Newcastle University
Institute of Neuroscience

British Society of Audiology
Promoting excellence in hearing and balance

BSA BASIC AUDITORY SCIENCE 2018

3rd – 4th September

Newcastle University

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GN

PHONAK life is on

Welcome to BAS 2018

A warm welcome to Newcastle upon Tyne and to this year's BSA Basic Auditory Science meeting. This book contains all the information you need to get the best possible experience at the meeting. However, if at any point you require assistance please don't hesitate to ask a member of the organising committee.

We follow the tradition of previous meetings with a single poster session over two days interspersed by four sessions of talks. We have divided the poster time to allow breaks between oral presentations and plenty of time for interaction. We have also suggested times, designated by poster number, when presenting authors should be at their posters. We hope this gives presenters more opportunity to see the other posters and to engage with one another.

The meeting has always been a great venue for students and early career researchers. Generous financial support from Sonovo/Phonak has enabled us to continue that tradition by subsidising student attendance and funding the student poster prizes. The posters will be judged over the course of the first day, and the awards will be made during the conference dinner, giving you the chance to view the winning posters the next day. We are grateful to our illustrious panel of judges, Brian Moore, Alan Palmer and Ian Winter, for giving their time to assess the posters.

We are delighted that the BSA Ted Evans Lecture is returning to Basic Auditory Science. This year's lecture, generously supported by the GN Store Noord Foundation, will be given on Tuesday by Professor Andrew King. Andy is well known to many of us, as are his contributions to auditory neuroscience. This year he was honoured by election to the Royal Society, so it is highly appropriate that we in the auditory community should honour him in the same year.

We hope you enjoy your stay in this great northern city. The meeting takes place in the final week of the Great Exhibition of the North, and one of the venues for the exhibition, the Discovery Museum, is opposite the meeting hotel. So if you want to see Stephenson's Rocket and other engineering marvels that emerged from the industrial crucible of the North East, now's your chance!

Once again, a very warm welcome to the 'Toon', and we hope that you enjoy the meeting.

Adrian, Ann, Bas, Hannah & Sasha

Meeting overview

Organising committee
Adrian Rees
Ann Fitchett
Bas Olthof
Hannah Maxwell
Sasha Gartside

Information online:
All information regarding the meeting is at: **https://conferences.ncl.ac.uk/bas2018**

Venue
The venue for the meeting is the Armstrong Building, Newcastle University, NE1 7RU (See map)

Registration
The registration desk will be in the entrance hall to the King's Hall and will be open from 08.30. Please register when you arrive and collect your badge and abstract book. Coffee and tea will be available in the registration area.

Posters: Kings Hall, Ground floor Armstrong Building.
All posters will be shown continuously during the meeting. So presenters get a chance to see the other posters, we have suggested times at which presenters should be at their posters: even numbers on Monday afternoon and odd numbers on Tuesday morning. The time at which the presenter will be at their poster is marked above each abstract in this book, but presenters are of course free to be at their posters at other times.

Poster boards will hold posters up to size A0 in portrait orientation. Please ensure you use the correct board number for your poster. You will be provided with sticky Velcro disks to attach your poster to the board. Please do NOT use any other means of attachment!

Refreshments will be available in the final 30 minutes of each poster session in the vicinity of the King's Hall.

Posters entered in the competition will be judged by Brian Moore, Alan Palmer and Ian Winter.

Posters competing for the student poster prizes are marked by this symbol

Talks: Spence Watson Lecture Theatre, 2nd floor, Armstrong Building.
Take the main staircase in the entrance hall. The lecture theatre is immediately to your left on the second floor. There is also a lift from the ground floor.

Talks will be 15 minutes in duration + 5 minutes for questions. Chairs will be asked to keep talks strictly to time, please assist them by keeping to these limits. We would prefer you to use our computer for your talk if you can, but you can bring your own laptop if you wish. To allow for swift transitions between talks, speakers are requested to see Bas Olthof in the hour before your session is due to begin to upload your slides, or test that your own device connects.

Lunch & Refreshments: Rm 2.13, 2nd floor Armstrong Building
Lunch and refreshments during breaks between talks sessions will served be in a room on the second floor on the other side of the staircase. During poster sessions refreshments will be served in or around the King's Hall. Lunches are included in your registration fee.

Dinner: Monday 3rd Sept. Chandelier Room, The Assembly Rooms, Fenkle Street, NE1 5XU. (See map)
Dinner will be served at 19.30. Wine or a choice of soft drinks is included with your meal, and more will be available for purchase. There will also be a cash bar available from 19.00 before dinner and after dinner until midnight. Please bring your badge to the dinner as it serves as your ticket. Dinner has been ordered according to the dietary preference you expressed when you registered for the meeting. Please do not deviate from that choice otherwise there may not be enough of the right food for others! The poster prizes will be awarded during dinner.

Pre-dinner drinks.
Should you wish to meet people for a drink before dinner, there are several places near the Assembly Rooms:

Tilley's Bar, 105 Westgate Rd, Newcastle upon Tyne NE1 4AG. Excellent real ale pub.

The Forth Hotel, Pink Lane, NE1 5AJ.

The Old Town Wall, Pink Lane, NE1 5HX.

Pink Lane Coffee, 1 Pink Lane, NE1 5DW. Excellent coffee house, serving coffee from their own roastery. Open 7.30am -6pm

Pubs and cafes
Near the Armstrong Building:
The Trent House, 1-2 Leazes Lane, NE1 4QT. Good real ale pub. Bar with a pool table upstairs.

Bar Loco, 22 Leazes Park Rd, NE1 4PG. Lively bar with seating outside.

The Strawberry, 7-8 Strawberry Pl, NE1 4SF. Opposite St James's Park. Now with roof terrace! A must for any Newcastle fans!

Le Petit Choux, 11 Leazes Cres, NE1 4LN Coffee shop & patisserie owned by 'a mum and her two daughters'. Everything hand made on the premises. Open: 7.30am-4pm

Quilliam Brothers' Tea House, 1 Eldon Place, NE1 7RD. Popular location serving a huge variety of teas, accompanied by cakes and snacks. Open: 10am-Midnight

Accommodation:
Holiday Inn Express Newcastle City Centre, Waterloo Square, NE1 4DN
The hotel (see map) is a short 10-15 min walk from the university, and 10 minutes from the Assembly Rooms

Conference venue

Armstrong Building, NE1 7RU, Newcastle upon Tyne

Transport information

Getting to Newcastle

By Train
Central Station is a 20-minute walk from the university through the city centre. There is a metro station at Central Station and the nearest station to the university is Haymarket (5 min journey, 5 min walk to the Armstrong Building). See below for more information about the Metro.

By Car
Parking is not generally available on campus, but there are spaces for people with limited mobility, please contact us beforehand if you need such space.

The nearest city car parks are:

Claremont Road car park (NE2 4AA) nearest public parking to the Armstrong Building. £1.30 per hr from 08.00-18.00. No time limit. Get there early, it fills up quickly.

Grainger Town Multi-storey (NE1 4EU) nearest to Holiday Inn Express. £1.00 per hr from 08:00 - 17:00 max £6.00. No time limit

Details of all car parks: https://community2.newcastle.gov.uk/apps2/car-parks or https://en.parkopedia.co.uk; All car parks accept coins and phone payments, some accept debit and credit cards.

By Air
Newcastle Airport is about 25 minutes from the city centre by taxi or metro. There is a metro station at the airport and the line goes to Haymarket, the nearest station to the university. You need an All Zones single ticket, price £3.40. The travel time assumes normal traffic, please allow plenty of time for your journey back to the airport!

By Metro
Metro trains run frequently during the day. The service starts around 05.45 and stops about 23.30. Single tickets are valid for 90 minutes, day passes are valid all day long, on the day of purchase. Tickets need to be purchased before entering the platform and can be bought by designated ticket machines which accept cash, all major credit and debit cards as well as Apple pay.

By Taxi (private hire)

Blueline Taxis 0191 262 6666

Five Star Taxis 0191 222 0555

Noda Taxis 0191 222 1 888

Uber also operates in Newcastle

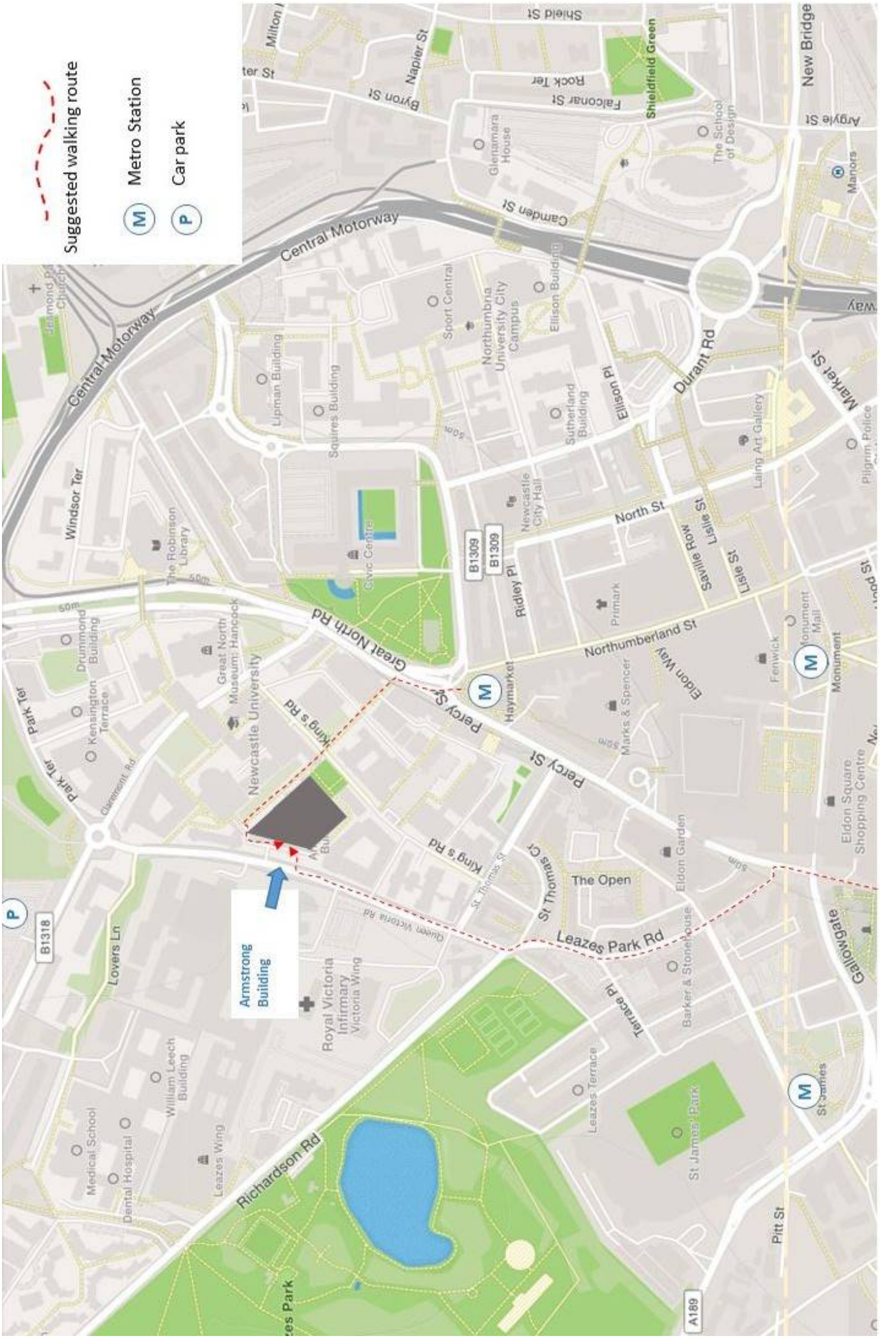
By Bus

Bus tickets can be purchased on board from the driver, only single or full day tickets are available. Tickets can be purchased using cash and contactless debit and credit cards.

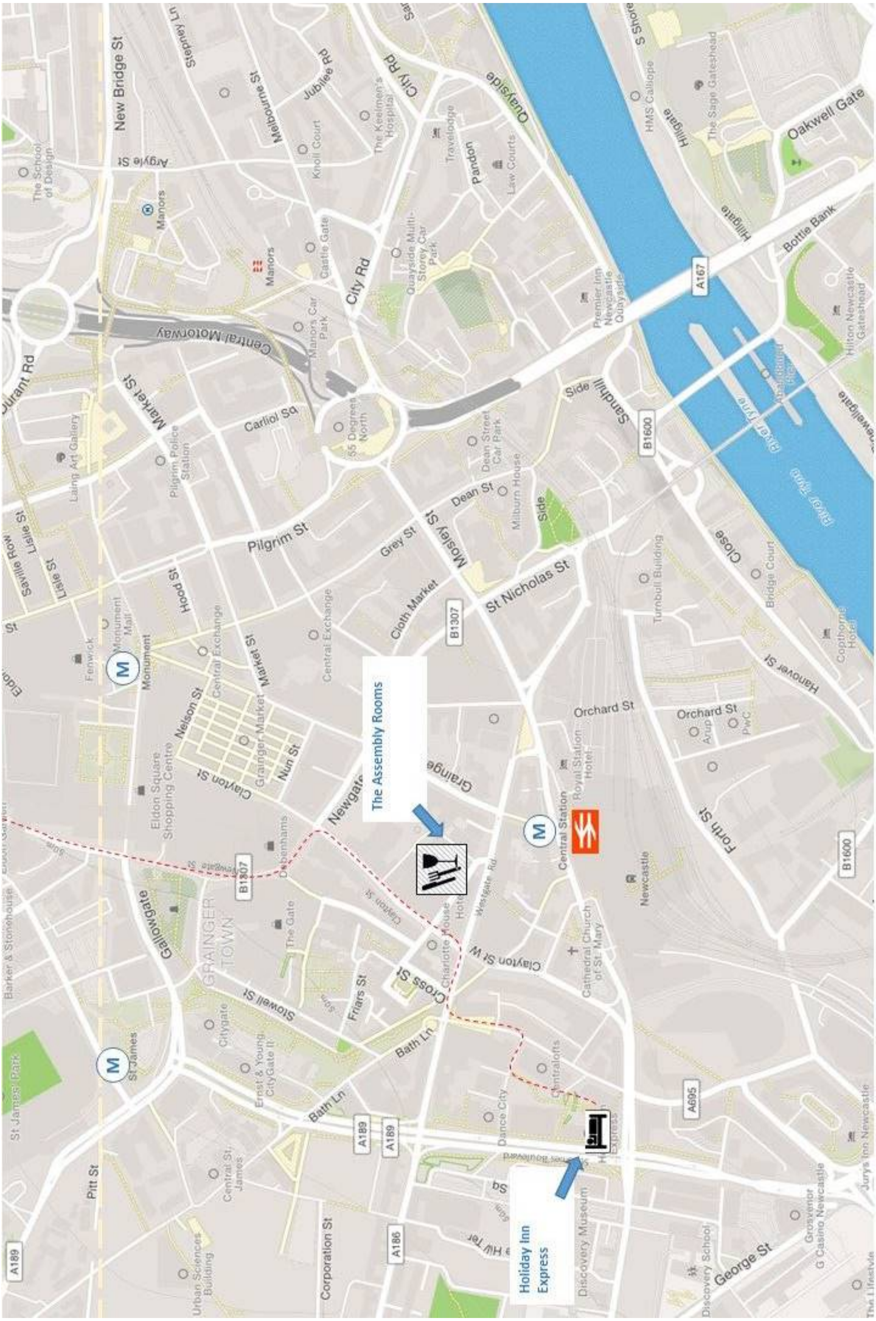
By Mobikes

You may see bright orange Mobikes around the city, these are available to hire and are dockless. Download the app, pay a £15 (returnable) deposit and enjoy 30 minutes of cycling for 50p. After use they can be left in any safe and convenient place.

x | City Map



Suggested walking route
Metro Station
Car park
Armstrong Building
Central Motorway
Great North Rd
Percy St
King's Rd
Leazes Park Rd
Queen Victoria Rd
Richardson Rd
Newcastle University
Great North Museum: Hancock
Civic Centre
Haymarket
Northumberland St
North St
Ridley Pl
Saville Row
Lisle St
Eldon Way
Eldon Garden
Eldon Square Shopping Centre
Monument
Monument Mall
Fenwick
Primark
Marks & Spencer
Laing Art Gallery
Durant Rd
Market St
Manors
New Bridge
Argyle St
Shieldfield Green
Falconar St
Rock Ter
Shield St
Byron St
Napier St
Camden St
Glenamara House
The School of Design
Northumbria University City Campus
Sport Central
Ellison Building
Ellison Pl
Sutherland Building
Squires Building
Lipman Building
Newcastle City Hall
B1309
The Robinson Library
Windsor Ter
Drummond Building
Kensington Terrace
Park Ter
Claremont Rd
Lovers Ln
B1318
Medical School
Dental Hospital
William Leech Building
Leazes Wing
Royal Victoria Infirmary Victoria Wing
St Thomas St
St Thomas Ct
The Open
Terrace Pl
Barker & Stonehouse
Leazes Terrace
St James' Park
St James
Gallowgate
Pitt St
A189
Jesmond Parish Church


The Assembly Rooms
Holiday Inn Express
New Bridge St
Central Motorway
Market St
Pilgrim St
Grey St
Mosley St
Dean St
St Nicholas St
Cloth Market
Grainger Market
Clayton St
Newgate
Grainger
Westgate Rd
Central Station
Royal Station Hotel
Orchard St
Forth St
Hanover St
Quayside
City Rd
Sandhill
Side
Close
Bottle Bank
Oakwell Gate
Hillgate
Gallowgate
Stowell St
Bath Ln
Corporation St
Pitt St
George St
Monument
St James
Eldon Square Shopping Centre
Discovery Museum
B1307
B1600
A167
A189
A186
A695

DAY ONE

Monday September 3rd 2018

08:30 – 09:15	**Registration ground floor Armstrong Building**
08:30	**Coffee, tea and refreshments**
	Poster presentations in King's Hall, Armstrong Building
09:15 – 11:00	**Poster Session 1**
10:30	**Coffee, tea and refreshments**
	Talks Session 1: Spence Watson Lecture, Theatre Armstrong Building **Chair: Lore Thaler**
11:00 – 11:05	**Adrian Rees** Welcome
11:05 – 11:25	**Emma Holmes** 'Normal' hearing thresholds and figure-ground perception explain significant variability in speech-in-noise performance
11:25 – 11:45	**Sara M. K. Madsen** Speech perception in noise and speech is similar for musicians and non-musicians in more ecologically valid environments
11:45 – 12:05	**John F. Culling** The effects of ceiling height and absorber placement on speech intelligibility in simulated restaurants.
12:05 – 12:25	**Rob Summers** Across-ear integration of acoustic-phonetic information under competitive conditions: Effects of attenuation increase in the presence of an extraneous formant
12:25 – 12:45	**Samuel Smith** Concurrent-vowel identification: machine recognition of the complete neural representation predicts human perception
12.45 – 13.40	**Lunch break: Rm 2.13, Armstrong Building**
13:40 – 15:00	**Poster Session 2 (even numbers presenting)**
14:30	**Coffee, tea & refreshments**

DAY ONE

Monday September 3rd 2018

Talks Session 2: Spence Watson Lecture Theatre, Armstrong Building Chair: Jennifer Linden & Llwyd Orton	
15:00 – 15:20	**Ian M. Winter** Where two become one: the representation of binaural pitch in the superior olivary complex.
15:20 – 15:40	**Llwyd Orton** Hyperexcitability with reduced vascular and axonal innervation as correlates of auditory cortical dysfunction in the A30P mouse model of dementia with Lewy bodies
15:40 – 16:00	**Jane Mattley** Opposite abnormalities in gap-in-noise sensitivity in the auditory midbrain and thalamus of a mouse model of developmental disorder
16:00 – 16:20	**Jennifer F. Linden** Hearing loss, auditory sensorimotor gating deficits, and cortical interneuron abnormalities in a mouse model of 22q11.2 Deletion Syndrome
16:20 – 16:40	**Yukiko Kikuchi** Predictive auditory sequence learning modulates inter-regional oscillatory coupling in human intracranial recordings
Business Meeting: Spence Watson Lecture Theatre, Armstrong Building	
16:45 – 17:30	**Business Meeting**
Pre-drinks & Dinner	
19:00 – Midnight	**Dinner and drinks at The Assembly Rooms**

DAY TWO

Tuesday September 4th 2018

Poster presentations in King's Hall, Armstrong Building

08:40 – 10:00 **Poster Session 3 (odd numbers presenting)**

08:40 **Coffee, tea and refreshments**

Talks Session 3: Spence Watson Lecture Theatre, Armstrong Building

Chair: Hedwig Gockel

10:00 – 10:20 **Jacques A. Grange**
Cochlear implant sound coding inspired by speech statistics.

