyses will be presented to determine the relative contribution of the mapping, anatomical placement, neural health, and conduction pathway variables in explaining variance in performance outcomes.

W55: BELIEFS TOWARD CURRENT AND INCREASED SOUND PROCESSOR WEAR TIME IN ADULT CI USERS

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Introduction. Despite the success of cochlear implants, variability in speech and communication outcomes remains high. One variable that has recently gained more attention in the adult population is consistent sound processor wear time (e.g. Busch et al., 2017; Holder et al., 2020). Holder et al. (2021) showed that improved consistency of sound processor usage in a small group of users yielded significant improvements in speech perception scores. However, the beliefs towards current and increased sound processor wear time in a large adult CI population remain to be explored.

Method. A survey was sent out to adult Cochlear® CI users across 4 markets (US, UK, ANZ and DE) at the end of December 2022, and data from 1238 users was collected. The majority of respondents (55%) were seniors (65-84 yrs).

Results. First, we explored their beliefs on their current time-on-air behavior. Across all age groups, users believed their average amount of time-on-air to be 15.4 hrs/day. Furthermore, only half of the respondents indicated that throughout their cochlear implant journey, their audiologist/clinician discussed how much time they should be spending wearing their sound processor. In case this topic was brought up by their audiologist/clinician, the recommendation was to wear it “as much as possible/the more the better”. As a result, there was general agreement that the more time spent wearing their sound processor, the better they would be able to hear and communicate, although this was correlated to age. Furthermore, the majority of users believed they wore their sound processor across a range of different sound environments, and enough to meet their needs (85%), however, this was lower amongst 85+ (75%). There was a desire amongst 19-49-year-olds (32%) to wear their sound processor in more situations than they currently do. Second, attitudes toward hearing progression were explored. For the respondents, hearing progress to them was beyond clinical measures, it meant real-world outcomes, or the benefits, from being able to hear better and improve social interaction. As such, most respondents (85%) also felt that their hearing progress was more about ‘how they felt than about any specific measure’. However, older recipients did rely on their clinicians more to understand how they were progressing.

Conclusion: Existing CI users claim they are wearing their sound processors for a maximum number of hours already (15.9 hrs), in the mind of CI users, they are wearing it enough to meet their needs. This, however, differs from the actual usage we get through data logs, with time on air averaging 10.5 hours per day. The discrepancy between beliefs and reality provides us to unveil impactful insights to CI users. By informing and involving them in their CI care, we aim to empower them and maximize their hearing potential.

W56: IMPROVING THE CI-AIDED AUDIOGRAM: IS IT WORTH MEASURING ELECTRICAL THRESHOLDS?

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Cochlear implant (CI) aided soundfield audiograms give insight into a patients' access to soft sounds and are often used to verify processor programming. When electrical stimulation thresholds (T-levels) are behaviorally measured, CI-aided thresholds are predictable, within a small range, based on the acoustic-to-electric transform function. This is because speech processors map a predetermined dB HL level to the T-level for a given electrode. CI patients who use a given device with a given sensitivity setting are expected to have the same aided soundfield audiogram—as long as the electrical thresholds programmed in their speech processor have been measured correctly and have not changed since programming. However, in order to save valuable time, T-levels are sometimes estimated rather than behaviorally measured. Commonly used T-level estimates are 8% or 10% of the electrical maximum comfortable level for a given electrode. We investigated the extent to which CI-aided thresholds and speech perception are affected by the use of measured versus estimated T-levels. We collected and tabulated over 300 aided audiograms from the adult cochlear implant patient population at the NYU Cochlear Implant Center. Patients with device failures, NF2, and other anomalies were excluded. Patients were divided into two groups: those with measured electrical CI thresholds and those with estimated electrical CI thresholds. Individual aided thresholds were considered, as well as the average aided thresholds across all frequencies. As expected, CI-aided thresholds for the measured electrical threshold group fall within a predictable range and the vast majority of the measured group have average CI-aided thresholds lower than 35 dB HL. In contrast, over 20% of the estimated electrical threshold group had CI-aided threshold higher than 35 dB HL. Both CNC word scores and AzBIO sentence scores in quiet were higher for the measured electrical CI threshold group, and we found a significant correlation between average CI-aided thresholds and speech perception scores. This suggests that measuring T-levels in patients with elevated CI-aided thresholds may improve their speech perception in quiet.

W57: EFFECT OF INNER EAR MALFORMATIONS ON RELATIONSHIPS BETWEEN INTRAOPERATIVE ECAP RESPONSES AND POSTOPERATIVE AUDITORY PERFORMANCES

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Currently, inner ear malformations are no longer considered contraindications for cochlear implant due to advances in surgical techniques and accumulations of practical cases. Individuals with mild IEM (including enlarged vestibular aqueduct and incomplete partition type II) are reported with compatible outcomes as normal individuals. Those with severe IEM (including cochlear aplasia, cochlear nerve aplasia, IP type I and III) could also benefit from CI such as better detection of environmental sounds. This study explored the influence of inner ear malformations on intraoperative ECAP responses and their association with postoperative auditory performances. Among 222 ears implanted with CI, 38 had mild IEMs and 26 had severe IEMs. While mild IEM group had comparable ECAP thresholds and achieved similar CAP scores to normal group, severe IEM group showed significantly elevated ECAP thresholds and lower CAP scores. Definite negative relationship existed between ECAP thresholds and CAP scores obtained from all subjects. The inverse relationship between ECAP thresholds and CAP scores may suggest that electrophysiological responses measured during surgery may be a potential indicative factor for postoperative auditory performance in CI population.

W58: ASSESSMENT OF COCHLEAR IMPLANT HEARING OUTCOMES USING ECOLOGICAL MOMENTARY ASSESSMENT (EMA) IN BOTH CONTROLLED AND REAL-WORLD SETTINGS

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Evidence from laboratory tests of speech understanding in quiet and noisy conditions demonstrate the high effectiveness of cochlear implants (CIs) for individuals with severe-to-profound hearing loss. However, benefits in real-world listening conditions are more challenging to capture and are thus less understood. Common retrospective methods, such as questionnaires, to assess real-world hearing performance and device benefits of devices may be inaccurate and unreliable due to recall bias and insufficient knowledge of the acoustic environment. To address this, we used an Ecological Momentary Assessment (EMA) smartphone app to record current, or very recent, subjective feedback ratings alongside objective acoustic parameters of the listening environment of adult CI recipients, in both controlled laboratory settings and in the real world. Using EMA, we aimed to characterise the acoustic features of environments that CI users find most challenging, and the internal factors (such as cognition, attention, personality, and lifestyle) which influence their self-ratings on perceived environmental noisiness, device benefit, and speech understanding. Twenty adult CI recipients participated in laboratory and real-world data collection. Laboratory testing included cognitive tests, questionnaires, EMA, and the NAL Dynamic Conversation Test. Five acoustic scenes, that capture a range of commonly encountered sound levels and signal-to-noise ratios (SNRs), were reproduced with a spherical array of 41 speakers in an anechoic chamber to evaluate speech comprehension, practice use of the EMA tool, and provide anchors for later EMA results from the real-world part of the study. After laboratory testing, each participant recorded their everyday listening experiences with the EMA app over four weeks of take-home testing. Laboratory results showed that self-rated communication difficulty increased significantly as sound level increased and as SNR decreased. We also found a positive correlation between CI experience and cognitive performance. Linear mixed-effect modelling of the real-world EMA data revealed that perceived noisiness was influenced by both spectro-temporal properties and the sound level of the environments. Self-reported communication factors (listening effort, conversational participation, frustration, and speech understanding) were best associated with environmental sound level, and together with internal factors were predictive of self-reported CI device benefit. In conclusion, through in situ self-ratings and concurrent recording of key acoustic features, EMA can provide valuable insights into the real-world experiences and challenges of CI recipients. This information has potential to better tailor technologies for individuals' everyday needs and evaluate the functional efficacy of these technologies in the real world.

THURSDAY POSTER ABSTRACTS

Th1: FEASIBILITY OF INTERBRAIN SYNCHRONY BETWEEN COCHLEAR IMPLANTED CHILDREN AND THEIR MOTHER: A FNIRS STUDY

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Introduction: The development of a child's language and communication depend on their hearing ability. However, deaf children face communication challenges, and may use a cochlear implant to compensate for their hearing loss. To date, no study has been conducted to determine inter-brain synchrony (IBS) between cochlear implanted (CI) children and their mothers. Using conventional neuroimaging techniques to measure IBS has proven difficult due to incompatibility between many imaging techniques and CIs. However, functional near infrared spectroscopy (fNIRS) can be used for this population as it is compatible with cochlear implants. We will demonstrate the feasibility of measuring IBS in CI children and their mothers and gain a deeper understanding of the behavioural and neurological basis of language processing in this population. Particularly, we will examine whether IBS between CI children and mother pairs differs from that between normally-hearing children and mothers, and whether different kinds of task condition result in greater IBS.

Method and results: Children aged 4-6 years, with CIs and normally-hearing, and their mothers will take part in this hyperscanning study. Mother-child pairs will play freely with age-appropriate toys in a naturalistic environment for five minutes under two conditions: interactive, where both play together like at home, and independent, where they are required to play separately. To map IBS, fNIRS hyperscanning will be performed with a series of 2x2 optode arrays over the bilateral inferior frontal gyrus and temporo-parietal junction of both the child and mother participants.

Conclusion: This study aims to better understand the feasibility of measuring inter-brain activation between children with CIs and their mothers, allowing us to expand our knowledge of the neural drivers behind the development of parent-child communicative behaviours after hearing loss and subsequent restoration via CIs.

Th2: ELECTRICALLY EVOKED COMPOUND ACTION POTENTIALS AS MARKER FOR SPIRAL GANGLION NEURON DAMAGE AND DEGENERATION

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Speech perception in cochlear implant (CI) users is likely influenced by heterogeneous degeneration of spiral ganglion neurons (SGN). However, the interpretation of human psychophysical and electrophysiological results is difficult, as reliable markers of locally restricted SGN damage are still missing. The aim of the study was to 1) assess the effect of acute damage and chronic degeneration along the SGN, after focal micro lesions on electrical hearing and to 2) derive non-invasive, electrophysiological markers for the location and size of the SGN damage.

The guinea pig was used as animal model to quantify changes in electrically evoked compound action potential (eCAP) recordings either directly following (max 4 h; ‘acute’) or 8-12 days after (‘chronic’) a mechanical ~430 μm lesion to the SGN in the basal turn. We recorded from 10 ears for comparison of pre- versus post-lesion values (acute) and compared 13 chronic-lesioned ears to 8 healthy, control ears. For stimulation with the CI, hair cells were acutely deafened by intracochlear infusion with neomycin. For electrical stimulation we used a 6-contact CI electrode, with biphasic pulses of alternating leading polarity in monopolar configuration. The eCAP responses were recorded to stimulation both close to (‘ON’) and distant to (‘OFF’) the lesion. We assessed both the, clinically relevant, early N1P1 eCAP component to averaged polarities and the late N2P2 component for separate analysis of anodic-leading and cathodic-leading stimulation.

Both the acute and the chronic lesions had significant global effects (i.e. for both ‘ON’ and ‘OFF’ lesion stimulation) on the eCAP input/output functions. As compared to pre-lesion values and control ears, the thresholds were elevated and the maximal peak-to-peak amplitudes were reduced. When assessing changes restricted to ‘ON’ lesion stimulation (i.e. local effects) there was a distinction between acute damage and chronic degeneration: The threshold polarity effect (PE = cathodic - anodic response) was sensitive to acute, but not chronic lesions and showed significantly lower thresholds to cathodic- than anodic-leading stimulation after soma lesions. The derived Max/Max-index (i.e. saturating eCAP amplitude normalized to the respective stimulation current) was reliably elevated at an individual level after chronic, but not after acute lesions. Thereby, the lesion size explained more than 60% of its variance in the chronic cases.

We conclude that the change in threshold PE is due to the specific nature of acute lesions with remaining excitable axons at the lesion site. The Max/Max-index was sensitive to locally restricted chronic lesions, and is thus, suggested as clinical marker for heterogeneous SGN survival. We propose a multi-stage diagnostic procedure to assess cochlear health which can be performed without a priori knowledge on the presence and location of lesions.

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Th3: BONE DENSITY-BASED SELECTION OF OPTIMAL STIMULATION SITES FOR BONE CONDUCTION IMPLANTS

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Introduction: Bone conduction implants are used to treat conductive or mixed hearing loss and single-sided sensorineural deafness. Recently, we proposed to consider the bone mineral density in the preoperative planning procedure using quantitative computed-tomography (CT) [1]. We hypothesized that regions of denser bone should be preferred for implant placement to ensure optimal mechanical transmission. In this ex-vivo validation study, we aimed to investigate whether positions with higher bone density indeed lead to better transmission to the cochlea.

Methods: Quantitative CT imaging was performed in five Thiel-fixed whole head cadaver specimen. For both ears, topographic bone thickness and density maps were computed and density was quantified at retroauricular positions using the column density index (CODI)[1]. Retroauricular positions covering CODI values from 2 to 13 mg HA/mm2 were identified to fix the abutment screw. A bone anchored hearing aid (BAHA 110 PowerTM, Cochlear, Australia) was used for stimulation. Laser Doppler vibrometry was used to measure the velocity of the cochlear promontory under bone conduction stimulation between 100 Hz and 10kHz. The displacement and acceleration of the cochlear promontory were also computed from the velocity. In addition, the output force level of the actuator was measured with an artificial mastoid (Type 4930, Bruel & Kjær, Denmark) and the distances between implantation sites and the cochlea were measured with the open-source software 3D Slicer. Statistical analysis was performed using a linear mixed-effects model.

Results: Overall, our measurements are in accordance with literature [2]. We found a statistically significant association between the CODI and cochlear promontory acceleration. The effect was statistically significant throughout the tested frequency spectrum, with an average improvement of the cochlear promontory acceleration of 0.82 dB re 1 mm/s2 per mg HA/cm2. The distance from the implantation site showed a significant relation with the levels of normalized promontory acceleration (decrease of the acceleration level by 0.14 dB per mm of distance added).

Conclusion: The acceleration of the cochlear promontory increases when the implant is placed in bone regions characterized by higher CODI values. The CODI seems to have a larger impact on the acceleration levels of the CP than the distance between the implantation site and the cochlea. Our results indicate that the CODI represents a valid index to assess bone regions for optimal transmission of mechanical vibrations. The use of the CODI in a surgical planning environment could therefore potentially lead to better aided audiological outcomes.

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Th4: A ROBUST METHOD FOR REMOVING ARTIFACTS FROM RECORDINGS OF ELECTRICALLY EVOKED COMPOUND ACTION POTENTIALS EVOKED BY SINGLE PULSE AND PULSE TRAIN STIMULATION

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Background: Artifact rejection techniques have enabled the recording of electrically evoked compound action potentials (eCAPs) despite the presence of a large voltage decay following electrical stimulation (i.e., stimulation artifact). However, each existing artifact rejection technique has some known limitations (Baudhuin et al., 2016; He et al., 2017). In our previous studies, we excluded up to 25% of our eCAP recordings because of artifact contamination that remained after applying the modified forward masking artifact rejection technique (He et al., 2016; Riggs et al., 2021; He et al., 2022a, b). To address this issue, we utilized our large dataset of eCAP recordings to develop a new method for removing stimulation artifacts from eCAP traces evoked by single pulse or pulse train stimulation .

Methods: The stimulation artifact was characterized as a rational function by analyzing 3,200 eCAP recordings. For single pulse stimulation, a rational function was fit to the beginning and the end of an individual probe-only recording and then subtracted from the recording to provide the artifact-free eCAP waveform. For pulse-train stimulation, a rational function was fit to the beginning and the end of the waveform obtained by subtracting the masker-only recording from the masker + probe recording. The fit function was then subtracted from this resulting waveform to provide the artifact-free eCAP waveform. eCAP waveforms obtained with the new method were systematically compared to eCAP waveforms obtained using two-pulse forward masking (FM) and modified forward masking (MFM) for single pulse and pulse train stimulation, respectively.

Results: For single pulse stimulation, the eCAP waveforms obtained with the new method matched the eCAP waveforms that were verified to be artifact-free when utilizing FM. The eCAP amplitude and peak latencies obtained with FM were highly affected by varying the masker level and/or the masker-probe interval, while the eCAP amplitude and peak latencies were equal across all conditions when using the new method. For pulse train stimulation, typical neural adaptation (NA) functions and neural adaptation recovery (AR) functions were obtained with the new method for cases in which artifact contamination remained after using MFM. In all other cases, NA functions and AR functions were similar when obtained using the new method and when using MFM.

Conclusions: The new method developed in this study is a viable alternative that addresses several major limitations of traditional artifact rejection techniques for obtaining artifact-free eCAPs.

