BASIC AUDITORY SCIENCE MEETING 2019

4th-5th September, University College London

Sponsored by:

Welcome to BAS 2019

Organising committee: Jennifer Linden (Chair), Fatima Ali, Alex Billig, Jenny Bizley, Maria Chait, Andy Forge, Jonathan Gale, Natallia Kharytaniuk, Torsten Marquardt, Neil Roberts, Roland Schaette, Joe Sollini, Stephen Town, Magdalena Zak.
Many thanks also to Jim Sinclair and Jo Innes.

Programme Committee: Maria Chait, Andy Forge, Jennifer Linden, Torsten Marquardt, Roland Schaette.

UCL Ear Institute, University College London, London, UK

https://www.ucl.ac.uk/ear/events/2019/sep/basic-auditory-science-2019

DAY ONE - Wednesday 4th September 2019

08:30-11:00	**Registration** (Jeffery Hall Foyer)
08:30-11:00	**Coffee, tea & refreshments** (Jeffery Hall)
09:00-11:00	**Poster Session #1** (Jeffery Hall)
11:00-13:00	**Talk Session #1** (Elvin Hall) Session Chair: *Jennifer Linden*
11:00-11:15	Welcome and Opening Remarks *Jennifer Linden*
11:15-12:15	Ted Evans Lecture *Karen Steel FRS FMedSci* "What can mice tell us about human deafness?"
12:15-13:00	Poster Teasers (10 x 2min, multiple presenters)
13:00-14:00	**Lunch** (Jeffery Hall)
14:00-16:00	**Talk Session #2** (Elvin Hall) Session Chair: *Michael Akeroyd*
14:00-14:20	*Bas Olthof*, "Multiple non-auditory cortical regions innervate the auditory midbrain"
14:20-14:40	*Rhiannon Brook*, "The developmental time course of minimum audible angle and localisation of speech in babble"
14:40-15:00	*Felix Schneider*, "Neural correlates of figure-ground segregation in anterolateral fields of the monkey auditory cortex"
15:00-15:20	Coffee break in Jeffery Hall
15:20-15:40	*Katie Smith*, "The formation of excitable microdomains in the auditory nerve follows a defined spatio-temporal pattern"
15:40-16:00	*Emanuele Perugia*, "What does the TEN test test at low Sensation Levels?"
16:00-18:00	**Poster Session #2** (Jeffery Hall) - odd numbers presenting
18:00-18:30	**Business Meeting** (Elvin Hall)
18:30-19:30	**Drinks / Cash Bar** (Jeremy Bentham Room)
19:30-22:00	**Conference Dinner** (Jeremy Bentham Room)

DAY TWO - Thursday 5th September 2019

08:30-11:00	**Coffee, tea & refreshments** (Jeffery Hall)
09:00-11:00	**Poster Session #3** (Jeffery Hall) - even numbers presenting
11:00-13:00	**Talk Session #3** (Elvin Hall) Session Chair: *Deborah Vickers*
11:00-11:20	*Wiebke Lamping*, “A coding strategy to remove temporally masked pulses and its effect on speech perception by cochlear implant listeners”
11:20-11:40	*Masa Švent,* “NMDA receptors modulate presynaptic function and Ca^{2+} dynamics in the dorsal cochlear nucleus”
11:40-12:00	*Alex Billig*, “Distinct contributions of primary and non-primary auditory cortical fields to regularity processing”
12:00-12:20	Coffee break in Jeffery Hall
12:20-12:40	*Adrian Jacobo*, “Notch-mediated polarity decisions in lateral line hair cells”
12:40-13:00	*Kerry Walker*, “Local variance in auditory cortical tonotopy across species arises from complex frequency receptive fields”
13:00-14:00	**Lunch** (Jeffery Hall)
14:00-16:15	**Talk Session #4** (Elvin Hall) Session Chair: *Christian Füllgrabe*
14:00-14:20	*Roshni Biswas*, “Assessment of pan-European prevalence of tinnitus using a standardised set of questions across countries”
14:20-14:40	*Hannah Maxwell*, “Reduced expression of nitric oxide synthase in the parahippocampal region in rats with tinnitus”
14:40-15:00	*Navid Banafshe,* “Auditory pathology in *Klhl18* mutant mice”
15:00-15:20	Coffee break
15:20-15:40	Maria Bitner-Glindzicz Memorial Talk and Poster Prize Presentation *Sally Dawson*
15:40-16:00	Ray Meddis Memorial Talk and Poster Prize Presentation *Ian Winter*
16:00-16:15	Closing Remarks *Jennifer Linden*
16:15	**End of Conference**

Meeting Venue and Information

UCL Institute of Education, Bedford Way, is at the heart of Bloomsbury, London's university district. It has exceptional transport links within London, with the rest of the UK and the world. The underground (subway) is within easy walking distance from Russell Square (nearest), Euston, Euston Square, Tottenham Court Road, Goodge Street and Warren Street Stations. National and international rail links are within fifteen minutes walking distance at Euston and Kings Cross St Pancras, with all London's principal railway stations within 25 minutes by bus or tube. Our nearest airport, Heathrow, is less than an hour away by public transport, and all London airports are easily accessible.

Venue Address: Institute of Education, 20 Bedford Way, London, WC1H 0AL.

Registration: Jeffery Hall Foyer, Level 1.

Talks: Elvin Hall (Level 1). Contributed talks should be 15 min long. Talk slots are 20 min to allow 5 min for questions and transition time.

Posters: Jeffery Hall (Level 1). Posterboards are 1m in height and 2m in width, and posters should be in A0 landscape format. Velcro will be provided. Top-ranked abstracts not chosen for the oral presentations will be considered for a Memorial Poster Prize. These Poster Prizes have been established by the UCL Ear Institute this year in memory of Professor Ray Meddis and Professor Maria Bitner-Glindzicz, two fixtures of the UK auditory science community who died in 2018. The two prizes are each worth £250, and will be judged based on the poster presentation at the meeting.

Lunch/Refreshments: Jeffery Hall (Level 1)

Conference Dinner: Jeremy Bentham Room, Main UCL Campus, Gower Street, London, WC1E 6BT (enter through the main quad, see map on page 9).

Accommodation address: John Dodgson House, 24-36 Bidborough Street, WC1H 9BL. See map on page 8.

WiFi Log-in Instructions:

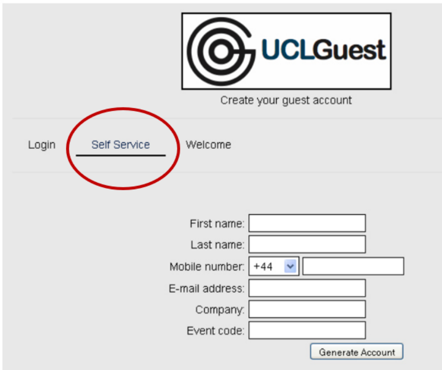
1. Connect to the UCLGuest Wireless Network.

2. Open a web browser (e.g. Safari or Google Chrome) and navigate to a page you haven't visited recently (which is not saved in your cache). The browser will automatically redirect to the UCLGuest Welcome page.

Troubleshooting: If this fails, delete the history on the browser and try access a website that you knows works, but that you do not access frequently e.g. http://www.bbc.co.uk.

If this does not work either, type the IP address of the UCLGuest Server in the web browser: https://128.40.211.59. Click "Open Network Login Page" and this should redirect you to the UCL Guest login page.

3. Click on Self Service; enter your information and the event code 'bas2019' in the fields provided.



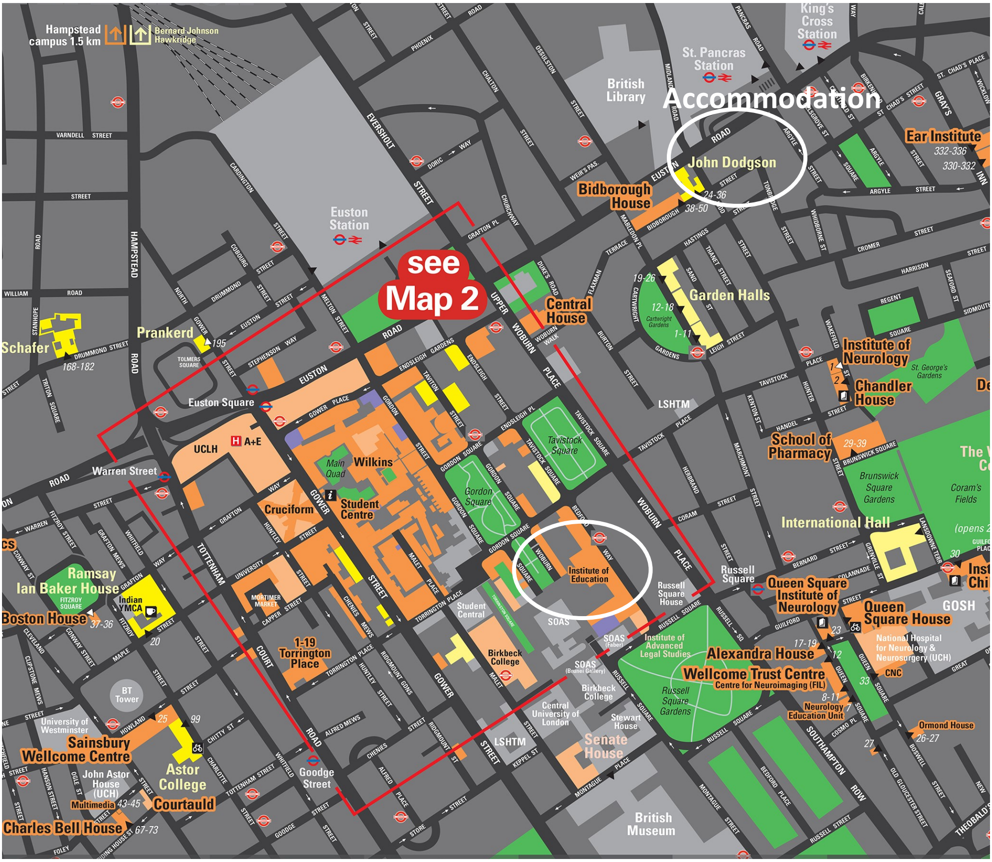
4. Click Generate Account.

5. Your username and password will be displayed on the screen; these details will also be sent to your e-mail address. Make a note of and copy your username and password as you will need them each time you log into UCLGuest (the system will not remember your login details). The details will be valid for the duration of your event, so you do not need to create a new password each time you want to log in (see step 8).

6. On the next page, paste the password and click on Login. (Please be aware it may take up 60 seconds for your account to become active after it's been generated, if you cannot log in please wait a short while and try again).

7. Click Accept on following page and you will be connected to the Wi-Fi.

8. In case you are logged off automatically, you can go back to the UCL start page and click on Login rather than Self Service. Use the password you created when you logged in the first time in order to re-connect to the Wi-Fi.