10:20 – 10:40 **Tobias Goehring**
Effect of a Site-Selection Strategy based on Polarity Sensitivity on Spectro-Temporal Resolution and Speech Perception by Cochlear Implant Users

10:40 – 11:00 **Judith Okely**
Longitudinal associations between hearing and cognitive abilities in the Lothian Birth Cohort 1936

11:00 – 11:20 **Chris Plack**
Reliability and interrelations of proxy measures of cochlear synaptopathy

11:20 – 11:40 **Coffee break in poster area**

Ted Evans Lecture: Spence Watson Lecture Theatre
Armstrong Building

11:40 – 12:40 **Andrew J. King FMedSci FRS**
The Adaptable Auditory System

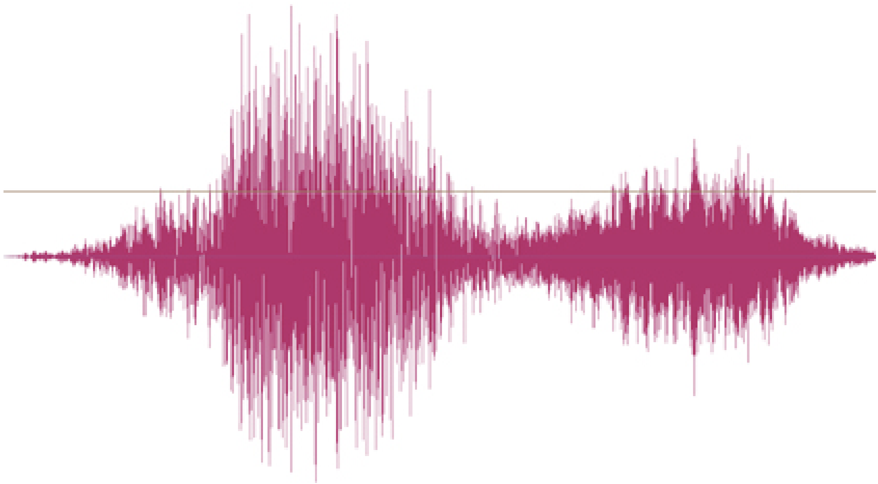
12.40 – 13.40 **Lunch break: Rm 2.13 Armstrong Building**

DAY TWO

Tuesday September 4th 2018

Talks Session 4: Spence Watson Lecture Theatre, Armstrong Building Chair: Chris Plack	
13:40 – 14:00	**Florian Doleschal** Comodulation masking release with randomly fluctuating flanking bands
14:00 – 14:20	**Hedwig Gockel** Detection of mistuning in harmonic complex tones at high frequencies
14:20 – 14:40	**Liam Norman** Human echolocation: Evidence for predictive coding of emission spectral content, but not emission intensity or temporal onset
14:40 – 15:00	**Roberta Bianco** Implicit learning of patterns in rapid sound sequences: behavioral evidence.
15:00 – 15:20	**Brian C.J. Moore** The (lack of) effect of musical training on frequency selectivity
15:20 – 15:30	**Adrian Rees** End of meeting
15:30	**Coffee, tea and refreshments**

Oral Presentations



Talks Session 1

T.01 'Normal' hearing thresholds and figure-ground perception explain significant variability in speech-in-noise performance

E. Holmes[1], T.D. Griffiths[1,2]

[1]Wellcome Centre for Human Neuroimaging, UCL, London, U.K.; [2]Institute of Neuroscience, Newcastle University, Newcastle upon Tyne, U.K.

Speech-in-noise (SIN) perception is a critical everyday task that varies widely across individuals and cannot be explained fully by the pure-tone audiogram. One factor that likely contributes to difficulty understanding SIN is the ability to separate speech from simultaneously-occurring background sounds, which is likely not well assessed by audiometric thresholds. A basic task that assesses the ability to separate target and background sounds is auditory figure-ground perception. Here, we examined how much common variance links speech-in-noise perception to figure-ground perception, and how this relationship depends on the properties of the figure to be detected.

We recruited 96 participants with normal hearing (6-frequency average pure-tone thresholds < 20 dB HL). We presented sentences from the Oldenburg matrix corpus (e.g., "Alan has two old sofas") simultaneously with multi-talker babble noise. We adapted the target-to-masker ratio (TMR) to determine the participant's threshold for reporting 50% of sentences correctly. Our figure-ground stimuli included one based on Teki et al. (2013) in which each 50 ms time window contains random frequency elements; participants were required to detect certain elements (the "figure") that remained fixed for 300 ms. We also tested figures of longer duration that changed in frequency over time, mimicking the formants of speech. Participants had to discriminate gaps that occurred in the "figure" or "background" components—a task that cannot be performed based on global stimulus characteristics. We adapted the TMR to determine the participant's 50% threshold for discriminating gaps in the figure-ground stimuli.

Average audiometric thresholds at 4-8 kHz accounted for 15% of the variance in SIN performance, despite recruiting participants with hearing thresholds that would be considered clinically 'normal'. Figure-ground performance explained a significant portion of the variance in SIN performance that was unaccounted for by variability in audiometric thresholds.

These results in normally-hearing listeners demonstrate that SIN performance depends on sub-clinical variability in audiometric thresholds. In addition, the results show that we can better predict SIN performance by including a measure of figure-ground perception alongside audiometric thresholds. Importantly, the results support a source of variance in speech-in noise perception related to figure-ground perception that is unrelated to audiometric thresholds, consistent with previous work demonstrating cortical contributions to both speech-in-noise and figure-ground perception. These results highlight the importance of considering both central and peripheral factors if we are to successfully predict speech intelligibility when background noise is present.

Acknowledgements
This work was supported by funding from the Wellcome Trust (WT091681MA) and the National Institutes of Health (NIH; DC000242-31).

References
Teki, S., Chait, M., Kumar, S., Shamma, S.A., & Griffiths, T.D. (2013). eLife, **2**, 1–16.

T.02 Speech perception in noise and speech is similar for musicians and non-musicians in more ecologically valid environments

Sara M.K. Madsen[1], Marton Marschall[1], Torsten Dau[1] and Andrew J. Oxenham[2]

[1] Hearing Systems Group, Department of Electrical Engineering, Technical University of Denmark Ørsteds Plads, Building 352, 2800 Lyngby, Denmark ; [2] Department of Psychology, University of Minnesota, 75 East River Parkway, Minneapolis, MN, 55455, USA

Several studies have measured speech perception in noise and competing speech in non-musicians and highly trained musicians to investigate the effect of musical training, but the results have been inconclusive. Most studies find little or no benefit of musicianship. Nevertheless, two recent studies found a sizeable musician advantage in conditions where the target and two natural speech maskers were separated by ±15° in azimuth (Clayton et al., 2016; Swaminathan et al., 2015). These studies used highly similar speech signals from a closed-set matrix test for both the target and masker, did not include reverberation, and used average head-related-transfer functions to simulate spatial separation, which can limit externalisation. It is not clear if the musician advantage observed generalizes to more natural situations.

The present study attempted to replicate the earlier findings and to extend them using more realistic speech material in conditions with and without reverberation. The target and two speech or noise maskers were either colocated or spatially separated by ±15° in azimuth. The speech experiments were conducted in a large anechoic chamber using a virtual sound environment with a spherical array of 64 loudspeakers. The study also measured F0 discrimination limens (F0DLs), interaural time difference limens (ITDLs), and attentive tracking (Woods and McDermott, 2015) in a double-walled acoustically shielded booth. Sixty-four young listeners (32 musicians and 32 non-musicians) were tested. The two groups were matched in age, gender, and IQ as measured with Raven's Advanced Progressive Matrices.

The musicians exhibited enhanced F0DLs, ITDLs and better attentive-tracking abilities. However, there was no musician advantage in any of the speech perception tasks, providing no evidence that musicians are better at understanding speech in more ecologically valid situations. It is not clear why it was not possible to replicate the previous results, but the difference may be related to the large within-group variability observed in both the present and previous studies.

References

Clayton, K. K., Swaminathan, J., Yazdanbakhsh, A., Zuk, J., Patel, A. D., and Kidd, G. (2016). PLoS One, 11, 17

Swaminathan, J., Mason, C. R., Streeter, T. M., Best, V., Kidd, G., and Patel, A. D. (2015). Sci Rep, 5, 1.

Woods, K. J. P., and McDermott, J. H. (2015). Curr. Biol, **25**, 2238–2246.

T.03 The effects of ceiling height and absorber placement on speech intelligibility in simulated restaurants.

John F. Culling, Rada Gocheva, Yanyu Li, Nur Kamaludin

School of Psychology, Cardiff University, Tower Building, Park Place, Cardiff, CF10 3AT, U.K.

The intelligibility of speech was measured in simulated rooms with parametrically manipulated acoustic features. In Expts. 1 and 2 binaural room impulses were generated using a simple ray-tracing model for rectangular spaces. In order to simulate more complex geometries, including representations of furniture and room occupants, Expts. 3 and 4 used CATT Acoustic™. The rooms were designed to simulate restaurant environments with either three or nine occupied tables. In Expt. 1, rooms of equal total absorbance were compared, but with most absorption located either on walls or on the ceiling. Wall absorption produced shorter reverberation times and improved speech reception thresholds (SRTs). In Expt. 2 rooms differed in ceiling height. Lower ceilings produced shorter reverberation times but *poorer* SRTs. Both total absorbance and reverberation time were thus poorly correlated with speech intelligibility. A psychoacoustic model of spatial release from masking (Jelfs et al., 2011) produced very accurate predictions of SRTs, based on the binaural room impulse responses for each expt. (r=0.96, r=0.99). Expt. 3 also varied ceiling height, but in combination with the effect of ground-level acoustic clutter, formed by furniture and room occupants. As predicted by the model (r=0.97), both high ceilings and acoustic clutter produced better SRTs. Expt. 4 compared acoustic treatments of the ceiling in the presence of the acoustic clutter. As predicted by the model (r=0.99), continuous acoustic ceilings were more effective at improving SRTs than suspended panels, and suspended panels were more effective if they were acoustically absorbent on both sides. The results suggest that the most effective control of reverberation for the purpose of conversational intelligibility is provided by absorbers placed vertically and close to the room occupants.

References

Jelfs, S., Culling, J.F., & Lavandier, M. (2011) Hear. Res., 275, 96–104

T.04 Across-ear integration of acoustic-phonetic information under competitive conditions: Effects of attenuation increase in the presence of an extraneous formant

R.J. Summers and B. Roberts

Psychology, School of Life and Health Sciences, Aston University, Birmingham B4 7ET, UK

Speech perception depends on the integration of acoustic-phonetic information across frequency and time and, in some circumstances, across ears. Previous research using consonant-vowel syllables in which one ear receives the first formant (F1) and the other receives the second and third has shown that dichotic release from masking allows F2 and F3 to remain effective speech cues even after substantial attenuation (Rand, 1974).

This study used three-formant analogues of open-set natural sentences and extended the approach to include competitive conditions. Target formants were presented dichotically (F1+F3; F2), either alone or accompanied by an extraneous competitor for F2 (i.e., F1±F2C+F3; F2) that listeners must reject to optimize recognition. In experiment 1, F2C was absent and F2 was attenuated in 6-dB steps (range: -6–48 dB). Consistent with Rand (1974), intelligibility was largely unaffected until attenuation >30 dB and F2 still provided useful information at 48-dB attenuation. In experiment 2, F2 was attenuated in 12-dB steps (range: 0–36 dB). F2C was created by inverting the F2 frequency contour and using the F2 amplitude contour without attenuation. When F2C was present, 12-dB attenuation was sufficient to cause some loss of intelligibility; the effect was large when attenuation ≥24 dB. This interaction suggests that some mandatory across-ear spectral integration occurs, such that informational masking arising from F2C rapidly swamps the acoustic-phonetic information carried by F2 as its relative level is attenuated.

There are some parallels with how listeners integrate formant ensembles with mixed source properties – e.g., our ability to use the acoustic-phonetic information carried by a sine-wave formant may be impaired greatly by the presence of a buzz-excited competitor in the other ear (Roberts et al., 2015; Summers et al., 2016). Together, these findings suggest that stimulus context may be critical to our ability to integrate relevant acoustic-phonetic information, and to overcome interference, even in situations where that information is available (unmasked) in the peripheral response.

Acknowledgements
Supported by ESRC (Grant number ES/N014383/1).

References

Rand, T.C. (1974). J Acoust Soc Am, **55,** 678-680.
Roberts, B., Summers, R.J. & Bailey, P.J. (2015). J Exp Psychol Hum Percept Perform, **41,** 680-691.
Summers, R.J., Bailey, P.J. & Roberts, B. (2016). J Acoust Soc Am, **140,** 1227-1238.

T.05 Concurrent-vowel identification: machine recognition of the complete neural representation predicts human perception

S.S. Smith[1,2]; A. Chintanpalli[3]; M.N. Wallace[1,2]; A. Hockley[1,2]; M.G. Heinz[4]; C.J. Sumner[1,2]

[1]MRC Institute of Hearing Research, University of Nottingham, Nottingham, UK.; [2]Hearing Sciences, Division of Clinical Neurosciences, School of Medicine, University of Nottingham, Nottingham, UK.;[3]Department of Electrical and Electronics Engineering Birla Institute of Technology & Science, Pilani-333 031, Rajasthan, India.; [4]Weldon School of Biomedical Engineering, Purdue University, West Lafayette, IN 47907, USA.

An increasing difference between the fundamental frequencies (F0) of concurrently presented vowels improves their identification, denoted an 'F0 benefit'. The classical model of this observation is able to replicate an 'F0 benefit' only qualitatively (Meddis & Hewitt, 1992) and requires temporal processing unverified in neurophysiological studies. Moreover, the model makes deterministic decisions resulting in very poor predictions of listener confusions. Significant flaws in this model, and within other attempts (Micheyl & Oxenham, 2010), imply we do not understand how listeners solve this simple instance of the 'cocktail party problem'.

We present our model of concurrent-vowel identification. The model optimally compares presented neural responses to stored templates using a high-dimensional naïve Bayes classifier, returning a confusion matrix. These templates describe the integrated representations of each concurrent-vowel pair, combined over all F0s. This contrasts with previous models that assumed a segregation process separated out individual vowel representations based on F0 differences, followed by a comparison with templates of individual vowels.

When spectro-temporal neural responses are simulated from a 'linear' recreation of the auditory nerve, the model can qualitatively and quantitatively replicate an 'F0 benefit'. This is despite having no explicit temporal processing of F0 cues. Simply, when there are larger F0 differences between vowels there is more information available for classification. Additionally, the model makes quantifiable predictions of listener confusions with a high degree of accuracy ($R>0.9$).

The model's generality allows it to also handle neural responses recorded in vivo. Using multi-channel electrodes in the guinea pig inferior colliculus we recorded spiking activity in response to each concurrent-vowel pair. When only mean firing rates were made available, the model again predicted confusion patterns strikingly similar to human listeners. By providing spike timing information (PSTH bins≤10ms), the model's performance improves with increasing F0 difference.

Overall, our model is much closer to predicting human performance at the concurrent-vowel identification task than previous models. The work promotes the use of ideal observer principles to develop our understanding of how listeners solve the 'cocktail party problem'.

References

Meddis, R. & Hewitt, M.J. (1992) JASA, **91**, 233-245
Micheyl, C. & Oxenham, A.J. (2010) Hear. Res., **266**, 36-51

Talks Session 2

T.06 Where two become one: the representation of binaural pitch in the superior olivary complex.

Sami Alsindi[1], Roy D. Patterson[1], Arek Stasiak [1], Mark Sayles[2] Ian. M. Winter[1]

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Many vibrating objects, including the vocal apparatus and musical instruments, produce sounds which evoke pitch percepts. Animals may exploit this perceptual dimension to parse multi-source acoustic environments. Representations of simple pitch-evoking sounds exist in neural activity throughout the auditory pathway, from cochlea to cortex. Therefore, defining the critically important neural sub-populations underlying pitch is challenging. Binaural-pitch percepts are *not* generated by either ear alone, but rather emerge *within* the brain. However, their neural substrate is unknown. To begin the search for such a substrate we have chosen to record the responses of single units in the superior olivary complex (SOC).

Data were obtained from normal-hearing (based on round-window cochlear action potential thresholds), anaesthetised and normothermic, pigmented guinea-pigs (*Cavia porcellus*). Experiments were performed in accordance with the Animals (Scientific Procedures) Act 1986 (Amendment Regulations 2012) following ethical review by the University of Cambridge Animal Welfare and Ethical Review Body. Glass-insulated tungsten microelectrodes were positioned at the surface of the dorsal cochlear nucleus under operating-microscope control, and advanced para-sagittally through the brainstem at 45° to the horizontal plane using a hydraulic microdrive. We collected spike times in response to several pitch stimuli. These included: dichotic complex tones (one tone in each ear, with a fixed frequency difference between them), dichotic harmonic tone complexes, diotic iterated rippled noise (Gaussian noise delayed and added back to itself [comb filtering], identical in both ears), and dichotic repetition pitch (Gaussian noise with a small inter-aural time difference between the two ears).

We also recorded the responses of single units in the SOC to simple stimuli. We can readily identify the responses of the four principal ascending nuclei as described in other species and we are therefore confident that the guinea pig is a suitable model for studying this region. We found units that represent the binaural pitch of a variety of sounds in their temporal discharge patterns. Our data highlight that the SOC is useful for more than sound-source localisation in terms of changes in firing rate.

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T.07 Hyperexcitability with reduced vascular and axonal innervation as correlates of auditory cortical dysfunction in the A30P mouse model of dementia with Lewy bodies

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Hearing impairment has recently been shown to be associated with all types of dementia, yet the nature of the relationship between these two conditions is under investigated. Non-motor features of dementia with Lewy bodies (DLB) include auditory hallucinations in a third of patients. Hallucinations have previously been associated with cortical gamma oscillations (30-80 Hz). We employed a mouse model of DLB that over-expresses human mutant α-synuclein (A30P), known to lead to familial DLB, to investigate possible changes in gamma oscillations and cortical excitability. Kainate (0.4-1mM) induced oscillations in auditory cortex in slices from A30P mice had a faster peak oscillatory frequency than slices from wild type control mice at both 3 (young) and 12 months of age (adult), with adult oscillation power being lower than young in both groups. Concentration-dependent increases in kainate and $GABA_A$ receptor antagonist GABAzine showed greater excitability in aged A30P slices, with ictal discharges being common in this group. Confocal imaging of multi-channel fluorescence immunohistochemistry found phosphorylated α-synuclein (P129-αSYN) in primary sensory cortical pyramidal neurons, but not association areas, in young and adult samples, with strongest P129-αSYN+ cell density in layer II/III of auditory cortex in adults. Intriguingly, we found a reduction in auditory cortex capillarisation and external capsule myelination in adult A30P compared to other groups. Taken together these data demonstrate age-dependent increases in auditory cortex hyperexcitability related to pathological accumulation of human phosphorylated α-synuclein, which are associated with decreases in vascular and axonal integrity. These findings may provide mechanistic insights into auditory cortex dysfunction in DLB. Future work will attempt to replicate these findings in human patients and tissue donors.