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Th5: TOWARDS OBJECTIVE ELECTRODE-SELECTION STRATEGIES BASED ON NEURAL TEMPORAL ENVELOPE ENCODING IN COCHLEAR-IMPLANT USERS

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There is a large variability in speech perception outcomes across cochlear-implant (CI) users. One factor that partially contributes to this variation is the neural health in the periphery, which can vary along the electrode array of the implant. The across-array variation in neural health is affected by etiology of hearing loss and cochlear implantation, and is therefore subject-specific. Since temporal envelope cues are crucial for speech perception with a CI, previous studies have shown that there is potential of deactivating electrodes based on poorer behavioral measures of temporal envelope processing to improve speech perception. However, behavioral measures are typically time-consuming and require active feedback from the CI user. A potential objective measure to probe temporal envelope processing is the electrically-evoked auditory steady-state response (eASSR). Recently, the across-array variation of eASSRs has been shown to strongly correlate with speech perception in noise in CI users [Gransier et al. (2020) Ear. Hear. 41, 591-602]. In the present study, we investigate whether electrode-selection based on individual across-array eASSR patterns has the potential to improve speech perception in CI users. If successful, automatic and objective electrode-selection procedures based on regions in the cochlea that are still highly capable of neural modulation encoding, may be developed in the future which can be employed during CI fitting sessions in order to optimize speech perception performance in CI users.

Participants in this study were adult CI users with a Cochlear™ Nucleus implant. First, we stimulated each electrode of the implant array in monopolar mode with 40-Hz amplitude-modulated 900 pulses-per-second pulse trains, and recorded eASSRs by means of EEG. We used the custom BioSemi HyperRate EEG system with a sampling frequency of 262 kHz in order to be able to remove the EEG-contaminating electrical artifacts with linear interpolation. Second, the across-array variation of measured eASSR strength was used as a basis for the electrode-selection algorithm. Two experimental MAPs with 12 electrodes (MAPs A and B) were created for each participant: MAP A contained the set of electrodes that is considered better at conveying temporal envelope cues, and MAP B contained the set of electrodes that is considered poorer at it. The acute change in speech perception when switching from the clinical MAP to one of the two experimental MAPs was assessed using speech perception tasks in quiet and in noise. Additionally, subjective feedback from the participants was collected.

To date, we have collected eASSR measurements from six participants. Across-array eASSR patterns already show considerable variation across these participants. We are currently conducting further measurements with remaining participants, as well as evaluating the electrode-selection strategy based on the eASSR patterns through speech perception tests. Results will be presented at the conference.

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Th6: THE EFFECT OF STIMULATION WAVEFORM ON ELECTRICALLY ELICITED STAPEDIUS RESPONSE THRESHOLD (ESRT) IN NEURO COCHLEAR IMPLANTS

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Background: The stapedius muscle located in the middle ear has a protective function against loud sounds. Activation of this muscle in response to strong electrical stimulations in cochlear implant (CI) patients may be used to objectively determine the most comfortable level (so-called C-level or MCL) in CI users. The eSRT (electrically elicited Stapedius Reflex Threshold) is defined as the minimum amount of electrical stimulation that elicits a measurable contraction of the stapedius muscle. Researchers have reported different values for the detection rate of eSRT ranging from 16% to 87%. It seems that the setup and its corresponding recording and acquisition parameters (e.g., employed CI device, ipsi versus contra, basal versus apical, probe tone frequency, …) may change the detection rate of eSRT to a big extent.

Approach: Standard clinical field reports seem to indicate that the detection rate of eSRT is lower in Oticon Medical (OM) Neuro CI system than in the competitors’ systems. Single electrode stimulations are rarely able to invoke eSRT response, so in practice a group of electrodes are stimulated (typically 3 to 5) in OM CI system to obtain an eSRT response. We did a pilot study to investigate if the stimulation waveform may influence the eSRT and its detection rate. Noteworthy to mention that in Neuro system the loudness is coded by pulse-width modulation of electrical stimulations, whereas other manufacturers use amplitude modulation to encode the loudness.

Method: Our study was executed on four ears (three CI patients). Ipsi and contra lateral eSRTs were simultaneously recorded using two Titan devices. Stimulations were applied at two different pre-set amplitudes for each patient (low: the amplitude in the main fitting program, high: ~10 current unit bigger than the low). For each stimulation amplitude, the pulse duration was gradually increased until the eSRT could be elicited or the uncomfortable loudness level (UCL) was reached. This procedure was repeated three times where the stimulating electrodes were composed of single-electrodes, a group of 3, and a group of 5 electrodes centered at Apical, Low-Mid, Mid, High-Mid, and Basal areas.

Results: Our pilot study shows that the shape of the stimulating pulse (i.e., low vs. high amplitude) has an important effect on the eSRT detection rate. At a given stimulation charge the pulse with the higher amplitude (and thus lower width) increases the eSRT detection rate, but not necessarily modifies the eSRT level (i.e., the charge level).

Our data shows that stimulations using single electrodes rarely invoke eSRT. Zero and nine electrodes (out of the 20 total measured electrodes on 4 ears) invoked eSRT at low and high stimulation amplitudes, respectively. The eSRT charge level was measured to be about 45 nC that is relatively a big charge level to be tolerated by some patients. Higher amplitudes lead to higher detection rates and fewer electrodes need more charge. The stimulation based on the group of (3, 5) electrodes, increased the number of eSRT responses to (1, 5) and (11, 15) electrodes at low and high amplitudes, respectively. It also decreased the average injected charges per electrode to about (35, 30) nC. We could only record simultaneous ipsi and contra lateral eSRTs on 2 patients. The right ear of the 3rd patient was not generating any eSRT at any stimulation level and mode. We did not see a meaningful difference between the ipsi and contra lateral responses in terms of eSRT detection rates and levels.

Significance: Our study suggests that eSRT is perhaps invoked by the energy of the stimulating pulses, but not the charge. It also suggests that eSRT is obtained easier when the stimulation is applied on multiple electrodes because the CI patients can tolerate the injected charge, but still benefit from the loudness summation effect.

Th7: PUPILLOMETRY AND SUBJECTIVE RATINGS OF TASK DIFFICULTY YIELD CONFLICTING RESULTS IN CI USERS WHEN USING THE DUTCH-FLEMISH MATRIX TEST

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Background
Pupillometric responses and subjective ratings have both been identified as valid measures of listening effort in normal hearing and hearing-impaired listeners. It is known, however, that subjective and objective measures of listening effort can produce different outcomes, because they reflect different modalities of cognitive load. In this study, we have investigated pupillometric and subjective assessment of listening effort in cochlear implant (CI) users and compared their outcomes to normal-hearing (NH) controls.

Methods
A group of 25 adult, mostly elderly CI users performed the Dutch/Flemish Matrix test in quiet and in multi-talker babble noise at different signal-to-noise ratios (SNRs). The SNRs were chosen based on the individual's speech-recognition threshold (SRT), namely SRT, SRT + 5 dB and SRT + 10dB. During testing, pupillometry was performed and after testing subjective ratings of task difficulty were collected on a Likert scale. These data were compared to those of 18 young, NH listeners. Outcomes were analyzed with linear mixed modeling, a method comparable to RM ANOVA, but with the possibility to add random-effect variables (in this case, subject ID).

Results
Pupil responses of CI users did not significantly depend on the SNR ($P > 0.05$), whereas a significant effect of SNR was observed in NH listeners ($P < 0.05$). Subjective ratings of listening effort were significantly dependent on SNR in both groups ($P < 0.0001$).

Conclusion
Previous studies on listening effort have shown a dependency of the pupil response on task difficulty. We corroborate these findings for the Matrix test in young NH listeners, but in elderly CI users we found no such effect. We conclude that the test conditions may not have been optimal to assess the effect of task difficulty on the pupil response in typical CI users. For instance, other speech materials with more semantic context than Matrix sentences may be worthwhile to investigate. By contrast, subjective effort ratings depended significantly on SNR in both groups, corroborating earlier reports that these measures reflect different dimensions of listening effort.

Th8: ASSESSING ARRAY-TYPE DIFFERENCES IN CURRENT SPREAD IN COCHLEAR IMPLANT USERS USING THE PANORAMIC ECAP METHOD

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Cochlear implant companies manufacture devices with different electrode array types. Some have a straight geometry, and some are designed to 'hug' the neurons. The Panoramic ECAP method (PECAP) provides detailed estimates of peripheral neural responsiveness and current spread for individual patients. We are collecting PECAP measures from a large number of patients with different electrode array types so as to (a) obtain normative data for different array types to enable clinicians to identify electrodes that produce unusually wide current spread, and (b) validate the ability of PECAP to discriminate different amounts of current spread by comparing estimates between groups of patients with different array types.

At the time of submitting this abstract, the PECAP measurement was collected for 49 users of Cochlear® implant devices with a mixture of perimodiolar arrays (n = 20), slim straight arrays (n = 24), and slim modiolar arrays (n = 5). The data was obtained from four different centres in the United Kingdom, Australia, and Germany. The PECAP method was applied to these datasets to estimate peripheral neural responsiveness and current spread for each electrode as per the method described in Garcia, et al., 2021. The current-spread estimate was then compared between array types for each electrode. We expect that this sample size may increase as data collection is currently ongoing.

A part-way analysis of variance was computed with PECAP's current spread estimate as the output and array type (3 levels) and electrode (22 levels) as factors. After multiple comparison corrections, significant main effects of array type ($p < 0.0001$) and electrode ($p = 0.0005$) were both found, as well as a significant interaction ($p = 0.032$). A Tukey analysis found that slim-modiolar arrays showed the lowest current spread, followed by the perimodiolar arrays, and slim-straight arrays. Apical electrodes showed higher current spread than the rest of the array. Slim-straight arrays showed higher current spread than slim-modiolar arrays at the apex, specifically. A significant effect of array type was also found on the neural-responsiveness estimate ($p = 0.0163$), but with very small effect sizes capturing only ≈ 4 ± 1.5 % of the range of possible values.

This study suggests that there are differences in patterns of current spread between cochlear implant array geometries in Cochlear© devices when characterizing them using the PECAP method. As expected, slim-modiolar arrays show narrower current spread than straight arrays; the former are designed to hug the modiolus. The benefit appears greatest at the apex.

Th9: RECORDING OF CORTICAL POTENTIALS EVOKED ACOUSTICALLY AND ELECTRICALLY DIRECTLY THROUGH A COCHLEAR IMPLANT.

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Background: The auditory cortical evoked potential (ACEP) in cochlear implant (CI) users reflects central brain activity that is related to outcomes of cochlear implantation in children and adults. This brain response provides a useful objective assessment of outcomes in those who are unable to actively give feedback about their hearing, such as infant CI recipients. Current methods for measuring this brain response are impractical for widespread clinical application because they require additional hardware that is expensive and time-consuming to set up and use. Accordingly, the ability to measure the ACEP efficiently, and with no additional hardware by utilizing the CI itself as a sensor, is of significant clinical value. Previous attempts to record brain activity directly through the CI were not suited for widespread clinical use because the time to capture a single recording was lengthy and the recording was susceptible to artifacts (1,2) or the method used an invasive experimental percutaneous CI device to access intra-cochlear electrodes that are impractical for widespread adoption (3). We investigated if the auditory cortical potential evoked by acoustic (in CI users with residual hearing) or electrical stimulation can be recorded utilizing the intra-cochlear implanted electrodes and backward telemetry in a clinically viable timeframe in a large sample of adults and pediatric CI users.

Methods: The recording system utilized the measurement amplifier, A/D converter, and backward telemetry of the cochlear implant. Settings of the stimulation and recording system were optimized to minimize electrical stimulation artifacts and preserve biological signals using bench measurements on a closed-loop BNC load board and a CI submerged in saline. To assess if recordings measured directly through the CI were of biological origin, we compared them to simultaneous recordings acquired with scalp-surface electrodes of an external evoked potential recording system that was synchronized using a trigger signal extracted from the CI system. The biological origin was also inferred by assessing different factors known to affect the measures of ACEP in pediatric and adults CI users (Repeatability, age, stimulus level, bilateral CI; electrode stimulation, and recordings; CI outcomes). We tested 27 adults (10 bilateral) and 10 pediatric (4 bilateral) CI users, all implanted with the AB CI system.

Results: The ACEP evoked acoustically was possible to measure in 3 minutes in both adult and pediatric CI recipients (4). The ACEPs evoked electrically were measured in less than 5 minutes, showing that the measurement could be done in a clinically viable amount of time. The electrically stimulated ACEP through the CI varied with stimulus level, as a function of early and late implantation, pre- and post-lingual implantation, and first and second implant as would be expected of the biological response. Furthermore, the latency of the electrically stimulated ACEP through the CI is highly correlated with the latency of the scalp-recorded ACEP, further supporting the biological origin of the potential recorded through the CI. A significant association was found between CI e-ACEP and speech discrimination scores in quiet and in noise after implantation.

Conclusion: Auditory cortical activity evoked acoustically or electrically can be recorded directly through the CI in a clinically feasible way. This innovative technology opens the door for widespread clinical adoption of cortical auditory responses for tracking brain development after cochlear implantation. In addition to saving time and increasing convenience for audiologists wishing to utilize brain potentials in clinical practice, the technology may also improve fitting and outcomes for CI recipients who cannot give explicit feedback. Finally, the technology is a powerful tool for conducting research on brain maturation and plasticity after cochlear implantation.

Th10: FOURIER FILTER ENHANCED AVERAGING APPLIED ON ECAP AMPLITUDE GROWTH FUNCTIONS

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In most applications of electrophysiology, repeated recordings are averaged, filtered, and processed to isolate and parametrize the wanted parts of a signal. The processed recordings are typically still affected by distortions: either because of remains of unwanted parts within each recording, or by uncontrolled changes from one recording to another.

The presented approach targets this noise by combining multiple recording settings (RS). Repeated recordings are arranged as a continuous sequence of repeated RS blocks, the sequence which is transformed into frequency domain. The number of repeated blocks and RS are defining the frequency bins of controlled changes. Those frequency bins are isolated and transformed back to time domain to achieve a processed recording sequence for each RS.

The approach was applied to a dataset of ECAP (electrically evoked compound action potential) recordings following the stimulation paradigm of AutoART (automatic auditory nerve response telemetry) using a dedicated research tool. In a test-retest scenario, ten amplitude growth functions were recorded for electrode #6 (middle part) for 28 subjects. Stimulation consisted of a 60 Hz presentation of rectangular, alternating cathodic-anodic and anodic cathodic pulses having a fixed phase duration of 40 µs and inter-phase gap of 2.1 µs as well as a continuously growing amplitude (37.5 µV/s) until the subject stopped because reaching maximal acceptable loudness.

Recordings were performed on four different recording electrodes, defining RS to be four in this setup. After artifact reduction using alternating polarity, this resulted in 7.5 Hz repetitions of RS blocks of ECAP amplitudes in this context. The length of each continuous sequence was chosen to be equal to the range for averaging in AutoART. The ECAP amplitudes corrected for distortions were fed to AutoART resulting in a reduced distribution range of both thresholds and slopes compared to standard AutoART. The threshold range (=(max-min)/median) of 10.7% from the standard AutoART was reduced to 7.4% and for slopes, the range was reduced from 32.3% to 15.2% on average.

Th11: INVESTIGATING THE EFFECT OF BLURRING AND FOCUSING CURRENT ON ESTIMATES OF CURRENT SPREAD IN COCHLEAR IMPLANT USERS WITH THE PANORAMIC ECAP METHOD

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The Panoramic ECAP (PECAP) Method uses Electrically-Evoked Compound Action-Potentials (ECAPs) to estimate the variation in current spread and neural health along the length of the electrode array in individual cochlear implant (CI) users. PECAP provides a platform for detailed assessment of the effects of various stimulation types on the spread of electrical current within the cochlea. Some CI devices can provide so-called focused electrical stimulation by partially returning the electric current to adjacent, intra-cochlear electrodes (partial tripolar (pTP) stimulation). Another method attempts to achieve the opposite: to provide blurred stimulation by stimulating multiple electrodes simultaneously. We applied these manipulations to evaluate their effects on the spread of current when compared to stimulating in monopolar mode.

ECAPs were recorded using the forward-masking artefact-cancellation technique from 15 ears of Advanced Bionics CI users in monopolar mode for all electrodes activated in the participant's map and for every combination of masker and probe electrode. Three ears were excluded from analysis because we were unable to obtain ECAPs with sufficiently high SNR values to be processed by PECAP. For each participant, two test electrodes were selected that showed either the highest or the lowest focused detection thresholds. ECAP measurements that involved these two test electrodes (either as a probe or masker) were then obtained with the stimulation mode set to pTP and two blurred stimulation modes (with 3 and 5 electrodes stimulated simultaneously) in the two test electrodes. Stimuli for all presentation modes (monopolar, pTP, or blurred) were scaled to comfortable loudness for each participant. If it was not possible to achieve at least 50% partial tripolar stimulation at comfortable levels before reaching compliance, the pTP condition was not collected. The inclusion criteria resulted in n=12 ears for the blurred stimulation modes and n=8 ears for the pTP stimulation mode. Data were then submitted to the PECAP algorithm, and the current-spread estimate for the test electrodes was compared between the monopolar condition and the focused and blurred conditions.