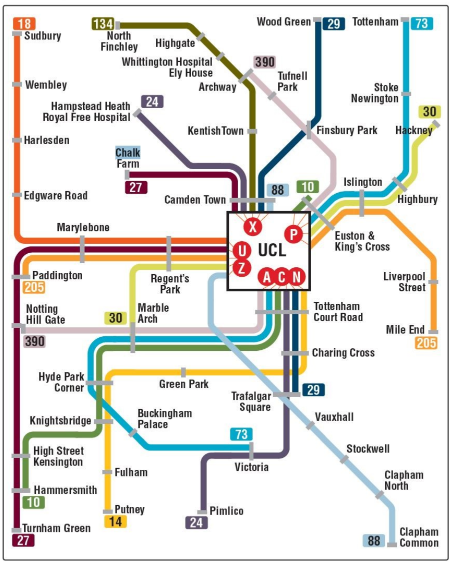
How to reach UCL's Bloomsbury Campus

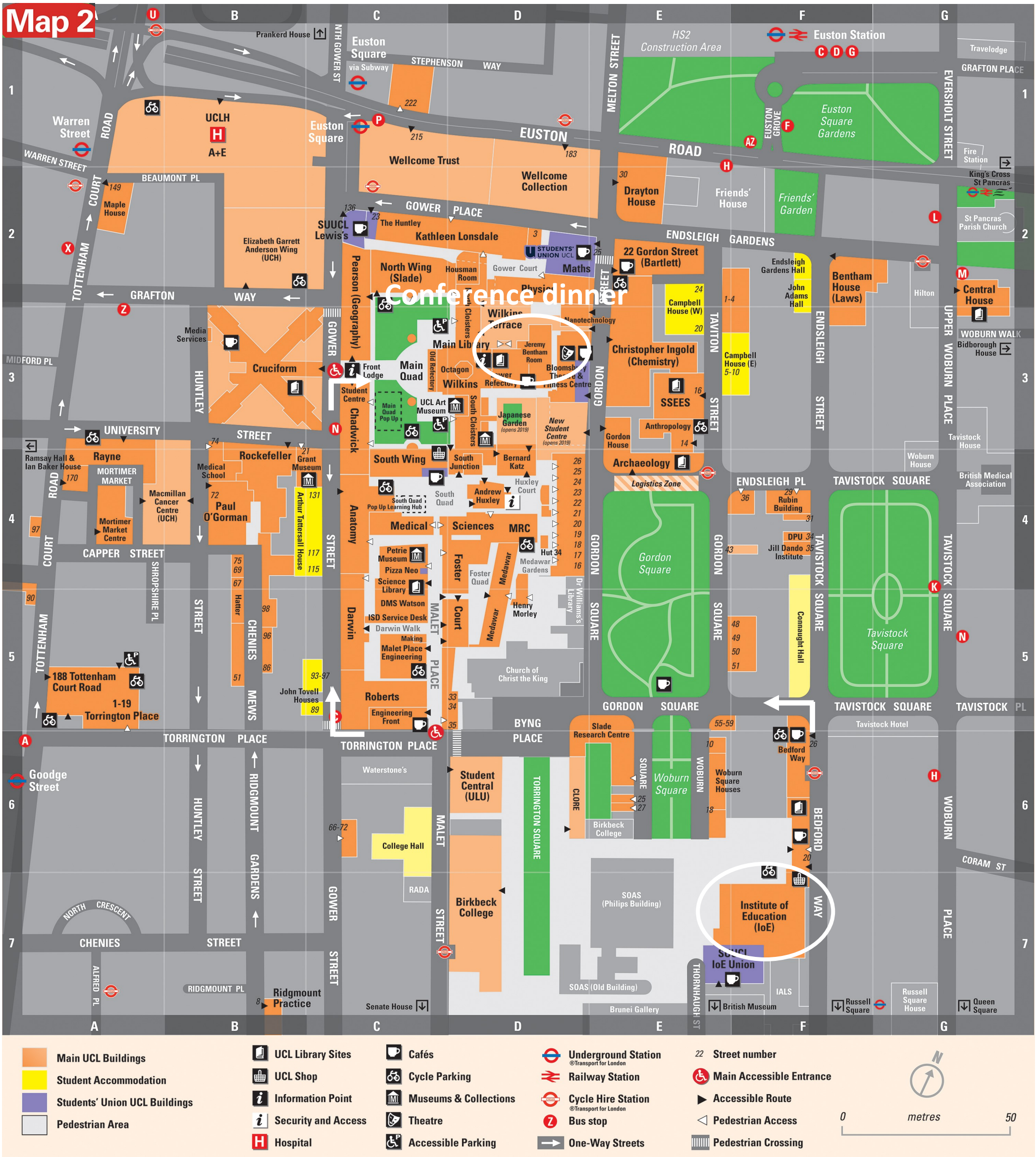
By train :

From station:	Take tube line:
Charing Cross	Northern line (northbound) to Goodge Street / Warren Street
King's Cross & St Pancras	Metropolitan / Circle line (westbound) to Euston Square or Piccadilly line to Russell Square
St Pancras Intl.	Metropolitan / Circle line (westbound) to Euston Square
Liverpool Street	Metropolitan / Circle line (westbound) to Euston Square
London Bridge	Northern line (northbound) to Euston
Marylebone	Bakerloo line (eastbound) to Baker Street, change to Circle / Metropolitan / Hammersmith & City line (eastbound) to Euston Square
Paddington	Hammersmith & City / Circle line (eastbound) to Euston Square or Elizabeth line (crossrail) to Tottenham Court Road *(opens Dec. 2018)*
Victoria	Victoria line (northbound) to Warren Street
Waterloo	Northern line (northbound) to Goodge Street / Warren Street

By bus:

Bus stops indicated on map 2





Please note that the Bloomsbury area has metered parking and visitors are therefore strongly advised not to travel to UCL by car. UCL is within the congestion charging zone.

Sightseeing in London

We hope that you have an enjoyable time in one of the most interesting and vibrant cities in the world; there really is an endless list of things to do. Have a look at some of the suggestions below which will help you make the most of your time.

Transport in London: The fastest way to travel around London is by the tube (London underground). If you have time to spare, a bus ride is a pleasant way of seeing the city and you will see more of the architecture and sights that London has to offer. Buses no longer accept cash to pay for fares. If your bank card shows the contactless payment symbol, you can use it to pay as you go on all Transport for London services straight away – you'll pay an adult rate fare. Otherwise, purchase an Oyster card and top up at any underground station. Oyster pay as you go is also accepted on the MBNA Thames Clippers' (river bus) services. You can find more information at Tourism Info Centres at Kings Cross/Euston stations. However, we advise to ditch the tour buses and river cruises. The best way to explore London is on foot!

Museums and Places of Interest: The British Library, British Museum, Wellcome Collection are nearby and within 10-15 minute walk of the venue. The Science Museum, Victoria & Albert Museum and National History Museum are about 25 minutes away (nearest tube station is South Kensington). For art-lovers, head to National Portrait Gallery (Leicester Square) and Tate Modern (Southwark).

Theatre and Concerts: You can get some good deals on plays, musicals, opera, ballet, etc. if you book online in advance. Have a look at **www.lastminute.com, http://www.uktickets.co.uk** and **http://www.discounttheatre.com/.**

Local Shopping: Brunswick Shopping Centre is situated approximately 5 minute walk from the Institute of Education, and has a good selection of retail shops and restaurants including Strada, Yo Sushi, Nandos, Giraffe and Carluccios. You can find a Waitrose supermarket as well as pharmacies here too. There is also a Tesco opposite Russell Square Station. Slightly farther afield, there are large concentrations of shops and restaurants on Marchmont Street near Tavistock Place; just north of King's Cross and St Pancras stations; and on Tottenham Court Road near Oxford Street.

Restaurants/cafes in the vicinity of IOE:
Crazy Salad (33-35 Woburn Pl, WC1H 0JR) and Pret (WC1H 9LT) offer options just round the corner towards Tavistock Square, and as mentioned Brunswick Shopping Centre also has many options. The King of Falafel (17 Hunter St, WC1N 1BN) is a good choice for vegans and is a 5 minute walk away, just past Brunswick.

Towards Goodge Street/Charlotte Street, there are many options including Wahaca (19-23 Charlotte St,W1T 1RL) for Mexican and bibimbap (10 Charlotte Street, W1T 2LT) for Korean food. Franco Manca (98 Tottenham Court Rd,W1T 4TR) and ICCO (46 Goodge St, W1T 4LU) are great for pizzas and Amorino (21 Goodge Street, W1T 2PJ) for ice-cream.

Ciao Bella (86-90 Lamb's Conduit St, WC1N 3LZ) is an Italian restaurant offering very good food and nice atmosphere approximately 10 minutes walk from the institute (advisable to phone and book).

Public Houses: A few local pubs in the vicinity of IoE

The IoE bar is the closest and best-priced!
The Marquis Cornwallis (31 Marchmont St, WC1N 1AP) and the Resting Hare (Woburn Walk, WC1H 0JW) are nicer but more expensive.
Towards Kings Cross Station, head to Harrison's Gastro Pub (28 Harrison St, WC1H 8JF) or the traditional Norfolk Arms Pub (28 Leigh St, WC1H 9EP) that also serves Spanish tapas.

Useful websites:

www.tfl.gov.uk - Transport for London, for tube map and journey planners.
www.visitlondon.com
www.londontown.com
www.timeout.com/london - Some alternative events that London can offer.

ORAL PRESENTATIONS

Ted Evans Lecture 2019

What can mice tell us about human deafness?

Professor Karen P Steel FRS FMedSCi

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Deafness is very common in the population, with around one in a thousand children born with a permanent hearing loss and over half of us having a significant hearing loss by the time we reach our 70s. We know that environmental factors contribute to hearing loss, such as drugs, infections and loud sounds, but genetics also plays a critical role. We have used mice with mutations causing deafness as tools to identify candidate genes for involvement in human deafness and molecular pathways involved in normal hearing. The normal process of hearing, the pathological features of hearing impairment, and the genes underlying deafness are all very similar in mice and humans. Over 400 genes are known to be involved in hearing impairment in mice or humans or both, and we have evidence from a large-scale mouse screen that around 1000 genes will be involved in total. This makes deafness a highly heterogeneous disease. Furthermore, our analysis of deaf mouse mutants indicates that the underlying pathological processes are also very diverse. These findings emphasise the importance of developing better diagnostic tools to determine the key sites of dysfunction in the auditory system. Better diagnostic tools will enable stratification of groups of subjects with similar pathologies for clinical trials of medical treatments, and then allow selection of the most appropriate treatment for each person coming into the clinic. Our findings in the mouse have enabled us to identify several molecular networks involved, some of which are "druggable", and these will be relevant to progressive hearing loss whatever the trigger. Our goal is to provide evidence that progressive hearing loss can be treated using a drug-based approach.

T01. Multiple non-auditory cortical regions innervate the auditory midbrain

B.M.J. Olthof, A. Rees, S.E. Gartside
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Our understanding of the world relies on integrating sensory and cognitive information to create a coherent percept. For the perceptual experience of sound this requires the integration of ascending and descending streams of information. The networks sub-serving this integration are unclear. The inferior colliculus (IC), the midbrain nucleus in the auditory pathway, processes virtually all ascending auditory information and receives extensive descending connections from the auditory cortex (Bajo and King, 2013 for review). However, we do not know the extent to which the IC receives inputs from non-auditory cortical structures that would enable other senses and cognitive processes to influence hearing.

Using retrograde tracers injected into the IC, we identified all cortical regions that project to the IC. By injecting anterograde tracers into these identified cortical regions, we defined the regional and cellular targets of cortical projections in the IC. Male Lister hooded rats (250-300g) were anaesthetised and received injections of Retrobeads (Lumafluor®) into the IC, or fluorophore-conjugated dextran into the auditory, prefrontal, somatosensory, and visual cortices. Three days following Retrobead injection or 7 days following dextran injection, rats were transcardially perfused and brains were harvested and sectioned coronally at 40 µm. IC sections from dextran injected animals were immunolabelled labelled for GABA.

Retrograde tracing revealed that, in addition to dense descending projections from auditory cortex, the IC is also heavily innervated by the visual, somatosensory, motor, and prefrontal cortices. Cortical neurons projecting to the IC are concentrated in layer V/VI and have pyramidal morphology. While all these descending connections are bilateral, those from sensory areas show a more pronounced ipsilateral dominance compared with those from the motor and prefrontal cortices.

Anterograde tracing revealed that projections from non-auditory as well as auditory, cortical areas innervate all three subdivisions of the IC. Most cortical projections terminate on the somata and proximal portions of the dendrites. Both GABAergic and glutamatergic neurons are targeted. Intriguingly, some neurons in the IC receive innervation from multiple cortical regions.

These findings suggest that auditory perception and behaviour is served by a network that includes extensive descending connections to the midbrain from sensory, behavioural, and executive cortices.

Acknowledgments:
Supported by the BBSRC (BB/P003249/1)

References:
Bajo VM, King AJ (2013). Frontiers in Neural Circuits 6.

T02. The developmental time course of minimum audible angle and localisation of speech in babble

R.E. Brook[1], P.T. Kitterick[1,2], J.G. Barry[3], M.A. Akeroyd[1]
[1] *Hearing Sciences, Division of Clinical Neurosciences, School of Medicine, University of Nottingham, Nottingham, NG7 2RD*
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[3] *Nottingham University Hospitals NHS Trust, Queen's Medical Centre, Nottingham NG7 2UH*

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, but are poorer in the presence of speech babble (Boothalingam et al., 2016). This may compromise their listening in real world environments, which could in turn affect their language acquisition and educational outcomes. This potential impact means it is important to know more about how children localise in babble.