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T.08 Opposite abnormalities in gap-in-noise sensitivity in the auditory midbrain and thalamus of a mouse model of developmental disorder

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The BXSB/MpJ-Yaa mouse is a powerful animal model for studying the neural mechanisms of gap-detection deficits. Around 30-50% of BXSB/MpJ-Yaa mice have small cortical malformations called ectopias. Previous work has shown that ectopic mice have more difficulty detecting very short gaps in noise than non-ectopic mice (Clark et al. 2000). Furthermore, minimum gap durations required to elicit significant changes in the activity of auditory thalamic neurons are longer in ectopic than non-ectopic mice (Anderson and Linden 2016). Moreover, sound-offset responses --- transient increases in firing at sound termination --- are less common in auditory thalamus of ectopic mice, suggesting the hypothesis that the abnormal thalamic gap-in-noise sensitivity might arise from a deficit in sound-offset responses (Anderson and Linden 2016).

To determine whether neural deficits in gap-in-noise sensitivity and sound-offset responses in the auditory thalamus of ectopic mice are inherited from the midbrain, we made extracellular recordings from the inferior colliculus (IC) in 10 ectopic and 10 non-ectopic BXSB/MpJ-Yaa mice. Mice were anaesthetised with urethane (as in the previous thalamic study), and neural responses recorded with 16-channel microelectrode arrays (Neuronexus). In contrast to the previous results from the lemniscal (primary) auditory thalamus, in IC we found that minimum gap durations for evoking responses to gap-in-noise stimuli were shorter in ectopic than non-ectopic mice, for neurons with V-shaped tuning curves typical of the lemniscal IC (rank-sum $p<0.001$; ectopic n=133 recordings, non-ectopic n=79). However, in agreement with previous thalamic results, we found that the proportion of cells with sound-offset responses in IC was significantly reduced in ectopic mice (9% in ectopic, 15% in non-ectopic across all IC recordings; Fisher's exact test $p=0.03$). These results indicate that the offset-response deficit in auditory thalamus of ectopic BXSB/MpJ-Yaa mice may be inherited from the IC. Moreover, the observation that in ectopic mice, minimum gap duration thresholds are abnormally high in auditory thalamic neurons but abnormally low in IC neurons suggests a critical role for midbrain and/or thalamic circuitry in development of gap-detection deficits.

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T.09 Hearing loss, auditory sensorimotor gating deficits, and cortical interneuron abnormalities in a mouse model of 22q11.2 Deletion Syndrome

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Children with the chromosomal microdeletion that causes 22q11.2 Deletion Syndrome (22q11DS) have a 25-30% risk of developing schizophrenia. An estimated 40-70% of patients with 22q11DS also have hearing loss, mostly from otitis media (OM). In the *Df1/+* mouse model of 22q11DS, similar rates of hearing loss and OM occur (Fuchs et al. 2013) and have been shown to arise from haploinsufficiency of the TBX1 gene within the minimum 22q11DS deletion region (Fuchs et al. 2015). However, the relationship between hearing loss and susceptibility to schizophrenia-relevant brain and behavioral abnormalities in 22q11DS is unknown. Here we report a link between hearing loss, deficits in auditory sensorimotor gating, and abnormalities in parvalbumin-positive auditory cortical interneurons in a mouse model of 22q11DS.

Using the auditory brainstem response (ABR), we found that 60% of *Df1/+* mice had hearing loss in one or both ears. However, suprathreshold cortical auditory evoked potentials (AEPs) were similar in *Df1/+* and WT mice. The ratio between AEP P1-N1 or N1-P2 amplitude and ABR wave I amplitude was significantly higher in *Df1/+* mice with hearing loss than in WT mice or *Df1/+* mice without hearing loss, suggesting an increase in central auditory gain in *Df1/+* mice with hearing loss.

Behavioural measures similarly revealed an influence of hearing loss. Acoustic startle response (ASR) thresholds were significantly higher in *Df1/+* than WT mice. Prepulse inhibition (PPI) of ASR was reduced in *Df1/+* mice relative to WT for prepulse cues with fixed sound level, as has previously been reported. However, there was no significant difference in PPI between *Df1/+* and WT mice when the prepulse cue sound level was adjusted to be constant relative to startle threshold for each animal.

Finally, in immunohistochemical studies, we found that the density of parvalbumin-positive (PV+) interneurons in the auditory cortex was significantly reduced in *Df1/+* compared to WT mice. This abnormality arose primarily in *Df1/+* mice with hearing loss, suggesting cortical compensation for loss of input. Overall, the results indicate that *Df1/+* mice have reduced hearing sensitivity and elevated startle thresholds, but also increased central auditory gain and reduced density of PV+ inhibitory interneurons in auditory cortex. Moreover, PPI of acoustic startle in *Df1/+* and WT mice differs for prepulse cues of fixed sound level, but not when the cue level is adjusted relative to startle threshold. Thus, the findings suggest a complex interaction between hearing loss and auditory brain and behavioural abnormalities in 22q11DS models.

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T.010 Predictive auditory sequence learning modulates inter-regional oscillatory coupling in human intracranial recordings

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Dynamic environments generate sequences of sensory events that affect brain oscillations at different frequencies. Moreover, feed-forward and feed-back interactions are evident in oscillatory phase and frequency interactions, yet little is known about how learning-related plasticity changes oscillatory dynamics in neural networks. Using intracranial recordings from both human and monkey auditory cortex, we had previously reported phase-amplitude coupling between low-frequency phase and gamma amplitude in auditory cortex after the learning of temporal relationships in sequences of speech sounds drawn from an Artificial Grammar (AG; Kikuchi et al., 2017). In the monkeys as an animal model, the prior results pointed to oscillatory influences on auditory cortex neurons emanating from other brain regions. Here, we sought to identify the sources of these influences using the extensive coverage with depth and grid recording electrodes offered by human intracranial recordings in epilepsy patients being monitored for surgery. We used the same AG learning paradigm as in the prior study, where participants were first exposed to representative rule-based sequences of nonsense words. In the subsequent testing phase, we presented the participants with sequences that were either consistent with the AG or contained specific violations of learned ordering relationships. Inter-regional phase interactions were measured by phase angle differences between recording sites weighted by the evolution of the transitional probabilities over all previously encountered sequences. Sequencing-related modulation of oscillatory phase coupling was observed between auditory cortex (Heschl's gyrus, HG) and a number of sites, including the hippocampus, lateral superior temporal gyrus, anterior temporal lobe and inferior frontal gyrus (IFG). Further analyses showed that frequency-specific phase coupling tracked the changes in transitional probabilities within three oscillatory bands (theta: 3-8 Hz, beta: 15-29 Hz, gamma: 40-100 Hz). Moreover, during initial learning, HG interacted with the hippocampus and IFG. A more extensive network was involved after the learning phase, with cortical network modulation in response to violations of the learned sequencing relationships involving a broader set of regions. Oscillatory phase-based coupling in human intracranial recordings provides insight into inter-regional neural interactions at different stages of predictive sequence learning, which refines hypotheses for further testing using monkeys as a model system.

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Talks Session 3

T.011 Cochlear implant sound coding inspired by speech statistics.

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Typically, cochlear implant (CI) processors analyse sound through a bank of evenly spaced filters on a log-frequency scale, before extracted temporal envelopes modulate the excitatory current passed through implanted electrodes. However, factor analysis (FA) shows that the information carried by speech modulations is distributed in bands whose width grows non-monotonically with frequency (Grange & Culling, 2018). Given that the spread of excitation (SOE) along the spiral ganglion limits the number of independent channels in CI users to eight or less (Friesen et al., 2001), optimizing transmission of information within those eight channels must be considered in the design of sound coding strategies. An FA-derived scree plot shows that seven channels should suffice to transmit most of the speech information, which might explain why speech-reception thresholds (SRTs) using a cochlear implant simulation without SOE improve markedly more slowly beyond seven channels.

The present study tests whether FA-inspired mapping might improve speech intelligibility. Simulations with normal-hearing listeners employed a pulsatile vocoder (Bräcker et al., 2009) and adaptively measured SRTs for two levels of SOE (200 and 8 dB/oct) x six numbers of channels (4, 5, 6, 8, 11, 22) x three mapping strategies. The first strategy (CIS) used a cochleotopic channel distribution and simulated electrodes aligned with the channel centre frequencies. The second and third strategies used FA-selected channels, with simulated electrodes selected from a fixed 22-electrode array; in the second (FA_w), selected electrodes were evenly and maximally spaced, thereby limiting channel interaction, but leading to spectral warping; in the third (FA_u), the selected electrodes were those with place frequencies closest to channel centre frequencies, leading to an almost unwarped electrode map.

Overall, simulating SOE significantly elevated thresholds and removed the significant benefit of additional electrodes seen without SOE. The FA_w strategy was far superior to CIS or FA_u, in that at the optimum 8-11 channels, FA_w SRTs with SOE equated CIS SRTs without SOE. With a simulated benefit in the 3-4 dB range, the FA_w approach appears very promising. Since an FA-inspired strategy is voice specific, the effect of voice differences on the efficacy of such a strategy remains to be established.

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T.012 Effect of a Site-Selection Strategy based on Polarity Sensitivity on Spectro-Temporal Resolution and Speech Perception by Cochlear Implant Users

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Thresholds of asymmetric pulses presented to cochlear implant (CI) listeners depend on polarity in a way that differs across subjects and electrodes. It has been suggested that lower thresholds for cathodic-dominant compared to anodic-dominant pulses reflect good local neural survival. We evaluated the hypothesis that this polarity effect (PE) can be used in a site-selection strategy so as to improve speech perception and spectro-temporal resolution. Detection thresholds were measured in 8 users of Advanced Bionics CIs for 80-pps, tri-phasic, monopolar pulse trains where the central high-amplitude phase was either anodic or cathodic. Two experimental MAPs were then generated for each subject by deactivating the five electrodes with either the highest or the lowest PE magnitudes (cathodic minus anodic threshold). Performance with the two experimental MAPs was evaluated using two spectro-temporal tests, STRIPES and SMRT, and with speech recognition in quiet and in noise. Performance was also measured with an experimental MAP that used all electrodes, similar to the subjects' clinical MAP. The PE varied strongly across subjects and electrodes, with substantial magnitudes relative to the electrical dynamic range. There were no significant differences in performance between the three MAPs at group level, but there were significant effects at subject level - consistent with previous reports of a large variability in CI users' performance, and in the potential benefit of site-selection strategies. The STRIPES but not the SMRT test successfully predicted which strategy produced the best speech-in-noise performance on a subject-by-subject basis. The average PE across electrodes correlated significantly with subject age, duration of deafness and speech perception scores, consistent with a relationship between PE and neural health. These findings motivate further investigations into site-specific measures of neural health and their application to CI processing strategies.

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T.013 Longitudinal associations between hearing and cognitive abilities in the Lothian Birth Cohort 1936

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Background
Cross-sectional and longitudinal findings have established a link between hearing impairment and cognitive function in later life, leading to the suggestion that hearing loss may be a potentially modifiable risk factor for cognitive decline. However, the direction and specificity of the association between auditory and cognitive health remains unclear.
Methods
Using longitudinal data from the Lothian Birth Cohort 1936, we tested whether premorbid cognitive ability, measured in childhood, is associated with later-life hearing ability, and, whether this link confounds associations between auditory and cognitive health in later life. In addition, we tested whether the strength of association between hearing and cognitive ability level (at age 76) and change (between age 76 and 79) varies as a function of cognitive domain (verbal memory, crystallised ability, processing speed and visuospatial ability).
Results
We found some evidence that childhood cognitive ability is negatively associated with hearing impairment risk at age 76; however, this association did not survive correction for multiple testing. The most consistent association between cognitive and hearing abilities, assessed in older age, was between higher crystallised ability at age 76 and lower risk of hearing impairment at age 76 (age and sex adjusted estimate: -0.137, p = 0.001). The magnitude of this effect was reduced following adjustment for childhood cognitive ability, and was non-significant in the fully adjusted model, which additionally included demographic factors, smoking status and history of chronic disease.
Conclusion
In addition to providing further evidence of a link between cognitive and auditory health in later life, our findings illustrate that this association may, in part, be confounded by cognitive abilities at earlier life stages.

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T.014 Reliability and interrelations of proxy measures of cochlear synaptopathy

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Noise exposure can destroy synapses between inner hair cells and auditory nerve (AN) fibres, without widespread loss of hair cells or elevation of cochlear thresholds (Kujawa and Liberman, 2009). Termed 'cochlear synaptopathy', this pathophysiology has been observed directly in a variety of animal models (Kujawa and Liberman, 2015), but investigations in living humans rely on proxy measures of AN function. Numerous procedures have been developed, typically based on the auditory brainstem response (ABR), envelope-following response (EFR), or middle-ear muscle reflex (MEMR). Some metrics correlate with synaptic survival in animal models, but translation between species is not straightforward; measurements in humans likely reflect greater error and greater variability due to non-synaptopathic sources (Hickox et al., 2017). The present study assessed the reliability of seven measures, as well as testing for correlations between them.

Thirty-one audiometrically normal young women underwent repeated measurements of ABR wave I amplitude, ABR wave I growth with level, ABR wave V latency shift in noise, EFR amplitude, EFR growth with stimulus modulation depth, MEMR threshold, and an MEMR difference measure.

Intraclass correlation coefficients (Shrout and Fleiss, 1979) indicated good-to-excellent reliability for the raw ABR and EFR amplitudes, and for all MEMR measures. The ABR and EFR difference measures exhibited poor-to-moderate reliability. No significant correlations, nor any consistent trends, were observed between measures.

Although the raw measures are reliable, showing low measurement error, the lack of correlation between measures provides no indication that they are dependent on the same underlying physiological processes, for example, cochlear synaptopathy. Hence, proxy measures of cochlear synaptopathy should be regarded with caution, at least when employed in young, normally hearing adults.

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Talks Session 4

T.015 Comodulation masking release with randomly fluctuating flanking bands

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Natural sounds often contain coherent envelope fluctuations in different frequency regions (Nelken et al., 1999), which may be used by the auditory system in complex sound mixtures to separate sounds from different sources. A psychoacoustic effect that supports this hypothesis is "Comodulation Masking Release" (CMR, e.g., Verhey et al., 2003, for a review). CMR describes the reduced masked threshold of a (sinusoidal) signal if the masker has coherent level fluctuations in different frequency regions compared to a condition without this comodulated frequency components.

A frequently investigated setting is the flanking-band paradigm in which a narrow band on-frequency masker (OFM) and one or more spectrally distant flanking bands (FBs) are presented simultaneously. The magnitude of CMR can be defined as the level difference between the masking situation with coherent envelope fluctuations of the masker bands and the situation with uncorrelated envelopes of the masker bands or the OFM alone.

In general, the centre frequency of the flanking bands in previous experiments remained constant over time. In this study, it is examined if CMR also appears if the centre frequencies of the FBs fluctuate randomly over time. One FB was spectrally above and one below the OFM. The fluctuation and the centre frequencies were either chosen on a relative or absolute frequency scale. Results for both spectral conditions indicate that the magnitude of CMR depends on the frequency range in which the FBs' centre frequency can fluctuate and the spectral distance between the OFM and centre frequencies of the FBs.

The results may provide further insights into the mechanisms underlying the processing of comodulated sounds and thus a further understanding of the object binding mechanisms in the human auditory system.

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T.016 Detection of mistuning in harmonic complex tones at high frequencies

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Lau *et al.* (2017) showed that thresholds for discriminating the fundamental frequency (F0) of harmonic complex tones containing only very high frequency components were quite low (at about 5%), even though the frequency discrimination of those components, when presented alone, was very poor (between 20-30%). They attributed this finding to the operation of central place-based pitch-sensitive neurons. Here, we first replicated measurement of the F0 discrimination thresholds (F0DLs) for diotic and dichotic stimulus presentation (odd harmonics in one ear and even harmonics in the other). Then, we probed the characteristics of the hypothesized pitch-sensitive neurons by measuring the detection of mistuning of a single harmonic in the stimuli.

We mistuned the 8th harmonic in complex tones containing harmonics 6-10 of an F0 of 1400 or 280 Hz with components presented either diotically or dichotically. The harmonics had random starting phases for each presentation. The level was 55 ±3 dB SPL for the inner components (harmonics 7-9) and 49 ±3 dB SPL for the edge components; the level randomization was independent across components and presentations. The tones were presented in a continuous threshold equalizing noise background with a level of 45 dB SPL/ERB_N at 1 kHz, via Sennheiser HD 650 headphones. Subjects had to have very good high-frequency hearing. Twenty five young musically trained subjects were tested, eight of whom (aged 20-28 years) passed the initial screening stages.

F0DLs were not significantly different between diotic and dichotic conditions for either the low or the high F0. This replicates Lau et al's finding and is consistent with the idea that F0 discrimination was not based on temporal envelope fluctuations. Mistuning detection thresholds for both F0s were very low in the diotic condition, consistent with listeners detecting peripheral interactions ("beats") between nearby harmonics, even in the high-frequency region where it has been proposed that auditory filters are narrower than commonly assumed. In the dichotic condition, subjects reported that, for the low F0, the mistuned component "popped out" and this led to good performance. For the high F0, no such effect was heard and performance was close to chance. Thus, if there are pitch-sensitive neurons at very high frequencies, they do not provide a basis for perceptual segregation based on mistuning. The results are compatible with the idea that phase-locking information is necessary for perceptual segregation of a mistuned component to occur.

Acknowledgements
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T.017 Human echolocation: Evidence for predictive coding of emission spectral content, but not emission intensity or temporal onset

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Motivation
A popular framework for understanding human brain function is predictive coding, according to which information is gained by comparing incoming events to expected events. In source hearing, for example, sounds are more accurately detected when their temporal onset or spectral frequency is predictable (e.g. Lawrance *et al,* 2014; Greenberg & Larkin, 1968). It is not understood, however, whether predictive coding plays a role in human echolocation. Echolocation differs from source hearing because information is not only carried by the echo itself, but also by acoustic relationships between emission and echo. Here we tested whether the predictability of the echolocation emission, in terms of temporal onset, intensity or spectral frequency, would improve echo detection. We also considered the effect of echolocation expertise by testing expert echolocators as well as newly trained sighed and blind people.

Methods
Participants listened to recordings of echolocation sounds via headphones and judged whether or not they heard an echo on each trial. In some trial blocks the emission remained the same (i.e. it was predictable), whereas in others it changed across trials (i.e. it was unpredictable) either in its temporal onset (within the range 0 – 2000 ms), intensity (in steps of 6 dB) or spectral frequency (in 500 Hz steps). Sounds had been obtained through binaural sound recordings (B&K 4101, Tascam DR-100 MK2, 96kHz, 24bit) in an anechoic room, with a loudspeaker (Fostex FE103En) producing artificially generated emissions (a 500 ms noise burst or a ~5 ms click). A wooden disk (50 cm diameter) was either positioned at a distance of 1, 2 or 3 m from the loudspeaker, or not present at all.