PECAP analysis revealed an increase in current spread as a result of blurred stimulation applied at the apical side of the array, but not at the basal side. No difference in current spread was found between simultaneously stimulating 5 electrodes compared to 3, and no effect of whether the electrode showed a high vs low focused threshold was found on current spread. Regarding pTP stimulation, PECAP showed that in 2 out of 8 ears, stimulating in pTP mode actually increased the estimate of current spread with respect to monopolar mode. In one ear the current spread was reduced, and in the remaining 5 ears there was no significant effect of pTP stimulation on the current spread estimate. Overall, the results suggest that blurred stimulation more effectively increases current spread at the apical side of the array than the basal side, and that in some cases pTP stimulation may increase current spread instead of reducing it.

Th12: DOES SIMPLE IMPEDANCE REFLECT INTRASCALAR TISSUE IN THE IMPLANTED COCHLEA?

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Introduction: The growth of intrascalar tissue (e.g., fibrous tissue and new bone) following cochlear implantation is a potential threat to the long-term preservation of both electrical and acoustical hearing in implanted patients. Developing tools for monitoring this tissue non-invasively, and developing ways to control it, are important objectives. Simple impedance measures (Z=V/I), which are a common non-invasive test of implant integrity, might enable monitoring of changes in the cochlear environment. Impedance, in a general sense, is a measure of how much a system resists the flow of electrical current. Thus, increases in impedance might reflect growth of intrascalar tissue. In this study, we monitored impedances in guinea pigs over time after implantation and assessed their relationship to intrascalar tissue evaluated histologically at endpoints after long-term cochlear implantation.

Methods: Forty-eight adult male guinea pigs were chronically implanted with a banded cochlear implant in either a hearing ear, an ear treated with neomycin and inoculated with a neurotrophin, or an ear treated with only neomycin. Bipolar (impedance for current flowing between two electrodes spaced at ~0.75 mm center to center) and monopolar impedances (for current flowing between an intracochlear electrode and a return electrode on the surface of the skull) for a 1 kHz, 1 µA rms sinusoid were measured several times a week for 4 to 21 months after implantation. Monopolar impedances for 30 µs/ph, 2.1 µs IPG pulses were also measured in a subset of these animals over this same time period. Then, histology (mid-modiolar sections) was performed near the primary measurement intracochlear electrode and the intrascalar tissue at this location was evaluated in two ways: (1) Tissue between the implant footprint and the spiral ganglion neurons was ranked as: low, medium, or high following the classification procedure reported by Swiderski et al., JARO, 2020, and (2) Tissue located in the entire cross-sectional area of the scala tympani in the region of the primary electrode was quantified in terms of percent filled with bone, percent filled with fibrous tissue, and both combined. Impedance trends over time were assessed, and tissue rankings or percentages, were compared to long-term impedance levels (average of the last 10 measures taken before the animal was euthanized).

Results: Histology revealed a wide range of intrascalar tissue types, distributions and amounts in both assessed scala tympani regions. Individual impedance trends over time were variable, and not specific to an amount or type of intrascalar tissue. For the 1 kHz sinusoidal stimulus, bipolar and monopolar impedances obtained near the time of euthanasia were highly correlated with each other. For both stimulus types, simple impedance was not correlated with amounts of fibrous tissue in the scala tympani. However, impedance was significantly correlated with the amount of new bone (sinusoids: bipolar $r2 = 0.51$, $p<0.0001$; monopolar $r2 = 0.64$, $p<0.0001$; pulses: monopolar $r2 = 0.67$, $p<0.0001$).

Conclusion: The presence of bone in the scala tympani had a significant relationship to simple impedance, accounting for a little more than 50% of the across-subject variance, but the amount of intrascalar fibrosis was not predicted by simple impedance.

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Th13 USING AN APP-BASED DATA COLLECTION TOOL TO MEASURE IMPEDANCES REMOTELY IN EVERYDAY LIFE

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Cochlear implant fittings are optimized based on performance and subjective evaluations of recipients as well as characterizations of objective device function such as electrode impedance. Impedances are typically measured during in-person visits to the clinic which can be separated by months to years. This has not been considered problematic, given that the implicit assumption has been that electrode impedances do not fluctuate in between visits for experienced CI users. As such, programming actions undertaken based on impedances measured during clinic visits are assumed to be relevant for every day listening in between clinic visits. However, the reality is that impedances fluctuate day-to-day, and this variability has been attributed to illness (particularly with upper respiratory symptoms), biological conditions causing fluctuations of hormones, inflammatory responses, foreign-body reactions, etc. (Sainz et al., 2003). In cases for which there is a considerable increase in electrode impedances, the implant may no longer be able to provide high enough voltage to deliver required stimulation levels; thus, this could potentially impact sound perception including overall loudness, speech perception, and sound quality.

This study used an app-based remote assessment tool to characterize daily impedance values and the degree of day-to-day fluctuation in a population of CI users with at least three months of CI experience. At the time of abstract preparation, we had recruited 14 study participants. Participants were asked to measure impedances through the AB remote monitoring app at least once per day at roughly the same time for a period of three months. App notifications were enabled to allow daily reminders at the time selected for each participant. Study compliance was monitored on a weekly basis and participants who missed measurements were sent a reminder to make the daily measurements.

Preliminary results show that the majority of participants were able to complete the impedance measurements in a timely manner without much involvement from the researchers. Six out of 14 participants did not miss a single impedance measurement, and 11 out of 14 participants missed fewer than 10% of measurements over the course of the study. Preliminary analyses furthermore show that while large impedance fluctuations are rare, impedances do fluctuate from day-to-day. The median impedance fluctuation within the span of a week was 0.27 kOhm (range: 0 - 6.8 kOhm). Over the course of the three-month study period the median fluctuation was a little higher at 0.72 kOhm (range: 0 - 8.2 kOhm).

This study shows that an app-based data collection tool can be used to make objective measurements such as electrode impedances outside the clinic environment. This pilot project demonstrates feasibility of collecting remote electrode impedance data without direct clinician or researcher oversight. From a research perspective, remote data collection can ultimately afford enrollment of large participant populations for any given study. From a clinical perspective, the ability to monitor impedances remotely opens the door to uncover optimization opportunities to CI program parameters between clinic visits.

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Th15: CT-BASED MAPPING AT INITIAL ACTIVATION: A LONGITUDINAL CROSSOVER STUDY OF MUSIC AND SPEECH PERCEPTION

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Background. Music perception remains challenging for many cochlear implant (CI) recipients, due perhaps in part to the frequency mismatch that occurs between the electrode-neural interface and the frequencies allocated by the CI programming. Individual differences in ear anatomy, electrode array length, and surgical insertion can lead to great variability in the positions of electrodes within the cochlea, but these differences are not typically accounted for by current CI programming techniques. Flat panel computed tomography (FPCT) can be used to visualize the location of the electrodes and calculate the corresponding organ of Corti characteristic frequencies. Such FPCT-based CI frequency mapping may improve pitch perception accuracy, and thus music appreciation, as well as speech perception.

Objective. Test the hypothesis that long-term (1 year) use of CT scan-based frequency maps, beginning on the first day of CI activation, will improve CI user performance in the areas of speech and music perception, as compared to the use of default frequency maps.

Methods. Subjects underwent a FPCT scan after CI surgery and a FPCT-based map was provided to their clinical audiologist for use during CI activation. Subjects utilized the CT-based map for 1 year and then completed a crossover phase for 1 month while using the manufacturer-specified clinical default frequency map. A speech and music test battery as administered at 1, 3, 6, 12 and 13 months, consisting of CNC words in quiet, AzBio sentences in noise, closed set phoneme identification, a novel harmonic consonance-dissonance task, a novel pitch interval comparison task, and the Distorted Tunes Test.

Results. At the time of the CIAP meeting, we anticipate 9 subjects will have completed the 13-month study and 4 additional subjects will have finished the 6-month test session. Preliminary results utilizing 6-month test data from 12 subjects show CNC word scores within the expected range (avg 64% std dev 17%), although the primary comparison will be between the chronic use of the CT-based map at 12 months and chronic use of the clinical default map at 13 months.

Conclusion. We will report on music and speech performance of a CI cohort (n=9) who have completed a 13-month crossover study comparing CT-based mapping, beginning at initial activation, with clinical default frequency mapping.

Th16: TOWARDS USING COCHLEAR IMPLANT ELECTRODES TO RECORD CORTICAL RESPONSES TO SUSTAINED HIGH-RATE STIMULATION

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Objective measures of neural responsiveness help us to program cochlear implant (CI) software for patients who cannot provide consistent feedback, such as children. Electrically-Evoked Compound Action Potentials (ECAPs) are the most common of these measures, are easy to measure, and are widely used in clinical settings. However, they only reflect the response of the auditory nerve, require slower stimulation rates than used in clinical coding strategies in order to extract neural responses from electrical artefacts, and show limited correlations with behavioural thresholds and comfort levels. Cortical responses to short or slow-rate stimuli correlate better to behavioural threshold and comfort levels, but generally require the use of Electroencephalogram (EEG) systems. ALternating-Frequency Interleaved Electrical Stimulation (ALFIES) is a method for recording cortical responses to sustained fast-rate electrical stimuli in CI users. It uses two high-rate, interleaved, amplitude-modulated pulse trains that – when recorded with an EEG system – contain electrical artefacts at the amplitude modulation frequencies but, importantly, not at their distortion product. It both successfully extracts neural responses from these electrical artefacts and more closely matches the stimulation parameters of clinical coding strategies. However, it has so far only been measured using a custom-made hyper-rate (264 kHz) EEG system.

To improve clinical applicability, we are investigating whether it is possible to record ALFIES responses using either a standard-rate EEG system or – even better – the electrodes already available in the cochlear implant. In this exploratory study, we leveraged the new flexibility of the telemetry system in the NIC4.3 research platform provided by Cochlear to stimulate using two interleaved amplitude-modulated pulse trains and to record in the gaps between the pulses using the electrodes of the cochlear implant. These amplitude modulation rates were either 80 and 120 Hz, 74 and 111 Hz, or 86 and 129 Hz. Simultaneously, we recorded the responses using either a hyper-rate or standard-rate EEG system in the same manner as described previously in Carlyon, et al, 2021. We varied both the stimulation mode by delivering pulses in bipolar mode and in monopolar mode, as well as the implant electrodes used to record the neural responses, using both intra-cochlear and extra-cochlear electrodes. This was done with the aim of separating the stimulation and recording electrical circuits, as well as including as much of the dipole of the auditory cortex in between the two recording electrodes as possible. Data were analysed and compared both from the NIC4.3 system and the EEG system for the significance of power and the phase at the frequency of the distortion product between the two amplitude modulation rates of the two pulse trains (37, 40, and 43 Hz). From the variation in the phases of the response to different distortion product frequencies, we then calculated the group delay of the response to infer the locus of the neural generator. Preliminary results from one participant indicate that it is possible to obtain a cortical neural distortion response to continuous high-rate electrical stimuli using a standard-rate (2048 Hz) EEG system.

Preliminary results from two further participants suggest that it may also be possible to record neural distortion responses using the telemetry system and the electrodes of the cochlear implant. However, these have a shorter group delay than the thalamic/cortical responses observed using the EEG system, and so may reflect a more peripheral source and/or be at least partially influenced by electrical artefact. Further studies are underway to (1) separate the quadratic and cubic distortion products by shifting the amplitude modulation rates i.e. to 82 and 120 Hz, and (2) use NIC4.3 to investigate the feasibility of recording Electrically-Evoked Auditory Brainstem Responses (EABRs) or Cortical Auditory Evoked Potentials (CAEPs) using the CI electrodes. The results will be used to develop objective measures of cortical and/or brainstem responses that can be obtained without specialist equipment and in a time-efficient manner.

Th17: 1704: PREDICTING ELECTRODE-MODIOLAR DISTANCES IN COCHLEAR IMPLANT RECIPIENTS USING MONOPOLAR, THREE-POINT AND FOUR-POINT IMPEDANCE MEASUREMENTS

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Objective: This study aimed to investigate the relationship between cochlear implant (CI) electrode distances to the modiolus and electrical impedance measurements made at the CI's electrode contacts. We introduced a protocol for “three-point impedances” in which we recorded bipolar impedances in response to monopolar stimulation at a neighboring electrode. We aimed to assess the usability of three-point impedances and two existing CI impedance measurement methods (monopolar and four-point impedances) for predicting electrode positioning during and directly after CI insertion.

Methods: Impedances were recorded during stepwise CI electrode array insertions in cadaveric human temporal bones, and after full insertion of the array during standard CI surgery in human CI recipients. The positioning of the electrodes with respect to the modiolus was assessed immediately prior to or after the impedance recordings using cone beam computed tomography. Linear mixed regression analysis was performed to assess the relationship between the impedances and electrode-modiolar distances. The experimental results were compared to clinical impedance data and to an existing lumped-element model of an implanted CI.

Results: In human temporal bones, three-point ($t(275) = -6.25$, $p<0.001$) and four-point impedances ($t(275) = -7.24$, $p<0.001$) strongly correlated with electrode-modiolar distance. In contrast, monopolar impedances were only minimally affected by changes in electrode positioning with respect to the modiolus. An overall model specificity of 62% was achieved when incorporating all impedance parameters. This specificity could be increased beyond 73% when prior expectations of electrode positioning were incorporated in the model. Preliminary analyses of data collected in human CI recipients ($n = 8$) showed a significant correlation between three-point impedance and electrode-modiolar distance ($t(115) = -2.15$, $p<0.05$).

Conclusion: Three-point and four-point impedances are promising measures to predict electrode-modiolar distance in real-time during CI insertion, and after full insertion of the CI electrode array.

Th18: NEW INSIGHTS IN THE ELECTRICALLY EVOKED COMPOUND ACTION POTENTIAL

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The electrically evoked compound action potential (eCAP) is a clinically important objective measure of the electrode-nerve interface. The morphology of this response can be parameterized by the amplitudes and latencies of the first negative (N1) and second positive peak (P2) that often exhibits a double-peak characteristic (P2a, P2b). The remaining charge in the tissue and cochlear implant electronics adds an artefact superimposed onto the neural response. However, it is still being debated how the morphology of the eCAP response is generated [1,2].

In the present study, eCAPs were continuously recorded in 103 chronically or acutely implanted guinea pigs during the euthanasia process that was performed to obtain quantified histology of spiral ganglion cells and peripheral processes for various studies. Using a PULSAR implant (MED-EL, Innsbruck, Austria), anodic- and cathodic-first biphasic current pulses were presented at a fixed supra-threshold level. Artifact reduction was performed separately for both pulse types by subtracting the corresponding post-mortem artifact-only recording from the traces.

All animals demonstrated not only a slow and continuous decrease of the eCAP response amplitude but also a significant change of the morphology: the P2b peak disappeared shortly after the cardiac arrest and later also the P2a was lost. The fading of the N1 lasted on average 1.7 times longer than the fading of P2. A linear relationship was found between the decrease of peak amplitude towards the baseline and the increase of the latency. No correlation was observed between the SGC or PP density and the duration. A remaining onset stimulus artefact was observed that also disappeared over time, which indicates that the stimulus artifact has both an active and a passive component.

The observations indicate that eCAPs are multi-component responses of several potentially independent generators.

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Th19: CORTICAL TRACKING OF SPEECH PERCEPTION: EFFECTS OF INTELLIGIBILITY AND SPECTRAL DEGRADATION

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The ability to characterise the correspondence between continuous speech and the neural response of a patient, such as that recorded using electroencephalography (EEG), could be highly advantageous to clinicians and for cochlear-implant (CI) fitting. Although the feasibility of quantifying this relationship (‘cortical tracking’) is recently established in experimental settings, its interpretation and underlying mechanisms remain unclear.

As a preliminary step to applications with cochlear implants, and to achieve a high level of control over the listening conditions, we investigate typically hearing, English-speaking participants’ EEG during the presentation of natural and CI-simulated speech using vocoding. For the latter, we further manipulate spectral degradation to emulate the detrimental interaction between CI electrode channels caused by current spread. By using two different languages (English and Dutch), we disentangle the effects of acoustic quality from intelligibility, with all stimuli produced by one bilingual male speaker. To address the confound of waning attention during non-intelligible conditions, we introduce a novel prosody-based detection task that can be performed, with or without language understanding, concurrently with EEG recording.

Cortical tracking was statistically significant in all conditions, as measured by the linear correlation coefficient between the original and decoded speech envelopes (mean R values from 0.12 up to 0.17). The EEG data reveal that cortical tracking was slightly, but significantly, reduced for non-intelligible speech; however, we find no clear effect of vocoding nor of current spread. With regards to the behavioural results, we confirm that the prosody-detection task is performed with high accuracy across listening conditions (89 – 99% correct), although both intelligibility and spectral degradation appear to adversely impact reaction times. Hence, although we do see behavioural differences as a result of spectral degradation, these differences were potentially too small to be captured by our EEG analysis of cortical tracking.