Here we report the first studies to accurately quantify the developmental time course of minimum audible angle and localisation of speech in babble abilities of participants aged 6-29 years. The relationships between performance in localisation, detection and identification of speech in babble were also examined. All participants spoke English as their first language, had normal hearing and no learning/language disorders. A ring of 24 loudspeakers was used for all tasks. The target stimuli were colour words from the CRM corpus, and the babble was made up of 6 spatially separated IEEE sentences.

Study 1 mapped the developmental time course of localisation in babble abilities of 68 participants age 6-29 years, finding that performance could be fitted using an exponential function with a time constant of 5.5 years and adult-like performance occurred around 15-17 years. Study 2 investigated relationships between detection, identification and localisation in babble abilities in 40 participants age 10-28 years, finding that performance (d') was highest in identification, followed by localisation and detection which were similar. Study 3 built on these findings by testing 17 adults age 19-30 years at more challenging SNRs and adding another localisation task. There were smaller differences between tasks but generally detection performance was highest. Study 4 mapped the developmental time course of minimum audible angle in babble at four different SNRs in 50 participants age 6-21 years. These trajectories were fitted with exponential functions, the time constants of which depended on SNR. The age at which adult-like performance occurred also varied with SNR.

Acknowledgments: Funded by an MRC studentship to Rhiannon Brook.

References:

Boothalingam S, Macpherson E, Allan C, Allen P and Purcell D (2016). *J Acoust Soc Am*, 139(1): 247-262.
Lovett RES, Kitterick PT, Huang S, Summerfield AQ (2012). *J Speech Lang Hear Res*, 55 (3): 865-878.

T03. Neural correlates of figure-ground segregation in anterolateral fields of the monkey auditory cortex

Felix Schneider[1], Fabien Balezeau[1], Yukiko Kikuchi[1], Chris Petkov[1], Alexander Thiele[1], Timothy Griffiths[1]
[1] *Institute of Neuroscience, Newcastle University, Newcastle upon Tyne, United Kingdom*

Across sensory modalities, figure-ground segregation is critical for scene analysis. This is a particularly challenging problem in the auditory system where different sound objects emanating from the same spatial location have to be dynamically decoded using spectro-temporal features that are difficult to segregate from noisy backgrounds. Previous imaging studies have shown an involvement of non-primary auditory regions in both humans[1,2] and macaques[3], however, the underlying neural mechanisms remain unknown. The aim of this study was to identify the neurophysiological correlates of figure-ground segregation in the auditory cortex of macaque monkeys using fMRI-guided electrophysiological recordings.

We investigated neuronal responses to stochastic figure-ground stimuli in two macaques. We recorded spiking and local field potentials (LFPs) in the auditory core and surrounding belt while the animals performed a Go/No-Go figure detection task. We show a significant increase in firing rate to auditory figures across cortical areas, with shorter response latencies in the anterior compared to the posterior recording regions. A figure modulation index revealed a comparable effect size across fields but we found a higher fraction of figure-ground responsive cells in the anterolateral auditory cortex. Generally, higher figure coherence causes earlier and larger increments in firing rate. The analysis of LFPs revealed figure-ground related changes in the beta and gamma band.

Our results indicate that this form of auditory scene analysis depends on anterolateral auditory fields and suggest that bottom-up information is first integrated in subpopulations of neurons further along the ventral processing pathway in the auditory cortical hierarchy. These neurons respond to a broad range of frequency bands and can detect temporally coherent elements devoid of simple mathematical relationships between acoustical components. Our results confirm and extend with direct neurophysiolocal evidence earlier fMRI studies[1,3].

References:

1. Teki, S., Chait, M., Kumar, S., von Kriegstein, K. & Griffiths, T. D. Brain Bases for Auditory Stimulus-Driven Figure-Ground Segregation. *J. Neurosci.* **31**, 164–171 (2011).
2. Teki, S. *et al.* Neural Correlates of Auditory Figure-Ground Segregation Based on Temporal Coherence. *Cereb. Cortex* **26**, 3669–3680 (2016).
3. Schneider, F. *et al.* Auditory figure-ground analysis in rostral belt and parabelt of the macaque monkey. *Sci. Rep.* **8**, 17948 (2018).

T04. The formation of excitable microdomains in the auditory nerve follows a defined spatio-temporal pattern

K. Smith and D. Jagger
UCL Ear Institute, University College London, London, UK

Type I spiral ganglion neurons (SGNs) in the auditory nerve transmit acoustic information from cochlear inner hair cells (IHCs) to the brainstem via action potentials. The ion channels responsible for action potential initiation and propagation are organized into discrete functional “microdomains” (Hossain et al., 2005; Smith et al., 2015), the assembly of which most likely depends on associated glial cells. These microdomains include the spike generator region located a short distance from the IHC synapse, and nodes of Ranvier distributed along SGN neurites. In severe cases of sensorineural hearing loss, the peripheral neurites of SGNs can degenerate substantially. Regenerative strategies aiming to regrow SGN neurites must recapitulate the complex organisation of microdomains in order to fully restore function to the auditory nerve. Here, we investigated the sequence of events involved in microdomain assembly and maturation during mouse cochlear development.

Using enhanced resolution (Airyscan) confocal imaging of immunolabelled mouse (C57BL/6J) cochlear vibratome sections, we examined the localisation of various nodal proteins and ion channels during postnatal development (postnatal day P4-P30). The nodal proteins AnkyrinG and Neurofascin-186 were the earliest detected proteins (~P4), where they co-localised at immature clusters. These proteins then formed a heminodal arrangement with the paranodal protein Caspr, and ‘approaching’ heminodes could be observed along the same neurite from ~P6, suggesting that nodal assembly occurs by the fusion of two heminodes. The timings of nodal assembly differed along the length of SGNs. Along peripheral neurites, >90% of nodes of Ranvier had assembled by P10, whereas >40% of nodes of Ranvier along central neurites were still immature at this age. The peri-somatic nodes of Ranvier developed even later with a large proportion (>50%) of immature heminodal arrangements still observed at P12, after hearing onset. Refinement of the spike generator region also continued after hearing onset, as has been reported in the rat (Kim and Rutherford, 2016).

These results present a defined spatio-temporal pattern of microdomain formation during maturation of the auditory nerve and provide an insight into the mechanisms involved in microdomain assembly, a process that must be recapitulated in regenerative strategies targeting sensorineural hearing loss.

Acknowledgements: Supported by an Action on Hearing Loss/Dunhill Medical Trust Pauline Ashley Fellowship to K.S (PA24) and a BBSRC grant to D.J (BB/M019322/1).

References:

Hossain, W. A. et al. (2005) J. Neurosci. 25(29):6857-6868
Smith, K. E. et al. (2015) J. Neurosci. 35(32):11221-11232
Kim, K. X. and Rutherford, M. A. (2016) J Neurosci 36, 2111-2118

T05. What does the TEN test test at low Sensation Levels?

M. A. Stone[1], E. Perugia[1], G. Prendergast[1], R. E. Millman[1], C. J. Plack[1.2]
[1]*Manchester Centre for Audiology and Deafness, School of Health Sciences, University of Manchester*
[2] *Department of Psychology, Lancaster University*

Despite the physiologically observed degradation due to noise exposure of the non-human inner haircell and its associated structures, there has been little progress in developing clinical tests that identify such degradations. The Threshold-Equalizing Noise (TEN) test (Moore et al. 2004) assesses for the existence of 'dead regions' in the cochlea: it is used to determine regions of the cochlea where there are no functional neural pathways. As such, it has a pass/fail criterion. The possibility exists that elevated TEN thresholds, insufficiently elevated to classify a dead region, may be indicative of a 'sick region'.

109 participants were recruited in the age range of 29 - 72 years as potential first-time hearing aid wearers. Their hearing ability ranged from normal to a mild high-frequency loss. Participants' lifetime noise exposure was recorded using a structured interview (NESI, Guest et al., 2018), recording duration of activity as a function of estimated level exceeding 100 dBA, and a proxy for musical experience. For each participant, routine audiometry and TEN tests were performed. The TEN test was performed at 12 and 24 dB sensation level (SL) relative to their air-conduction threshold (AbsThr) and at 750, 1000, 3000 and 4000 Hz.

Except for testing at 1000 Hz at 12 dB SL a strong correlation between elevation of TEN threshold and AbsThr threshold was observed, even for values of AbsThr indicative of 'normal hearing'. The correlations remained of a similar strength after controlling for NESI, musical experience or age. Very rarely was a threshold elevation observed sufficiently indicative of a dead region.

Results from the TEN test appears to include a modest involvement of outer hair cell function, possibly confounding any potential to identify a 'sick region'. The lack of correlation of threshold elevation with either NESI or age suggest that the TEN test only identifies gross changes in inner hair call function.

Acknowledgements: The authors are supported by the NIHR Manchester Biomedical Research Centre and by the Medical Research Council, UK (MR/L003589/1 and MR/M023486/1).

References:

Guest, H., Dewey, R. S., Plack, C. J., Couth, S., Prendergast, G., Bakay, W., & Hall, D. A. (2018). *Trends Hear*, 22:1–10.
Moore, B.C.J., Glasberg, B.R., & Stone, M.A. (2004). *Ear Hear*, 25:478–487

T06. A coding strategy to remove temporally masked pulses and its effect on speech perception by cochlear implant listeners

Wiebke Lamping[1,2,3], Tobias Goehring[3], Jeremy Marozeau[2], Robert P. Carlyon[3]
[1]*Department of Clinical Neurosciences, University of Cambridge, Cambridge,* CB2 0SZ
[2]*Hearing Systems Section, Department of Health Technology, Technical University of Denmark, DK-2800, Kgs. Lyngby, Denmark*
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Speech recognition in noisy environments remains a challenge for cochlear implant (CI) recipients. Unwanted current interactions both in the spectral and in the temporal domain are likely to impair performance. Here we investigate the effect of reducing the number of overall current pulses on speech perception. This was done by implementing a psychoacoustic forward-masking model acting in the temporal domain, the temporal integrator. The model was used to identify and remove current pulses that were less likely to be perceived by the recipient. The decision criterion of the temporal integrator was set so as to control the percentage of pulses removed in each condition. In experiment 1, speech in quiet was processed with a standard Continuous Interleaved Sampling (CIS) strategy and with 25, 50 and 75% of pulses removed. In the second experiment, performance was measured for speech in noise with the CIS reference and with 50 and 75% of pulses removed. Speech intelligibility in quiet revealed no significant difference between reference and test conditions; hence the number of current pulses could be reduced by up to 75% without harming performance. For speech in noise, results showed a significant improvement of 2.4 dB when removing 50% of pulses while performance was similar to the reference when 75% of pulses were removed. Further, by reducing the overall amount of current pulses by 25, 50, and 75% but accounting for the increase in charge necessary to compensate for the decrease in loudness, average power savings of 20.5, 36, and 57.5%, respectively, could be possible for this set of listeners. We can conclude that removing temporally masked pulses may improve speech perception in noise and will result in substantial power savings.

Acknowledgements: We are grateful to Rikke Skovhøj Sørensen for helping with the recruitment of participants and the data collection. This work was supported by the Oticon Centre of Excellence for Hearing and Speech Sciences (CHeSS) as well as by award MR/S002537/1 from the U.K. Medical Research Council (MRC) to author WL, by award RG91365 from the U.K. MRC to author RC, and by Action on Hearing Loss (Grant 82) to author TG.