Results
Echo detection performance dropped when emission spectral content was unpredictable. In contrast, there was no effect of predictability of temporal onset or intensity. Effects were the same for both clicks and noise bursts. Expert echolocators performed better than both sighted and blind control groups, but all groups showed the same effect of stimulus predictability.

Discussion
All sounds were complex sounds containing emissions as well as echoes at various time delays and intensities (brought about by the three distances used to make the recordings). Thus, it was unlikely that participants used a simple low-level decision rule to detect the echo. Overall, these results suggest that during echolocation the human auditory system engages in predictive coding for spectral frequency of the emission, and this is not determined by expertise in echolocation.

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T.018 Implicit learning of patterns in rapid sound sequences: behavioral evidence.

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Learning reoccurring patterns in the acoustic environment is fundamental to sensory perception, and to optimize behavior. Recent findings show that the brain is highly sensitive to the emergence of regular patterns in rapidly evolving sound sequences and that this processes relies on memory processes in the hippocampus (Barascud et al., 2016). We sought to understand to what extent information about previously encountered patterns is stored by the brain. In a series of behavioral auditory experiments, participants were exposed to rapid sequences of 50 ms tone pips arranged in random to regular order, with the latter being cycles of 20 tones (1000 ms duration per cycle). We show that repeated exposure to regular patterns (targets) enhances the ability to detect them emerging from the random order. We obtained five main results. First, the reaction times to transitions from random to regular patterns show a remarkable learning effect after few re-occurrences of the targets (3 targets repeated 15 times). Second, implicit memory of the pattern, as reflected by heightened detection performance, persisted after 24 hours. Third, learning is however disrupted if the exposure phase is interrupted by blocks where targets are absent. Fourth, learning occurs also when listeners are exposed to different several reoccurring targets, and, fifth, even during passive listening. Together, these results indicate that seemingly irrelevant reoccurring patterns in the acoustic environment have an immediate effect on behavior through rapid learning and long-term memory consolidation. These findings implicate a rather high auditory memory capacity supporting rapid acquisition of knowledge about structure in temporally evolving sounds.

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T.019 The (lack of) effect of musical training on frequency selectivity

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It is widely believed that the frequency selectivity of the auditory system is largely determined by processes occurring in the cochlea. If this is the case, musical training would not be expected to influence frequency selectivity. Consistent with this, Fine and Moore (1993) estimated auditory filter shapes using the notched-noise method at a centre frequency of 1 kHz and found no difference in the sharpness of the filters for musicians and non-musicians. However, more recently, Bidelman et al (2014; 2016) reported that psychophysical tuning curves (PTCs) estimated using a fast method with a sweeping masker (Sek & Moore, 2011) at a centre frequency of 4 kHz were sharper for musicians than for non-musicians.

This study was conducted to explore the origin of the discrepancy across studies. It is possible that the results for the fast PTCs were influenced by the detection of beats and by off-frequency listening, and that musicians were more adept at selecting the most appropriate detection cues as the masker frequency changed. To assess this possibility, auditory filter shapes were estimated using three methods: fast PTCs; “traditional” PTCs obtained using several fixed masker centre frequencies (for which the optimal detection cues were stable within a run); and the notched-noise method (for which beat detection has little influence and off-frequency listening is limited). The discrepancy across studies might also reflect the difference in signal frequency. To assess this, all measures here were obtained using a signal frequency of 4 kHz. Ten musicians and ten non-musicians were tested.

For all methods, the data were fitted assuming that each side of the auditory filter had the shape of a rounded-exponential function. The sharpness of the auditory filters was estimated as the Q10 value (centre frequency divided by the bandwidth at the 10-dB down point). The results showed no significant difference between musicians and non-musicians in Q10 for any of the methods, but detection efficiency tended to be higher for the musicians. This is consistent with the idea that musicianship influences general auditory proficiency but does not influence the peripheral processes that determine the frequency selectivity of the auditory system.

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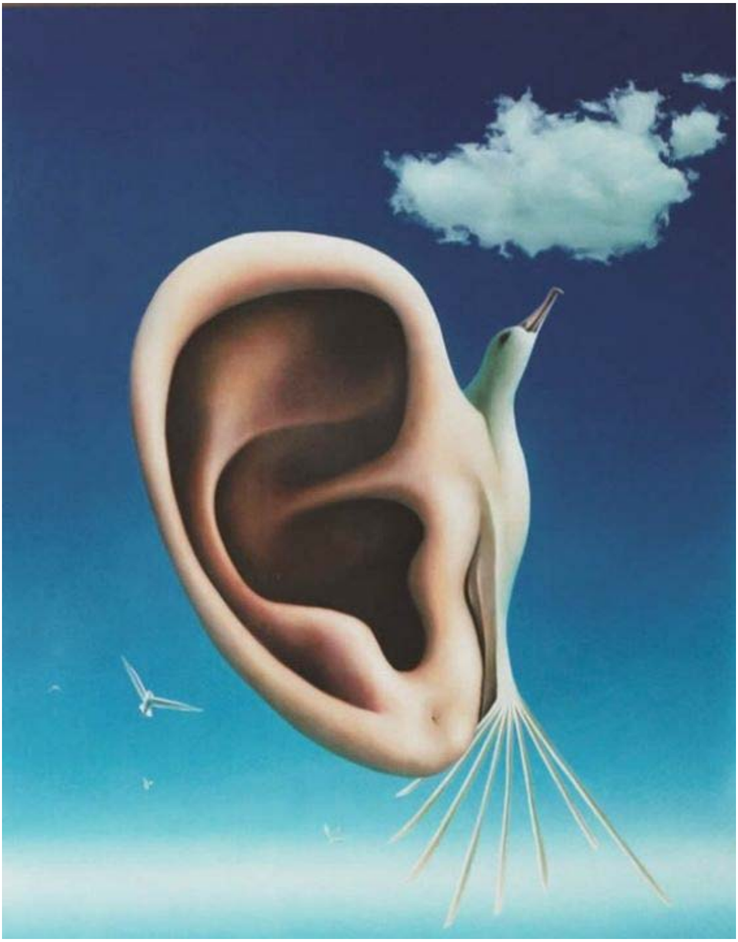
Poster Presentations



P.01 Active tracking of sound textures: a human intracranial study

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A network consisting of auditory cortex, hippocampus, and inferior frontal gyrus has been proposed to support auditory working memory (Kumar et al., 2016). However, human intracranial recordings are yet to reveal hippocampal high gamma activity, a neural spiking correlate, during memory for tones. Recordings from the rat hippocampal complex indicate that cells that support navigation can also form discrete firing fields for particular sound frequencies (Aronov et al., 2017). Critically, this is the case only when the animal adjusts a sound to match the frequency of a remembered target, but not during passive listening. For humans performing such a task, recruitment of navigation circuits may stem from a cognitive association between height in pitch and in physical space (Rusconi et al., 2006). Here, we study the neural underpinnings of memory for and tracking of sound textures that vary continuously in a single dimension but have no such spatial association. Subjects were patients implanted with electrodes to localize epileptic activity. Stimuli were concatenated chords, each containing between 4 and 100 simultaneous 200-ms tones randomly distributed in frequency over a 4-octave range. Fixing the number of simultaneous tones ("density") while varying their frequencies from chord to chord gave rise to textures that were more "beep"-like at lower densities and more "noise"-like at higher densities (these terms were used to describe the sounds to subjects in language that avoided spatial metaphors). In each active trial, subjects listened to a 2-s sound of fixed target density, which they were to remember over a subsequent 2-s retention period. They then heard a 15-s texture, the density of which they adjusted using button presses to match the density of the target. Preliminary analyses of sound-induced neural activity revealed robust (high) gamma responses in Heschl's gyrus and superior temporal gyrus, with concurrent low frequency (4-30 Hz) power decreases over a range of frontal, temporal, and parietal sites. (High) gamma responses were also observed in right hippocampus and right inferior frontal gyrus; these were greater during active adjustment than in a passive listening condition with similar auditory stimulation. Activity at one hippocampal site was also present during target presentation and the subsequent silent retention period. Ongoing work includes conducting motor/attention control experiments, and applying multivariate analyses to study the link between behaviour and the strength of target representations across the putative auditory working memory brain network.

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P.02 Changes in sensitivity to binaural temporal-fine-structure information as a function of audiometric threshold and age: A meta-analysis

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The ability to process binaural temporal fine structure (TFS) information, which influences the perception of speech in spatially distributed soundscapes, declines with increasing hearing loss and age. Due to the relatively small sample sizes used in previous studies (e.g. Füllgrabe et al, 2015), and the population-unrepresentative distribution of hearing loss and ages within study samples (e.g. King et al, 2014), it has been difficult to determine the relative and combined effects of hearing loss and age on binaural TFS sensitivity.

The aim of this study was to survey published and unpublished studies that assessed binaural TFS sensitivity using the TFS-Low Frequency (LF) test (Hopkins and Moore, 2017). Results from 19 studies were collated, yielding sample sizes of 147 to 648, depending on the test frequency (250, 500, 750 and 850 Hz). At least for the test frequency of 500 Hz, each of five adult age groups ("young adults": 18 to 39 years, "middle-aged adults": 40 to 59 years, "young-old adults": 60 to 75 years, "old-old adults": > 75 years) was well represented (with ≥ 67 data points) and the distribution of audiometric thresholds at the test frequency within each age group was similar to that for the population as a whole.

Binaural TFS sensitivity declined with increasing age across the adult lifespan and with increasing hearing loss in old adulthood. For all test frequencies, both audiometric threshold and age were significantly negatively correlated with TFS-LF sensitivity (with r varying from −0.19 to −0.64) but the correlation was always significantly higher for age than for audiometric threshold. Regression analyses showed that the standardized regression coefficient was greater for age than for audiometric threshold, and that there was a significant interaction; the effect of increasing age among older listeners was greater when the hearing loss was ≥ 30 dB than when it was < 30 dB.

Acknowledgements
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P.03 Subcortical & Cortical Parametric Electrophysiological Recordings of the Auditory Change Complex: SUPER ACC

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Discrimination abilities have typically been measured in normally hearing (NH) adults by using the Auditory Change Complex (ACC), which is a cortically generated potential elicited by a change occurring within an ongoing, long-duration auditory stimulus. In cochlear implant (CI) users, the electrically-evoked ACC is elicited by a change in electrode stimulation occurring during stimulus presentation. In addition to this cortical component, subcortical measures provide further information about the auditory processing abilities in both NH listeners and CI users. In particular, the frequency-following response (FFR) is thought to faithfully reflect the frequency encoding at the level of the brainstem. Interestingly, recent research suggest that it is possible to simultaneously record both subcortical and cortical physiological activity in NH listeners.

This aim of this preliminary research project was twofold: first, to evaluate whether it is possible to record both the FFR (subcortical) and ACC (cortical) responses in NH adults. Second, to determine the best possible parameters to do so.

Electrophysiological responses were recorded in four NH adults while they were listening to 16-second-long pure tone sequences. The fundamental frequency (F0) of these sequences was either steady or changing throughout the sequence. In the "changing" sequences, both the switching rate and the F0 varied parametrically. We investigated three switching rates (1 Hz, 2.5 Hz and 6.5 Hz) and seven frequency-range changes covering the low- (300-700 Hz) mid- (1000-1500 Hz) and high- (2500-3000 Hz) frequency range, with small or large frequency separations. The seven conditions were as follow: 320 versus 340 Hz, 320 versus 480 Hz, 320 versus 640 Hz, 320 versus 1320 Hz, 1320 Hz versus 1520 Hz, 1320 versus 3120 Hz and 2620 versus 3120 Hz, selected to cover important speech frequency range. We predicted that, in NH adults, the ACC (cortical) response would not be affected by the frequency content but by the frequency separation and switching rate between tones of a sequence. On the contrary, the FFR (subcortical) would be affected by the frequency content – and in fact, would disappear at higher frequencies in NH listeners – but not by the frequency separation nor the switching rate between tones. Preliminary results will be presented and discussed with respect to potential applications for CI users.

Acknowledgement
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P.04 Using tactile stimulation to improve speech-in-noise performance in cochlear implant users

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Many cochlear implant (CI) users achieve excellent speech understanding in quiet listening conditions, but most perform poorly in the presence of background noise. An important contributor to this poor speech-in-noise performance is the limited transmission of low-frequency sound information through CIs. Recent work has suggested that tactile presentation of this low-frequency sound information could be used to improve speech-in-noise performance for CI users. The primary aim of the current study was to test whether tactile stimulation could enhance speech-in-noise performance in CI users using (1) a tactile signal derived from the speech-in-noise using an algorithm that could be applied in real-time, (2) a stimulation site appropriate for a real world application, and (3) a vibration signal that could readily be produced by a compact, portable device. Our previous work has suggested that training may be important in maximizing the benefit of tactile stimulation, so a secondary aim of this study was to establish the effectiveness of a short training regime. We measured speech intelligibility in multi-talker noise with and without vibro-tactile stimulation of the wrist in CI users. These measurements were made before and after training, which involved 20 minutes of exposure to speech-in-noise with concurrent tactile stimulation. Early results suggest tactile stimulation may improve speech-in-noise performance after training, and that training is important in establishing this improvement. If the approach used in this study is found to be effective, then it could offer an inexpensive and non-invasive means of improving speech-in-noise performance in CI users.

P.05 Non-auditory projections to the inferior colliculus; a tracing study.

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The inferior colliculus (IC), the principal midbrain nucleus in the auditory pathway, processes and integrates virtually all ascending auditory information. In addition, the IC receives extensive descending connections from the auditory cortex (Bajo and King, 2013). These cortico-collicular connections play an important role in auditory processing, and may sub-serve auditory predictive coding. Although the cortico-collicular projections from the auditory cortex to the IC are well established, little is known about the extent to which the IC receives inputs from non-auditory structures. Here we aimed to map all the projections to the IC in the rat using retrograde and anterograde tracers.

Six Lister hooded male rats (250-300g) were anaesthetised and received injections of retro beads (Lumafluor®) into the IC. Animals were allowed to recover and, 72 hours later, were transcardially perfused with heparinized 0.1 M PBS and 4% PFA. Brains were harvested, post fixed, and cryoprotected in 30% sucrose. Coronal sections (40 μm) through the whole brain were cut using a cryostat. The sections were collected on slides, air dried, dipped in DAPI to label the nuclei and stored at -20 C. All sections were visually inspected for the presence of retro beads using a wide field microscope with appropriate filters. The presence of beads was recorded, and mosaic images were obtained at high power using a wide field microscope.

As expected, the auditory cortex showed a high density of retro beads. We also observed projections to both cortices and central nucleus of the IC from many non-auditory regions including, but not limited to, prefrontal, somatosensory (S1 and S2 but not barrel field), motor (M1, M2), and visual (V1, V2) cortices, nucleus accumbens, amygdala, hypothalamic areas, superior colliculus and the dorsal raphe nucleus. In subsequent studies we injected fluorescently labelled dextran anterograde tracers into auditory, prefrontal, somatosensory, and visual cortices in eight rats. The presence of fluorescent labelling in the IC confirmed the results of the retrograde experiments. Moreover, these studies highlighted that different regions of the IC receive varying densities of projections from auditory and non-auditory cortical regions.

These results demonstrate that the IC receives more extensive projections more non-auditory structures than previously believed. This is consistent with the IC not only integrating auditory information but also combining it with information from several other sensory modalities as well as cognitive and limbic inputs.

Acknowledgements
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P.06 The distribution of cell and neurotransmitter markers in the auditory cortex of rats in a tinnitus model

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There is considerable interest in discovering biological signatures for tinnitus (the perception of a phantom sound) to improve our understanding of its origins, and develop effective treatments. Changes in cortical gamma oscillations have been reported in tinnitus in humans, however, their contribution to the tinnitus percept is controversial (Sedley et al 2012). In an *in vitro* study in rat auditory cortex using animals in which tinnitus was induced by acoustic over exposure, Cunningham et al (2018) reported a reduction in the peak frequency of kainate induced gamma activity. Fast-spiking GABAergic, parvalbumin interneurons are necessary for the generation of gamma oscillations, and activation of the NMDA receptor influences the frequency of gamma oscillations in the hippocampus (Mann and Mody, 2009). Using immunohistochemistry we investigated the distribution of parvalbumin, the NMDA receptor subunit, GluR1, and the enzyme that catalyses the production of the neuromodulator nitric oxide (nNOS), in the left and right auditory cortices of rats that underwent right ear unilateral acoustic over exposure and tinnitus testing.

Anaesthetised Long Evans rats were exposed to a 16 kHz tone at 116 dB for 1 hour with the left ear plugged and tested for tinnitus with the gap-pre-pulse inhibition of the acoustic startle (GPIAS) paradigm. Animals with reduced inhibition of acoustic startle at 1 or more test frequencies were deemed 'tinnitus' animals. Exposed and control rats were deeply anaesthetised with sodium pentobarbital and transcardially perfused with 4% paraformaldehyde. Primary antibodies targeting parvalbumin, GluN1 and nNOS, were applied to free floating 30μm coronal sections and detected using secondary fluorescent antibodies. Labelling was visualised with a Nikon A1 confocal microscope and labelling intensity was compared between the left and right cortices in 'tinnitus' animals and unexposed control animals.

Parvalbumin and GluN1 labelling occurred across the cortical layers whilst cell bodies labelled for nNOS were most densely distributed in the superficial and deep layers of the auditory cortex. Neuropil throughout the cortex expressed nNOS. The mean intensity of nNOS labelling was significantly reduced in the cortex of 'tinnitus' rats compared to controls, with the largest reduction occurring in the left cortex (contralateral to the exposed ear). There were no consistent differences in labelling intensity for parvalbumin and GluN1, between groups or between hemispheres. These results suggest that acoustic overexposure causes a reduction in the expression of nNOS in the auditory cortex, which could contribute to the changes in gamma oscillations observed *in vitro* in this tinnitus model.

Acknowledgements
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P.07 Frequency discrimination tasks in naïve listeners: measuring auditory processing or something else?

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Psychophysical methods are widely used to measure auditory processing in studies of naïve listeners, often children, such as in the prolific literature on developmental dyslexia. Paradigms are often shortened, and 'thresholds' are sometimes compared across different task-designs. Yet a meta-analysis shows that published effect-sizes for dyslexia/control group comparisons of frequency discrimination depended significantly on the trial-design used.

We compared frequency discrimination performance at 1 kHz using different trial-designs: a standard 'AXB' task and a 2AFC task using sequences of 5 tones of either the same or alternating frequencies. The tasks were chosen because they yielded the largest and smallest effect sizes respectively in the dyslexia literature. Full psychometric functions with 60 trials were plotted, enabling rough estimations of lapse rate as well as thresholds and slope. We compared thresholds and lapse rates between tasks, and also explored correlations with cognitive variables in a group of 24 naïve adult listeners.

As expected, 75% correct thresholds across the tasks were significantly correlated (rho = 0.52, $P < 0.01$); however this correlation appeared to be determined by a small group of outliers with unexpectedly high thresholds on both tasks - as high as 20 Hz on the AXB task where trained listeners discriminate 1-2 Hz. Excluding 6 listeners, whose thresholds exceeded 2 standard deviations of the mean, rendered the correlation between the two thresholds non-significant.

As predicted by signal detection theory the tone-sequence task yielded higher thresholds and steeper psychometric functions. However, the ratio of AXB thresholds to tone-sequence thresholds was 3:1; slightly higher than the predicted 2:1 (based on the square root of 4 exposures to the contrast between tones in the sequence task vs. one in the AXB task). In the dyslexia literature it has been suggested that the sequence task places less of a burden on cognitive resources than tasks like the AXB, which could explain the relative difference in thresholds. However there was no significant difference in lapse rate for performance on either task, and there was no significant correlation between thresholds in either task and cognitive variables such as working memory.