In conclusion, determining the audiological relevance and potential application of cortical tracking requires a nuanced understanding of the interpretation of this measure and what specific aspects of acoustic speech processing it is capable of representing. The lack of an effect of CI-simulation and spectral degradation on cortical tracking in both intelligible and non-intelligible conditions under sustained auditory attention suggests that cortical tracking may not reveal subtle differences in spectral resolution, but could in principle be used as an objective measure of speech envelope tracking with cochlear implants. This highly controlled study adds to previous findings to pave the way for developing objective speech tracking measures with relevance to clinical applications for cochlear implants.

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Th20: ASSESSMENT OF BINAURAL INTERACTION IN SSD CI USERS FROM AUDITORY BRAINSTEM RESPONSES

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In 2021, Bernstein et al. showed a relatively large interaural mismatch between intracochlear positions for electrical and acoustic stimulation in single sided deaf cochlear implant (SSD CI) users. The results of the study suggest that reducing this mismatch may improve binaural processing.

The auditory brainstem response (ABR) and the electrically evoked ABR (eABR) can be used to objectify neural processing in the auditory brainstem of acoustic hearing subjects and bilateral CI users, respectively. To examine for an existing binaural processing, the binaural interaction component (BIC) is often considered in research. It is calculated by the subtraction of the sum of the unilateral evoked (e)ABRs (left and right) and the binaural evoked (e)ABR. The BIC is difficult to derive reproducibly in normal-hearing subjects (Sammeth et al., 2021). In contrast, Hu and Dietz (2015) showed, that in bilateral CI users BIC can be derived more robustly. In the current study, we recorded BIC in SSD CI users. To find electrode/frequency pairs allowing for place-matched stimulation, intracochlear electrode locations were analyzed based on Digital Volume Tomography (DVT) scans. Further, amplitude and stimulation timing (Zirn et al., 2015) were balanced for recordings.

Results showed reproducible BICs in two out of five SSD CI users. In those subjects with identifiable BIC, (e)ABRs were also recorded for stimulation on intracochlear electrodes adjacent to the anatomically matched one. These recordings reveal an alteration of BIC the larger the intracochlear distance and thus the larger the interaural place-of-stimulation mismatch gets. Concluding, BIC can be an objective biomarker for binaural processing in a subset of SSD CI users.

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Th21: THE POTENTIAL OF OBJECTIVE T-LEVEL DETERMINATION IN CI RECIPIENTS USING ENVELOPE FOLLOWING RESPONSES

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Cochlear implants (CIs) restore hearing in people with severe to profound hearing loss by electrically stimulating the auditory nerve. The correct tuning of the stimulation parameters is crucial for optimal hearing performance. These parameters are repeatedly adjusted during so-called CI fitting sessions, in an interactive procedure between a clinical expert and the CI recipient. However, for a number of reasons, objective CI fitting is becoming increasingly important due to its potential for automation, reduction of clinical effort, and accommodation of the expected increase in CI users. Objective measures, such as the electrically evoked auditory steady-state response (EASSR), are electrophysiological measures of neural responses following the stimulation of the CI. They can be recorded via electroencephalogram (EEG), and can be used to make an objective statement about the CI stimulation parameters. For example, the presence of EASSRs in EEG recordings with decreasing stimulation level can be used to objectively determine the minimal current stimulation level (T-level) used in the CI stimulation strategy. A major challenge in using EEG recordings of EASSRs are the stimulation artifacts from the implant itself, which contaminate the recordings and make the interpretation of the presence of the EASSR prone to be false positive. However, a recently introduced method [Schott et al. (2022) -10.23919/EUSIPCO55093.2022.9909607], based on system identification (SI), has shown promising results to overcome this problem and enable objective fitting using EASSRs, obtained with clinical stimulation settings of the CI (900pps, monopolar mode). A remaining shortcoming is the necessity of at least two EEG recordings at different modulation frequencies, to reliably separate EASSR and stimulation artifact. In this contribution, we present an improved objective measure for CI users that allows reliable response detection within a single recording. It is adapted from the envelope following response (EFR) [Purcell et al. (2004) - 10.1121/1.1798354] and tailored to the use in CI recipients. The preliminary results show, that we can record EFRs in CI recipients and that we can separate them from the stimulation artifact, using the SI method. The response properties, i.e., response latency and amplitude, are similar to conventional EASSR response latency and amplitude. EFRs are therefore potentially better suited for objective T-level detection, as they can be detected with a single EEG recording.

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Th22: INSIGHTS FROM MULTI-LEVEL ECOCHG RECORDED ACROSS THE FULL ELECTRODE ARRAY

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Background: In the past few years, it has become possible to make electrocochleography (ECochG) recordings using only the cochlear implant (CI) system. This convenience has led to an increase in intra-operative ECochG recording, with the goal of reducing cochlear trauma by providing real time feedback to the surgeon during insertion of the electrode array. The feedback is usually the cochlear microphonic' s (CM) signal level. Analysis has shown that changes in hearing levels following CI surgery are related to drops in CM amplitude, although these drops do not explain all cases. This work set out to examine the CM recorded from each of the electrode contacts, for several different audiometric frequencies and for different acoustic stimulation levels. The intention was to examine the cochlea in much more detail so as to help interpret the intra-cochlear recordings and how these relate to changes in residual hearing following surgery .

Method: CM recordings were attempted around 12 months post-surgery from 12 ears implanted with Advanced Bionics HiRes90k cochlear implants, for which intra-operative CM monitoring data were already available. Electrode scan recordings were made, where CM was recorded from each of the 16 electrode contacts in turn. Tone bursts were delivered via an insert earphone and recording made using the AIM 1.0 medical grade Windows tablet (Advanced Bionics LLC, Valencia CA). The first recording attempted was for a 500 Hz stimulus, delivered at 115 dB SPL: the same stimulus used by default for intra-operative monitoring. Where valid data were obtained, and time allowed, further recordings were made for 10 dB reductions in stimulus level, until the noise floor was reached. This process was then repeated for 250 Hz, 1,000 Hz and 2,000 Hz. On the same day as ECochG recording, unaided audiometric hearing thresholds were obtained for each implanted ear. The CM recordings were analysed to determine whether, 1) the data were monotonically organized in keeping with the stimulus level, 2) the amplitude was 6 dB or more higher on any electrode contact other than contact 1 (the default for intra-operative recording), 3) the growth in CM amplitude for 10 dB increases in stimulus level, 4) whether CM amplitude peaks varied across electrode contacts in keeping with the adapted stimulus frequency and 5) how these data help interpret the intra-operative recordings.

Results: A total of 27 recordings were attempted across the 12 ears, with 18 recordings (67%) being successful. For the 2,000 Hz stimulus, three recordings failed to provide data above the system noise floor. A further 4 ears did not provide valid data for two or more stimulus levels, meaning that 8 of the 12 ears (67%) provided data sets that could be analysed. The maximum CM level recorded across participants had a mean value of 40 µV (range 1.2 to 352 µV). In 14 of the 18 recordings (78%), the amplitude on some other contact was 6 dB or higher than the amplitude on contact 1. The mean growth for a 10 dB change in stimulus level was 2.6 (range 1.4 to 4.9), or 8.3 dB. Analysis with respect to the unaided free-field hearing levels is ongoing.

Conclusions: A considerable number of ears, 67%, returned these extended data sets 12 months or more following CI surgery, confirming that residual hearing can be preserved some time. Simply analysing the CM amplitude from only the most apical contact is not sufficient to characterize the cochlea. Predicting hearing levels using a simple 1:1 rule to extrapolate to threshold ignores the considerable variation in growth rates across ears. Making electrode scans for at least three different stimulus levels is recommended so as to better interpret the monitoring traces made during electrode array insertion and to better predict unaided hearing levels on the basis of CM amplitude.

Th23: DETECTION OF CHANGES IN AMPLITUDE MODULATION DEPTH AND RATE CAN PREDICT SPEECH UNDERSTANDING IN COCHLEAR IMPLANT USERS – A BEHAVIORAL AND ELECTROPHYSIOLOGICAL STUDY

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Introduction. Cochlear implant (CI) users rely on low-frequency temporal envelope modulations (TEMs) to understand speech. Variability in the ability to encode TEMs may explain some of the outcome variability among CI users. TEMs can be expressed as amplitude modulations on different CI channels. Electrophysiological assessment of TEM encoding may provide a more objective measure of speech understanding than traditional speech tests, and it can be linked to CI fitting, thus pointing the way towards closed-loop CIs. The acoustic change complex (ACC) is an electrophysiological measure of change detection at cortical level.

Methods. We used the ACC to assess amplitude modulation detection (AMD) and amplitude modulation frequency discrimination (AMFD) abilities with a clinical electroencephalography (EEG) system. We measured AMD-ACC and AMFD-ACC in twelve adult CI users (age: 40-82). Additionally, we assessed AMFD thresholds in a psychoacoustic task. Both tasks, electrophysiological and psychoacoustic, were performed with direct electrical stimulation at a single basal compared to a single apical electrode, and at a modulation frequency of 10 Hz compared to 40 Hz. Electrophysiological measures were assessed with a novel 3-stimulus paradigm that allowed us to simultaneously record onset/offset cortical auditory evoked potentials (CAEPs), ACCs, and auditory steady-state responses (ASSRs). We correlated electrophysiological and behavioral results with the speech-in-noise understanding scores across subjects.

Results. Electrophysiological responses were significantly higher for apical than for basal stimulation. There was no significant difference between the 10 Hz and 40 Hz modulation frequencies. The signal-to-noise ratio (SNR) of AMFD-ACC was low, and N1 amplitudes did not correlate with speech-in-noise performance. We found a significant correlation between behavioral AMFD thresholds and speech-in-noise scores, and between AMD-ACC N1 amplitude and speech-in-noise scores.

Relevance. Assessing TEM encoding through ACC may help clinicians to predict speech recognition in a more objective manner, even in patients who are unable to provide active feedback. AMD-ACC and AMFD-ACC hold potential as clinically applicable measures. However, the SNR of AMFD-ACC needs to be improved, e.g. by more repetitions, better EEG amplifiers or invasive EEG electrodes.

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Th24: SUPERIOR SOUND LOCALIZATION ABILITIES WITH BILATERAL MIDDLE EAR IMPLANTS FOR PATIENTS WITH BILATERAL CONDUCTIVE HEARING LOSS

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Objectives: Bilateral conductive/mixed hearing loss limits speech perception in complex listening conditions and directional hearing. Potentially these patients can benefit from reconstruction of the ear, bone-conduction devices (BCDs) or active transcutaneous middle ear implants (Vibrant Soundbridge, VSB). However, many studies demonstrate that treatment does not result in optimal hearing and that patients implanted with bilateral BCDs demonstrate lateralization instead of localization of sounds. They perceive sounds as coming from the far-left side or the far-right side. We hypothesized that the limited benefit of BCDs is related to stimulation of the contralateral cochlear thru bone-conduction. Patients with middle-ear implants receive stimulation of the ipsilateral cochlear only and therefore their localization abilities might be better compared to patients who are fitted with BCDs.

Methods: Sound localization in both the horizontal (-70° to 70° azimuth) and vertical (-35° to 40° elevation) plane is measured in a sophisticated mobile setup by measuring the natural head-pointing response towards perceived sound locations (Wasmann et al., 2020). In this setup loudspeakers are not visible so subjects can only rely on auditory information, enabling to test binaural hearing (ITDs and ILDs) and the use of monaural sound level cues and monaural spectral cues (Arras et al., 2022). Patients with bilateral conductive or mixed hearing loss were tested in unilateral, bilateral and unaided conditions.

Results: We demonstrate that patients with conductive hearing loss, implanted with bilateral VSBs, can process binaural cues. Their localization abilities were nearly as good as the normal hearing control group. Patients with sensorineural hearing loss demonstrated lateralization of sounds. In the unaided condition patients can localize sounds in the horizontal plane by using remnant binaural cues. However, the inter-subject variability in sound localization abilities could not be explained by these cues.

Conclusion: This is the first study demonstrating almost accurate sound localization abilities when listening with bilateral applied hearing implants. We conclude that middle ear implants, stimulating only the ipsilateral cochlea, can be the preferred treatment option for listeners with bilateral conductive/mixed hearing loss, and that this topic needs further investigation.

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Th25: ELECTROPHYSIOLOGICAL MEASURES OF TEMPORAL PITCH PROCESSING IN AN ANIMAL MODEL OF COCHLEAR ELECTRIC STIMULATION

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Most cochlear-implant (CI) users show poor sensitivity to pitch conveyed by the periodicity of electric stimulation, contributing to impaired perception of music and of speech amid competing sounds. Single-unit recordings in cats have demonstrated that low-frequency ear and brainstem pathways apparently are specialized for transmitting temporal fine structure (TFS), but those pathways are not stimulated selectively by today's clinical CIs. Moreover, the transmission of electric TFS measured at the level of the cat midbrain declines over the course of ~6 months of auditory deprivation. Here, we are developing non-invasive EEG measures of temporal processing in the cat animal model that could permit the ongoing study of effects of deafness and of various experimental modes of electrical stimulation.

Cats were deafened bilaterally and implanted unilaterally with 8-channel intracochlear electrode arrays (Advanced Bionics). Every two weeks thereafter, cats were sedated and the electric Frequency Following Response (eFFR) and the Auditory Change Complex (eACC) were recorded with scalp electrodes. The eFFR measured neural phase locking to unmodulated pulse trains that varied in rate from 43 to as high as 643 pulses per second (pps). The eACC measured cortical sensitivity to 36 or 66% changes in rates of unmodulated pulse trains. The electric-hearing results were compared to a recent study in normal-hearing cats that used trains of bandpass acoustic pulses to simulate CI stimulation of the basal cochlea.

As in normal hearing, eFFR spectral amplitudes tended to decline with increasing pulse rate, and yet often were significant up to the highest pulse rates tested. Neural latencies were given by the group delay, computed from the rate of change in eFFR phase lag across pulse rates. At low pulse rates (<200 pps), latencies were relatively long, consistent with thalamocortical sources, whereas higher stimulation rates (>300 pps) elicited shorter latencies, consistent with lower-brainstem sources. Surprisingly, eFFR to high pulse rates was observed even after 6 months of deafness with minimal electrical stimulation over that span of time. Our ongoing research will address longitudinal effects of deafening and electrical stimulation.

The eACC resembled normal hearing in that response magnitudes were sensitive to the size of the pulse rate change and were larger for increasing rates compared to decreasing rates. Unlike normal-hearing ACC, however, the eACC magnitude tended to grow monotonically with increasing baseline rate, suggesting a confound of increasing loudness for higher pulse rates. Ongoing work seeks to identify the relative contributions of rate and loudness sensitivity as reflected by the eACC in chronically deafened cats.

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Th26: EXPLORING THE USE OF OTOPLAN TO ASSIST WITH PLANNING ECOG INTRAOPERATIVE MONITORING STRATEGIES

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Introduction: Intraoperative electrocochleography (ECoG) monitoring provides real-time feedback regarding cochlear responses to acoustic stimulation during cochlear implantation, which can inform decisions during electrode array insertion. Although a decrease in response magnitude can indicate intracochlear trauma, interpretation is complicated when using an intracochlear recording electrode due to the simultaneous changes in location and orientation relative to the multiple ECoG generators during advancement. This preliminary investigation explores whether electrode array length and estimated insertion angle is related to complex ECoG magnitude patterns or unexpected hearing-preservation outcomes for the broader purpose of investigating ways to improve and individualize monitoring strategies.

Methods: This is a retrospective review of a subset of patients who received MedEl devices. Cases were considered if there was residual acoustic hearing preoperatively, Otoplan estimates of electrode insertion angle and estimated characteristic frequency, and intracochlear ECoG monitoring. Descriptive variables include (1) changes between post- and pre-operative audiometric thresholds, (2) ECoG magnitude patterns, (3) electrode array type (Flex 20, 24, 26 or 28), (4) estimated characteristic frequency of the most apical electrode at full insertion, (5) the difference between the estimated characteristic frequency at the apical electrode site and the stimulus frequency, and (6) degree of pre-operative hearing loss at frequencies higher than the ECoG stimulus frequency. Cases demonstrating unanticipated hearing-preservation outcomes compared to ECoG predictions will be explored in more detail.

Results: Data collection is ongoing. At present, one case has been identified with better hearing preservation outcomes than expected based on the intraoperative ECoG magnitude drop (500-Hz stimulus). The most apical electrode of the Flex 26 array was estimated to have a final position at full insertion corresponding to the 482.9 Hz characteristic place of excitation. Additional cases will be evaluated to see what patterns emerge.

Conclusion: It is worth exploring whether personalizing strategies for ECoG monitoring based on the electrode array information has the potential to improve real-time interpretation of intracochlear ECoG recordings, and ultimately outcomes for patients.