T07. NMDA receptors modulate presynaptic function and Ca^{2+} dynamics in the dorsal cochlear nucleus

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Recent studies have shown that acoustic over-exposure, leading to gap-detection deficits in a rodent model of tinnitus, also increases glutamate release at dorsal cochlear nucleus (DCN) multisensory synapses[1]. This activates NMDA receptors (NMDARs) and leads to saturation of long-term potentiation[1] (LTP). The aim of this study was to investigate the presynaptic role of NMDARs in modulating synaptic release in the DCN. Whole-cell recordings were used to record miniature excitatory postsynaptic currents (mEPSCs) from DCN fusiform cells in CBA mice. Miniature EPSCs were isolated using tetrodotoxin (1µM) and recorded in the presence of NMDAR agonist (500nM NMDA) with and without antagonist (50µM D-AP5). Data on mEPSCs were analysed using multi-comparison Friedman tests with Dunn's correction. All values are reported as mean±SD. In 7 out of 12 fusiform cells, NMDA increased mEPSC frequency (decreasing inter-event intervals from 2.25±1.46s to 1.17±0.80s, $p<0.05$). The effect was reversed by the subsequent addition of D-AP5 (inter-event interval 3.33±2.42s, NMDA vs NMDA+D-AP5 $p<0.01$, control vs NMDA+D-AP5 $p>0.99$, $F=11.14$, $n=7$). NMDA had no effect on mEPSC amplitude ($p=0.62$, $F=1.14$, $n=7$) or decay time constant ($p=0.49$, $F=2$, $n=7$). This selective effect on mEPSC frequency indicates a presynaptic effect of NMDA receptors. This was further assessed in transgenic mice expressing SyGCaMP2-mCherry, a ratiometric Ca^{2+} sensor reporting Ca^{2+} level changes in presynaptic boutons[2]. Epifluorescence imaging of DCN molecular layer showed that perfusion of NMDA (n=5) caused a small but significant increase in baseline fluorescence compared to control slices ($n=5$, $p_{interaction}<0.05$, $p_{drug}<0.01$, $p_{time}=0.36$, 2-way ANOVA with Tukey's multiple comparisons test). D-AP5 decreased the peak fluorescence response (from 101.2±5.9% to 77.1±8.6% F/F_0, $p<0.01$, Wilcoxon test, $W=-36$, $N=8$ slices) evoked by parallel fibre stimulation (50Hz, 1s). Multiphoton imaging showed that D-AP5 decreases the peak F/F_0 per bouton (from 1.4±0.2 to 1.3±0.2 F/F_0, $p<0.0001$, Wilcoxon test, $W=-1281$, $n=57$ boutons, $N=4$ slices) without changing the number of responding boutons (from 62.9±15.9% to 52.3±22.2%, $p=0.06$, unpaired t-test with Welch's correction, $t=1.9$, $n=24$, $N=4$). In conclusion, blocking NMDARs after acoustic over-exposure is likely to decrease basal glutamate release at DCN multisensory synapses and reverse the effects on LTP saturation and gap detection deficits observed following acoustic over-exposure[1].

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T08. Distinct contributions of primary and non-primary auditory cortical fields to regularity processing

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Making sense of the auditory environment is facilitated by the identification of repeating acoustic structure. The human auditory system rapidly and automatically detects regular patterns in tone sequences, as evidenced by distinct signatures in neural activity at the time of their emergence, over the course of repetition, and after the sequence ends (Barascud et al., 2016; Southwell & Chait, 2018). The contribution of different fields within auditory cortex to each of these signatures has not been firmly established, but may shed light on different stages of processing of regularities in sound. We recorded intracranially from seven human subjects who were undergoing monitoring to identify epileptic seizure foci. Electrode coverage included primary and non-primary auditory cortical fields on the superior temporal plane and superior temporal gyrus. We presented 4.5-s sequences of 50 -ms tone pips, each sequence consisting of consecutive sets of the same 5 or 10 frequencies ordered either consistently ("regular") or inconsistently ("random") from set to set, while subjects listened without performing any task. Clear spectral peaks at the *tone* repetition rate (20 Hz) were present at contacts in primary auditory cortex (posteromedial Heschl's gyrus), and these were significantly greater for regular compared to random sequences in a subset of subjects. In one case, patterns of length 5 were associated with greater power at the *pattern* repetition rate (4 Hz) in primary cortex, during regular compared to random sequences. A broader set of non-primary sites, including in anterolateral Heschl's gyrus, planum polare, and superior temporal gyrus, displayed effects of regularity and alphabet size, either at the time of pattern emergence or following sequence offset. These effects varied in latency and direction across sites and subjects. Ongoing work will further characterise this variability, with a view to better establishing the contribution of distinct neural sources to auditory regularity processing.

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T09. Notch-mediated polarity decisions in lateral line hair cells

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The development of mechanosensory epithelia, such as those of the auditory and vestibular systems, results in the precise orientation of mechanosensory hair cells and consequently directional sensitivity. After division of a precursor cell in the zebrafish's lateral line, the daughter hair cells differentiate with opposite mechanical sensitivity. This process produces neuromasts containing equal numbers of hair cells of two opposite polarities, half of them sensitive to caudad water movement and half to rostrad flow.

Through a combination of theoretical and experimental approaches, we show that Notch1a-mediated lateral inhibition produces a bistable switch that reliably gives rise to hair cell pairs of opposite polarity (*1*). Using our mathematical model of the process, we predict the outcome of several genetic and chemical alterations to the system, which we then confirm experimentally. Following the predictions of our model we are able to alter the ratio of rostrad to caudad cells in the neuromast by titrating the concentration different inhibitors of the Notch pathway. We confirm these results by generating a transgenic fish line that constitutively expresses the Notch intracellular domain in hair cells, and also by analysing Notch1a$^{-/-}$ fish.

We then show that Notch1a downregulates the expression of Emx2, a transcription factor known to be involved in polarity specification, and acts in parallel with the planar-cell-polarity system to determine the orientation of hair bundles (*2*). By analysing the effect of simultaneous genetic perturbations to Notch1a and Emx2 we infer that the gene-regulatory network determining cell polarity includes undiscovered polarity effectors.

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T10. Local variance in auditory cortical tonotopy across species arises from complex frequency receptive fields

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Tonotopic organization has been a widely accepted property of the primary auditory cortex (A1) for over 50 years. It has been demonstrated in numerous electrophysiological and wide-field imaging studies across a wide range of mammals. However, this understanding has been challenged by recent studies in mice using 2-photon calcium imaging (2PI) to examine the activity of individual A1 cells with unprecedented spatial sampling rate. These studies have shown that, although the expected tonotopic organization is visible at a large scale, neighboring neurons can have vastly different best frequencies (BFs) [1,2]. It remains unclear whether this "salt and pepper" tonotopy is a general feature of mammalian A1, or a peculiarity of mice. To answer this question, we injected GCaMP6 in the A1 of 8 ferrets and 18 mice, and imaged neuronal responses to pure tones (0.3 - 50kHz; 30 - 100dB SPL) in layers II/III under medetomidine-ketamine anesthesia. Consistent with reports in mice, ferrets showed global tonotopic organization across A1, but within a local imaging field the neuronal BFs were highly variable (2.4 +/- 0.1 octaves/mm). Ascribing a BF to a neuron assumes that it prefers a single frequency, which is not always the case. Therefore, we categorized neurons' Frequency Response Areas (FRAs) as having either a clear single peak, two distinct peaks, or a more complex frequency response. We found that much of the local variation in BF is due to the presence of double and complex FRAs, and even global tonotopy is disrupted within complex neurons. When we normalized BF variance by the anatomical length and frequency range of the tonotopic axis, we found no difference between the local BF variance of single peaked neurons in ferret and mouse A1. However, ferrets had a larger proportion of double and complex neuronal FRAs. Our results show that similar spatial organization principles are present in rodent and carnivore A1. More neurons in the ferret appear to be suited for across-frequency integration, and these are less spatially constrained by tonotopy.

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T11. Assessment of pan-European prevalence of tinnitus using a standardised set of questions across countries

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Accurate figures for the prevalence of tinnitus are crucial to understanding its burden on society. However, currently available estimates for tinnitus are remarkably broad: the reported prevalence ranges anywhere between 5% and 43% (McCormack et al., 2016). The aim of our study was to estimate the pan-European prevalence of tinnitus, using the same set of standardised questions across countries.

Between 2017-2018, we conducted a computer assisted personal interview survey on tinnitus in 12 European Union Member States (Bulgaria, England, France, Germany, Greece, Ireland, Italy, Latvia, Poland, Portugal, Romania and Spain). We took considerable care to ensure that the translations of the questions were matched. For each country, around 1000 adults (aged ≥18 years) were recruited, representative of the general population in terms of sex, age, socio-economic characteristics and habitat. In total, 11427 subjects (5404 men and 6023 women) were enrolled. The overall prevalence of any tinnitus was found to be 14.7% (ranging from 8.7% in Ireland to 28.3% in Bulgaria). Prevalence was no different in men (14.1%) and women (15.2%; $p=0.086$). Severe tinnitus was found in 1% of participants (ranging from 0.6% in Ireland to 4.2% in Romania), with higher prevalence in women (1.4%) compared to men (1.0%; $p=0.034$). The overall percentage of individuals reporting at least one clinical visit for tinnitus was 6.8%, with 5.7% in men and 7.5% in women ($p<0.001$). Prevalence substantially increased with increasing age (p for trends <0.001).

Our study is the first to report pan-European tinnitus prevalence using standardized questions. Once generalized to the overall European Union population, our results indicate that 75 million, that is more than 1 in 7 adults suffer from tinnitus.

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T12. Reduced expression of nitric oxide synthase in the parahippocampal region in rats with tinnitus

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Tinnitus is associated with changes in neuronal properties throughout the auditory system. However, neuroimaging studies in patients with tinnitus also demonstrate increased functional activity beyond the auditory pathway in the parahippocampal gyrus (De Ridder & Vanneste, Brain Stimul, 7, 709, 2014) - a region with limbic connections involved in memory and contextual processing.

In animals with tinnitus, increases in the expression of neuronal nitric oxide synthase (nNOS) -a catalyst of nitric oxide (NO) synthesis – have been reported in the cochlear nucleus (Coomber et al. Front Neurol, 6, 53, 2015), while we have reported an increase in nNOS in the inferior colliculus and a decrease in the auditory cortex (Maxwell et al, Ps815, ARO, 2019). Here we investigate whether there are also differences in nNOS expression in the parahippocampal region (Brodmann's areas 35 and 36) between rats with tinnitus following unilateral acoustic over-exposure and controls.

Anaesthetised Long Evans rats were noise exposed (16 kHz tone at 116 dB SPL, 1 hour) with the left ear plugged. Subsequently they were tested for tinnitus with the gap, pre-pulse inhibition of the acoustic startle paradigm. Animals with reduced inhibition of startle were classified as 'tinnitus'. Tinnitus and (unexposed) control rats were deeply anaesthetised and transcardially perfused with 4% paraformaldehyde. Brains were removed, cryoprotected, and sectioned. nNOS expression was determined by immunohistochemistry using rabbit anti-nNOS and Alexa 568 conjugated goat anti-rabbit antibodies. Labelling was imaged with a Nikon A1 confocal microscope.

Neurons labelled for nNOS were densest in layer II, with prominent labelling bordering the rhinal sulcus where areas 35 and 36 meet. nNOS labelled somata were also dense in layers V and VI. In tinnitus compared to control rats, nNOS labelling intensity was significantly lower in areas 35 and 36, in both hemispheres, across all layers (three way ANOVA, main effect of condition: p=0.001 (area 35) and p=0.005 (area 36)). In area 36 the number of nNOS positive neurons did not differ between control and tinnitus rats. However, in area 35, there were significantly fewer nNOS positive neurons in tinnitus rats (main effect of condition: p=0.018) with the greatest difference in layers V/VI (condition by region interaction: p=0.05).

These results support the involvement of NO in the pathophysiology of tinnitus and suggest that in addition to effects on the auditory pathway, tinnitus also impacts brain regions concerned with memory and cognition.

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T13. Auditory pathology in *Klhl18* mutant mice

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Following a large-scale screen of new mouse mutants using Auditory Brainstem Response (ABR) recording, we discovered an allele of the *Klhl18* gene, *Klhl18^{lowf}*, with progressive hearing loss predominantly affecting low frequencies. *Klhl18^{lowf}* was a spontaneous missense mutation of *Klhl18* (9:110455454 C>A; V55F), predicted to have a damaging effect on protein structure.

Our aims here were (1) to investigate potential cochlear pathologies that could be associated with the impairment and (2) to analyse suprathreshold responses to characterise temporal processing capacity in mutants and controls.