It is assumed that shared variance between thresholds on the two tasks reflects common sensory processing, i.e., sensitivity to pitch differences. These results suggest that other factors beyond sensory processing of pitch differences are controlling a large proportion of the variance in performance on one or both of these tasks, with implications for interpreting the literature.

P.08 Differential sub-nucleus interactions between GAD67$^+$ neurones and IBA1$^+$ microglia suggest a role for microglia in inhibitory synaptic processing in the inferior colliculus

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Inhibition is an essential component of auditory processing. The inferior colliculus (IC) is comprised of a high proportion (ca. 20-30%) of GABAergic inhibitory neurones (Merchan et al., 2005). While microglial cells (a type of glial cell that have the ability to traverse the parenchyma) are known to respond to pathological conditions, they have also been noted to interact with neural somata and synapses under 'normal' conditions. However, the role of microglia in the auditory pathway is presently unknown. In this study, we employed confocal imaging of multi-channel fluorescent immunohistochemical staining to identify Iba1$^+$ microglial interactions with neurones expressing the GABA synthesising enzyme GAD67, as well as ubiquitous pre-synaptic (synaptophysin) and putative excitatory (homer1) and inhibitory (gephyrin) post-synaptic markers in the IC of young pigmented guinea pigs (n=4). Matching previous reports, we found a high density of GAD67$^+$ neurones in ventral (high frequency) regions, with fewer cells in dorsal IC. High-magnification images revealed Iba1$^+$ processes innervating GAD67$^+$ somata and synaptic terminals. Iba1$^+$ cells in dorsal cortex made 1) greater number of contacts with GAD67$^+$ cells and synaptophysin$^+$ pre-synaptic terminals than central nucleus or lateral cortex; 2) their somata were closer in proximity to their targets; 3) Iba1$^+$ cells were more densely packed; and 4) expressed a greater number of ramifications in the dorsal cortex than central nucleus or lateral cortex. In contrast to dorsal cortex, Iba1$^+$ cells in ventral central nucleus 1) contacted a greater number of GAD67$^+$ neurones; 2) had fewer ramifications but 3) longer branches, enabling each cell to contact GAD67$^+$ neurones and synaptic terminals at further distances from the soma. These data highlight that under 'normal' conditions, Iba1$^+$ cells in IC have varied morphologies, possibly related to the sub-region dependent processing in which they are involved. The close association of Iba1$^+$ processes with somata and synapses, coupled with the greater number of ramifications in dorsal cortex, an area associated with extensive corticofugal input, suggests a role for microglia in plastic changes in IC that requires further study.

Acknowledgements:
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P.09 Superfine Acuity in Depth for Human Echolocators using Mouth Clicks

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Some people who are blind have trained themselves in echolocation using mouth clicks. Whilst there have been previous investigations into the acuity of human echolocation with respect to depth, previous reports were either limited to single cases of blind experts or to samples of sighted people trained in the experimental task, but lack of experience otherwise. Here, we report data from a group of 8 blind people with experience in mouth-click based echolocation (daily use for >3years).

Method

The work was conducted in an echo-attenuated and sound insulated room. Objects to be echolocated were wooden disks (28.5cm or 80cm diameter) presented one at a time in front of the participant around a reference distance of either 50cm (28.5cm diameter only) or 150cm (both 28.5cm and 80cm diameter). On each trial the object was first presented at the reference distance, and subsequently at a comparison distance that was either closer or farther away than the reference distance (following an adaptive staircase procedure). Participants' task was to judge if the comparison was either closer or farther away than the previously presented reference. We also measured the mouth-clicks that people made during the task.

Results

Average 75% JNDs were 3.3cm (SD: 1.8) (28.5cmdisk at 50cm), 7.5cm (SD: 2.9) (28.5cm disk @ 150cm) and 6.6cm (SD: 2.8) (80cm disk @ 150cm). JNDs expressed in cm were significantly smaller in 50cm as compared to 150cm reference distances, but there was no difference between the large and small disk. When expressed as Weber fractions (i.e. JND as percentage of the reference distance), performance did not differ significantly across any of the conditions. In sum, experts could reliably perceive a 5% change in the depth of an object placed in front of them regardless of distance and size. Mouth clicks were louder for weaker reflectors (i.e. same object at farther distance; smaller object at same distance), suggesting an adaptive mechanism to increase SNR.

Discussion

Our estimate of echolocation acuity in depth is better than previous best estimates in sighted samples (JNDs ~20% (Schoernich, et al., 2012), (Wallmeier and Wiegrebe, 2014)) and also better than the best single case threshold reported to date (JND 12% (Wallmeier and Wiegrebe, 2014) or 16% (Kellogg, 1962). Whilst our data emphasize adaptation of the auditory system in blind human echolocators, it remains unclear how this high level of performance is achieved (i.e. echo delay, echo intensity or spectrum, or combinations of these variables).

Acknowledgments

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P.010 Nitric oxide in the ventral cochlear nucleus as a tinnitus generation mechanism

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Tinnitus chronically affects an estimated 10-15% of adults and is characterised by the perception of sound independent of external stimuli. Nitric oxide synthase (NOS) expression has been studied in guinea pig ventral cochlear nucleus (VCN) where it is located in a sub-population of each cell type. Following unilateral acoustic over-exposure, a within-animal asymmetry of NOS expression was found exclusively in animals that developed tinnitus (Coomber et al., 2015). The decrease in NOS expression in the contralateral VCN was observed as soon as 1 day after acoustic-over exposure, and the asymmetry in NOS expression was strongest at eight weeks after noise exposure. This provided evidence for a role of nitric oxide (NO) in tinnitus, and not simply as a biomarker for hearing loss.

Here, we describe the use of iontophoresis to apply the NOS inhibitor L-N^G-Nitroarginine methyl ester (L-NAME) to single units within the VCN of the anaesthetised guinea pig during auditory activation or N-methyl-D-aspartate (NMDA)-evoked excitation. Upon isolation and characterisation of a single unit, hour-long, pure tone pulse-trains were presented at the characteristic frequency (200 ms tone pip, 1000 ms repeat rate, 3600 repeats). Spontaneous and auditory-driven firing rates were recorded over the hour while drugs were applied iontophoretically.

When blocking NO production with L-NAME, changes in firing rate correlated with behavioural evidence of tinnitus. The proportion of neurons decreasing their auditory-driven firing rate in the control group, noise exposed non-tinnitus and noise exposed tinnitus groups during L-NAME application were 9%, 5% and 37% respectively. Therefore, in tinnitus, endogenous NO appears to increase excitability in a larger proportion of neurons, producing an increase in transmission through the auditory system with potential to contribute to the 'increased central gain' thought to be present in tinnitus. This NO-mediated excitation also correlated with the strength of behavioural evidence tinnitus.

Repeating this experiment with NMDA-evoked excitation as opposed to auditory input showed again an increase in excitability, but following noise exposure, with no specific effect of tinnitus. This suggests noise exposure produces changes postsynaptically, with a presynaptic effect of NO in tinnitus increasing transmission.

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P.011 The role of uneven overtones in the prediction of suppression

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The dual-resonance nonlinear (DRNL) filter model by Meddis et al. (2001) has been used to predict nonlinear effects in peripheral processing like compressive input/output functions and two-tone suppression. It consists of gammatone and lowpass filters in two parallel paths that represent the passive linear and active nonlinear basilar membrane response. The nonlinear path features a compressive input/output function for instantaneous compression. With suitable parameters, the suppression areas from psychoacoustic experiments in human hearing were succesfully predicted by the DRNL filter (Plack et al., 2002).

This study shows, that the predicted suppression areas feature regular dips for low-side suppressors in some cases. They are caused by uneven overtones of the suppressor tones that add energy to the filter and counteract the suppression effect. The predicted effect depends on the phase relation between suppressor and suppressee in the simulation and was never investigated in psychoacoustic experiments to the knowledge of the authors.

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P.012 NMDA receptor dependent plasticity at dorsal cochlear nucleus multisensory synapses: a potential target for tinnitus?

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Recent studies have shown that acoustic over-exposure which leads to gap detection deficits in a rodent model, also increases synaptic release of glutamate at dorsal cochlear nucleus (DCN) multisensory synapses. This activates NMDA receptors (NMDARs) and leads to a saturation of long-term potentiation (LTP) at those synapses (Tagoe et al, 2017). The aim of this study was to investigate the presynaptic role of NMDARs in modulating synaptic release and plasticity at DCN multisensory synapses, using extracellular and whole cell recordings in the DCN fusiform cell layer, and presynaptic calcium imaging using SyGCaMP2-mCherry-expressing transgenic mice. Blocking NMDARs with 25 µM D-AP5 caused a reversible decrease in the spontaneous firing rate of DCN fusiform cells, showing that basal NMDAR activation maintains the spontaneous firing rate of those cells. D-AP5 also decreased the fluorescence associated to presynaptic release, indicating that NMDAR activation promotes or participates in Ca^{2+}-dependent release at DCN multisensory synapses. NMDAR activation also increased paired-pulse facilitation of synaptic currents at those synapses, which suggests a decrease in presynaptic release probability. High frequency stimulations of afferent parallel fibres (HFS, 100 Hz, 1 s, with depolarisation to -30 mV, applied twice at a 20 s interval) induced long term potentiation (LTP) of synaptic currents while low frequency stimulations (LFS, 2 Hz, 10 min) or D-AP5 applied after the induction of LTP reversed the amplitude of potentiated responses to their pre-LTP levels. LFS and D-AP5 applied prior to HFS, stopped the induction of LTP suggesting that NMDA receptors are involved in the process of synaptic DP. Together, these findings show that NMDAR activation facilitates synaptic release at DCN multisensory synapses, increasing the spontaneous firing in principal cells. Moreover, results indicate that NMDARs are involved in the expression and maintenance of LTP, and their inhibition triggers DP. In conclusion, blocking NMDA receptors at DCN multisensory synapses could be used as a strategy to depotentiate LTP after acoustic over-exposure, restore basal firing frequency of DCN fusiform cells and alleviate gap detection deficits classically used as an experimental model of tinnitus.

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P.013 Directed effective connectivity in the human and monkey brain: Auditory cortex impact on inferior frontal gyrus, hippocampus and anterior cingulate cortex

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The correspondences or differences between human and nonhuman primates in connectivity between auditory cortex and other brain regions remain open questions: What is the evidence for evolutionary conservation or specialization in effective connectivity between auditory cortex and brain regions that in humans are implicated in language, memory or learned vocal production? Here we had the opportunity to directly compare electrical microstimulation of site-specific contacts available in human epilepsy patients being monitored for surgical resection. We also conducted comparative auditory cortex microstimulation in two rhesus macaques. Microstimulation was combined with functional Magnetic Resonance Imaging (fMRI) to assess the directed effective connectivity induced by electrically stimulating auditory cortical sites. Stimulation of primary auditory cortex (field A1) in the macaques resulted in significant fMRI responses in several brain regions ($p < 0.05$, cluster corrected), including the inferior frontal cortex (areas 44 and 45), regions of the hippocampus and the anterior cingulate cortex. In the monkeys, we also compared the stimulation of primary field A1 to sites in the caudal belt adjoining the non-primary fields CL and CM. In human patients with clinically implanted depth electrodes in Heschl's gyrus (HG), we microstimulated contacts located in the medial HG (a primary like region of auditory cortex; $n = 17$; 2 excluded from a total of 19 because of poor MRI registration). Stimulation of the medial HG resulted in significant fMRI responses in inferior frontal cortex, parts of the hippocampus and anterior cingulate cortex. These observations suggest a considerable amount of correspondence between humans and monkeys in effective connectivity between auditory cortex and other brain regions, which in humans have been implicated in various language functions, cognition or learned vocal production.

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P.014 Passive human echolocation works in the presence of background noise

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Motivation

Echolocation is a form of perception based on the interpretation of sound reflections to understand the environment. Research has shown that people can echolocate, for example using mouth clicks (Thaler and Goodale, 2016). Here we investigated how human echolocation is affected by background noise. We also investigated if experience in echolocation plays a role by testing three expert echolocators, as well as sighted people trained in the echolocation task for the purpose of the study.

Method

Participants listened to recordings of echolocation sounds via headphones and judged the presence (detection task), distance (distance task) or lateral position (angle task) of sound reflectors in the recordings. Echolocation sounds had been obtained through binaural sound recordings (B&K 4101, Tascam DR-100 MK2, 96kHz, 24bit) in an anechoic room using a manikin, whose mouth was positioned behind a loudspeaker (Fostex FE103En) that emitted artificially generated emissions (~5 ms click, modelled after human mouth clicks). In addition to echolocation sounds, we also recorded three different types of background noise (white noise, speech babble, clicks) with the same setup, but with loudspeakers placed to the side of the manikin. During training -- without any background noise-- all subjects reached a level of 90% accuracy. Following training, individuals were tested in the task whilst one of the three types of background noise sounds was digitally added to the echolocation sounds. We used an adaptive staircase procedure to calculate the level of signal-to-noise ratio (SNR) at which subjects performed the task with 71% accuracy.

Results & Discussion

Participants tolerated more background noise in the angle task (mean SNR: -25), as compared to detection (mean SNR: -6.2) and distance tasks (mean SNR: -9.5), suggesting that the task relying on binaural cues was more immune to background noise than tasks that could be performed based on monaural cues. Across all tasks, participants tolerated more 'click' background noise (mean SNR: -25.6), as compared to babble (mean SNR: -6.9) or white noise (mean SNR: -8.1), suggesting that intermittent background noise was easier to deal with than continuous background noise. Expert echolocators and sighted controls showed the same pattern of performance, suggesting that these effects arise regardless of expertise.

Conclusion

People can judge location, distance and presence of sound reflecting surfaces even in acoustically challenging situations. A practical implication of our results is that people should make louder clicks to increase SNR for effective echolocation in noisy environments.

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P.015 Analysis of the microRNAs signature in an animal model of tinnitus

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Tinnitus, the phantom perception of sound, is a condition experienced by approximately 30% of people at some point in their lives. About 10% will live with persistent tinnitus. So far, there is no cure available, only symptoms can be treated. Thus, there is a significant, but so far unmet need for targeted therapies and biomarkers. The aim of this study was to identify specific microRNAs (miRNAs) in a rodent model of tinnitus.

Wistar rats were anesthetised and bilaterally exposed to a loud (110 dB SPL) single tone (14.8 kHz for 2 hours). Age-matched control animals underwent anaesthesia but were unexposed to the loud single tone. The noise exposure induced a shift in the hearing threshold after 24h that generally recuperated within 2 weeks' time. Animals were assessed for tinnitus using the gap-induced prepulse inhibition of acoustic startle response. Under normal condition, the presence of a silent gap in a continuous acoustic background serves as the pre-pulse and induces an inhibition or reduction of a loud noise-induced startle reflex. The testing phase consisted of mixing a pseudo random sequence of 12 startle only trials (with no gaps) with 12 silent trials (gap condition), both embedded in similar background noise preceding the startle stimulus. Animals with putative tinnitus exhibit deficits in detecting the gap as the tinnitus fills the "gap". RNA was extracted from blood, brainstem and cochlea of the control, tinnitus, and non-tinnitus groups by using appropriate RNA extraction kits and a library preparation was performed. The samples were sequenced on an Illumina MiSeq Sequencer as single end reads with a length of 35 base pairs. Subsequently, a quality control of the reads were performed and mapped to a reference sequence, normalised, and tested for differential expression.

Identified dysregulated miRNAs might provide a better understanding of the molecular mechanism resulting in tinnitus and help to screen for novel drug targets. In addition, miRNA signature of the blood might be used as potential biomarkers for tinnitus.

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P.016 Allocentric sound localization in ferrets

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Spatial position is a critical feature of sounds in both human and non-human hearing. Humans can describe sound position within a number of coordinate frames including those defined relative to the observer (head, eyes, etc.) or environment. However, it is unclear whether other animals also perceive sound location in multiple coordinate frames, and particularly if animals can report sound location in the world independently from themselves. Neurons within the ferret auditory system can represent world-centered sound location (Town et al, 2017) suggesting that world-centered auditory perception may be possible for these animals. Here, we tested if ferrets could accurately report world-centered sound location across different head directions within a two-choice allocentric sound localization task.

In our task, subjects reported the positions of one of two speakers producing a short burst of broadband noise (150 or 250 ms), located at opposite sides of a test arena. Behavioral report was made at two arbitrarily positioned response ports that were not co-located with sound sources; trials were initiated and test sounds presented while the animal was at a central response platform located equidistant between sound sources. Across trials, the central platform was rotated (360° range, 30° intervals) so that sound location relative to the head or eyes could not be used to solve the task. We found that ferrets ($n = 2$) learnt to accurately report the location of sound sources at each head rotation (binomial test, $p \leq 0.002$ for each angle) and thus report sound location in the world independently of sound angle relative to the head.

Within our task, head rotation was constant within a session (i.e. blocks of 30-80 trials) and therefore the task could also be performed successfully by rapid relearning of head-centered cues. If this was true, animals should fail to generalize spatial discrimination immediately after the head was rotated while learning took place. However, animals performed accurately (>70%) immediately on the first trials after 180° shifts in head rotations (compared to <65% without rotation); thus ferrets did not need to adapt to changes in head-centered cues but rather generalized without the need for relearning.

Our results show that ferrets developed a rule-based strategy based on the absolute position of sounds in the world, independent of head orientation. Thus our work suggests that, like humans, other animals can also perceive sound location in allocentric coordinates.

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P.017 Efferent activation by means of a notched-noise precursor affects binaural notched-noise masking data

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In a notched-noise experiment with a fixed masker spectrum level, thresholds decrease as the notch increases, in agreement with the assumption that the masker energy falling within the passband of the auditory filter centred at, or close to the signal frequency, determines threshold. Notched-noise data for interaural parameters of the signal that differ from those of the masker indicate effectively wider binaural than monaural auditory filters (Nitschmann & Verhey, 2013). Verhey et al. (2017) investigated how the activation of the medial olivary complex (MOC) affects filter bandwidth results for a 1-kHz signal. A broadband noise precursor preceding the signal-masker complex elicited the MOC reflex. For both signal phases, the addition of the precursor resulted in effectively wider filters, which is in agreement with the hypothesis that cochlea gain is reduced due to the presence of the precursor. The maximum binaural masking level difference (BMLD) was, however, considerably smaller than in previous binaural notched-noise studies.

This study presents data of a following-up study where a lower signal frequency was used (500 Hz) to increase the BMLD and a notch was introduced into the precursor noiseband to reduce masking of the signal by the precursor. The precursor notch width was either 400 Hz or 800 Hz. Thresholds were measured for a 10-ms signal in the presence of a 30-ms notched-noise masker (notch width of 0 or 400 Hz) which was either presented simultaneously or in a forward-masking paradigm, where the signal was presented immediately after masker offset. The temporal gap between precursor offset (when precursor was present) and signal was 55 ms. As expected, the threshold curves for the forward-masking paradigm were steeper than the corresponding curve obtained using the simultaneous-masking paradigm. In contrast to Verhey et al. (2017), the precursor steepened the threshold curve for detecting the diotic signal in both the simultaneous- and forward-masking paradigm and hardly affected thresholds in the dichotic signal conditions. The data are discussed in the light of masker (self-)suppression and the frequency specificity of the MOC reflex.

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P.018 Precision of auditory space is asymmetric between front and rear hemifields

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In the front hemifield, the precision of auditory space depends on the location of sound sources relative to the head. For instance, the minimal audible angle (MAA) is smaller near the midline, a region where binaural cues change more rapidly as a function of azimuth. Towards the interaural axis, however, precision is worse and the cues change less dramatically. A common assumption is that measures like MAA behave in a similar way for sound sources place in rear hemifield. Spatial precision is thought to be symmetric between front and rear hemifields.