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Th27: INTER-BRAIN SYNCHRONY BETWEEN CHILDREN WITH COCHLEAR IMPLANTS AND THEIR MOTHER: AN FNIRS STUDY

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Introduction: Successful mother-child interactions are thought to contribute to a child's linguistic and socio-emotional development. Evidence from neuroimaging studies suggest that coordinated neural activity, called inter-brain synchrony (IBS) promotes social interactions and could potentially be the mechanism facilitating effective communication. However, investigations of IBS between mother-child pairs have so far focused predominantly on typically developing children. Here we propose to explore IBS between deaf children with cochlear implants (CI) and their mothers using functional near infrared spectroscopy (fNIRS) hyperscanning which allows for simultaneous recordings of brain activity of two or more people. fNIRS is a non-invasive imaging technique that is compatible with CIs. We will also examine the verbal and non-verbal cues that might influence IBS in this population. Specifically, we will investigate the effects of conversational patterns and eye-gaze on IBS between mother-child pairs.

Aims: We will demonstrate the feasibility of measuring IBS between deaf children with CIs and their mothers. We also aim to gain a deeper understanding of the behavioural and neurological basis of language processing in this population compared with normally-hearing children.

Methods: Twenty children aged 4-6 years, with CIs and their mothers, and a control group of 20 normally-hearing children and their mothers, will take part in this hyperscanning study. Mother-child pairs will be tested simultaneously while engaging in unstructured free play with age-appropriate toys in a naturalistic environment. The experiment will be comprised of two five-minute conditions i) interactive play where the pairs play together and ii) independent play where the pairs play separately. To map IBS, fNIRS hyperscanning will be performed using four 2x2 optode arrays placed over the bilateral inferior frontal gyrus and temporo-parietal junction of both the child and the mother. Verbal and non-verbal communicative patterns will also be assessed by coding conversation and eye-tracking patterns.

Anticipated Impact: This study aims to establish the feasibility of measuring IBS between children with CIs and their mothers. This will expand our knowledge of the neural mechanisms underlying the development of mother-child communicative behaviours after hearing loss and subsequent restoration of hearing with CIs.

Th28: 1817: MULTIFREQUENCY ELECTROCOCHLEOGRAPHY AND ELECTRODE SCAN TO MONITOR HAIR CELL FUNCTION DURING COCHLEAR IMPLANT ELECTRODE PLACEMENT

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Introduction
Electrode insertion trauma is one of the leading factors for residual hearing loss following cochlear implantation. Generally, a low-frequency acoustic stimulus (e.g., 500 Hz) is used to perform electrocochleography (ECochG) and generate cochlear microphonics (CM), and the most apical electrode from the cochlear implant (CI) electrode array is used to measure the electrical potential, monitor hair cell function, and guide CI electrode placement. A decrease in CM amplitude during CI electrode placement is presumed to represent cochlear trauma and is used to pause, retract, and/or alter electrode placement. Advancement of the recording electrode beyond the multiple sites of CM generation can lead to a decrease in CM amplitude, which can be misinterpreted as cochlear trauma. If the decrease in CM amplitude is due to the advancement of the recording electrode, then peak amplitude measured during electrode placement should correlate with peak amplitude measured during electrode scan performed immediately after electrode placement. In the present study, multi-frequency CM measurements and electrode scan were used to differentiate between the two different mechanisms that can lead to a decrease in CM amplitude during electrode placement.

Methods
Intraoperative multi-frequency CM and electrode scan measurements were performed in 10 cochlear implant recipients (average age = 73.1 years, SD = 10.4). All patients received an Advanced Bionics HiFocus SlimJ electrode array. Three or four-frequency acoustic tone bursts with stimulus levels of 100 dB HL were used to generate the CM.

Results
Multi-frequency CM measurements are likely to show a simultaneous decrease in CM amplitude measured for the test frequencies during electrode insertion trauma, whereas a decrease in CM amplitude at one test frequency and a gradual increase in CM amplitude at other test frequencies are indicative of the advancement of the recording electrode beyond one of the multiple sites of CM generation or characteristic frequency along the basilar membrane. Electrode scan measurements show that in the majority of the patients, the decrease in CM amplitude during electrode placement is at least partly or completely attributed to the advancement of the recording electrode through the cochlear space.

Conclusion
Multi-frequency ECochG and electrode scan can differentiate cochlear trauma from the advancement of the recording electrode through the cochlear space as a mechanism for a decrease in CM amplitude during CI electrode placement. This can prevent unnecessary alterations during CI electrode placement and the risk of losing residual hearing that comes from those alterations.

Th29: FAST TRACKING EARLY INTERVENTION FOR INFANTS WITH HEARING LOSS.

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Although newborn hearing screening has made a great impact on the speed at which early invention can be applied for infants, there are still delays between diagnosis and optimal intervention that need to be decreased to ensure each child can reach their full potential for language development. For example, delay points may be:

- being able to accurately prescribe a hearing aid for infants with Auditory Neuropathy (or know whether one is appropriate);
- knowing whether a hearing aid would be sufficient for language development (AN and severe+ SNHL) is a cochlear implant a better option
- Objective programming for cochlear implants, and verifying the programming of all hearing devices

fNIRS technology can provide solutions at each of these points in the clinical care pathway. Our research has developed test methods and analysis algorithms that have been verified to produce clinically-relevant accuracy for speech discrimination testing and to verify audibility. Current results in 31 normal hearing sleeping infants (ages 2-18 months) show 100% sensitivity and 100% specificity for detection of of speech sounds and 95% sensitivity and 100% specificity for speech sound discrimination in the same infants.

In our presentation, we show examples of how the fNIRS test was used in a range of hearing-impaired infants with cochlear implants, or hearing aids, and in those who were diagnosed with auditory neuropathy.

We are well on the way to develop a clinic-friendly fNIRS device that can be used in clinics to provide objective and automatic results for clinicians.

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Th30: THE IMPORTANCE OF HEARING PRESERVATION IN CHILDREN WITH COCHLEAR IMPLANTS AND PREOPERATIVE RESIDUAL HEARING

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Introduction: Children with preoperative normal-to-moderate low-frequency hearing and severe-to-profound high-frequency hearing loss with poor speech recognition can be considered for a cochlear implant (CI). When these non-traditional pediatric CI recipients maintain residual hearing, they can be fit with electric-acoustic stimulation (EAS). When residual hearing is lost, they are fit with full-electric stimulation (FES). A growing body of research using standard speech perception batteries has shown that pediatric CI recipients with EAS or FES experience better performance than observed preoperatively. The present report reviews preliminary data from children who maintain residual hearing and use EAS and those who lose residual hearing and are fit with FES on measures of speech recognition and prosodic identification task to identify the contributory benefits of residual hearing in children.

Methods: Pediatric CI recipients who presented with a low-frequency pure-tone average (LFPTA; 125, 250, and 500 Hz) of 75 dB HL or better at the preoperative evaluation were considered for inclusion in this prospective clinical trial. Those with functional hearing preservation were fit with EAS and those whose LFPTA exceeded 75 dB HL were fit with FES. At the time of analysis, 22 children (EAS: n= 12, FES: n=_10) had completed the study endpoint (12-months post-activation). Performance was assessed with recorded speech recognition materials (i.e., CNC words and BKB-SIN), and a prosodic perception task. The prosodic task required the participants to repeat a semantically neutral sentence that varied in pitch to indicate a question versus a statement. Their repetitions were recorded and rated as either questions or statements by blinded reviewers. These ratings were analyzed for accuracy.

Results: At 12 months post-activation, there was no significant difference in speech recognition between groups for CNC words or BKB-SIN. The EAS group outperformed the FES group on measures of prosodic identification. There was a strong negative correlation between degree of low-frequency hearing post-activation and prosodic accuracy.

Conclusion: Children with normal-to-moderate low-frequency hearing and severe-to-profound high-frequency hearing loss may demonstrate similar outcomes in word recognition and sentence recognition in noise whether hearing is preserved or not. Children who were fit with EAS are significantly better at identifying questions versus statements when compared to those using FES. The degree of post-activation residual hearing is strongly correlated with performance on prosodic identification tasks. Hearing preservation in children plays an important role in accessing auditory cues that impact spoken language development.

Th31: COMPARISON OF SPREAD OF ACTIVATION AND INTERACTION BETWEEN CHANNELS DURING ELECTRICAL AND OPTOGENETIC STIMULATION IN THE MOUSE COCHLEA.

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Introduction: Electrical stimulation via the cochlear implant is a highly efficient way to activate spiral ganglion neurons. However, the spread of electrical current lowers the spatial resolution of activation and can cause interactions if the electrodes were to be simultaneously stimulated. Optogenetics is a technique that has the potential to improve the precision of neural activation because light is used to selectively stimulate neurons that are modified with light-sensitive opsins. We hypothesised that the spread of activation and interaction between channels during the optogenetic stimulation would be low compared to electrical stimulation alone. Hence, we compared the spread of activation during optogenetic stimulation against acoustic and electrical stimulation.

Aim: To compare the activation width in the inferior colliculus of the auditory midbrain during acoustic, electrical, or optogenetic stimulation of the mouse cochlea and to measure the interaction between channels during simultaneous stimulation for each of these modalities.

Method: The mouse electrical cochlear implant consisted of 4 platinum rings (0.21-0.29 mm ø) and the optical cochlear implant (LED array) consisted of 5 micro-LEDs (453 nm; 0.27 x 0.22 mm). The arrays were implanted in the acutely deafened mouse cochlea through the round window, and neural activity was recorded from the inferior colliculus of the auditory midbrain. The micro-LEDs were controlled by an in-house custom-built LED driver and the electrodes were controlled by a benchtop electrical stimulator, both via customised script (Igor software). The spread of activation was compared using the activation width at D-prime of 1 and 2 above the threshold. Interactions between channels were compared by measuring the threshold shift on one channel during simultaneous co-stimulation of another channel at different set intensities relative to the threshold and at differing channel pitches.

Results: Our studies have confirmed that optogenetic stimulation of cochlear neurons results in a significantly narrower spread of activation compared to electrical stimulation in the cochlea ($P<0.05$, T-test). The average activation width at D-prime of 1 and 2 above threshold during electrical stimulation was 0.47 ± 0.049 mm and 0.72 ± 0.065 mm, respectively, while activation width during optogenetic stimulation was 0.22 ± 0.024 mm and 0.38 ± 0.035 mm, respectively, the latter being similar to the activation width during acoustic stimulation. Interaction between channels with adjacent channels during optogenetic stimulation was significantly lower and around 5 fold less compared to the electrical stimulation ($P<0.05$, T-test).

Conclusion and Significance: The narrow spread of activation and reduced channel interactions achieved via optogenetic stimulation could increase the number of independent channels and could allow simultaneous stimulation, which is vital in improving the spatial resolution of cochlear implants.

Th32: PREDICTING COCHLEAR IMPLANT OUTCOMES IN CANDIDATES WITH RESIDUAL HEARING

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Objectives: As outcomes for cochlear implants have improved, patients with significant residual hearing who receive limited benefit from amplification may now be candidates. Given that hearing preservation is not guaranteed, it is important to be able to predict outcomes for these patients after implantation. We hypothesize that tests of suprathreshold auditory abilities are better predictors of speech outcomes post-implantation than the audiogram.

Design: We are testing adult patients with steeply sloping hearing pre-operatively on a battery of psychoacoustic, audiometric, and demographic measures preoperatively using their acoustic hearing. As part of their candidacy evaluation, subjects also had an audiogram and aided speech evaluation using CNC words and AzBio sentences in quiet and noise (+10 dB SNR). For early data collection, the spectro-temporally modulated ripple test (SMRT) was used as the metric of suprathreshold auditory ability. We have expanded the preoperative test battery for new patients. At least 3 months post-operatively, speech perception was measured in the everyday listening condition. This was using electroacoustic stimulation (EAS) for those who preserved hearing and electric only for those who did not. An unaided audiogram was also measured.

Results: SMRT was correlated with speech outcomes for all three tests, while pre-operative and post-operative audiograms were not. Preoperative audiograms and speech perception were correlated with SMRT. Pre-operative speech perception was correlated with post-operative speech for AzBio +10 only. Data for other psychoacoustic tests (temporal resolution, binaural processing) will be presented for individual cases.

Conclusions: SMRT measured preoperatively with acoustic hearing appears to predict postoperative speech perception with a CI, regardless of hearing preservation. Spectro-temporal resolution may be a predictive factor for outcomes with a cochlear implant in patients with residual hearing. While the mechanism underlying this is unclear, it seems that suprathreshold auditory abilities are related to cochlear health and the "quality" of residual hearing.

Th33: THREE-DIMENSIONAL ANALYSIS OF THE EFFECTS OF TISSUE RESPONSE ON HEARING

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Chronic cochlear implantation and stimulation is known to produce a fibrotic tissue response within the cochlea. This tissue response would be expected to impact hearing; however, previous studies have failed to produce a conclusive correlation between the two. We hypothesise this lack of correlation may be due to limitations in conventional histological techniques – analysis from two-dimensional microtome sections, being unrepresentative of the impact that can occur due to implantation and stimulation. We have leveraged recent developments in tissue clearing – a process whereby normally opaque tissue is rendered transparent; and developed a method to allow for three-dimensional analysis of sensory hair cells and fibrotic response to implantation within an intact cochlea.

Normal hearing adult guinea pigs (n = 7) were noise deafened using 10kHz 120dB SPL for two hours. After 28 days the left cochlea was implanted with an intra-cochlear electrode array and received either low- (50 uC/cm2) or high-charge density (400 uC/cm2) stimulation for 4 weeks. Hearing assessments (auditory brainstem response recordings) were performed prior to implantation and at the conclusion of the chronic stimulation period. Cochleae were collected; immunofluorescently stained with myosin viia labelling for hair cells and smooth muscle actin (SMA) labelling the fibrotic tissue encapsulation; and cleared in ethyl cinnamate. The whole cochlea was imaged on a lightsheet microscope, and images were rendered in 3D using Imaris software. Imaris was also used to generate a frequency map and create a volumetric surface of the hair cells and fibrotic electrode tract.

Chronic implantation and stimulation resulted in significant hearing loss in both low- and high-charge density groups, with a trend towards more loss in the middle region (4-8kHz) in the high-charge density group. The hearing loss was consistent with preliminary histological findings of greater hair cell loss in implanted cochleae, particularly associated with the fibrotic tissue encapsulation. However, there was no overt difference in hair cell survival between low- and high-charge density groups.

Three-dimensional visualisation of the cochlea offers unprecedented insight into how fibrotic tissue response to implantation can affect hair cell survival. In addition, 3D frequency mapping allows for the identification of tissue responses and hair cells at frequency specific locations. Using a range of pathophysiological markers, this study demonstrates a novel method that provides an accurate assessment of the cochlea following implantation. This improved validation tool will be used in developing treatments to reverse or prevent cochlea damage.

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Th35: BEHAVIOURAL DISCRIMINATION OF SIMPLE SPEECH SOUNDS IN CATS WITH PARTIAL HEARING AND A COCHLEAR IMPLANT.

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BACKGROUND: The expansion of criteria for cochlear implantation to include patients with substantial residual hearing has focused interest on the benefits of combined electro-acoustic stimulation. Although such stimulation via a cochlear implant and hearing aid in the same ear has been shown to improve speech understanding, particularly in noise, and to increase the aesthetic quality of sound, more research is required to understand the physiological mechanisms underlying these benefits. A limiting factor to performing this research has been appropriate animal models of partial hearing loss and chronic multi-channel cochlear implant use. In this study, we present behavioural discrimination data from the partially-deafened, chronically implanted and stimulated cats.

METHODS: Animals were partially deafened via acoustic over-exposure (120dB, 16kHz, 100mins, free-field) at 4 months of age and chronically implanted with an 8 contact intracochlear electrode inserted ~50% the length of the cat scala tympani, representing a tip electrode position of around 4 kHz. Two weeks later, chronic stimulation was commenced from a modified clinical cochlear implant and speech processor (Nucleus 5, Cochlear Ltd., Sydney, Australia). A cohort of similarly aged normal hearing animals were also used. Animals were trained on a go/no-go positive reinforcement discrimination task in their home cages and were free to engage in the task at any time. Cats performed 100-400 trials per day and, once trained in the procedural aspects of the task, rapidly learnt the discrimination task. Successful performance on a pure tone vs. frequency-modulated (FM) tone discrimination task was used as an inclusion criterion before performance on a speech discrimination task was tested. The task consisted of either a hard (‘bad’ vs. ‘bid’) or easy (‘hop’ vs. ‘bid’) CVC discrimination, with stimuli presented at ~ 60 dB SPL in various levels of background noise.