We used confocal microscopy to assess numbers of synapses. Our results revealed no significant difference in the number of synapses in 6 week old *Klhl18^{lowf}* homozygotes at the 12 kHz and 24 kHz cochlear regions compared with controls. Stereocilia of *Klhl18^{lowf}* were imaged using Scanning Electron Microscopy. We observed abnormal morphology of inner hair cell stereocilia which were tapered towards the tip in homozygous mutants at the 6 and 12 kHz region when compared to wildtypes in four week old mice. A less pronounced structural defect was observed in heterozygous mutants. At three weeks, preliminary results reveal a similar tapering of inner hair cell stereocilia towards the tip at apical cochlear frequency regions in mutant *Klhl18^{lowf} when compared to controls.*

To characterise temporal processing we used click stimuli with varying repetition rates in four week old *Klhl18^{lowf}* mutant mice. Homozygotes responded with more severely-reduced ABR wave I amplitudes with increasing repetition rates. Heterozygotes have an intermediate phenotype.

The underlying low frequency hearing impairment and the observed ABR wave I amplitude reductions in mutant *Klhl18^{lowf}* are associated with an abnormality of stereocilia morphology and intermediate phenotypes are found in heterozygous mutants in both electrophysiology and structure.

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POSTER PRESENTATIONS

P01. Bilateral cross-talk cancellation in normal hearing participants using bilateral bone transducers

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Bone-anchored hearing aids are a commonly used method of treating conductive hearing loss, but the benefit of bilateral fitting is limited due to interaural cross-talk. Such cross-talk could be removed using cross-talk cancellation. The present study adapts a psychophysical method developed by Mcleod (2017) to measure the relative amplitude and phase from two bone transducers to produce cancellation at the cochlea. Participants wore two bone transducers and adjusted the relative amplitude and phase of bilaterally presented tones to lateralise the precept to one ear. Strong lateralisation is produced by a large inter-cochlear level difference, indicating destructive interference at one cochlea. This technique was completed bilaterally at frequencies between 1.5 and 8 kHz in steps of 62.5 Hz. The phase and amplitude data collected was used to create cancellation filters for each ear. These filters were used in a cross-talk cancellation network and the effectiveness of the crosstalk cancellation was assessed by measuring masked tone thresholds with tone and noise on different transducers. When the network was employed, the stimuli consisted of noise and a cancellation tone on one transducer, and a tone and cancellation noise on the other. It was expected that the cancellation signal would remove the crosstalk, allowing the listener to hear the tone at one cochlear and the noise at the other with reduced cross-talk. Tone reception threshold testing was performed at 2, 3, and 4 kHz in both ears. The use of the bilateral cross-talk cancellation network improved tone reception thresholds by between 2.5 and 8.5 dB.

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P02. Using vibrotactile stimulation to improve speech-in-noise performance for cochlear implant users

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Cochlear implant (CI) users often find understanding speech-in-noise to be one of the most challenging listening tasks. Delivering certain speech cues (e.g., fundamental frequency [F0] and amplitude envelope) via vibrotactile stimulation has been found to improve speech perception in noise (Huang et al. 2017; Fletcher et al. 2019). Brown and Bacon (2009) found that F0, amplitude envelope and voicing cues significantly enhance the speech-in-noise performance of simulated CI users when presented acoustically. However, voicing cues were found to provide slightly less benefit. The current study aims to evaluate which speech cues are most effective for enhancing speech-in-noise performance when delivered through vibrotactile stimulation on the wrists. Each participant in this study was trained for 90 minutes in each of the following conditions: voicing, amplitude envelope, F0, and without vibrotactile cues. Preliminary results from this study will be presented, and we expect to observe results similar to those of previous studies. It is hoped study's finding will further clarify our understanding regarding the most useful vibrotactile cues. Ultimately, the goal is to integrate such cues in an inexpensive and non-invasive device to improve speech-in-noise performance of CI users.

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P03. Announcing round 1 of the challenges to revolutionise hearing device processing

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One in seven UK adults have hearing difficulties, yet only 40% of people who could benefit from hearing aids have them, and most people who have the devices don't use them often enough. A major reason for this low uptake is the perception that hearing aids perform poorly. Improving how hearing devices deal with speech in noise has the potential to improve many aspects of health and well-being for an aging population.

Here we announce the first round (of three) of twin “Challenges” to do just that, aiming to generate revolutionary improvements in signal processing for hearing devices. They are inspired by the fields of speech recognition and synthesis, where using challenges is a proven technique for accelerating research.

The first Challenge round (“living room”) will focus on a single target source of speech, e.g. a family member, in a moderately reverberant environment with typical background noises for the home. We will supply to entrants: (1) generative models that enable a large new database of speech and background recordings to be combined in sufficient quantities for machine learning; (2) actual speech perception data obtained from a panel of hearing-impaired listeners of documented audiological status; (3) “baseline”, modular models of hearing impairment, hearing aids, speech intelligibility and speech quality. By supplying this infrastructure we hope to minimize the “barriers to entry” and so encourage new research groups to enter, especially those in speech technology who may lack the facility needed to work directly with hearing impaired listeners.

Two challenges are available, so that researchers can choose where their skills can contribute most. The purpose of the “Processing Challenge” is to develop new and improved approaches for hearing device signal processing, giving improved speech signals that will be listened to for scoring by our panel. The purpose of the “Perception Challenge” is to improve methods to predict our listening panel’s individual speech intelligibility and quality, given knowledge of their audiological status. Future challenge rounds will make the listening circumstances progressively harder, add further auditory characterisations of the listening panel, and develop improved computational models of impairment, aiding, intelligibility, and quality.

We expect to open Round 1 in October 2020 for a closing date of June 2021 and results in Autumn 2021.

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P04. Sound-offset sensitivity in individuals with speech-in-noise perception difficulties

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Difficulty perceiving speech in noisy backgrounds is a common symptom of developmental disorders in humans, and often occurs without any apparent loss of peripheral hearing. Recent studies in a mouse model of human developmental disorders reported an auditory brain abnormality specific to the processing of sound offsets (Anderson & Linden, 2016). Sound offsets provide information relevant to auditory scene analysis and speech discrimination, and therefore may play an important role in speech-in-noise perception. However, there are no validated psychoacoustical tests for assessing sensitivity to sound offsets in human subjects. We designed a psychoacoustical test battery to assess performance on tasks thought to depend on sound-offset sensitivity, including gap detection, duration discrimination, forward masking, and discrimination of vowel-consonant-vowel (VCV) stimuli in noise. Here, we report results of these psychophysical tests in participants with and without speech-in-noise perception difficulties. All participants had normal peripheral hearing sensitivity on standard audiometric tests. We recruited participants with speech-in-noise difficulties from an Auditory Processing Disorder support group and used a Speech, Spatial and Qualities of Hearing Scale (SSQ; Gatehouse & Noble, 2004) questionnaire to confirm self-reported difficulty with speech perception in noisy situations. We then tested: (a) gap-detection thresholds; (b) duration discrimination thresholds for ‘filled’ versus ‘empty’ intervals (i.e., time elapsed between onset and offset of a noise or between two successive clicks); and (c) detection thresholds for a click following a noise at various delays between the end of the noise and the click. We also tested discrimination of VCV stimuli using 16 consonants in 3 vowel environments and 5 varying levels of background multi-talker babble noise. In participants with self-reported speech-in-noise perception difficulties, we found significant impairments in consonant discrimination in noise, and differences compared to controls in the putative psychophysical measures of sound-offset sensitivity. We discuss the variation of offset sensitivity in normal and abnormal temporal processing. Our findings suggest that people with speech-in-noise perception difficulties may also have abnormal sensitivity to sound offsets.

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P05. The effect of head movement on the perception of monaural intensity changes

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Recent investigations of binaural auditory image stability during head movement have shown that static sources appear to move slightly with the direction of head movement (Freeman et al., 2017). This is the auditory equivalent of the visual Filehne illusion, where stationary objects appear to move during smooth pursuit eye movement.

In this study, we hypothesised that the perception of monaural intensity changes would be altered by head movement, thus identifying whether the auditory Filehne illusion is a monaural or binaural effect.

Preliminary static head experiments showed that perceptual judgements of monaural intensity changes were affected by the direction of intensity change, and the final intensity of the stimulus, in line with previously published results (Teghtsoonian et al., 2005).

In the main experiment, listeners were first trained to move clockwise for 1 second then anticlockwise for 1 second (or vice versa) at a rate of approx. 40°s^{-1}. In the first condition, listeners were randomly presented with pink noise or a pink-spectrum tone complex in a two interval forced-choice task. In the first interval, the listeners moved their heads as trained, and the intensity of the sound changed by ±6 dB with head movement, approximately the amount of broadband intensity change that occurs monaurally during a head movement over 40°. In the second interval, the listener’s head was static, and the presented stimuli changed by between 0 and 12 dB (±12 dB rove) in the same direction as the first interval, and asked to judge which sound changed more in intensity.

In the second condition, listeners were presented with exactly the same stimuli as recorded in the first task, but kept their heads static in both intervals. A difference in intensity change judgement between the two conditions would reveal an effect of head movement on the perception of monaural intensity changes.

Results will inform our understanding of the effect of head movement on basic auditory perception, and refine our theory of where in the auditory system the auditory Filehne illusion emerges.

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P06. Fundamental frequency cues for brief or competing sound sources.

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Pitch is a salient perceptual quality that underlies our musical experience, interpretation of speech, and ability to attend to a single speaker in a crowded room. The fundamental frequency (F0) of a complex sound is the main physical determinant of perceived pitch, and it can be mathematically derived from either the spacing of the sounds' harmonic components or the temporal periodicity of the sound wave. Previous research suggests that humans can extract F0 using either of these cues, but our pitch perception is dominated by resolved harmonics[1,2]. It is unclear if the auditory system extracts these cues through two independent mechanisms[3], and what roles these cues play in more complex listening situations. Our first experiment tests the theory that periodicity cues are extracted independently through a spike-timing based mechanism, and resolved harmonic cues from a harmonic template[3,4]. We measured listeners' pitch discrimination thresholds for harmonic complex tones (HCTs) containing either resolved or unresolved harmonics. We hypothesized that listeners would require longer duration tones to extract F0 from temporal cues than the harmonic template, as multiple phases are needed to calculate the interphase interval. We found that listeners performed more poorly for shorter duration HCTs, but similarly across both F0 cue conditions. Thus, there was no evidence of cue dominance or independent mechanisms. In our second experiment, we measured pitch discrimination performance on a similar task with similar stimuli, but in the presence of a distractor stream of HCTs. Here, listeners performed better when resolved harmonics were available, but only when signal-to-noise of the target stream was sufficiently low. Together, our results suggest that a simple model of two independent F0 extraction processes does not predict human pitch discrimination performance for short duration sounds presented in silence, however resolved harmonics may allow us to better attend to a target sound source in an acoustically crowded environment.

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P07. Modeling human auditory stream segregation through non-parametric Bayesian inference

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When hearing a sequence of auditory tones (e.g. L-H-L-H-L-H-L-H) human subjects can either perceive these as fused into a single ‘stream’ or segregated into two separate ‘streams’, dependent on the specifics of the stimuli (Bregman, 1994, Van Noorden, 1977). Such perceptual grouping of sequential auditory cues is traditionally modeled using a mechanistic approach (e.g. Beauvois & Meddis 1991). The problem however is essentially one of source inference – a problem that has recently been tackled using statistical Bayesian models in visual and auditory-visual modalities (Shams & Beierholm, 2010). Usually the models are restricted to performing inference over just one or two possible sources, but human perceptual systems have to deal with much more complex scenarios.

To characterize human perception we have developed a Bayesian inference model that allows an unlimited number of signal sources to be considered: it is general enough to allow any discrete sequential cues, from any modality. The model uses a non-parametric process prior, hence increased complexity of the signal does not necessitate more parameters. The model not only determines the most likely number of sources, but also specifies the source that each signal is associated with.

The model gives an excellent fit to data from an auditory stream segregation experiment in which the pitch and presentation rate of pure tones determined the perceived number of sources. Likewise, it is able to explain several known results in the literature (e.g. Bregman, 1978), as well as make testable predictions. We have developed a novel experimental paradigm to test these theoretical claims, and report results from three experiments.