We tested this assumption by measuring MAA for a range of azimuths, front and back. Broadband noise stimuli were presented using a ring of 48 speakers. To investigate whether participants made small head movements to maximize precision, a 'head-dependent' condition was created that stabilised azimuths relative to the measured head angle within the ring.

For naïve listeners (N=22), MAAs were substantially worse for sounds in the rear hemifield compared to the complementary location in front. The exception was for sounds on the midline, where no difference was found for front and back. The pattern of findings remained the same whether locations were 'head-dependent' or not.

We investigated whether these findings generalised to minimum audible movement angle (MAMA) and speed discrimination. Using experienced listeners (N=3), MAMAs were found to be worse in the rear hemifield than in front. Unlike MAAs, this included sounds near the midline, which were similarly poorer in the rear hemifield. The speed discrimination task, however, did not show the same asymmetry between front and rear hemifields. Neither did it show a marked difference in performance between midline and interaural axis. Speed discrimination may be a less sensitive task due to the wider range of locations visited by moving stimuli.

Overall, our results show that the precision of auditory space is not symmetric about the interaural axis. It is unclear whether the lower precision in the rear hemifield arises from deficits in binaural or monaural cues, or both.

P.019 Banking on a voice: the influence of perceived vocal trustworthiness on monetary investments in an economic game

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Human voices are ubiquitous in our daily lives, and key to many of our social interactions. We make rapid, automatic judgements of social traits – such as trustworthiness – when presented with voices, and such judgements are highly consistent across listeners (Ponsot et al., 2018). Although not fully understood, the acoustic correlates of these "first impressions" are increasingly under scrutiny (Ponsot et al., 2018). However, it remains unclear whether voice-based first impressions affect our behaviour towards others, and – if they do – how they interact over time with the voice owner's observed behaviour.

Similar questions have been asked about face-based first impressions. These questions are often explored using economic games, such as the investment game. In this game, participants decide how much money to invest in a partner; the investment is multiplied by a fixed factor, and the partner chooses how much of this larger amount to return. The game therefore provides a means of measuring trust and – if it is repeated several times within the pair – assessing learning and reputation formation. When examining face-based judgements, participants view their "partner's face" before playing the game. In reality, the "partner" is the computer, and their behaviour is pre-determined to be either generous or mean. Existing studies suggest that faces judged as more trustworthy accrue higher initial investments; additionally, although first impressions influence investments during early rounds of repeated games, they become less important in later rounds compared to the partner's actual behaviour (Chang et al., 2010). Initial work suggests that the investment game might prove a fruitful means of investigating similar judgements in the voice domain (Torre et al., 2015), but this has not been systematically explored.

We used an investment game to investigate whether voices judged to differ in trustworthiness accrue different initial investments, and/or whether first impressions of the voice interact with the behaviour of the "partner" over time to influence investments. Voices were those of young, male SSBE speakers producing short, neutral phrases (e.g. "Hello, it's me"). Speakers were instructed to produce two versions of each token, with instructions designed to manipulate perceived trustworthiness. Tokens were pre-rated to ensure that the two versions did indeed differ significantly in perceived trustworthiness. Participants (N=84) were recruited and tested via online platforms (Prolific/Gorilla), and were randomly assigned to one of 4 conditions (2 voice [trustworthy, untrustworthy] x 2 behaviour [generous, mean]). Participants played 40 rounds of the game, and heard one phrase from their partner before making each investment. Results will be reported at the conference.

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P.020 Vibrotactile stimulation in the form of the amplitude envelope enhances speech perceptual performance

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When we communicate with people in a noisy environment, such as at a conference, we supplement our hearing with visual information about the speaker's lips to improve our comprehension. Although there have been many studies of auditory-visual interactions, there has been much less work investigating interactions between hearing and touch (Yau et al., 2009), or whether such interactions can improve speech comprehension (Huang et al., 2017). Such interactions might be predicted since auditory and tactile signals are both perceptually processed as vibrations. In this study, we used the perceptual commonality between auditory and tactile signals to test whether the provision of tactile vibrations to the finger influences participants' ability to discriminate spoken speech in background noise.

Thirty-nine normal hearing participants performed a speech-in-noise task (Rosen et al., 2013) both with and without vibro-tactile stimulation in the form of the amplitude envelope for each sentence. The target stimuli were IEEE sentences (Rothauser, 1969) embedded in "speech-babble" background noise played over headphones. All sentences had similar phonetic content and five key words that were for scoring participants performance, e.g., "It snowed, rained and hailed in the same morning". A score of 3-5 words increased the difficulty by reducing the speech-to-noise ratio (SNR) by 1 dB. The SNR increased by 1 dB if participants scored 0-2 words. The amplitude envelope for each sentence was extracted by full-wave rectification and low-pass filtered by a 25-Hz cut-off Butterworth filter. A 120-Hz vibro-tactile carrier frequency was modulated by the filtered envelope to create the vibro-tactile stimulus which was delivered during auditory-tactile trials using a vibro-tactile device applied to the tip of the index finger. The tactile stimulus was varied between participants to compare high (5V), moderate (4V) and low (3V) intensity stimulation.

A 2x3 mixed design ANOVA revealed a significant difference between the auditory-only (M= 1.6 dB) and the auditory-tactile (M= -2.1 dB) condition ($F(1,36)=5.136$, $p=0.03$), but tactile stimulus intensity had no significant effect on participants' performance. Thus, participants tolerated more masking noise (lower SNR) with the provision of tactile stimulation than without tactile stimulation within the range of intensities tested. Interestingly, a correlation analysis showed participants who performed worse during auditory-only blocks improved the most during auditory-tactile blocks ($r=0.641$, $p<0.001$). These results indicate that providing the speech envelope as a tactile stimulus leads to small, although significant improvement in speech in noise performance. Further studies will investigate whether tactile information confers a greater advantage in hearing-impaired listeners.

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P.021 The effect of visual distractors and location switch onset cues on speech intelligibility when listening through a gaze-controlled acoustic beamformer

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Hearing aids equipped with super directional beamforming microphone arrays provide high signal-to-noise ratio (SNR) improvements for signals directly in front of the listener. This improvement, however, makes listening to off-axis talkers more difficult. In multi-talker conversations, a listener wearing such hearing aids needs to dynamically allocate attention and turn their head to different talkers for these SNR improvements. Controlling the direction of the beamformers with eye-gaze could partly alleviate this need because people naturally use eye-gaze to follow conversational partners. The aim of the current experiment is twofold. First, to investigate how visual distractors common for a conversation would interfere with speech intelligibility when listening through a gaze-controlled beamformer. Second, to investigate how onset cues of a conversational turn would influence speech intelligibility at the time of the location switch.

Participants with various levels of hearing loss were listening to single-word targets presented every 1.5 seconds in continuous noise in a sound-dampened chamber. The targets were presented from either to the left (30°) or right (-30°) such that the location of the target switched at random intervals, simulating a turn-taking conversation. Each target was accompanied by the simultaneous visual presentation of a static face of a person just below the loudspeaker. In separate conditions, participants were presented with (a) visual distractors consisting of six silent speaking faces on six video monitors presented in front of the participant, (b) visual cues 500 ms or 1000 ms before the switch of the sound location. The beamforming was simulated in real-time using motion-tracking, eye-tracking, and an array of loudspeakers. The direction of the beam was fixed either to the horizontal head angle or gaze angle. The performance will be assessed in terms of intelligibility of the speech tokens presented just after a switch of the target and this will be related to individual head movement behaviour. The role of visual distractors and cues on absolute performance as well as gaze-controlled benefit will be discussed.

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P.022 Auditory Figure-Ground Analysis in a Non-Human Primate Model

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Segregating sounds in a noisy environment is a fundamental aspect of scene analysis. Inability to detect figures from noisy background is a ubiquitous problem in both cochlear hearing loss and in disorders of central sound processing. In normal human listeners, emerging evidence suggests that auditory objects are detected with remarkable sensitivity and robustness based on a mechanism that detects temporal coherence in different frequency bands (Teki et al. 2013). Human imaging studies demonstrate a system including auditory cortex in the superior temporal sulcus (STS) in non-core homologues and in the intraparietal sulcus (IPS) during preattentive, stimulus-driven figure-ground decomposition of stimuli (Teki et al. 2016; Teki et al. 2011).

We have developed a primate model in a species in which the system organisation can be compared to humans more easily than in other mammals. The eventual aim is to achieve an understanding of figure-ground analysis at the neuronal level based on systematic recordings that are not possible in humans.

We present data from behavioural experiments to measure the ability of rhesus macaques (n = 2) to detect target sounds in a noisy background using stimuli and parameters determined by the previous human work (Teki et al. 2013). A Go/No-Go task with bar release measured the detection of figures by keeping some frequencies constant in a random chord sequence where each chord had duration of 50ms. Parallel functional imaging using fMRI on 2 subjects demonstrated the network for detection of 10-component figures presented over 40 chords with a duration of 50ms. Sparse imaging was used. A contrast between scans after presentation of figure plus ground and control trials after ground only demonstrated activity in the parabelt and in the lateral rostrotemporal belt area (RTL).

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P.023 Do noise-induced latency shifts of the auditory brainstem response to speech reflect deficits in neural synchrony?

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Understanding speech in noisy environments is crucial for human communication, but can be impaired even when hearing is clinically normal. Noise is known to increase the latency of the auditory brainstem response (ABR) to speech sounds, and it has been suggested that this latency increase may reflect neural timing deficits underlying speech-in-noise difficulties in individuals with clinically normal hearing (Anderson et al., 2010; Parbery-Clark et al, 2009). However, we have recently shown that speech ABR latencies are strongly influenced by the weighting of response contributions from different cochlear frequency regions, because lower-frequency cochlear regions elicit considerably slower responses than higher-frequency regions (Nuttall et al., 2015). Here, we explore whether this purely cochlear influence on speech ABR latencies might also explain some of the latency increase as a result of noise. For that, we compared the effect of noise on the classical "broadband" speech ABR with the effects on frequency-restricted speech ABR contributions, obtained using the "derived-band" method. We used two different noise levels, corresponding to 20 and 10 dB signal-to-noise ratio (SNR). As expected based on previous results, the latency of the broadband speech ABR was significantly increased in both noise levels compared to quiet. In contrast, the latencies of the derived-band speech ABR were only minimally changed by the noise. Instead, the noise caused a substantial re-weighting of the derived-band amplitudes, suppressing the amplitudes of the higher-frequency derived-band responses, whilst having less or no effect on the amplitudes of the lower-frequency responses. A computer simulation showed that this re-weighting could account for a major proportion of the latency increase in the broadband response. Our results suggest that noise-induced latency increases in speech ABRs are caused primarily by cochlear rather than neural mechanisms, and that frequency-restricted measurements are essential for estimating this substantial confound.

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P.024 BOLD response to auditory object properties in the monkey auditory cortex

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Introduction

This work addresses how cues for the perception of auditory objects are represented in the macaque auditory cortex. We focus on how timbral cues are represented in the macaque auditory cortex: specifically the spectral flux dimension of timbre corresponding to the change in spectrum over time. Previous human work suggests differences in the representation of the timbral property of spectral flux in core and belt homologues (Overath el al., 2008).

We sought differences in the relationship between BOLD and r in core and belt cortex.

Methods

Individual core and belt areas were defined on two subjects using tonotopic mapping and myelin mapping (Joly et al., 2014). We measured the BOLD response corresponding to spectral flux using a synthetic stimulus that affords manipulation of flux independently of bandwidth (Overath el al., 2008). Spectral flux was characterised in terms of the Pearson correlation (r) between amplitude spectra of adjacent timeframes.

Sparse EPI images were acquired on a 4.7T upright Bruker scanner whilst subjects carried out visual fixation (TR/TA = 10s/1.35s). We presented stimuli with five different r values 45 times each in a randomized order. A generalized linear model (GLM) analysis implemented in SPM12 allowed single-subject inference to determine the relationship between BOLD and r in individual core and belt areas.

Results

In macaque core areas, BOLD activity decreased significantly as a function of increasing r (or decreasing spectral flux). In belt and parabelt, BOLD activity decreased as a function of increasing r with less negative slope than in core.

Conclusions

The data show a difference in the relationship between BOLD and spectral flux in macaque core and belt where the slope becomes more positive between core and belt areas. In the previous human study the slope changed from zero in core homologues to positive in belt homologues (as opposed to changing from negative in macaque core to less negative in macaque belt). Whilst the perception of pitch by macaques appears similar to humans (Joly et al., 2014) we speculate that different timbre organisation might underlie differences in sounds that are relevant to the two species.

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P.025 Ganong shifts for noise- and sine-vocoded speech continua in normal-hearing listeners

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Speech perception involves interpreting incoming sensory information in the context of stored linguistic knowledge. Lexical bias is the tendency to perceive an ambiguous speech sound as a phoneme that completes a word rather than a non-word (Ganong, 1980); the more ambiguous the auditory signal, the greater the reliance on lexical knowledge. For example, a speech sound ambiguous between [g] and [k] is more likely to be perceived as [g] when preceding [Ift] and as [k] when preceding [Is]. The magnitude of this difference—the Ganong shift—also increases when the listener experiences high cognitive load—e.g., a concurrent visual task—limiting the resources available to process the acoustic-phonetic information (Mattys et al, 2012). The effect of stimulus naturalness has received less attention than that of stimulus quality – changes in naturalness may affect cognitive load without necessarily affecting intelligibility.

An eight-step series between monotonized natural tokens of [gI] and [kI] was created using morphing software. Two continua—"gift"–"kift" and "giss"–"kiss"—were derived by adding [ft] or [s] to each step. High-resolution modulated-noise-band (MNB, 16-band) and modulated-sine-band (MSB, 32-band) versions were derived from these continua. Ganong shifts and reaction times were measured and compared across the natural, MNB, and MSB stimuli. The vocoded stimuli differed from one another in spectral density (MSB is sparse) and naturalness (MSB sounds highly unnatural; MNB sounds like whispering).

The effect of stimulus condition on the size of the Ganong shifts was different from its effect on reaction times. Ganong shifts were substantially larger for MSB than for MNB or natural stimuli, despite the greater number of channels for MSB than for MNB stimuli and the broadly similar slopes of their identification functions. The longer reaction times of similar duration observed for both types of vocoded stimuli, relative to the natural stimuli, indicate a similar slowing of processing speed and imply a similar reduction in stimulus quality. The different pattern observed for the Ganong shifts suggests that they are strongly influenced by the relative spectral sparsity and less natural timbre of the MSB stimuli, perhaps reflecting a higher perceptual load associated with processing them despite their high intelligibility.

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P.026 Comparative study of methods for predicting speech-in-noise performance using evoked responses

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A number of methods have recently been proposed for analysis of evoked responses to speech and speech like stimulus. It has been suggested that such methods may allow for evaluation of speech-in-noise performance objectively using EEG evoked responses. An accurate objective measure of speech in noise performance would be of significant clinical value, particularly when assessing hard to test patients or patients that are unable to respond, such as infants or patients with dementia. However, it is not currently clear which analysis methods are most suitable for prediction of behavioral measures.

The proposed study aims to evaluate the viability of three evoked-response recording methods for estimation of behavioral speech in noise metrics: speech-ABR (Anderson et. al, 2013), the Temporal Response Function (TRF) (Vanthornhout et. al, 2018) and fundamental waveform correlation (Forte et. al, 2017). Evoked responses will be recorded for each method at various signal-to-noise ratios (SNRs). Analysed responses will then be used to predict psychometric functions measured using a behavioral speech-in-noise test (such as the Oldenberg Matrix speech test). Using both normal hearing and hearing impaired listeners, the study will focus on evaluation of prediction accuracy and will also consider the clinical applicability of such methods. It will provide insight into the effects of noise at different SNRs on speech-evoked responses and into the relationship of these responses with current behavioral measures of speech-in-noise performance.

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P.027 The perception of dynamic pitch in speech and non-speech

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Pitch in speech varies continuously and delivers information on linguistic structure as well as paralinguistic information on a speaker's identity and emotional state. And although pitch plays a significant role in communication, we have little understanding on how dynamic pitch is perceived.

The focus of this study was to investigate how the perception of pitch height is affected by the direction of the pitch movement (rise-fall forming 'peak' vs. fall-rise 'valley') and F0 turn shapes (sharp turn vs. plateau). In addition, the project aimed to understand whether pitch contours are perceived differently in speech compared to non-speech, i. e., whether linguistic information interacts with the auditory information. This question arose because in speech perception the shape of pitch movement affects the perceived height and timing of the pitch event. Two examples are the findings that a F0 plateau following a rise sounds higher than a sharp peak with the same maximum F0 (Knight 2008) and that pitch perception may differ for the same amount of change in F0 depending on whether it is rising or falling (Hsu et al. 2015). Whether these perceptual effects are unique to speech sounds has not been thoroughly explored.

This paper will discuss results of an experiment that used 3 stimulus types [speech, nonsense, complex tone], 2 directions of pitch movement [peak, valley] and 2 turning point types [sharp turn, plateau] (all crossed). The speech stimuli were four English sentences: 'is Lemmy near Nelly?', 'is Nelly near Lemmy?, 'does Mona know Nina?', and 'does Nina know Mona?'. From them, duration and intensity contours were extracted and embedded in nonsense and complex tone stimuli. Nonsense stimuli were reiterated speech. Complex tones were harmonic complexes with energy between 200 Hz and 6000 Hz. All stimuli had a reference line F0 (F0 at start and end of stimulus) of 200Hz. All stimuli had two F0 turns; the first one always formed a sharp turn and the second one was either a sharp turn or a 100 ms plateau. The difference between the reference line and the first turn was always 5.4 semitones and that between the reference line and the second turn varied between 3.4 and 7.4 semitones. All stimuli were resynthesised with Praat. Young native English speakers with normal hearing listened to stimuli of all three types and judged which turning point sounded higher for the 'peak' stimuli or lower for the 'valley' stimuli.

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P.028 Localisation of speech in noise: a developmental perspective from childhood to adult

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The ability to localise speech in noise is important for listening in noisy real world environments. It is known that children can successfully localise in quiet at an adult-like level by 6 years of age (Lovett et al., 2012), and children aged 7-16 years old can localise in broadband noise at a similar level to adults (Boothalingam et al., 2016). However, children are poorer in the presence of speech babble (Boothalingam et al., 2016). This would be expected to compromise their listening in real world environments, which could in turn affect their language acquisition and educational outcomes (Shield and Dockrell, 2008). This potential impact means it is important to know more about how children localise sounds in noise.

Here results from two studies investigating the development of localisation in noise abilities are presented. For both studies all participants spoke English as their first language, had normal hearing and had no learning or language disorders. A circular ring of 24 loudspeakers was used to run speech localisation, identification and detection in babble tasks. For all the tasks the stimuli were colour words from the CRM corpus, and the babble was made up of 6 spatially separated IEEE sentences.

For the first study we measured localisation of speech in babble and in quiet, non-verbal IQ, digit span and dichotic digits. Localisation performance was defined as threshold from an adaptive track that varied signal-to-noise ratio in response to correct/wrong location judgements for signals from -30, -15, 0, 15 or 30 degrees. Children aged 6-13 years old and adults aged 18-30 years old participated. We found that the children were significantly worse at localising speech in babble than the adults but that performance gradually improves over this age range. The trajectory of this improvement was accurately fitted by an exponential function.

A second study, with participants aged 11-25 years old, is further investigating this developmental trajectory. The study is also examining if the limits of localisation are due to limits in detection or identification of speech in babble.