RESULTS: The partial deafening produced a hearing profile with near-normal hearing below 2 kHz and a sharply sloping loss above that frequency, resulting in profound deafness above 8 kHz. Normal hearing animals (n = 2) were able to perform the hard discrimination task with a threshold signal-to-noise ratio of ~15 dB, while none of the partially-deafened animals (n = 3) were successful at this task. Partially-deafened animals were, however, able to perform the easy discrimination with a threshold signal-to-noise ratio of ~30 dB.

CONCLUSIONS: The partially-deafened, chronically implanted and stimulated cats provide a good model to examine the physiological mechanisms underlying the benefits of electro-acoustic stimulation.

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Th36: WIDE-FIELD CALCIUM IMAGING FOR EVALUATING COCHLEAR IMPLANT STIMULATION STRATEGIES IN THE AUDITORY CORTEX

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Cochlear Implants (CI) are an effective neuroprosthesis for humans with profound hearing loss, enabling deaf adults to have phone calls without lipreading and babies to have successful language development. However, CIs have significant limitations in complex hearing situations, motivating the need for further research including in animal models. One major challenge in electrophysiology in CI animals lies in excluding the CI electric artifacts from the recording, since they are orders of magnitude larger than the amplitude of action potentials. To circumvent this problem, we have set up an imaging system allowing us to monitor neural activity in the auditory cortex (AC) of CI supplied rats using the Ca++ sensitive dye OGB-488. Here we describe an initial experiment with this setup, in which we recorded cortical responses to 4 different stimulation patterns which were delivered across 3 CI channels to the contralateral ear. We then investigated whether the discriminability of the AC response patterns (which we assume to be predictive of the perceptual discriminability of the patterns) depends on pulse rate (300 and 1800 pps were tested) and on whether or not pulses were delivered interleaved or simultaneously across channels. While pulse rate had only a very modest effect on the discriminability of the neural responses, the stimulation mode had a major effect, with simultaneous sampling, perhaps surprisingly, allowing much better pattern discrimination than interleaved sampling. The result suggests that allowing collisions of pulses on neighboring channels may not always be detrimental, at least if partial overlaps of pulses, in which anodic and cathodic pulse phases might cancel, are avoided.

Th37: DETERMINING THE REQUIRED NUMBER OF HIGH-FREQUENCY ELECTRICAL STIMULATION CHANNELS TO IMPROVE SPEECH INTELLIGIBILITY IN INDIVIDUALS WITH RESIDUAL LOW-FREQUENCY HEARING.

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High-frequency sensorineural hearing loss with good low-frequency hearing is a common and debilitating diagnosis seen in clinical practice. Many patients with this “ski-slope” hearing loss configuration report significant difficulty understanding speech due to the loss of high-frequency information. This difficulty hearing and communicating has been linked to social isolation and reduced quality of life, emphasizing the need for targeted treatment. Currently, no optimal treatment options are available for these patients to improve speech intelligibility. Hearing aids cannot provide adequate amplification or clarity for high-frequency speech information, and cochlear implantation may damage residual low-frequency hearing due to intracochlear trauma caused by the insertion of the electrode array. Thus, there is a need for a medical solution that can target this specific degree and configuration of hearing loss to improve communication abilities and quality of life in these patients.

One possible solution is to provide high-frequency information via extracochlear stimulation using electrodes placed on the cochlear promontory. This approach is less invasive than traditional cochlear implantation and therefore provides an opportunity to restore audibility and clarity of high-frequency speech information while preserving low-frequency acoustic hearing. This approach is under development and has been shown to stimulate spiral ganglion neurons and provide discriminable frequency channels in animal and human models. However, it is unclear how many high-frequency channels are needed to facilitate improvements in speech understanding and how much the number of channels depends on the bandwidth of low-frequency hearing.

To address this question, we used a vocoder to simulate extracochlear high-frequency stimulation. We then varied the low-frequency acoustic cutoff in three conditions (750, 1000, and 1500 Hz) and measured CNC word recognition for each cutoff as the number of simulated extracochlear channels increased from one to four. Our goal was to determine how many simulated channels were needed to improve speech intelligibility for a given cutoff of low-frequency hearing. This information is crucial for demonstrating the feasibility of extracochlear stimulation and will guide further refinements in the device with the ultimate goal of improving communication ability and quality of life in patients with steeply sloping high-frequency hearing loss.

Th38: TOWARDS EXTRACOCHLEAR ELECTRIC-ACOUSTIC STIMULATION OF THE AUDITORY SYSTEM

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Introduction: Combined electric-acoustic stimulation (EAS) has been shown to provide great benefits for CI-users with low-frequency residual hearing (Turner et al. 2004; Büchner et al., 2009; Wilson et al., 2012). However, cochlear implantation remains traumatic and carries the risk of causing high-frequency hearing loss after insertion of the electrode array. This is one of the reasons why EAS is only recommended for patients with limited residual hearing at low frequencies. Extracochlear electrical stimulation has the potential to minimize cochlear trauma, thus providing benefits of electrical stimulation to a larger number of patients with substantial residual hearing. However, it is not known to what extent extracochlear electric stimulation can be used in conjunction with residual hearing.

Objective: The purpose of this study is to investigate potential benefits of extracochlear electrical stimulation combined with acoustic stimulation. For this, the feasibility of extracochlear electrical stimulation at the round window was examined in CI users with partially inserted electrode arrays. We refer to these subjects as partial insertion EAS users. Furthermore, the benefit of single electrode basal electric stimulation in combination with acoustic stimulation was investigated. Speech understanding as well as consonant identification performance was evaluated with and without electrical stimulation in normal hearing (NH) subjects using vocoder simulations and in CI users.

Methods: Potential benefits of single electrode extracochlear electric stimulation was evaluated in NH subjects using vocoder simulation as well as in partial insertion EAS subjects. In these subjects some electrodes of the CI are placed inside and some others outside the cochlea, so that it is possible to investigate benefits of electrical stimulation delivered through electrodes located close to the round window. Improvements in speech understanding and logatome identification using single electrode electric stimulation were evaluated in 5 NH subjects using vocoder simulations as well as in 5 partial insertion EAS users. Low-frequency information of speech was delivered up to a cutoff frequency via acoustic stimulation. High-frequency information of speech above the cutoff frequency was delivered either acoustically using a single-channel vocoder (in NH subjects) or via electrical stimulation through single CI electrodes located close to the round window (in partial insertion EAS users).

Results: The results of the study show that speech reception thresholds obtained from low-frequency acoustic hearing significantly improved by approx. 8 dB signal to noise ratio (SNR) on average if combined with simulated single channel electrical stimulation in NH subjects ($p=0.022$). Moreover, a trend towards improved consonant identification (12% on average) was observed for the same listening condition. Preliminary results in partial insertion EAS subjects showed that extracochlear electric stimulation can elicit sound sensations. In this population, a trend towards improved consonant recognition was obtained combining acoustic stimulation and single electrode extracochlear electric stimulation.

Conclusions: This study shows promising results for the benefit of extracochlear electric-acoustic stimulation. However, further research is needed to optimize hearing performance and reduce side effects resulting from extracochlear electrical stimulation.

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Th39: TOWARDS A CELL-BASED TREATMENT FOR HEARING LOSS; EXPLORING THE VIEWS OF PATIENTS AND THE PUBLIC.

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Background: A first-in-human clinical trial of Rincell-1, a pluripotent stem-cell based therapy for hearing loss associated with auditory nerve dysfunction developed by Rinri Therapeutics, is currently under development. In the trial, patients with severe-to-profound hearing loss will receive Rincell-1 alongside standard clinical care (cochlear implantation).

Objectives: Given the novelty and demands of this trial, the views of people with living experience of hearing loss are crucial to establish and must be considered early in the protocol development process. This will not only support recruitment and improve retention to the clinical trial but also to enable us to minimise participant burden and optimise participant support.

Methods: A series of four focus groups will be carried with each of the following groups: i) cochlear implant users, ii) hearing aid users, iii) people with auditory neuropathy and iv) a mixed group comprised of hearing loss charity representatives and carers/significant others of people with hearing loss. Each focus group will be comprised of approximately 4-6 participants and will last approximately 1 hour. The following topics will be discussed: i) participant support during the trial, ii) participant burden during the trial, iii) patient reported outcome measures and iv) participant tolerability and acceptability of trial procedures and side effects.

Anticipated Impact: This study will offer a unique account of factors that should be considered during protocol and study design development in clinical trials of novel advanced therapies for hearing loss from the viewpoints of people with lived experience of hearing loss. It highlights the importance of incorporating feedback from patients when conducting research as their perspectives differ from those of research teams and healthcare professionals, particularly in the case of first-in-human clinical trials that pose unpresented challenges.

Th40: 1693: DENDRITIC COMPLEXITY OF LAYER III AND V PYRAMIDAL CELLS IN THE CONGENITALLY DEAF AUDITORY CORTEX

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Sensory deprivation is an environmental factor affecting the developmental process of cortical structures, recently shown by thickness measurements of macroscopic brain structure, revealing thickening and thinning in specific regions of the auditory cortex (Gordon et al., 2022, Cerebral Cortex). The absence of peripheral stimulation further leads to functional changes in the auditory brain (Kral et al., 2019, Ann Rev Neurosci), as well as reduced structures in granular and infragranular layers of the auditory cortex (Berger et al. 2017, J Comp Neurol).

A possible factor involved in the changes in the “deaf” auditory cortex are alteration in morphology of pyramidal neurons. For this purpose, we used (i) Sholl analysis of the dendritic patterns (Sholl, 1953) and (ii) somatic and dendritic analysis obtained from digitized sections and automatically reconstructed neuronal trees using machine learning. A comparison between adult congenitally deaf cats (n=6) and normal hearing controls (n=6) was performed in layer III and V pyramidal cells in primary and secondary auditory fields (AI, AII, DZ) and in the associated Brodmann area 7 from the same sections. Used brain tissue was perfused, cut with a cryostat 50µm thick frontal brain section, stained with SMI-32 antibody (Mellott et al., 2010, Hear Res) and digitized using a KEYENCE BZ-9000E microscope. Quantitative analysis was performed using KARMENstudio, a fully automated machine learning based software that was applied on digitized neuronal images. In total, 3450 pyramidal neurons in layers III and V were analyzed in the present study.

We found systematic significant differences between layer III and layer V pyramidal neurons, particularly pronounced in basal dendritic length in the deaf cats not present in the hearing control group. In addition, we found significant differences in dendritic lengths in layer V between deaf and hearing cats. All together these data support the previous study on reorganization of deep cortical layers (Berger et al., 2017) and demonstrate that a part of these differences is due to changes in the dendritic trees. Our data confirm that neurons developmentally deprived of their adequate input reorganize their dendritic tree. Absence of sensory input leads to layer-specific reorganization in morphology of pyramidal neurons.

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Th41: CORTICAL DEVELOPMENT FEATURES IN CONGENITAL DEAFNESS CHILDREN AFTER AUDITORY BRAINSTEM IMPLANT

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Objectives: The aim of this study is to present our experience and results of auditory brainstem implantation in children with congenital non-tumor deafness and to investigate the cortical developmental and functional connection features after ABI in children, and their relations to behavioral outcomes.

Materials and Methods: Retro-sigmoid or retro-labyrinthine approach was applied for ABI surgery. EABRs was intraoperatively performed to find out optimizing position of electrode paddle on the cochlear nucleus, and was postoperatively applied during activation and following fitting to determine the objective function of each electrode. The pure tone listening test (PTA), categories of auditory performance (CAP), infant-toddler meaningful auditory integration Scale (IT-MAIS), the meaningful use of speech scale (MUSS), speech intelligibility rate (SIR) and charge level of threshold of electrically evoked auditory brainstem responses (eABRs) were assessed in participants. The electroencephalogram (EEG) and functional near-infrared spectroscopy (fNIRS) were used to record cortical neural responses to auditory mismatch negativity (MMN) paradigm.

Results: ABI was successfully performed in all cases without intra-operative and post-operative major complications. The average active electrode ratio was 83% ±19% at first activation (n=49) and 76% ±15% at 12 months after 1st fitting (n=21). At 24 months after 1st fitting, 61.5% reached CAP-II≥5; 69.2% reached IT-MAIS/MAIS≥35 and 38.5% reached IT-MAIS/MAIS 40; 46.2% reached MUSS≥25; 92.3% children presented improvement on SIR and 30.8% reached SIR≥3. The fNIRS oxygen concentration analyses revealed more efficient functional-connections between the left auditory cortex and other cortices with longer implantation duration. The functional coherence of left auditory and frontal cortex was positively correlated to CAP (Spearman r=0.67 P=0.0019), IT-MAIS (Spearman r=0.69 P=0.0020) and SIR (Spearman r=0. 47 P=0.017) scores.

Conclusion: Cortical plasticity in congenital deafness children after ABI may contribute to the auditory and speech behavioral development, especially the connection between left temporal and frontal lobe. Auditory brainstem implantation has been a safe and feasible technique in young children who are contra-indicated to cochlear implantation, to restore the hearing and promote speech development.

Th42: ASSESSING SPEECH PROCESSING DURING A FUNCTIONAL NEAR-INFRARED SPECTROSCOPY TASK IN NORMAL HEARING LISTENERS AND COCHLEAR IMPLANT USERS

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Aims
Hearing outcomes after cochlear implantation (CI) vary considerably. There is evidence that plastic brain changes caused by hearing loss, correlate to different hearing outcomes. Our aim is to identify different brain activation patterns between normal hearing (NH) adults and CI users with good speech understanding. These patterns can delineate plastic brain changes and its role after surgery.

Materials and Methods
We recruited 26 NH and 16 CI participants (postlingually deafened, monosyllabic speech test > 75%). Using functional near infrared spectroscopy (fNIRS), we measured the concentration change of oxygenated (HbO) and deoxygenated hemoglobin (HbR) in temporal and occipital brain regions. During the measurement, the participants performed an audiovisual speech comprehension task (Oldenburg Sentence Test, OLSA). We presented the OLSA sentences in 4 different modalities: speech-in-quiet, speech-in-noise, visual speech (i.e., lip reading), and audiovisual speech. To complement our fNIRS data, we collected subjective and behavioral parameters (pure tone and speech audiometry, validated questionnaires, in-task comprehension questions, and listening effort ratings).

Results
During the OLSA speech stimulation we measured distinct activation patterns in the temporal and occipital regions in NH and CI subjects. During speech-in-quiet stimulation, we measured cortical activation bilaterally in the temporal regions of both groups (slightly stronger in NH subjects). During visual speech, we identified temporal activation in both groups (slightly stronger in CI subjects). Occipital activation during visual speech was widespread in NH and localized in CI subjects. The results show increased connectivity between occipital and temporal regions in experienced CI users compared to NH listeners. Listening effort ratings and reaction times to in-task comprehension questions were generally higher in the CI subjects, and they also reported experience with lip-reading.

Conclusion
We were able to use a clinically established language test to measure cortical activation patterns. We were also able to corroborate our findings with subjective and behavioral parameters. Compared to NH listeners, good performing CI patients showed altered temporal and occipital activity. These findings can be explained by plastic changes that are beneficial for speech understanding with a CI. In a further step, we will measure a cohort of CI users with poor performance in order to identify the plastic changes that are detrimental to adequate speech understanding. By comparing these cohorts, we will be able to derive neural markers of speech understanding.

Th43: NEURAL CORRELATES OF POST-ACTIVATION CHANGES IN LOUDNESS PERCEPTION BY ADULT COCHLEAR IMPLANT RECIPIENTS

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Multiple previous studies reported that average stimulation levels set during clinical fitting of cochlear implants (CI) for both children and adults increase during the first 24 months of CI use. However, the reasons for this phenomenon remain unclear. One hypothesis is that brain plasticity following CI activation leads to a decrease over time of the loudness percept evoked by a given level of electrical stimulation. However, the neural locus of such changes is not known, and might occur in a peripheral, brainstem or cortical region, or combinations thereof. Alternatively, or in addition, loudness judgements during the fitting process might be influenced by shifts in perceptual criterion and/or by prior expectations from the clinician programming the device. Physiological measures providing an objective estimate of the internal representation of stimulus level are therefore desirable to evaluate the trajectory of loudness perception during the early period of CI use.

We tested a set of electrophysiological measures that allowed us to measure the response to CI stimulation at different stages of the auditory system, including the standard electrically-evoked Compound Action Potential (eCAP) and Auditory Brainstem Response (eABR) to ~ 40-pulses-per-second (pps) pulse trains. By removing the high-pass filter used to measure the standard eABR we revealed an electrically-evoked Auditory Steady State Response (eASSR) with a group delay consistent with thalamic/cortical sources, allowing us to compare thalamic/cortical and brainstem responses with the same stimuli and at the same time. As a control for matured CI listening, amplitude growth functions (AGFs) for all measures were obtained from 7 long-term recipients of the Cochlear Nucleus CI. We also obtained eASSR AGFs to 500-pps pulse trains amplitude-modulated (AM) at ~ 40 Hz, more similar to the stimuli in clinical use. For a group of newly implanted CI recipients, we performed a longitudinal study obtaining these measurements on the day of CI activation and three later time points (1, 2 and 4 months post-activation). Threshold and comfort levels for 500-pps AM and 40-pps unmodulated pulse trains were collected at each time point. eCAPs, eABRs and eASSRs were measured at the comfort level at each time point, as well as at several lower levels at the 3 latest time points, allowing for the assessment of a shift in the AGF of each response over time. Specifically, we measured the stimulus level needed to obtain the same neural response amplitude at each time point and compared the change in these values to the change in comfort level. This allowed us to measure the fraction of the loudness change accounted for by each neural response, using the same units, namely stimulus level in dB. Longitudinal data collection is complete at all time points for 2 participants, with data collection from further participants ongoing; we anticipate reporting longitudinal data from 8-10 CI users.