The modelling approach is very general – it can be applied to any set of discrete sequential cues involving multiple sources – and it gives a simple, principled way to incorporate natural signal constraints into the generative model.

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P08. Behavioural and neural evidence for implicit memory for regularities in rapid sound sequences

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Sensitivity to acoustic statistical regularities is fundamental to many aspects of auditory perception and cognition. Recent work using repeated noise paradigms demonstrated robust, long-term auditory implicit memory for 'frozen' reoccurring white noise. Participant performance suggested that they become sensitive to an idiosyncratic, local spectral feature within the noise samples. Here we focus on implicit memory for sequences of auditory events - a specific arrangement of twenty different 50ms tone pips. Using behavioural methods, modelling and EEG in humans we ask (1) whether listeners can remember complex sequences of acoustic events (2) the limits on this memory (3) whether it requires active involvement with the sequence.

Building on previous work from our lab (Barascud et al, 2016), participants monitored novel rapid sequences of tone-pips for a transition from a random to a regular frequency pattern (repeating cycles of twenty 50 ms tone-pips). On half of the trials, sequences were random throughout; the other half contained a transition from a random to a regularly repeating pattern at a random time partway through the sequence. Most of the regular patterns were generated anew for each trial. Unbeknownst to the participants, several regular patterns (different for each listener) sparsely reoccurred across trials (every ~2.5 minutes). Compared with novel sequences, response time (RT) to reoccurring regularities became substantially faster within only a few reoccurrences, reflecting rapid learning of sequence structure. This benefit persisted after 24 hours, and up to 7 weeks; it was robust to pitch transposition, and to subsequent memorization of other patterns. Similar learning also occurred during passive exposure (i.e. when naive listeners were listening without performing a transition detection task).

Overall, we show that as regularities reoccur they are implicitly stored in memory, progressively up-weighted and more quickly retrieved to resolve the identity of sensory signals. EEG measurements from passively listening participants exposed to recurring patterns are also provided to demonstrate brain responses associated with sequence structure learning.

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P09. Towards a self-administrated language-free speech-in-noise test to diagnose hearing loss

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With the rise of smartphone use, it would be very useful to have a test that can be undertaken in non-clinical environment to diagnose hearing loss with the simplest possible stimuli. Speech tests however usually require the listener to have specific language skills.

We attempt to develop a self-administrated speech-in-noise test that is language free and can diagnose hearing loss. Stimuli are vowel-consonant-vowel (VCV) syllable that are shared in all tested languages. Instead of measuring percent correct, we predict hearing loss from the pattern on confusions.

We demonstrate that the approach works for a sentence test when using a machine learning algorithm for prediction. Here we extend the work and attempt to establish that the speech tokens are indeed language independent and how precise we can detect mild and moderate simulated hearing loss.

Method: 12 VCVs are recorded from an English native speaker and a Mandarin native speaker. The consonants in VCVs are English consonants that have counterparts in Mandarin, including /p b t d k g f s m n l w j/.

In experiment 1, psychometric functions are fitted for 12 VCVs are measured at fixed SNRs of 0, -5, -10- and -15-dB SNR (pink noise). Each experiment has 768 presentations (12 VCVs, 4 SNR, 2 speakers and 8 repetitions).

In experiment 2, tokens that generate similar perception and confusion in two groups will be selected to form various 4-stimulus sets. Presentation levels of each stimulus are adjusted to achieve equal intelligibility. Each set will be tested at fixed and adaptive SNRs. We aim to recruit 20 Mandarin and 20 English speakers.

In experiment 3, the stimulus will be used that showed least language dependence. Tokens are processed to simulate normal, mild and moderate high frequency hearing loss (using low pass filtering). Normal-hearing subjects from two language populations are recruited.

Both Mandarin and English listeners will be tested with the 4-alternative-forced-choice test with a 2 up, 1 down staircase method adaptive SNR so that resulting threshold is close to the 29 percent correct rate.

Results will be shown for all three experiments to demonstrate if our approach might be viable to further develop a language free speech test to diagnose mild to moderate hearing loss.

P10. Using frequency-specific measurements to distinguish effects of noise exposure, gender and hearing loss on the auditory brainstem response.

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Animal research has shown that noise exposure can lead to a loss of synapses between inner hair cells and auditory nerve fibres (Kujawa & Liberman 2009). In animals, it has been shown that this 'synaptopathy' manifests in the earliest wave of the auditory brainstem response (ABR), wave I, which is generated in the auditory nerve. In humans, the ABR depends on the subject's audiometric profile, and on other individual characteristics, such as age and gender, which is why, in previous studies, these characteristics were carefully matched between test subjects and controls. However, matching subjects, particularly in terms of hearing thresholds, may create its own biases, and so, our aim is to devise ABR recording methods that will obviate the need for subject matching. Here, we evaluate the usefulness of high-pass masking, which provides information on the profile of ABR contributions from different cochlear frequency regions (Don & Eggermont, 1978). We used a group of 26 young subjects with either low or high levels of noise exposure history. The low- and high-exposed groups were roughly matched for age, but not for gender or hearing loss. As a result, there were more males in the high- than low-exposed group (10/14 versus 3/12), and the high-exposed group had higher hearing thresholds, particularly, at higher frequencies (by ~11 dB between12.5-16 kHz). In conditions where the response included higher-frequency contributions, the high-exposed subjects exhibited a reduced wave V response compared to the low-exposed subjects. However, a similar effect was also apparent between subjects with poorer and better high-frequency hearing thresholds, and, to a lesser extent between males and females, suggesting that the effect would be unlikely to enable disambiguation of synaptopathy from other subject differences. Another effect, however, in the slope of the wave V latency as a function of cochlear frequency, seemed to be unique to the comparison between high- and low-exposed subjects, with the high-exposed subjects exhibiting a shallower latency slope than the low-exposed subjects. Wave I showed similar effects as wave V, both in amplitude and latency, but these did generally not reach significance, probably because wave I is smaller, and thus has a lesser signal-to-noise ratio, than wave V.

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P11. Ultrastructural defects in stereocilia and tectorial membrane in ageing mouse and human cochleae

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The ageing cochlea is subject to a number of pathological changes likely to play a role in the onset of age-related hearing loss (ARHL). Although ARHL has often been thought of as the result of the loss of hair cells, it is in fact a disorder with a complex aetiology, arising from changes to both the organ of Corti and its supporting structures. These include loss of hair cells, inner hair cell afferent terminals and spiral ganglion neurons, damage to the stria vascularis, and metabolic changes in several cell types (Howarth & Shone, 2006, Kidd III & Bao, 2012). In this study, we examine two ageing pathologies that have not been extensively studied despite their apparent prevalence; the fusion, elongation and engulfment of cochlear inner hair cell stereocilia, and the changes that occur to the tectorial membrane, potentially modulating its physical properties in response to sound. Our work demonstrates that similar pathological changes occur in these two structures in the ageing cochleae of both mice and humans. We examined the ultrastructural changes occur during stereocilial fusion, and identified lost tectorial membrane components that lead to changes in membrane structure to better understand how these pathologies occur and identify how they may be important in understanding the more subtle hearing pathologies that precede auditory threshold loss in ARHL.

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P12. Effects of head orientation and seating position on intelligibility of speech in a restaurant.

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A model of spatial release from masking in reverberant environments has proved successful in predicting a wide range of empirical data (Lavandier & Culling, 2010; Jelfs et al. 2011). The model can be used to accurately predict optimal listening tactics in such environments. Head orientation of around 30° away from the target speaker was predicted, and then shown empirically to improve speech intelligibility for normally hearing listeners (Grange & Culling, 2016a), hearing-impaired listeners (Grange et al. 2018) and cochlear implant users (Grange & Culling, 2016b). This degree of head orientation has been shown to be compatible with lip-reading and robust to reverberation (Grange & Culling, 2016b). Use of conventional directional microphones was predicted to work well in reverberation, and also produce better intelligibility with a head turn. However, location within a room, even one uniformly distributed with interfering sound sources, was predicted to have a strong influence on the effective signal-to-noise ratio and on the benefits of head orientation and directional microphones. Certain locations were predicted to bring all these benefits together and others to largely confound them. These differences were confirmed empirically using a virtual acoustic simulation for the benefits of signal-to-noise ratio and head orientation using virtual acoustics.

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P13. Dynamics underlying detection of auditory object boundary

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Auditory object analysis requires the fundamental perceptual process of detecting boundaries between auditory objects. However, the dynamics underlying the identification of discontinuities at object boundary is not known. We investigated the cortical dynamics underlying this process by employing a synthetic stimulus composed of frequency modulated ramps known as "acoustic textures", where boundaries were created by changing the underlying spectro-temporal coherence. We collected magnetoencephalographic (MEG) data from 14 subjects in 275-channel CTF scanner. We observed a very slow (<1 Hz) drift in the neuro-magnetic signal that started 430 ms post boundary between textures that lasted for 1330 ms before it decayed to baseline no-boundary condition. The response evoked by this drift signal was source localized to Heschl's Gyrus bilaterally which was shown in the previous BOLD study (Overath et al., 2010) to be involved in the detection of auditory object boundaries. This low frequency drift signal is consistent with a precision based predictive coding account of perceptual inference.

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P14. Binaural masking level difference as a function of noise bandwidth and noise delay

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The human binaural system can exploit differences between the interaural phase of a noise and a target tone to improve detection thresholds. The maximum masking release is obtained for detecting an antiphasic tone (Sπ) in diotic noise (N0). It has been shown in several studies that this benefit gradually declines as an interaural time difference (ITD) is applied to the N0Sπ complex. This decline has been attributed to the reduced interaural coherence of the noise. Here, we report detection thresholds for a 500 Hz tone in masking noise with up to 8 ms ITD and bandwidths from 25 to 1000 Hz. When reducing the noise bandwidth from 100 to 50 and 25 Hz the masking release at 8 ms ITD increases, in part because the narrower bandwidths result in a higher coherence length. For bandwidths of 100 to 1000 Hz, however, no significant difference was observed, indicating that an auditory filter with a bandwidth <100 Hz is operational and produces identical coherence for this group. Thus, our coherence-based model requires an effective "binaural" auditory filter bandwidth <100 Hz, in line with established monaural models but in contrast to delay line-based models for N0Sπ detection.

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P15. Modeling comodulation masking release with random variations of flanking-band centre-frequencies

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It is hypothesized that coherent envelope fluctuations in different frequency regions, a property of many natural sounds, are used by the auditory system to separate sounds from different sound sources. A psychoacoustic effect that is often associated with the sensitivity of the human auditory system to use this comodulation as a cue is comodulation masking release (CMR). A common CMR paradigm is the flanking-band experiment, where an on-frequency masker (OFM) and spectrally distant flanking bands (FBs) are presented simultaneously. A classical interpretation of CMR is that, in the comodulated condition either the off-frequency information is used to detect points in time, where the masker envelope amplitude is low (dip-listening hypothesis; Buus, 1985) or that the correlation of the output of the on- and off-frequency auditory channels serves as an additional cue. Both explanations have in common that they assume an across-channel process. Piechowiak et al. 2007 used a modulation filterbank approach with an across-channel process to account for the CMR in the flanking band experiment. The present study investigates if this model is also able to account for a CMR where the envelope in the off-frequency channels is no longer the same as in the on-frequency channel. In this experiment, the centre frequencies of the FBs were changed at each minimum of the envelope. The centre frequency was chosen randomly within a given frequency range around the average centre frequency of the FB. Two FBs were used, one spectrally below and one above the OFM. The centre frequency and the frequency range of the FBs were parameters of the experiment. They were chosen on either a linear or a logarithmic scale. The results depended on both the centre frequencies and the spectral ranges. The model by Piechowiak et al. predicted a CMR also for FBs with fluctuating centre frequencies but not all aspects of the data are captured by the model. In addition to the simulations with a modulation-filterbank based approach, the data are discussed in the light of an across-frequency correlation analysis and the dip-listening hypothesis and future implications for model development will be given.

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P16. Processing of infrasound and low-frequency sound by the human auditory and vestibular periphery auditory

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Sound, including low-frequency sound (LFS) and infrasound (IS), is not only detected by the cochlea, but also, at high intensities, by the vestibular system. Here, we present responses of the cochlea and the vestibular system during and after presentation of LFS and IS.