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P.029 A machine-learning test for the estimation of auditory filter shapes across frequency

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Shen and Richards (2013) described a machine-learning method for estimating parameters characterising the shape of the auditory filter based on notched-noise masking using a single signal frequency, fs. We extended this approach with a test that uses machine learning to obtain a probabilistic estimate of notched-noise thresholds as a function of fs and notch width. This allows fitting any auditory-filter model to the estimated thresholds, and allows estimation of the auditory filter shape over a wide frequency range.

Both normal-hearing and hearing-impaired subjects were tested. Five symmetric and four asymmetric notches were used. The frequency of the notch edge closest to fs ranged from 0.6fs to 1.4fs. The width of each noise band was 0.4fs. The signal level was fixed at 15 dB SL and the level of the noise was varied. The value of fs ranged from 500 to 4000 Hz, or up to the frequency where the hearing loss exceeded 40 dB HL. This limit was imposed to avoid high noise levels. Each trial consisted of three intervals, containing the signal, the noise, and the noise+signal, respectively. The task was to indicate whether or not the signal was heard in the third interval (yes-no). The stimulus for a given trial was chosen based on the results for previous trials so as to provide maximum information. A run consisted of 540 trials plus 54 catch trials with no signal in the third interval. The subject could take a break at any time. A run took between 48 and 61 minutes in total (compared to about 60 minutes to obtain two threshold estimates for each of nine notch widths at a single fs using conventional methods).

An auditory-filter model with three parameters (lower slope, pl; upper slope pu; detection efficiency, K) was fitted to the individual results for several selected values of fs. The obtained filters were similar to those estimated using the conventional notched-noise method in width and asymmetry.

The present test can complement machine-learning tests for the audiogram (Schlittenlacher et al. 2018a) and dead regions (Schlittenlacher et al., 2018b) to form an automated test battery that gives a detailed picture of an individual's hearing, which potentially may be used to obtain better initial fits of a hearing aid. For example, the frequency-dependent gain can be chosen based on the asymmetry of the auditory filters so as to reduce across-channel masking.

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P.030 Computational model for the modulation of speech-in-noise comprehension through transcranial electrical stimulation

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Introduction

Transcranial electrical stimulation (TES) can non-invasively modulate neuronal activity in humans. Recent studies have shown that TES with an alternating current that follows the envelope of a speech signal can increase the comprehension of this voice in background noise (Wilsch et al., 2018). However, how exactly TES influences cortical activity and improves speech comprehension remains poorly understood (Zoefel & Davis, 2017). Here we present a computational model for speech coding in a spiking neural network and employ it to investigate the effects of TES on the coding of speech in noise.

Methods

We established a computational model of a spiking neuronal network that encodes natural speech through entraining network oscillations in the theta and gamma frequency range. We used the network's output to classify simple acoustic stimuli as well as speech in different levels of background noise. We then simulated the effect of different external currents on the network dynamics as well as on the neural output and the associated speech coding. Finally, we analysed the behaviour of the computational model and its speech classification performance in different conditions to optimize the stimulation paradigm for enhancement of natural speech processing.

Results

The computational model generated coupled oscillations in theta and gamma frequency ranges. In agreement with experimental results, the slower theta oscillations reliably predicted the onsets of syllables and provided a temporal reference frame for the faster activity in the gamma band that encoded phonemes (Giraud & Poeppel, 2012). Classifying speech in different levels of background noise we obtained results comparable to normal human performance, with a 50% speech recognition threshold at approximately 0 dB SNR. Simulating the effect of simultaneous external current with a range of different temporal patterns we were able to identify temporal shapes that impeded as well as enhanced the neural coding of speech in noise.

Conclusion

The developed model provides an insight into the neural mechanisms through which speech-in-noise is processed in auditory cortex and how can TES enhance this processing. Moreover, our computational model allows to optimize temporal pattern of the stimulation for improving speech-in-noise comprehension.

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P.031 A computer model of auditory brainstem (SPON) offset units and their use in the study of psychophysical phenomena.

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Most computer models of the auditory periphery and brainstem exist to explain how physiology can be used to explain auditory phenomena obtained in psychophysical testing. This approach can be problematic because many neurons are stochastic and spontaneously active. As a result, there are few binary events in the brainstem activity that can be reliably equated with psychophysical yes/no decisions. However, one cell type in the brainstem superior olivary region typically shows little or no spontaneous activity and is silent during the presentation of simple unmodulated tones, but responds reliably at the *offset* of a sound. This provides the modeller with a relatively unambiguous 'offset detector' that can be used to make predictions in some psychophysical paradigms such as gap detection and amplitude modulation detection as a function of AM depth and frequency. The model presented here is based on a model developed by Kopp-Scheinpflug et al., (2011) to simulate the effects of intracellular *electrical* stimulation but it is embedded in a global multi-cell type model of brainstem activity responding to *acoustic* stimulation. The model will be illustrated using gap-detection and detection of amplitude modulation. It will also be used to illustrate how efferent activity in the crossed and uncrossed medial olivocochlear bundle might improve sensitivity to amplitude modulation in the presence of noise. This example helps to explain how the efferent system might facilitate speech recognition in noisy backgrounds (e.g. Brown, Ferry, & Meddis; 2010).

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P.032 Discovering the building blocks of hearing: a data-driven approach

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Experimental approaches to study hearing typically require simple stimuli to allow for controlled experiments. In order to improve our general understanding of features that are important for hearing in more complex environments, we propose a data-driven approach to determine good basic auditory features for speech processing. More specifically, we introduce a neuro-inspired feature detection model that relies on a modest amount of parameters. We show that our model is capable of detecting a range of features that are thought to be important for noise-robust speech processing, such as amplitude modulations and onsets. In order to identify currently unknown but important features within the parameter space of our model, we propose a dual analysis approach that leverages both information theory (in particular the Information Bottleneck principle) and supervised machine learning. Altogether our analysis framework of this new class of feature detectors may improve our current understanding of human hearing in challenging environments, both in terms of fundamental science and reproducing this ability in machine hearing systems.

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P.033 Amplitude modulation depth discrimination by cochlear implant users

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Most cochlear-implant (CI) processing strategies modulate the amplitude of high-rate pulse trains to convey the amplitude envelope of speech. However, not all of the modulation envelope may be necessary to perceive amplitude modulations (AM); the effective depth of the envelope may be limited by forward masking from the envelope peak. Two experiments studied the effective portion of the dynamic range (DR) contributing to the perception of amplitude modulation depth (AMD) by CI users, and how this depends on AM rate.

Nine users of the Cochlear device took part. The standard stimulus was a 1000-pps 448-ms pulse train modulated at 100% of DR, presented on electrode 16. Modulation rates were 15.625, 31.25, 62.5, 125 and 250 Hz. Experiment 1 used 3-Interval 2AFC adaptive trials with feedback; subjects indicated the 'different' (signal) stimulus, which was identical to the standard except for its AMD. Peak amplitude for all stimuli was fixed at MCL, and signal AMD was adjusted to determine the threshold (AMDT), defined in terms of %DR in decibels. Subjects could use any cue to detect the signal, including the possibility that it was louder than the 100%AMD standard. Experiment 2 used identical stimuli, but limited and monitored the use of potential loudness cues. It used 2-Interval 2AFC adaptive trials, and subjects were instructed to ignore loudness cues. To check whether they complied with this instruction we inserted 'catch-trials' with no feedback in which the lesser-modulated signal was made softer than the standard. Substantial between-subject differences were observed in both experiments; here we describe mean results.

For experiment 1, an rmANOVA revealed a highly significant effect of modulation rate on AMDTs, which were highest (best) at the 31.25-Hz rate. AMDTs dropped at higher rates consistent with the expected influence of forward masking, and at 15.625 Hz, where there were only seven modulation cycles.

Performance on the catch trials of experiment 2 indicated that, for about 80% of subject/AM rate combinations, subjects were not using loudness cues. The effect of modulation rate was not statistically significant, but was broadly similar to that in Exp. 1. Overall, AMDTs were significantly lower (worse) than in experiment 1, and, averaged across rates and subjects, were equal to about 35%. Hence in the absence of loudness cues the lower 65% of the dynamic range does not, on average, contribute to AMD perception for the stimuli used here.

P.034 Comparison of Auditory-Inspired Machine-Learning Models for Cochlear Implants

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Speech enhancement algorithms in cochlear implants often use spectral subtraction-based noise reduction which can provide the user with significant speech-recognition improvement in speech-shaped noise but modest or non-significant improvement in multi-talker babble noise. Such algorithms may provide optimal speech recognition only in a limited range of background-noise situations. Therefore, there is great interest in developing speech enhancement algorithms that are much more environment-specific, in particular machine-learning approaches. In this study, two auditory-inspired feature-extraction models, the Multi-Resolution CochleaGram (MRCG) model [Chen et al., 2014] and the Auditory Image Model (AIM) [Monaghan et al., 2017], were extensively compared on their noise classification efficacy using ensemble bagged of decision trees and support vector machines.

The first experiment involved 10 recordings of five sound types (speech or environmental noise, each approximately 30s long). The initial 20s was used for training and the remaining sequence used for testing (Saki and Kehtarnavaz, 2017). The AIM model displayed perfect classification accuracy in every single sound scenario and the MRCG model marginally poorer with classification accuracies still above 90%. In the second experiment, 10 IEEE sentences, speech alone or corrupted by eight different real-world noise types (presented at 0dB SNR) were used for training and 3 different IEEE sentences (also speech alone or corrupted) were used for testing. The performance of both MRCG and AIM models deteriorated (AIM more so than MRCG) compared to their performance in experiment 1: classification accuracy for MRCG and AIM dropped to 84.46% and 55.78%, respectively. For the third experiment, full sequence of the recordings in experiment 1 were used for training. Noise samples independent of those used in training were used for testing. The MRCG model tended to identify machinery frames as babble noise whereas AIM struggled in correctly identifying music frames.

Finally, 10 recordings of babble noise at different SNRs (clean speech, 0dB, 5dB, 10dB and 15dB SNR), were used for training and 3 other recordings of babble noise at the same SNRs were used for testing. The results showed that AIM model could better distinguish between various SNRs compared to the MRCG model.

Overall, the MRCG model gave more consistent results across experiments but the AIM model performed better in two out of four of the tests conducted. Future work will look into identifying characteristics of auditory model that when combined with the appropriate machine-learning approach best represents human performance in speech recognition in a variety of noise environments.

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P.035 The effect of head movement and dynamic range compression on the output of cochlear implants

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Dynamic-range compression is used in cochlear implants (CIs) to compensate for the greatly reduced dynamic range of CI listeners. It has been found that unlinked bilateral dynamic-range compression (DRC) in hearing aids (HAs) can affect the spatial location of sounds, reducing interaural level differences (ILDs) and causing sound sources to appear closer to 0 degrees azimuth and/or to be more diffuse (Wiggins and Seeber, 2011). The compressors in CI processors are often much stronger than hearing aids (e.g., CI compression ratios of 12:1 vs. 3:1 or less in HAs), and in some devices have much slower attack and release times. This may distort ILD cues, particularly when either the head or the source is moving. Because CI listeners rely strongly on ILDs for localization, this could severely degrade their spatial perception.

We investigated the effect of wideband compression on monaural and binaural level cues during simulated rotational head movements in the horizontal plane. Head movements were simulated by convolving static behind-the-ear hearing aid microphone impulse responses with short segments of speech-shaped noise and combining them at successive angles relative to the head. The resulting stimuli were then processed using a simulation of the front end of an Advanced Bionics CI. The simulator applied a high-pass pre-emphasis filter, and applied a slow-acting DRC with attack/release times of approximately 1.3/2.9 seconds, with a compression ratio of 12:1. All signals were above the threshold of the DRC. The simulator output an acoustic signal using a 16-channel tone vocoder; these channels were then summed and the short-time root-mean square value of this broadband envelope was used for analysis of the level changes.

For sound levels above the compressor threshold, ILDs on a static head were reduced to near 0 dB, in agreement with previous findings. Head movement induced an ILD whose change over time and maximum absolute value depended more on the speed and duration of that movement than on the position of the source relative to the head. Faster and shorter head movements induced the largest changes in ILD, and also resulted in the ILD continuing to change after the head had stopped moving. Hence when the head moves, unlinked, bilateral DRC has substantial and deleterious effects on the ILD cues that CI users rely on for sound localisation. Results of simulations with linked compressors that aim to preserve ILD cues will also be presented.

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P.036 Discrimination of Increments in Complex Stimuli by Hearing-Impaired Listeners

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The frequency-gain response (FGR) is the hearing-aid parameter which is fundamental to restoring audibility. FGR adjustments in the clinic, whether meeting real-ear targets or patient feedback, are routine. Fittings could be inefficient and patient feedback unreliable if adjustments are less than what is discriminable. Furthermore, if adjustments improve objective benefit but are not noticeable, it is unlikely self-reported benefit will reflect an improvement. To examine what FGR adjustments are discriminable, we measured the just-noticeable differences (JNDs) for increments from stimuli processed with prescription FGR curves.

JNDs were measured with hearing-impaired participants using a fixed-level, same-different task. Thirty-eight participants discriminated pairs of speech-shaped noises (SSNs), and forty-one participants discriminated pairs of male, single-talker sentences. For SSNs, single-band increments were made to a 0.25 kHz low pass (LP) band, 0.5-4 kHz octave bands, and a 6 kHz high-pass (HP) band. For sentences, single-band increments were made to 0.25, 1 and 4 kHz bands, and multi-band increments were made to LP, band-pass (BP) and HP bands. Broadband JNDs were also measured. Stimuli were presented over headphones. Logistic functions were fit to *d'* data, and JNDs were estimated at *d'* of 1, a common threshold in psychophysical research, and at *d'* of 2, a more sensitive threshold for clinical application.

At *d'* of 1, the single-band SSN JND was 3 dB across bands except from the 0.25 kHz LP band, for which the JND was 4.5 dB. Single-band sentence JNDs were 7 dB for 0.25 and 1 kHz, and 10 dB for 4 kHz. Multi-band sentence JNDs were 4 dB for the LP and BP bands, and 7 dB for the HP band. At *d'* of 2, the single-band SSN JND was 5 dB across bands except from the 0.25 kHz LP and 0.5 kHz band, for which the JND was 5.4 dB. Single-band sentence JNDs were 9 dB for 0.25 and 1 kHz, and 15 dB for 4 kHz. Multi-band sentence JNDs were 6 dB for the LP and BP bands, and 10 dB for the HP band. Broadband JNDs were similar across stimuli. There was some concordance between frequency-band and broadband discrimination. JNDs were independent of age and hearing ability. High-frequency sentence JNDs were likely elevated due to lower energy in corresponding bands. SSN JNDs provide perceptual evidence for current real-ear measurement tolerances. Sentence JNDs suggest caution when fine-tuning frequency-bands with live speech, as small adjustments are unlikely to be discriminable.

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P.037 High levels of very high-frequency sound and ultrasound in public and work places

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For many years workers have reported adverse symptoms resulting from exposure to very high-frequency sound (VHFS) and ultrasound (US), including annoyance, difficulty concentrating, tinnitus, and headaches. Recent work showing the presence of a new generation of VHF/US sources in public and work places has reopened the debate about whether there are adverse effects of VHF/US, and has identified weaknesses in standards and exposure guidelines. We present field measurements from a number of public and work places of devices such as pest deterrents and ultrasonic welders and cleaners. As well as demonstrating the presence of intense VHFS/US sources in both work and public places, our results highlight the special considerations that must be made when measuring VHFS/US sources. These include the impact of microphone size, the impact of the microphone's protective grid, and the sensitivity of measurements to small changes in microphone position. We propose a new protocol for measuring VHFS/US that avoids these pitfalls.

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P.038 Dynamic auditory localisation over loudspeakers and over headphones

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As we are always moving, constant integration of self-motion and sound-source-motion is required to render a stable percept of the auditory world. Within audiological and balance clinics, there is a consistent need for understanding and appraising the ability to integrate these motions. We have previously investigated the relationships between self-motion acuity, source-motion acuity and self/source-motion integration acuity. We found that thresholds for all three were independent of one another, indicating that integration needs to be measured on its own. Here, we propose two clinically viable tests of integration – front/back discrimination and stability – and compare these with traditional tests of localisation – static localisation and minimum audible movement angle (MAMA). The four tasks were conducted with 20 listeners in a sound-dampened chamber using a large ring of 24 equally spaced loudspeakers and a Vicon motion-tracking system. They were then conducted with all listeners over headphones using a custom-built, headphone-mounted, gyroscopic device with non-individualised head-related transfer functions.

In the static localisation task, listeners were asked to identify the apparent location of a 1.5 s modulated noise signal; localisation acuity was defined as root-mean-squared error. In the MAMA task, listeners had to identify the apparent lateral direction of movement of the same modulated noise signal; the MAMA was the smallest amount of movement required for accurate performance. In the dynamic front/back discrimination tasks, listeners had to turn their head from side to side and identify whether a similar noise signal came from in front of them or behind them. In this task, the sound source was centred on 0° (front) or 180° (behind), but moved as a function of head angle with a movement gain varying between trials from 0 to 2. A gain of 0 translated to a static location, but a gain of 2 meant source motion that could create a stable front/back illusion, causing an incorrect perception of source location. In the dynamic stability task, listeners were again asked to turn from side to side. As the sound moved in front of them, listeners were asked to adjust the gain until the sound appeared to be stationary.

Results for each individual task were compatible to previous findings. Headphone data tended to be more bimodal in the static localisation task, and more variable in the two integration tasks. Implications for the clinical application of these tasks in the appraisal of self/source-motion integration will be discussed.

Acknowledgements

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P.039 Effects of noise exposure on young adults with normal audiometric thresholds

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Background

Noise exposure can destroy synapses between inner hair cells and auditory nerve (AN) fibres, without widespread loss of hair cells or elevation of cochlear thresholds (Kujawa and Liberman, 2009). Termed 'cochlear synaptopathy', this pathophysiology has been observed in a variety of animal models and has been suggested as a possible cause of listening difficulties and tinnitus (Kujawa and Liberman, 2015). Here, we summarise the results of five research projects designed to investigate possible physiological and perceptual consequences of noise exposure in humans with normal audiograms.

Methods

All five projects recruited audiometrically normal adults aged between 18 and 40. Each involved a detailed self-report estimate of lifetime noise exposure (to activities with estimated sound level >80 dBA) and a measure of AN function: the amplitude of wave I of the auditory brainstem response. Other measures included envelope-following-response amplitude (used in two projects), middle-ear-muscle-reflex thresholds (one project), a measure of spatial speech perception in noise (three projects), a wide range of psychoacoustic measures (one project), and functional magnetic resonance imaging (fMRI; one project).

Results

Across all studies, no significant relations were observed between lifetime noise exposure and physiological measures of auditory nerve function, despite a wide range of exposures. Nor did lifetime noise exposure relate to behavioural measures, nor to changes in the central auditory pathways, as assessed via fMRI. Presence of tinnitus was, however, significantly associated with lifetime noise exposure, despite close audiometric matching between participants with tinnitus and controls.

Conclusion

The summarised research reveals no evidence for noise-induced cochlear synaptopathy in young humans with normal audiograms. Potential explanations, which are not mutually exclusive, include the possibility that all outcome measures are insufficiently sensitive to synaptopathy (results of animal models notwithstanding), that human cochlear synapses are far more resilient than those of animals, and that in humans synaptopathy is only prevalent in combination with an audiometric loss. It does appear that noise has the capacity to induce 'hidden' auditory changes leading to tinnitus in individuals with entirely normal audiograms, but we find no evidence to suggest that these changes relate to cochlear synaptopathy.