We hypothesize that the responses with most central origin (i.e. the eASSR) will show a changing relationship to stimulation level accounting partially, if not totally, for the changes in perceived loudness. eCAP and eABR data will be used to evaluate the contribution of earlier stages of auditory processing to the changes observed at the eASSR (i.e. cortical) level. We expect this experiment will shed light on the plasticity phenomena taking place following CI activation, with potential implications for CI fitting strategies, as well as for the evaluation of factors contributing to the progressive improvements in speech perception.

Th44: WHITE-MATTER MICROSTRUCTURE DIFFERENCES BETWEEN COCHLEAR IMPLANT CANDIDATES AND THEIR HEARING PEERS: A PILOT DIFFUSION TENSOR IMAGING STUDY

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Presbycusis occurs in one in three people in the United States between the ages of 65 and 74 years. Sensory degradation and/or deprivation due to hearing loss (HL) can result in significant changes in the gray and white matter of the brain. The cochlear implant (CI) is one of the primary treatments for individuals with severe HL. The main objective of this study is to examine the differences in white-matter microstructure between a group of individuals with severe to profound HL (ages ranging from 53 and 81 years) and are qualified to receive a (CI) versus their age- and sex-matched hearing peers using Diffusion Tensor Imaging (DTI). Tract-based spatial statistics (TBSS) were used to compare the two groups using a permutation test with 5000 permutations, and Threshold-Free Cluster Enhancement (TFCE) was used for multiple-comparison correction ($p < 0.05$). To date, data have been collected for six CI candidates and six matched controls. We found significantly lower Fractional Anisotropy (FA) values in the anterior corona radiata (ACR) in the group of CI candidates when compared to the control group. FA quantifies the white matter microstructure. Higher values of FA typically indicate greater white matter integrity and more organized fiber pathways, while lower values may indicate damage or disruption to white matter tracts. ACR is part of the limbic-thalamo-cortical circuitry and includes thalamic projections from the internal capsule to the prefrontal cortex. ACR transmits auditory information to and from the cerebral cortex in the central auditory pathway. These results indicate that white-matter microstructure is a sensitive measure to detect changes in structural auditory pathways due to HL in the brain. The data collection for this work is ongoing. The aim of this ongoing research is to investigate the potential use of DTI as a pre-implantation evaluation tool to improve the prognosis for CI candidates. Ultimately, this work will provide empirical evidence for developing an innovative pre-surgical intervention that has the power to increase FA values in specific brain regions along the auditory structural pathway before surgery. The novel pre-surgical intervention can be introduced to prepare the CI candidate’s brain to adapt to CI devices better.

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Th45: NEUROPLASTICITY IN RATS AND HUMANS WITH COCHLEAR IMPLANTS.

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Background: Speech perception with cochlear implants (CIs) almost always improve following initial activation. We hypothesize that neuroplasticity in the central auditory system plays a key role in improvements of speech perception. Addressing temporal, anatomical, and behavioral scales of neuroplasticity, however, is challenging. These can range from milliseconds to years, from minuscule synapses to neuron conglomerates, and from sound detection to speech perception. To bridge these scales, we perform comparative studies of neuroplasticity in adult-deafened humans and rats with CIs. Here, we track behavioral performance (spectral discrimination) in both humans and rats and relate these measures to speech perception (humans) and sensory encoding in the auditory cortex (A1, rats).

Methods: (Human Studies) Following initial activation of their CI, we sent subjects (N=3) home with a tablet loaded with validated tests of spectral acuity (quick-spectral modulation detection, QSMD) and temporal acuity (modulation-detection test, MDT; gap-detection). Subjects completed these tasks every other day for the first ~30 days following activation. Speech perception was tested periodically in-lab using standard tests of word and sentence recognition (CNC 30). (Rodent Studies) iEEG: we performed intercranial Electroencephalography (iEEG) recordings of the auditory cortex (A1) of normal hearing (tone-evoked, N=7) and deafened rats (CI-evoked, N=7). 2AFC training & whole-cell recordings we trained rats on a novel 2-alternative forced choice (2AFC) task for sound frequency discrimination, first using tones (N=18) and then, after deafening, using CI stimuli (N=5). Lastly, we measured excitatory and inhibitory postsynaptic currents (E/IPSCs) in rat auditory cortex (A1) neurons (N=12), evoked by individual CI electrodes prior to and after 2AFC training.

Results: (Human Studies) We found significant improvements in QSMD (frequency acuity) performance in 2 of 3 CI users and improvements in speech perception in the same 2 of 3 CI users. (Rodent Studies) iEEG recordings revealed reliable trial-by-trial tone and CI-evoked responses. After reducing these responses to a preferred frequency map, we found cochleotopic encoding of both tone-evoked and CI-evoked stimuli. A supervised PCA/LDA decoder suggests encoding of CI stimuli may be degraded compared to acoustic stimuli. Rats completed the 2AFC training task with high discrimination (d'>1) after ~3 weeks of acoustic training and, after deafening, ~1 week of CI training. Whole cell recordings revealed that CI-evoked excitatory and inhibitory postsynaptic potentials in A1 were significantly less correlated in untrained compared to 2AFC trained rats.

Conclusions: We found CI-use is related to improvement in both speech perception and spectral discrimination in humans and improvements in both spectral discrimination and cortical encoding (A1) in rats. Our next steps are to further elucidate the processes that result in improved speech perception and cortical encoding of CI stimuli, and potential relationships between the two.

Th46: COCHLEAR IMPLANT USERS IMPROVISING ON THE PIANO: A NEW METHOD FOR TRAINING PERCEPTION IN MULTIPLE DOMAINS

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Previous research with cochlear-implant users reported difficulties in the perception of music, vocal and emotional cues in speech, and understanding speech in multi-talker noise. Such complex auditory signals found in music or in cocktail- party situations remain challenging for CI users largely due to the degradation of information stemming from electrical stimulation. Through rehabilitation, CI users manage to adapt to these degradations to different degrees. However, though some empirical evidence promotes music as a training tool to improve music and speech perception, potential benefits are not unanimously shown across studies. One novel approach to boost rehabilitation in CI users is an improvisation-based musical training, Guided Audiomotor Exploration (GAME). As opposed to traditional score-based learning, improvisation-based training aims to engage dorsal cortical networks, which were previously linked to better speech outcomes after cochlear implantation. Thus, plastic changes brought about by the piano learning method could lead to improved central auditory processing in the speech domain as well as other near-transfer effects in the music domain. We present a three-arm randomized controlled study with a music training group, an active control training group and passive control group. We will present preliminary training-effect data speech-on-speech outcomes from 26 participants across three groups. We will further discuss the impact of heterogeneity among cochlear implant users and what influence this may have on interpreting findings.

Th47: 3D PRINTED COCHLEA MODEL FOR ELECTRODE INSERTION BENCH TEST

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Insertion force is one of the core criteria for evaluating a new cochlear implant electrode. This insertion force is directly linked to trauma of the soft tissue inside the cochlea, especially the delicate basilar membrane. Different studies have shown this effect and the link between forces and trauma. A normal insertion in a fresh temporal bone generates a reaction force of approximately 50-100mN, while abnormal insertions (uncomplete, fold over, basal kink) have increased forces of 150-200mN or more.

We have developed a test bench that is able to measure minute forces with a resolution of 0.1mN (0.1% of measured value) for our experiment force range of 0-100mN.

The testbench was equipped with a 3D printed cochlea, obtained by using a high precision stereolithography printer (SLA) with 20µm precision in all axis (x, y, z). The cochlea model consists of a hollow canal mimicking a scala tympani in a transparent bloc of polymer. The obtained accuracy is lower than 50µm in all dimensions. We verified the geometry with a 3D microtomography scan.
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Our digital workflow allows to transform any Dicom file into a highly accurate STL file (Chord height ≈1µm), with our Oticon Medical proprietary software Nautilus, and send it for 3D printing.

Th48: CONTROLLED CURVATURE ELECTRODE ARRAY WITH IONIC ELECTRO ACTIVE POLYMER-BASED MICRO-ACTUATORS FOR COCHLEAR IMPLANTATION

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During cochlear implantation, standard electrode arrays (EA) are surgically inserted to stimulate the auditory nerve and rehabilitate hearing in deaf patients. They are generally made of a silicone carrier and multiple iridium platinum electrode contacts. Due to their stiffness and passive nature, the insertion into the tympanic ramp by the surgeon, may result in trauma or incomplete insertion. In this work, we developed an original steerable EA for efficient insertion. This implant prototype has a tunable stiffness by adapting the thicknesses of materials and structures used. We propose a structure of the implant in three parts: the stimulation EA microfabricated with thin films, a module to make the implant active and a polymer holder micro-molded. The stimulation EA is a SU-8 negative photoresist with a density of 20 electrode contacts along a 25mm in length. The neutral line is used to run the 10µm wide gold tracks. Each site comprises a 0.45mm×0.40mm square gold electrode to maximize the stimulating surface. With a total thickness of 14µm the new EA stiffness is 0.6µN/µm at 2mm, which is 100 times lower compared to traditional EAs. Electrochemical properties and their influence on charge densities for safe neural stimulation limits of the fabricated electrodes were investigated. The charge injection and storage capacity were calculated for geometric and electrochemical surface area of the electrodes. Electrochemical Impedance Spectroscopy measurements were performed at 1Hz to 1MHz range, and impedance and phase values were obtained with respect to frequency domain.

In addition, we wish to control the curvature of the implant in the cochlea during its insertion using electronic conducting polymer (ECP) based micro-transducers able to bend under low electrical voltage stimulation. A trilayers based on Poly(3,4-ethyledioxythiophene): poly (styrene sulfonate) (PEDOT:PSS) as ECP is used to achieve a flexible beam where three micro-transducers are distributed and are able to work in air or in ionic liquid. The monolithic unit comprise the remote gold connections in contact with the bottom and top addressable ECP electrodes. Compared to state of the art, this new approach allows the fabrication of the smallest microbeam size for an ECP based micro-transducers fully integrated.

U-shape holders have been obtained with two methods: conventional metallic molding tool for MED-4750 PDMS injection, and with microfabricated SU-8 mold for polydimethylsiloxane (PDMS). Small reservoirs inside the PDMS have been added and filled with SU-8 in order to add rigidity along the thrust axis while keeping bending flexibility thanks to the PDMS reservoir separations. Note also that SU-8 added prevents the PDMS carrier from folding like an accordion. A successful insertion in the 3D printed cochlea model with an angle of 450° has been achieved obtaining a force peak around 30 mN. This novel prosthesis has the potential to improve control during the insertion, minimize friction forces, and reduce the risk of trauma during cochlear implantation.

Th49: OTICON MEDICAL RESEARCH TOOLS – PRACTICAL EXAMPLES OF THEIR UTILIZATION

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Oticon Medical (OM) R&T team provides a set of research tools to assist researchers to design and perform experiments with users of our cochlear implant (CI). These tools can be used either independently or combined to perform complex experimentation. In this work we briefly present some of our research tools and show examples of their use in different experiments. The Oticon Medical Experiment Platform (OMEXP) is a Python-based software platform, forked from the Opensesame project, that works as a sequencer, in which the researcher designs the experiments by adding and configuring plugins. Currently available plugins include audio calibration and mixing, standard adaptive procedures, HINT tests, pupillometry tools, among others. Generic Python code can be executed within the experiment, introducing more flexibility. With the OMEXP the experimental sequence is e xecuted automatically. The full OMEXP is provided as proprietary software, however a limited open-source version is also available.

Oticon Medical Research Platform (OMRP) is a hardware interface that can be used to acquire audio in 4 channels and to simultaneously control up to two OM cochlear implants by permitting direct communication with the implants to send stimuli and collect implant data. It can be used to study different types of pulses, with timing resolution up to 0.5µs, as well as stimulation strategies in a safe manner. OM-MHA (Master Hearing Aid) plugin collection is a set of proprietary MHA plugins with the basic blocks of OM signal processing stimulation strategies, as well as drivers for the OMRP. These can be used to test different parameter configuration and new signal processing features, either in real-time or by streaming pre-processed sequences of stimuli. Usually, MHA runs in a dedicated computer, to prevent the audio processing from being interrupted. The full OM research toolset also includes two other components that were not used in the experiment described in this work but are worthy to be mentioned: the Field Research Platform (OMFRP) designed to perform ecological momentary assessments; and the Virtual Reality Platform (OMVRP) for simulating visual and acoustic scenarios.

Recently, these tools have successfully been used together to evaluate OM's new stimulation strategy, CueTracker, in partnership with the University of Salamanca . A study protocol encompassing a variety of tests including word and sentence intelligibility, melodic contour recognition, pupillometry measurements, among others. The OMEXP controlled the experiment execution, comprising the selection and playing of audio files. The audio was directly transmitted to the audio input of OMRP and was processed in real-time by MHA according to the strategy configured with OM-MHA plugins. The OM-MHA drivers controlled OMRP to send the respective stimuli to the implant. Closing the loop, OMEXP gathered and stored the experiment results. The same toolset will be used in a future study on the influence of pulse rate and electrode location on pitch perception and frequency discrimination, also with the University of Salamanca . Here again, OMEXP will automate the experiment execution, controlling, for example, parameter adjustments and the production of stimuli to be presented to the user. OM-MHA plugins will receive from OMEXP the control commands and the required stimuli, that, differently from the experiments described above, are sequences of pulses to be executed by specific electrodes at precise timing. OM-MHA will then drive the OMRP to stimulate the CI user accordingly. Results data collection ad storage will be totally controlled by OMEXP as well.

In summary, OM has a set of research tools that can be employed in combination. This toolset allows for the execution of different experiments with CI users, ranging from testing completely new strategies with regards to speech and music perception, to basic research at electric pulse level, such as in the planned study on the effects of pulse timing in pitch perception and frequency discrimination.

Th50: DEVELOPMENT OF 32-CHANNEL COCHLEAR IMPLANT

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For decades, there have been efforts to make affordable CI systems with safety and efficacy. However, approches using manufacturable and automated process accompanies problems in biocompatibility qualification and manufacturing yield, respectively.

In this study, authors introduce 32-channel cochlear implant system for clinical use. Electrode array comprising of electrodes and lead wire is micro-machined at once on platinum-iridium film which have been used as raw material for commercial cochlear electrode array for 40 years. The team also have developed 32-channel stimulator and receiver ASIC with novel I-DAC technology which adjusting amplitude resolution to C-T level of each channel.

For clinical application, implant circuits and components are packaged in Ti6Al4V alloy cavity and platinum-ceramic feedthrough using brazing and laser-welding. Authos use commercial hearing-aid audio processor to minimize additional development cost. Developed CI system have gone through GLP-compliant tests for safety-qualification.

Authors expect this study can make progress for widespread use of cochlear implant in the world.

Th51: VISUALIZATION SYSTEM FOR REAL-TIME MONITORING OF ELECTRODE ARRAY INSERTION INTO THE HUMAN COCHLEA

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BACKGROUND
Cochlear implants (CIs) have been a significant breakthrough in the treatment of hearing loss, restoring speech understanding in individuals with partial and complete deafness [1]. One of the critical steps in CI surgery is the insertion of the electrode array into the cochlea because it determines the effectiveness of the electrical stimulation pulses delivered to the auditory nerve.

Although CIs are one of the most successful neural prostheses, the surgery for inserting the electrode poses a risk due to the complex anatomy of the inner ear, the delicate structures involved, and the variations in the anatomy between and within people. If the insertion trajectory of the electrode in the cochlea does not perfectly match the shape of the scala tympani (ST), the electrode can traumatize the thin walls of the ST or even translocate into one of the other two compartments (the scala vestibuli or the scala media). As a result, it can cause several complications such as inflammation and the potential for loss of residual hearing [2].

In recent years, atraumatic electrode insertion has received increased interest among CI surgeons and researchers in order to optimize hearing preservation. Although there are several monitoring techniques that can facilitate the insertion procedure, such as impedance and insertion forces measurements, cone-beam computed tomography, fluoroscopy, electrocochleography recordings, and optical coherence tomography; the surgeon relies primarily on tactile feedback to determine the trajectory of the insertion. Nevertheless, increased resistance can only be detected after the electrode has already touched the cochlear wall, potentially causing trauma [3]. Furthermore, most of these methods do not provide information on the actual position of the electrode inside the ST with respect to the cochlea walls at risk for trauma.