Free-field delivery of a low-frequency stimulus (90 s, 30 Hz, 120 dB SPL) caused slowly-cycling changes of the magnitude and frequency of spontaneous otoacoustic emissions, outlasting the stimulation by a few minutes.

Thresholds for activation of the vestibular system were estimated by recording vestibular evoked myogenic potentials (VEMPs) with very brief tone pips with frequencies between 40 and 120 Hz. Thresholds decreased from about 137 pedB SPL at 40 Hz to 118 dB pedB SPL (median, respectively). VEMPs were also evoked with supra-threshold acoustic or galvanic elicitors in the presence of a second, 12-Hz, 129-dB SPL continuous biasing tone. VEMP amplitudes were recorded as a function of the biasing tone phase in 45° increments. Only with acoustic VEMP elicitors a trend for phase-coupled VEMP amplitude modulation could be observed, indicating an operating point change of vestibular hair cells.

When assessing the health effect of LFS and IS, both the auditory and the vestibular system should be considered.

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P17. What do self-report measures of spatial hearing ask about – and what do they miss?

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The perception of location gives a natural spatial order to the auditory world; without any spatial hearing, the auditory world will be a jumbled-together mess. The spatial items of the SSQ (Gatehouse and Noble, 2004) are perhaps the most prominent psychometric measure of spatial hearing that is used in clinical and hearing research. Here, as the beginning of a wider project considering what matters most to people about their spatial hearing, we determined which listening tasks and listening circumstances the SSQ asks about, and how these relate to alternative self-report measures of spatial hearing.

A literature review was first performed, which identified four alternative self-report measures of spatial hearing: Localization Disabilities (Noble et al. 1995), the Amsterdam Inventory for Auditory Disability and Handicap (Kramer et al. 1995), the Spatial Hearing Questionnaire (Taylor et al., 2009), and the Questionnaire for Auditory Localization (Neelamegarajan et al., 2018). We classified their items by tasks of Direction, Distance or Movement, environment circumstances of Outside or Inside, whether the scenario involved a person, road-related sound, or other (e.g., dog barking), and what was specified about being able to see.

In general we found that items do not equally sample the space of potential tasks or circumstances. For instance, in terms of Direction, questionnaire items favoured left-right scenarios, whereas in terms of Distance, items tended to favour front-back scenarios. We found that all measures presented scenarios that focused on not being able to see where the sound was coming from, but quite why something cannot be seen was often not specified, even though it arguably matters if it is because (for example) it is dark, or because the sound is behind you.

In summary, the items of the SSQ and other spatial hearing questionnaires tend to cluster around certain areas, but they miss others that may be potentially important to people in considering why spatial hearing is important, especially in relation to audio-visual interaction.

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P18. Predicting impaired speech perception using automatic speech recognition

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Speech audiometry, i.e., the assessment of unaided and aided speech-identification performance, is a standard feature of the audiological assessment. However, performance on speech intelligibility tests generally depends on familiarity with the speech material (so the test material should not be used repeatedly) and on the listener's fatigue level (so the test should not last for long which, for example, is inconsistent with the exploration of different hearing aid settings). The feasibility of using objective measures based on automatic speech recognition (ASR) to predict human speech-identification performances has recently been investigated (e.g. Fontan *et al*., 2017; Kollmeier *et al*., 2016). The aim of this study (Fontan, Cretin-Maitenaz, & Füllgrabe, submitted) was to evaluate whether unaided speech intelligibility in quiet of older hearing-impaired (OHI) listeners can be predicted by ASR. Twenty-four OHI listeners completed identification tasks using speech materials of varying linguistic complexity and predictability (*i.e.*, logatoms, words, and sentences). An ASR system was used to recognize the same speech stimuli, processed to mimic some of the perceptual consequences experienced by each of the listeners (elevation of hearing thresholds, loss of frequency selectivity, and loudness recruitment). Strong correlations are observed between human and machine intelligibility scores. The simulation of loss of frequency selectivity decreased the strength of the correlation, indicating that spectral smearing has different effects on human and machine performances. Highest correlations were found for logatoms, suggesting that the prediction system reflects mostly the functioning of the peripheral part of the auditory system. In the case of sentences, the prediction of human intelligibility could be significantly improved when considering cognitive performance.

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P19. Estimating neural survival using a new version of the panoramic ECAP method

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

Here we present a new version of PECAP (PECAP2) that separately models the neural survival profiles and current spread from each electrode, and combines them to estimate the neural excitation patterns. An advantage over both PECAP1 and a similar method proposed by Biesheuvel *et al* (2016) is that changes to the neural survival parameter influence the excitation patterns from multiple adjacent electrodes in a biologically plausible way. Furthermore, knowledge of how neural survival and current spread vary along the cochlea may influence clinical decisions and fitting procedures. We show that PECAP2 is able to reconstruct a wide range of simulated excitation patterns, as well as identify dead regions simulated in human data. We also show that when data from DeVries *et al* (2016) are processed via PECAP2, the variations in predicted neural survival along the electrode array correlate significantly with detection thresholds obtained with focused stimulation. Finally, we evaluate other factors that might influence the measurement matrix and degrade PECAP2 accuracy, such as the reliability of each ECAP (evaluated with repeat measures), variations in refractoriness along the cochlea (evaluated by comparing ECAPs measured with alternating polarity), and recording electrode impedances.

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P20. An online survey to investigate the value of self-reported data for tinnitus sub-typing

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Tinnitus is a heterogeneous condition that can manifest itself in various ways regarding its perceptual characteristics and impact on the affected individual. Heterogeneity of the tinnitus population can be associated with differences in both general individual characteristics (e.g. co-existing conditions) and tinnitus-specific characteristics (e.g. tinnitus localisation) (van den Berge et al., 2017). However, it is not clearly established whether combinations of such traits can be used to define tinnitus subtypes, i.e. groups with similar tinnitus characteristics that are potentially associated with similar mechanisms. The aim of this study is to investigate the value of self-reported data for characterising such tinnitus subtypes. In order to collect the appropriate profiling-relevant information, we are using a questionnaire recently developed for this purpose, namely the European School for Interdisciplinary Tinnitus Research – Screening Questionnaire (ESIT-SQ) (Genitsaridi et al., 2019). Sets of variables that can define tinnitus subtypes will be investigated using unsupervised machine learning algorithms. Recruitment commenced in June 2019 and will continue until December 2019, targeting a sample of several hundred participants. Currently, 201 datasets from participants with tinnitus have been collected. Descriptive statistics and preliminary results based on this data will be presented. In the current sample, participants reported being affected by their tinnitus in different degrees; severely (n= 59), moderately (n= 66), slightly (n= 57), or not at all (n= 11). Tinnitus perception was also diverse. Pitch was reported as high (n= 134), medium (n= 46), or low (n= 10). Tinnitus localisation was lateralised to the left side (n= 68), to the right side (n= 43), or non-lateralised (n= 78). Thus, our methodology seems capable of capturing a diverse tinnitus sample. It is obvious that self-reported data are insufficient for capturing all aspects of tinnitus heterogeneity, since important information such as the audiological profile, is missed out. However, collecting large self-reported data can be useful for understanding heterogeneity of subjective conditions like tinnitus and chronic pain (Zhu et al., 2014). Identifying important variables and patterns within such data can be valuable for the design of future studies, informing decisions about inclusion criteria, selection of measures and stratified analysis of results.

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P21. Revisiting super-optimal perceptual integration for pitch at high frequencies

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Many contemporary pitch models and researchers assume that phase locking provides the dominant (or only) cue to pitch. However, Lau et al. (2017) provided evidence that a residue pitch (“missing F0”) could be extracted from high-frequency harmonics when all harmonics were above 8 kHz and where phase locking to the temporal fine structure was presumably absent. In fact, they reported super-optimal integration of information from individual components in a frequency discrimination task when all components were combined into a harmonic complex. This was argued to be consistent with (central) pitch-sensitive neurons that can derive F0 from place-based information. We tried to replicate this finding using stimuli identical to those of Lau et al., together with some additional conditions designed to reduce the ambiguity of information about the frequencies of the individual harmonics.

Using an adaptive two-alternative forced-choice procedure, we measured fundamental frequency difference limens (F0DLs) for complex tones containing harmonics 6-10 with F0s of 280 and 1400 Hz, and frequency difference limens (FDLs) for each harmonic of the complex presented alone. All (component) tones had random phases, a ±3 dB level rove, and were presented in a continuous threshold-equalizing noise (TEN). Tones were either presented for 210 ms in diotic TEN (as done by Lau et al) or presented for 1000 ms in dichotic TEN. Ten young musically trained subjects with very good high-frequency hearing participated.

Observed thresholds were lower overall by at least a factor of two than found by Lau et al, especially for the FDLs for the high-frequency region. Thresholds were significantly lower for the longer tones presented in dichotic TEN than for the shorter tones in the diotic TEN. As found by Lau et al, for the low F0, observed F0DLs were worse than predicted assuming optimal combination of frequency information from the individual harmonics and assuming that performance is limited by peripheral noise. This is in general agreement with previous studies that measured FDLs for the components in isolation. However, for the high F0, observed and predicted F0DLs did not differ significantly, in contrast to the finding of Lau *et al*. The present results are consistent with a possible role of pitch-sensitive neurons for the high-frequency region where phase locking is presumably absent and a role of phase locking for the low-frequency results.

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P22. Evaluating the effect of increased spread of excitation on speech-in-noise perception by cochlear implant listeners

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

Experiment 1 produced blurring by adjusting the spectral overlap of the analysis filters (CI input). Its effects were measured on speech-in-noise reception as a function of the amount of blurring applied to either all, or 5 out of 15, electrode channels. Large amounts of blurring applied to all channels significantly degraded speech-in-noise perception. Performance for each listener was constant up to some blurring knee point, above which it deteriorated. We argue that the blurring knee point may provide a method for evaluating the effects of spectro-temporal acuity on speech perception that is largely independent of cognitive influences. Indeed, higher knee points were significantly associated to better performance on a non-speech spectro-temporal task ("STRIPES", Archer-Boyd *et al,* 2018). Surprisingly, even extreme amounts of blurring applied to 5 out of 15 channels did not affect performance.

Experiment 2 applied blurring at the electrode level (CI output) to simulate a wider spread of information across the cochlea – similar to a wide current spread. In this case, a set of adjacent electrodes was used simultaneously instead of a single electrode per channel. Interestingly, SRTs were similar to Experiment 1 and there was again no effect of blurring when applied to a subset of channels.

We argue that these findings have important implications for channel-deselection and optimization strategies and their potential benefits on speech perception.

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P23. Using recurrent neural networks to improve the perception of speech in non-stationary noise by people with cochlear implants

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

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

The effect of the RNN algorithm on SI was further assessed with two groups of subjects. In experiment 1, 10 normal-hearing subjects listened to speech-in-babble stimuli through headphones and using a CI simulation based on noise-vocoded signals. The results confirmed the predictions of the objective measures and yielded a substantial mean benefit in speech reception threshold (SRT) of 2.9 dB. In experiment 2, 10 experienced users of Advanced Bionics CIs listened to speech in multi-talker babble and traffic noise. The results indicated significant improvements in SRT of 3.4 dB for speech in babble. A difference of 2 dB for speech in traffic noise was not significant. Furthermore, speech quality assessed using a rating procedure was significantly higher for the processed than for the unprocessed stimuli for the CI subjects and confirmed the pattern of SRT results.

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P24. Investigating the role of Hsp70 during stress granule formation in cochlear cells

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Both Hsp70 induction and stress granule formation are pro-survival mechanisms which have been independently implicated in response to different forms of cochlear stress. Stress granules (SGs) are cytoplasmic aggregates of mRNAs and RNA-binding proteins that regulate post-transcriptional gene expression during cellular stress. SGs optimise the translation of stress-responsive genes, through selective exclusion of RNAs for immediate translation during stress. We have previously shown that SG-induction during aminoglycoside treatment protects outer hair cells from death, indicating their potential importance during cochlear stress. In the inner ear, Hsp70 can mediate protection of hair cells from aminoglycoside-induced death (1). Recent studies in HeLa cells show that Hsp70 participates in the SG-clearance after stress, suggesting a significant association between Hsp70 and SGs. Here, we aim to investigate the relationship between Hsp70 and SGs in cochlear cells.