Acknowledgements

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P.040 Investigating auditory-visual cross-modal activations in post-lingually deaf cochlear implant users to different auditory and visual stimuli using fNIRS

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Cortical changes that occur with deafness and subsequent 'restoration' of auditory input with a cochlear implant (CI) have been proposed to contribute to variability in speech recognition outcomes in CI users. Evidence from neuroimaging studies suggests that auditory-visual cross-modal activation, i.e. activation in auditory areas of the brain in response to visual stimuli, is correlated with speech recognition performance. Specifically, a negative correlation has been reported between the amount of auditory cortex activation to purely visual stimuli in CI users and speech recognition performance. It has therefore been suggested that this cross-modal activation of the auditory cortex by visual inputs may limit the capacity for auditory recovery, post-cochlear implantation. However, a recent study by Anderson et al., (2017) reported that increased cross-modal activation of auditory brain regions by 'visual speech' stimuli from pre- to 6 months' post- cochlear implantation is associated with better speech understanding. Importantly, there has been variability across studies in terms of the types of visual stimuli used, e.g. 'basic' visual stimuli, such as checkerboards, vs. visual speech. We propose that this variability in relationship between cross-modal activations and speech recognition performance may be related to the differences in activations resulting from the variability in visual stimuli used. Certainly, studies in congenitally deaf cats have found strong evidence of cross-modal activity occurring in discrete portions of the reorganised auditory cortex, which were dependent on the specific visual function or task being assessed (Lomber et al., 2010).

We therefore aim to examine brain activations to different types of visual and auditory stimuli, and whether the type of stimuli used to investigate cross-modal activation influences the relationship with clinical speech recognition measures. This study will use functional near-infrared spectroscopy (fNIRS) – a non-invasive technique that is not susceptible to the electrical or magnetic artifacts common to other neuroimaging techniques during auditory stimulation, such as EEG and fMRI. Cortical activations to 'basic' (concentric gratings and beeps) and more 'ecological' (speech) visual and auditory stimuli will be assessed in experienced, post-lingual CI users and compared to age-matched controls, in auditory-only, visual-only and audiovisual conditions. These responses will be measured using optode arrays placed in bilateral auditory and visual regions of interest (ROIs). This activity will also be compared to functional speech recognition performance. Finally, as speech perception is influenced by cognitive processes, a range of relevant cognitive abilities will also be assessed. Preliminary findings will be presented.

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P.041 Hidden hearing loss and selective attention in the brainstem

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Cochlear synaptopathy or hidden hearing loss can be caused by noise exposure and ageing. Hidden hearing loss can cause differences in the response of the auditory brainstem, and a growing number of studies hint that this form of hearing loss accounts for the differences in the ability of normal hearing threshold listeners when communicating in challenging environments (Bharadwaj et al, 2014). However, it remains unclear if the condition actually occurs in humans, how it can be best diagnosed, and how exactly it impacts speech-in-noise processing.

Recently we proposed a method for measuring the brainstem's response to natural non-repetitive speech and employed it to show that the auditory brainstem already plays a role in selective attention (Forte et al. 2017). We thereby observed individual differences in the modulation of the brainstem response by selective attention. We therefore wondered if selective attention in the brainstem may be affected by cochlear synaptopathy and/or if ot correlates with other measures of hearing performance.

Firstly, we sought to develop a realistic computational model of the ABR to speech and to explore the effects of hidden hearing loss. We modified a model of the brainstem response to complex stimuli (Zilany et al., 2014) and employed it to investigate the neural response to continuous speech at different stages in the brainstem. We found significant responses and characteristic latencies for neural signals generated at the level of the auditory-nerve fibres, the cochlear nuclei and the inferior colliculus (IC). The latency of the response of the IC matched the latency that we found experimentally, suggesting that the scalp-recorded brainstem response to speech is dominated by the IC.

Secondly, we assessed young healthy listeners for their speech-in-noise comprehension, lifetime noise exposure, the middle ear muscle reflex, binaural hearing and different brainstem measures, including the brainstem response to continuous speech and its modulation by selective attention. We found that there was considerable variability in all measures across the participants. However, only few of the objective measures were able to explain the differences in speech-in-noise comprehension between the participants. Interestingly, we found that the modulation of the brainstem response by selective attention correlated with the performance in the speech-in-noise task.

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P.042 Do you know when you're being too loud? Aural detectability judgements in normal-hearing civilians

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Remaining acoustically undetectable whilst operating close to an enemy is important for the survivability and lethality of ground close combat soldiers. Such operations require stealth behaviour, where the soldier employs a set of behaviours to maximise the likelihood of their presence going unnoticed. We hypothesise that a fundamental aspect of this acoustic stealth behaviour is an aural detectability judgement, where the subject judges whether or not a nearby listener (i.e. enemy) would be able to detect a sound that the subject generates (for example, stepping on a twig, whispering commands). We aim to develop a novel method to investigate aural detectability judgements, and then employ the method to assess the effects of military experience and hearing loss on these judgements.

Here, we present details of the method and results from ongoing data collection in normal-hearing civilians. The experiment takes place in a semi-anechoic chamber and uses a virtual reality headset to present the visual environment of an open grassy field, with a 'target' stood at 25, 50 or 75 m away. The subject is presented with a sound via loudspeaker (twig, pine cone or whispered digit) at various levels. The subject's task is to judge, yes or no, would the target be able to detect that sound. The method of constant stimuli is used to obtain the proportion of yes responses for each condition (distance/sound/level), and subsequently plot a psychometric function. The estimated aural detectability threshold is then compared to a theoretically predicted 'true' threshold for that condition. We will present our latest pilot results and discuss future experimental work.

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P.043 Towards a diagnostic tool to determine the underlying pathology of hearing loss.

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As we move towards treatments for people suffering from hearing loss, it will be crucial to determine the nature of the pathology causing the impairment. For example, stimulating hair cell regeneration might be of little help to a patient with a deficit in function of the stria vascularis. As knowledge of the auditory system has advanced, it has become apparent that there are many causes of hearing impairment of cochlear origin. Whilst current clinical tools can give indications of certain broad classes of pathology such as conductive and sensorineural, a method to differentially diagnose different types of sensorineural pathology including strial dysfunction has proved particularly difficult to find.

Genetic approaches using mutant mice have proved to be excellent research tools to define the underlying pathology of different patterns of hearing impairment. There are currently around 400 genes known to play a role in mammalian hearing function and a large number of these have a defined lesion producing a specific functional deficit.

Here, we combine the power of mouse mutants with known lesions with clinically available measurements (auditory brainstem responses, ABR and distortion product otoacoustic emissions, DPOAE) and a simple threshold comparison method (Mills, 2006) to derive plots which may be helpful for differential identification of multiple classes of hearing loss.

Using an *S1pr2* mutant as a model of stria vascularis dysfunction, a *Klhl18* mutant as a model of Inner Hair Cell dysfunction, an *Ocm* mutant as a model of Outer Hair Cell dysfunction, and other mutants with mixed pathologies, we present data to suggest that it may be possible to differentiate some types of cochlear pathologies in humans with hearing loss.

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P.044 Neural processing of speech in children with sensorineural hearing loss

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Previous research has shown that even a mild (21-40 dB HL) or moderate (41-70 dB HL) sensorineural hearing loss (MMHL) can impair cortical processing of speech sounds, as evidenced by differences in event-related potential responses (P1-N1-P2-N2 and MMN) between children with MMHL and chronological age-matched normally hearing (NH) controls (Koravand et al., 2013). However, to date no studies have examined speech processing at the subcortical level in children with MMHL. Moreover, the effects of amplification on the neural encoding of speech are still poorly understood, with previous data suggesting a significant benefit at the subcortical (Anderson et al., 2013) but not the cortical level (Billings et al., 2007).

The aims of this project were to (i) investigate the cortical and subcortical processing of speech sounds in children with MMHL and (ii) evaluate the effects of amplification on the neural processing of speech in this group. To do so, cortical and subcortical EEG activity evoked by speech stimuli (/ba/-/da/) were simultaneously recorded in 18, 8- to 16-year-old children with MMHL and 16 age-matched NH controls. Subcortical processing was assessed using the frequency following response (FFR), an EEG component evoked at the subcortical level which reflects the encoding of the fundamental frequency (F0) and first few harmonics of complex auditory signals such as speech. For the MMHL group, stimuli were presented both unamplified (70 dB SPL), and with a frequency specific gain (without compression) based on their individual audiograms.

Preliminary analyses revealed that children with MMHL had smaller cortical responses than NH controls in both unamplified and amplified conditions, and did not show an MMN. In contrast, at the subcortical level, they showed a smaller FFR than NH controls in the unamplified condition only. With simulated amplification, children with MMHL demonstrated an FFR that was comparable to that observed in NH controls. Our findings suggest that the neural processing of unamplified speech may be impaired at both subcortical and cortical levels in children with MMHL However, consistent with previous studies in adults, amplification appears to benefit auditory processing at subcortical but not cortical levels in children with MMHL. Our results suggest that the deleterious effect of MMHL might accumulate throughout the auditory pathway, leading to an impairment of the cortical processing of speech sounds even with amplification. Possible mechanisms and clinical implications of these findings will be discussed.

Acknowledgements

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P.045 Auditory Training With and Without Visual Feedback in a Virtual Environment

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The spectral encoding of spatial features (due to direction-dependent filtering of the pinna, head, and torso) is described by the Head-Related Transfer Function (HRTF). The use of individual (anthropometrically-derived) HRTF characteristics may provide optimal spatial cues and an enhanced virtual experience for users of virtual reality (VR) displays. However there is a substantial body of work providing evidence of the plasticity of the human auditory system. A listener can recalibrate to new HRTFs (either entirely new or their own after modification), so good VR sound localisation may not require individualised HRTFs.

Short training programmes with generic HRTFs prior to immersion in a virtual environment may be more practical than acquiring individual HRTFs, especially if incorporating auditory or visual feedback. Most previous studies comparing auditory training with auditory training combined with visual feedback have not used comparable inter-trial intervals (i.e., the inter-trial interval for the auditory only condition is often much shorter than that for auditory training combined with visual feedback.

Sound localisation training was studied using generic HRTFs with an HTC VIVE head-mounted display. Three training conditions were compared: i) Auditory training only (AO), ii) Auditory training with Visual feedback (AV), and iii) No auditory training (Control). Inter-stimulus and inter-trial intervals were identical across experimental conditions. Ten normal-hearing participants were allocated to each experimental condition. Noise-bursts (1000 ms) were presented from -60^{o} to +60^{o} azimuth in the frontal hemisphere. A short practice session familiarised the participant with the test protocol, followed by a test session to acquire localisation data (day 1). For conditions AO and AV, localisation training to the auditory stimuli was undertaken on days 2, 3, and 4. For all conditions, further test sessions to obtain localisation data were conducted on day 4 (immediately after the last auditory training session) as well as on the 7th and 11th day post-training session (to investigate training retention).

Results showed that mean sound localisation errors were significantly reduced for the AO and AV groups compared to the Control condition, and that the AV condition resulted in a much more rapid reduction in localisation errors compared to the AO condition. The maximal improvement in localisation accuracy was attained after 4 days and this performance was maintained for up to the 11th day. With matched inter-trial intervals, auditory training with visual feedback results in rapidly reduced sound localisation errors compared to auditory training alone, with effects that persist for several days after training.

P.046 Using pupillometry in mice to study perception of rapid sound sequences

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Natural sounds – raindrops, bird chirps, footsteps, music - contain regularly repeating and evolving sound sequences. Efficient processing of such sounds by the auditory system likely requires analysis and representation of the statistics of such sequences. In human subjects, MEG and fMRI studies have shown that the auditory brain readily responds to transitions between repeated pure tones as well as from regular to random tone sequences and vice versa (Barascud et al. 2016). The same group used human pupillometry to show that transient pupillary dilations, which reflect activity of the noradrenaline-locus coeruleus system, can be used to track these transitions (Zhao et al., submitted; Zhao, 2018).

Here we have attempted to extend these pupillometry studies to mice, so as to inquire into the neural mechanisms underlying perception of changes in the statistics of rapid sound sequences. Following Barascud et al. (2016) and Zhao (2018), we used 50ms tone-pips to create 6 different conditions: (i) a repeating sequence of the same, randomly selected tone (CONST) (ii) a regularly repeating sequence consisting of two tones (REG2), (iii) a random sequence which drew from 12 frequency tones (RAND), (iv) a sequence with a transition from one repeating tone to another (STEP), (v) a sequence with a transition from REG2 to RAND (REGRAND) and, (vi) a sequence with a transition from RAND to REG2 (RANDREG). We recorded pupil diameter in two mice listening passively to repeated free-field presentations of these sounds, whilst head-fixed on a rotating cylinder.

We observed pupillary dilation at the onsets of the stimuli. However, there was no consistent change in pupil diameter at the sound transitions in STEP, REGRAND or RANDREG stimuli. We also found that running (>1cm/s), which correlated positively with pupil size, abolished the pupillary responses to the stimulus onsets.

Pupillary responses to stimulus onsets demonstrate the salience of sound onsets following silence, whilst the absence of pupillary responses to any of the transitions within the sound sequences could reflect lack of behavioural engagement with the auditory stimuli. This interpretation is supported by Zhao, 2018, who reported a transient pupillary dilation in humans in the STEP and REGRAND conditions but proved that this response requires attention to the stimuli. The disruptive effect of running on the pupillary response to sound onsets in mice may arise from a ceiling effect: maximal pupil enlargement obscures any transient pupil dilations that would otherwise be evoked by the sound onsets.

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P.047 Distinct mechanisms underlie recalibration to audio-visual spatial discrepancies across different timescales

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Dynamic changes in the environment require the human perceptual system to flexibly correct for discrepancies that may arise between modalities. In the Ventriloquism Aftereffect (VAE), pairing spatially discrepant auditory and visual stimuli leads to a spatial recalibration of auditory perception, shifting the perceived location of auditory stimuli in the direction of the visual offset. While recalibration effects have been observed following both extended and brief periods of adaptation, the relative contributions of discrepancies occurring across different timescales remains unclear. Here, we characterise the dynamics of the VAE and ask whether they reflect a unitary adapting mechanism operating over a single timescale, or multiple mechanisms tuned to distinct timescales. Human participants adapted to audio (pink noise bursts) and visual (2D Gaussian blobs) stimuli presented synchronously and across a range of azimuths, and with either zero spatial discrepancy or with the audio offset to the left or right of the visual stimulus by 20 degrees. Participants adapted for a range of durations – from 32 to 256 seconds – and after each adapting period reproduced the perceived location of a series of unimodally presented auditory stimuli. The VAE saturated rapidly but decayed slowly, suggesting a combination of both transient and sustained adaptation mechanisms. To distinguish between recalibration mechanisms operating at unitary and distinct timescales, we adapted participants to an audio-visual spatial offset for a long period (256s) and then de-adapted them to the opposite spatial offset for a shorter period (32s). VAEs elicited by adaptation were initially cancelled by de-adaptation, but subsequently recovered with further testing. This points to multiple recalibration mechanisms operating at distinct timescales – a short-term mechanism that decays quickly, driven primarily by the de-adaptor, and a long-term mechanism with a sustained response to the adaptor. These dynamics could only be adequately fit by a multiple-mechanism model monitoring audio-visual discrepancies over distinct timescales. Taken together, our results support a model in which the VAE is governed by multiple spatial recalibration mechanisms tuned to different timescales. Recent and remote recalibration mechanisms allow the perceptual system to balance rapid adaptive changes to transient discrepancies that should be forgotten quickly against slower adaptive changes to persistent discrepancies that are likely to be more permanent.

P.048 Effect of the number of amplitude-compression channels and compression speed on sound quality judgements of speech and music

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Multichannel amplification using fast or slow compression, as used in hearing-aid signal processing to compensate for variations in loudness recruitment across frequency and to provide appropriate frequency-response shaping, may adversely affect sound quality due to reduced spectral contrast (Plomp, 1988) and temporal and spectral distortion (Kates, 2010). The objective of this study was to assess the effect of the number of channels and compression speed on sound quality when the channels were used solely to implement amplitude compression, and not for frequency-response shaping.

Computer-simulated hearing aids were used where frequency-dependent insertion gain was applied using a single filter before the signal was filtered into 3, 6, 12, or 22 compression channels. The compression speed was either fast (attack 10 ms, release 100 ms) or slow (attack 50 ms, release 3000 ms).

Speech tokens presented at: (1) 50 dB SPL, in quiet; (2) 65 dB SPL, in quiet; (3) 65 dB SPL in two-talker babble (3 dB SNR); (4) 65 dB SPL in eight-talker babble (3 dB SNR). Music tokens were segments from: (1) A pop/easy rock song; (2) A classical chamber composition featuring harpsichord, flute, and mixed strings; (3) A choral piece featuring male voices and organ. The input level for music was 65 dB SPL.

Seventeen adults with sensorineural hearing loss compared each condition to all other conditions in a round-robin paired-comparison task. Participants could indicate whether they preferred A or B, and by how much, using a slider with a continuous scale that ran from much worse (□3) to much better (3), or if they had no preference (0). A preference score was calculated for each condition.

The outcomes of separate repeated-measures three-way ANOVAs indicated that for speech, scores were significantly high for slow compression than for fast compression ($F(16,1)=10.74$, $p=0.005$. There was a significant effect of token type ($F(48,3)= 3.715$ $p=0.029$, but no contrasts were significant when adjusted for multiple comparisons. The difference in ratings across compression speeds was greatest for speech in eight-talker babble, followed by 65-dB SPL speech in quiet, speech in two-talker babble, and 50-dB SPL speech in quiet. This was reflected by a significant interaction between speed and token type ($F(34.32, 2.15)=4.613$, $p= 0.015$). For music, there were no significant effects of the number of channels or the speed of compression.

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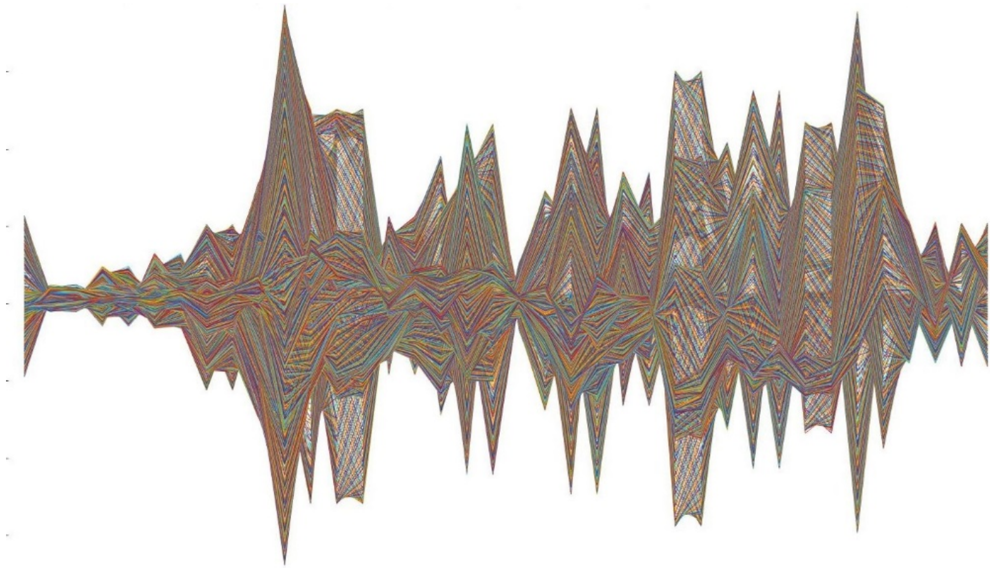
Delegate List



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