In the present study, we describe a visualization system that can be integrated into a cochlea electrode array, providing real-time video streaming of the cochlea inner structures during the insertion procedure.

METHODS
The visualization system includes a microcamera and a module for post-processing the images acquired, which are then sent to a computer to display. This allows for real-time monitoring and analysis of the images and provides a high level of accuracy and detail in the visualization process.

The micro-camera used in our design is the OVM6948 (Omnivision, USA). It integrates image array, signal processing, timing, and control circuitry, all on a single chip. It measures 0.65 mm x 0.65 mm with a z-heigh of 1.16 mm and has a resolution of 200 x 200 pixels. It is capable of capturing high-quality images and video at up to 30 frames per second. Despite its small dimension, the image sensor features advanced imaging technology, including microlenses and back illumination, which helps to improve image quality and sensitivity in low light conditions. Moreover, the camera chip is designed to be power efficient, with a low power consumption of 25 milliwatts, making it suitable for use in battery-powered devices such as CIs.

The micro-camera is merged with the tip of a conventional electrode array (Advanced Bionics, USA) and it is inserted into human cadaveric cochlea bones and 3D-printed models of the human ST.

RESULTS AND CONCLUSIONS
The device testing is ongoing. Images of the scala tympani can be recorded, and the path of the electrode can be monitored. To determine the mechanical properties of the electrode with the micro-camera at the tip, insertion forces are determined in the acrylic model of the human scala tympani. Insertion forces are comparable for electrodes with and without the camera .

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Th52: A NOVEL PROTOTYPE: THE HYBRID OPTO-ELECTRICAL COCHLEAR IMPLANT FOR HEARING RESTORATION

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BACKGROUND: Deafness and hearing loss are widespread in the world. At the moment, more than 1.5 billion people live with hearing loss. By 2050, nearly 2.5 billion people are projected to have some degree of hearing loss and at least 700 million will require hearing rehabilitation [1].

Implantable devices, such as cochlear implants (CIs) can help people with this disability. While CIs are widely implemented, their technology based on electrostimulation exhibits low spatial precision due to the current spreading in the cochlea. The interaction between neighbouring CI electrode contacts reduces the number of independent stimulation channels, thus affecting sound perception. Various methods have been developed to increase the number of independent channels for stimulation, including placing CI electrodes closer to the neurons and implementing multipolar stimulation to direct the electrical current towards the neurons. However, these approaches have not yielded significant advancements in CIs performance

An innovative method for neurostimulation involves using light, which has the potential to trigger responses from small groups of neurons, showing a spatial selectivity comparable with that of acoustical stimulation [2]. Optical stimulation, specifically infrared neurostimulation (INS), offers a promising solution to enhance CIs, without the need for prior genetic incorporation of light-sensitive molecules.

The integration of INS into a CI represents a promising advancement in the field of auditory neuroprosthetics. Yet, the successful implementation of this technology requires the consideration of various features, such as the number of electrical and optical stimulation channels, energy requirements, size of the CI, coding strategies, and efficient light delivery systems. The development of a hybrid opto-electrical CI (oeCI) represents a significant step towards overcoming these challenges. In this work, we describe a prototype of a hybrid oeCI.

METHODS: Our implant prototype has 24 electrical channels and 18 optical channels. Aiming to have a small implant, we chose a 6-layers design (board dimension 3.5x3.5 cm^2). The top layer accommodates two electrical drivers comprising 24 current stimulators capable of delivering pulses up to 2.5 mA. The bottom layer contains three optical drivers that offer output currents switching from constant to pulsatile mode (1 kHz). The outputs can switch light sources between different current levels defined by input voltages. These inputs are controlled by an integrated circuit containing 18 digital-analog converters (DACs). Both the electrical and optical drivers are governed by an ultra-low power 32-bits microcontroller.

To deliver light along the cochlea, we produced a bundle of waveguides, each comprises of a polymer core named OrmoComp and a polyimide cladding. Prior studies have measured the mechanical properties, including stiffness and insertion forces, of individual waveguides. In the present study, we will evaluate these properties for a bundle.

RESULTS AND CONCLUSIONS: The device testing is ongoing. A preclinical study will be conducted verifying the methodology and the prototype of the implant. Further experiments will analyze different cladding and core materials to reduce the propagation and bending losses of the waveguides. Moreover, we are developing an optical charge recovery system and channel blocker for safety considerations, which shortens the unused optical channels.

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Th53: OPTICAL PROPERTIES OF THE HUMAN COCHLEA BONE

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BACKGROUND: Optical stimulation has been proposed to offer superior benefits compared to electrical stimulation, due to its ability to directly excite neurons without contact and with high spatial precision. This enhanced precision allows for the activation of discrete and independent populations of neurons, resulting in a more precise control of neural firing patterns [1]. Light propagation in tissues is determined by optical properties of absorption and scattering, both being wavelength-dependent. These two events are quantified by the absorption (μa) and the scattering (μs) coefficients. These variables are defined such that, when a photon propagates over an infinitesimal distance ds, the probability for absorption and scattering is μa×ds and μs×ds, respectively. Because biological tissues are complex turbid media (multiple scattering events [2]), the spot size of the optical radiation at the target structure and the energy delivered to the target, can be affected by these properties. As a result, the decrease in spatial precision may nullify the advantage of optical stimulation over electrical stimulation.To better predict the neural population in the cochlea that will be stimulated using certain optical parameters (wavelength, optical power and beam profile), it is important to characterize the optical properties in the human cochlear bone, in the visible (for optogenetics) and near-infrared (for infrared neurostimulation) wavelengths, which are poorly explored in literature.

METHODS: To determine the optical properties of the human cochlea bone, we will use the Inverse Adding-Doubling method (IAD) [3] and several cochlea samples with thicknesses ranging 300 to 1000μm. The IAD is an iterative procedure that generates the optical properties of a slab-layered material when three parameters are provided: the measured transmittance MT (light transmitted by the sample normalized by the incident light), the measured reflectance MR (light reflected by the sample normalized by the incident light) and the measured unscattered transmittance MU (light passing through the sample without being scattered or absorbed normalized by the incident light). To determine these parameters, the cochlea sample is fixed in an integrating sphere (IS200, Thorlabs, USA). For the MT, the sample is positioned at the entrance port, which allows the forward scattered light to enter the sphere. For the MR, the sample is placed at the output port in order to diffuse the back scattered light in the sphere. For the MU, diaphragms with small apertures are located along the beam in order to filter out photons deviating from the straight path. Light of several wavelengths (450-1550 nm) illuminates the sample and the output of the sphere is connected to a powermeter. For the MU, photons passing the cochlea bone are collected with a multimode optical fiber.

RESULTS AND CONCLUSIONS: The study is ongoing. With the scattering and absorption coefficients, we will work in a model that will provide insights on light distribution in the cochlea bone, of importance in optical neurostimulation and neuromodulation.

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Th54: CODING STRATEGY FOR OPTO-ELECTRICAL HYBRID COCHLEAR IMPLANT

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Frequency-modulated phase coding is a novel strategy to encode acoustic information in future opto-electrical hybrid cochlear implants. The software controls pulse duration, amplitude, timing, and pulse rate. Compared to the already-approved methods on the market, the FMPC aims to increase performance for speech, speech-in-noise, and music perception.

Frequency selection: From the resulting gammatone-like spectrogram, a subset of frequency bands is selected. The number of frequency bands depends on the placement of the cochlear implant electrode and the width of the continuous frequency band. It is determined dynamically by the location of an electrode contact along the cochlea.

The decision to generate a pulse: The product of two terms, PowerProb*PhaseProb is compared with a random number (rnd) of the interval 0≤rn≤1, which is generated with a random number generator. A pulse is generated if this random number is smaller than the number calculated from the normalized rate and the phase. Wide frequency bands are stimulated electrically, and small frequency bands optically, where an electrical pulse is used to lower the threshold of the optical stimulation.

PowerProb: Intensity mapping depends on five critical parameters: the spontaneous rate (a0), maximum rate (a1), the threshold for stimulation (a2), level for nonlinear behavior (a3), and a value describing the slope after the level for nonlinear behavior (a4). While parameter a0 shifts the curve towards larger values, a1 limits the rate to the number selected. The threshold has significant effects on the mapping. Low threshold values result in a rapid increase in the rate and quick saturation, whereas large threshold values slow the rise but limit the maximum achievable rate. Smaller effects are seen from the parameters a3 and a4. The selected values for a0=0 and a1=1 limit the rate R to the interval 0≤R≤1. The input for the equation, the sound level p, is calculated from the acoustic power in each bin along a row of the gammatone-like spectrogram. In the present study, the length of one bin corresponded to 272 µs.

PhaseProb: Temporal fine structure mapping: In single auditory nerve fiber recordings, the probability for another action potential is maximum at integer numbers of cycles following the last action potential after an action potential is generated. Our code has been developed similarly. PowerProb is then modified by multiplying it by PhaseProb, a number of the interval (0≤PhaseProb≤1)*w_phase. The multiplier w_phase is a factor that can increase or decrease the phase effect. Initially, w_phase is selected to be 1.

Results: Pulse pattern map the intensity profiles seen in the spectrogram. Optical pulses are only produced for selected frequency bands. Pulse distribution is Poisson-like, with average pulse rates of about 150 Hz, with a range of up to 3,000 Hz.

Conclusions: Performance in humans will be tested once the first opto-electrical hybrid cochlear implant is available.

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Th55: 1606: IN-SILICO EVALUATION OF SOUND ENCODING OF OPTOGENETIC COCHLEAR IMPLANTS

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Electrical cochlear implants (eCIs)—the most successful neuroprosthetic devices so far—partially restore hearing in about a million people worldwide. The eCI users, though they obtain good speech perception in quiet environments, struggle to understand speech-in-noise. This limitation is majorly caused by the wide spread of current in the cochlea which leads to broad neural excitation limiting the number of perceptually independent frequency channels. A possibility to reduce the spectral spread and to increase the number of independent channels is to advance towards optogenetic cochlear implants (oCIs).

The optogenetic stimulation of the cochlea relies on channelrhodopsin (ChR) transduction of spiral ganglion neurons (SGNs) and requires a dedicated sound coding strategy. This project aims to assist the development of clinical oCIs by building a computational framework for their in-silico evaluation. It enables (a) running optical sound coding strategies, (b) predicting the light spread in a human cochlea using an optical ray-tracing model, (c) studying the response to light of SGNs transfected with ChR, (d) decoding neural activity following the optogenetic SGN activation, and (e) using objective intelligibility measures on the processed sound to evaluate coding strategy.

This modular framework can compare different coding strategy parameters, light emitter profiles, and ChRs. The spectral spread using optical stimulation was found to be lower than that with electrical stimulation. The effect of emitter-to-neurons distance and orientation, and the formation of scar tissue, were studied, highlighting directions for developing oCIs and soft surgery maintaining cochlear condition. The intelligibility results focus on the higher frequency resolution and lower time resolution of the oCIs. Overall, the model-based framework assists the development of oCIs and enables comparing them with state-of-the-art eCIs.

Th56: ROBOT-ASSISTED ELECTRODE ARRAY INSERTION FOR COCHLEAR IMPLANTATION: TECHNIQUE NOTE AND 3-YEAR REVIEW

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Objective: To explore the technique note, surgical and audiological outcomes of robot-assisted electrode array insertion during cochlear implantation in a single medical center.

Methods: We conducted a retrospective analysis of patients who underwent cochlear implantation in our department from October 2019 to December 2022. The study included four types of cochlear implants from three brands: Cochlear peri-modiolar arrays (CI512), and Med-EL, Nurotron lateral wall arrays (CS-10A TM, TL). The lateral wall arrays were inserted using the robot-assisted technique totally, while peri-modiolar arrays were inserted using a combination of robot-assisted and manual (semi-assisted AOS) techniques. Based on preoperative and postoperative imaging, a three-dimensional reconstruction was performed to analyze the scalar location of the intracochlear array.

Results: Robot-assisted technique was applied in 87 ears for cochlear implantation without any intra-operative and post-operative complications. The first 6 cases that underwent unilateral robot-assisted technique and contralateral classic technique showed similar mastoidectomy size in both ears. Additionally, the small cavity of infantile cases was found to be sufficient to accommodate the robot tools. In the 50 bilateral CI cases, the occurrence of scalar shift or translocation with robot-assisted technique appeared to be less, and the MCL at 1 year also appeared to be lower with robot-assisted technique, but further analysis with more cases is required.

Conclusion: The present study demonstrates that robot-assisted technique can be safely and effectively used in the insertion of electrode arrays during cochlear implantation. This technique offers the advantage of more minimally invasive insertion and potentially better auditory outcomes. Further studies with larger sample sizes and longer follow-up periods are needed to confirm these findings.

Th57: DEVELOPMENT OF NOVEL STIMULATION STRATEGIES AND TECHNIQUES FOR DIRECT ELECTRICAL STIMULATION OF THE AUDITORY NERVE USING A PENETRATING ELECTRODE ARRAY

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Background: Intraneural electrical stimulation of the auditory nerve with a penetrating electrode array can activate auditory nerve fibers more selectively and with reduced current spread compared to scala tympani stimulation using a cochlear implant (CI). A penetrating array also allows direct contact with low frequency fibers that are challenging to stimulate using a CI, due to the CI not being able to fully reach into the apical region of the cochlea. Leveraging these advantages, intraneural stimulation can potentially provide more accurate transmission of spectro-temporally complex signals such as human speech or music. Implementation of an auditory nerve implant (ANI) could help address common problems faced by CI users, such as difficulty hearing in the presence of background noise or in situations involving multiple speakers. The present work features further characterization of auditory nerve activation in the guinea pig model. Ultimately, we seek to develop new stimulation strategies that account for the unique activation properties and tonotopic organization seen in the auditory nerve as compared with the cochlea.

Methods: Prior to auditory nerve implantation, a 32-channel electrode array was implanted in the central nucleus of the inferior colliculus (ICC). Placement of the array was verified through stimulus response maps generated via presentation of acoustic stimuli (pure tones, 1-40kHz, 0-70dB SPL). A 16-channel electrode array was then implanted in the modiolar portion of the auditory nerve of ketamine-anesthetized guinea pigs. Electrical stimulation waveforms consisted of charge-balanced, biphasic pulses of varying current levels (20µA to 120µA), polarities (cathodic-first vs. anodic-first), and pulse widths (40µs/phase to 100 µs/phase). Differing electrode configurations (monopolar vs. bipolar) were also tested. Electrical tuning curves were generated for each stimulation site, which were used to determine the best frequency (BF) activated by each site.

Results: Electrical tuning curves showed significant differences in frequency activation when electrode configurations were changed. During bipolar stimulation, the activated frequency region in the ICC was more restricted (indicating reduced current spread) but also exhibited higher thresholds for activation as compared with monopolar stimulation. Depending upon relative placement of the two bipolar sites, the frequency regions most strongly activated were shifted towards higher or lower frequencies. The BF activated by each site varied with placement of the stimulating electrode in different portions of the nerve. In certain placements, electrical tuning curves for some sites showed simultaneous activation of both high and low frequency regions, indicating that those sites were in a portion of the auditory nerve in which high and low frequency fibers ran in close proximity to each another.

Conclusions: Bipolar stimulation can potentially be used to more precisely target specific frequencies during intraneural stimulation. This approach may lead to more accurate transmission of frequency information and possibly improved perception of complex sounds, especially in noisy environments. Our future experiments will involve stimulation using multiple shank electrode arrays that will allow for a more comprehensive sampling of the nerve’s frequency space. We also plan to explore multi-site stimulation strategies that will enable more broad-spread frequency activation without utilizing high current levels that can lead to unwanted current spread to non-targeted frequencies.

Th58: ZWITTERION MODIFIED COCHLEAR IMPLANTS RESIST POSTOPERATIVE INFECTION AND INFLAMMATION.

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The cochlear implant (CI), a high-tech electronic device replacing the entire cochlear function, is the primary treatment for over 466 million people with disabling hearing loss. Infection after CI is a common and worrisome complication despite the routine administration of the antibiotic. The reason for the poor effect of antibiotics infection is the formation of bacterial biofilms on the surface of CI. To solve this problem, we developed a copper-containing zwitterionic coating, which consisted of anti-adherent poly sulfobetaine methacrylate (PSB) and stable polydopamine (PDA). CuSO4/H2O2. Was added to accelerate this co-deposition reaction and enhance the anti-bacterial property. The preparation method was simple, rapid and suitable for clinical use. Using S.aureus and P.aeruinosa, the representative Gram-positive and Gram-negative bacteria of CI infection, in vitro and a mouse model, we showed that PSB/PDA(Cu) coating had high biocompatibility, excellent anti-inflammatory, strong anti-bacterial effects, and anti-biofilm properties. These results suggest that PSB/PDA(Cu) coating is a novel strategy for anti-bacterial to improve the outcomes of CI.

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