We used heat shock and arsenite stresses to generate SG-formation and study Hsp70 expression. UB/OC-2 cells assemble SGs after 1h of either heat shock or arsenite exposure. During a subsequent recovery period of 4h, the number of SGs decreases; qPCR and immunocytochemistry show that Hsp70 expression increases during recovery from heat shock stress (p<0.05), correlating with SG-clearance. Hsp70 mRNA levels peak after 2h of recovery from heat shock (>411-fold activation compared to untreated cells). In comparison, arsenite stress results in a slower and much reduced Hsp70 activation (>28-fold compared to untreated cells), indicating that there is stress-specific activation of Hsp70 in UB/OC-2 cells.

Secondly, we used RNA-immuno-fluorescence *in situ* hybridisation to locate Hsp70 mRNA in relation to SGs. High resolution microscopy indicates that Hsp70 mRNA is excluded from SGs during both types of stress, suggesting its preferential translation.

Furthermore, overexpression of Hsp70, using an adenovirus-mediated construct (Ad-Hsp70), decreases heat shock□induced SG-formation (p<0.005), indicating that there is a causative link between Hsp70 expression and a reduction in the number of SGs during heat shock. Interestingly, Hsp70 overexpression prior to arsenite stress does not affect SG-assembly.

Our data suggest that the protective effect of Hsp70 in the auditory system may involve interactions with the SG-pathway. Therefore, a better understanding of their relationship may contribute to the development of novel therapeutic strategies to avoid cell death during cochlear stress conditions.

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P25. Discovering the building blocks of hearing

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How can we determine the computational role in hearing of a particular neuron type or basic neural mechanism? We propose a computational approach that generalises the theory of efficient coding. Efficient coding states that early sensory neurons should optimally represent sensory data, subject to some constraint. However, to perform a useful computation (rather than representation), the brain has to select what information is relevant and discard the rest. Our approach to this is inspired by the information bottleneck method, which states that the results of neural computations should maximise the amount of relevant information (about an object in the external world) while minimising the amount of irrelevant information about the stimulus. We use machine learning methods as a tool because directly computing mutual information in high dimensions is impractical. We designed an auditory model with few parameters that simplifies and generalises a number of more detailed models and can explain a wide range of behaviours observed in auditory neurons. The model starts with a standard gammatone filter-based periphery, followed by a simple circuit that allows weighted excitatory and inhibitory cross-frequency integration, with different low pass filters and delays. The output is then fed into a machine learning model that we treat as a black box: it is simply a tool to carry out a task with the information that our model provides to it. The generalised model is trained on a phoneme recognition task using hundreds of hours of recorded audio from different speakers. For some parameters, our model performs well, with accuracies that are not far below human levels. With only the gammatone filtering and machine learning, performance drops substantially, suggesting that the additional neurons are playing an important computational role. Performance between different categories of phonemes (vowels, fricatives, plosives) is correlated according to similarities between these categories. We hypothesised that our model would show that onset sensitivity played an important role, but instead find the opposite, that the best performing neurons are onset suppressive. We further test our model in speech in noise and gender recognition tasks. Our framework is a powerful method to generate testable hypotheses and to relate low-level neural mechanisms to high-level cognition.

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P26. Decoding the auditory nerve - sensorineural pathologies in the auditory periphery and their effect on speech-in-noise intelligibility

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Speech intelligibility relies on the faithful coding of the spectro-temporal modulations that carry speech information. Given the limited dynamic range (30 dB) of auditory nerve (AN) fibres found in conventional measures of rate-level functions (RLFs), optimal speech coding relies on the auditory periphery adapting to changes in contextual sound level, ideally to an extent preventing AN-fibre saturation.

Here, we demonstrate that (1) acoustic and medial-olivocochlear reflexes enhance AN adaptation to context level so as to prevents the saturation of AN fibres and associated information loss, (2) the absence of efferent pathways and/or the loss of outer haircells cause speech-signal degradation, mostly due to the saturation of high-spontaneous-rate fibres, (3) general deafferentiation (via synaptopathy, inner haircell loss or loss of AN fibres), a reduction in endocochlear potential or inner haircell otoferlin depletion all elevate the internal noise floor and degrade the signal, as these pathologies can all cause, amongst other problems, stochastic under-sampling (Lopez-Poveda 2013 & 2014).

Human context-level adaptation was predicted using a physiological model of the auditory periphery (MAP, Meddis, 2006). RLF predictions were extracted from the modelled response of AN fibres for a 50 ms probe period, immediately following a 400 ms precursor that set context level. Probe and context levels were independently varied (0-100 dB range) for tone/noise bursts and adaptation exceeding 0.5 dB/dB was predicted. Disabling efferent reflexes halved the amount of adaptation, to the same level as previously measured in anaesthetized Guinea Pig (Wen et al., 2009). Thus, around half of the adaptation predicted by MAP emerges from efferent reflexes. Our predictions further suggest that human AN fibres could remain unsaturated in context levels up to 100 dB, well above natural speech levels.

Speech intelligibility in noise was measured in normal-hearing listeners attending to speech passed through a vocoder based on MAP (30,000 modelled AN fibres). Listeners´ speech-reception thresholds (SRTs) were compared between vocoded (with a ‘normal’ model or one of nine sensorineural pathologies) and unprocessed conditions at 65 dB (speech + noise). Our findings support a key role of efferent-based context adaptation in the optimal neural coding of speech modulations, validate a novel vocoder concept and perhaps suggest an alternative way to consider loudness coding.

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P27. Evaluating the effect of focussed stimulation on excitation patterns in humans and cats: human psychophysics and voltage measurements

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The spread of current along the cochlea is one of the main factors limiting speech understanding for Cochlear Implant (CI) users. Animal physiological recordings suggest that tripolar stimulation can reduce such spread of current. However, attempts to use tripolar stimulation in human CI users have not shown such a clear and consistent advantage. This might be due to anatomical differences, but also differences in the methods, since some paradigms are not easily comparable across species. We therefore develop a paradigm to measure tripolar and monopolar excitation patterns in both humans and cats, for use with both psychophysics and EEG. The aim is to identify which factors are important for a large benefit of tripolar stimulation to be observed.

Before measuring EEG in animals and humans, we first investigate the psychophysical excitation patterns of three different maskers: monopolar, partial-tripolar and a novel three-electrode “ralopirt” masker in which the current on the flanking and central electrodes have the same polarity, thereby potentially broadening the excitation pattern. For both the partial-tripolar and ralopirt maskers, we include conditions with 0 (tripolar+0, ralopirt+0) and 2 electrodes between the central and flanking electrodes (tripolar+2, ralopirt+2). The masker is always a continuous pulse train at 400 pps presented on a given electrode X. The probe is a 50-ms, 400-pps partial-tripolar pulse train, shifted in time by 1.25 ms and presented on electrodes X-2, X-1, X, X+1 and X+2. All maskers are loudness-balanced to the monopolar masker at a comfortable level. We measure detection thresholds for masked and unmasked conditions. We also measure the intra-cochlear voltage patterns elicited by the different maskers when loudness-balanced. In order to check for possible effects of facilitation, we present the masker and probe with all possible combinations of leading-phase polarity.

Results indicate no sign of facilitation, hence validating the use of an interleaved-masking paradigm. They also show no evident differences between either the psychophysical masked excitation patterns or the intra-cochlear voltage patterns of the tripolar+0, ralopirt+0 and monopolar maskers. Although tripolar+2 and ralopirt+2 elicit voltage patterns that are respectively narrower and broader than the monopolar masker at equal loudness, pilot results indicate no evident differences in their excitation patterns. We discuss possible reasons for this, including overall limited amount of masking as well as the relationship between intra-cochlear voltages and neuronal excitation patterns.

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P28. Figure-ground perception as a measure of central auditory grouping that covaries with speech-in-noise perception

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Speech-in-noise (SIN) perception is a critical everyday task that varies widely among people 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 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 the shared neural correlates that explain this common variance.

We recruited 97 participants with normal hearing (6-frequency average pure-tone thresholds < 20 dB HL) for a behavioural experiment. They reported sentences from the Oldenburg matrix corpus (e.g., "Alan has two old sofas"), which were presented simultaneously with multi-talker babble noise. The figure-ground stimuli were based on Teki et al. (2013) in which each 50 ms time window contains random frequency elements, and figure frequencies remained fixed over time. Performance on the figure-ground task explained significant variability in SIN performance that was unaccounted for by audiometric thresholds.

To examine the neural correlates of the shared variance, we recruited 44 participants for a functional magnetic resonance imaging (fMRI) experiment. We used a 2 x 2 factorial design, in which each participant completed figure-ground and speech-in-noise tasks at two different target-to-masker ratios (TMRs)—which were calculated for each participant based on adaptive procedures that estimated 60% and 90% thresholds for each task. Using Dynamic Causal Modelling, we found common effects of greater difficulty in both tasks that corresponded to disinhibition of left core and belt areas of auditory cortex.

These results in normally-hearing listeners demonstrate that we can better predict SIN performance by including measures 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. The neuroimaging results suggest this shared variance reflects common processes in left core and belt areas of auditory cortex. Overall, these results highlight an important role of fundamental grouping processes, which operate centrally, on the ability to understand speech when background noise is present.

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P29. Predicting the impact of hearing aid processing on speech intelligibility

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Speech intelligibility is a key factor for consideration when selecting and fitting hearing aids. Assessing speech intelligibility is a non-trivial task, since it can be influenced by a variety of factors including (but not limited to) language, speaker, intonation, accent, sentence structure, semantic content, the type of background noise and processing conditions. Currently, speech-in-noise tests applied to a cohort of listeners are the 'gold standard' by which speech intelligibility is assessed, but these are expensive and time-consuming to conduct. Several objective predictors, which can be calculated without human participants, have been designed which attempt to predict the ability of a hearing aid user to understand speech in various situations and processing conditions, but few of these have been robustly tested using recordings of real hearing aid outputs. As part of this research, recordings of NHS-issue behind-the-ear hearing aids using IEEE sentences in speech-shaped noise have been made. These were used to compare different hearing aid models and settings (primarily single-channel noise reduction). A study involving twenty-one normal hearing listeners indicates that single-channel noise reduction algorithms can significantly improve intelligibility of noisy speech ($p<0.05$), but no differences can be seen between three different hearing aid models currently available on the NHS. A low-cost, off-the shelf hearing aid performed significantly worse than the NHS prescribed devices. Objective speech intelligibility measures (HASPI, CSII and STOI (Kates & Arehart, 2005, Kates & Arehart 2014. Taal et al 2010)) were also applied to the recordings. So far, no objective metric has been found which can accurately predict the outcomes seen in this study, though general trends can be predicted. It is hoped that an objective procedure can be established which will enable accurate prediction of the relative speech intelligibility capabilities of different hearing aids and settings, therefore reducing the time and cost of hearing aid development and increasing user satisfaction.

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P30. Defining the concept of self-management of hearing loss: perspectives of hearing loss patients and hearing healthcare clinicians.

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Hearing loss is a chronic condition that needs ongoing management over many years as there is no cure**.** Globally, the prevalence of hearing loss is set to increase from 466 million to 900 million by 2050 (WHO, 2018). Hearing loss has a huge psychosocial impact to the individual and an economic one to the healthcare system. In the UK, the annual costs of hearing loss is thirty billion pounds.

The concept of self-management has been present and shown to be effective in other long-term chronic conditions such as asthma and diabetes (Barlow, et al., 2002), however it is relatively new for hearing loss. Hearing loss self-management refers to the knowledge and skills individuals utilize to manage the effects of hearing loss on a daily basis.

A mixed methods approach called concept mapping will be used in this study. This methodology will develop a diagram that shows relationships between concepts of self-management and hearing loss, identified by patients with self-reported hearing loss and hearing healthcare clinicians. This methodology stresses that prior knowledge is highly important in being able to learn or assimilate new concepts. Concept mapping is believed to aid creativity and these results can be used to guide evaluation or planning.

We hypothesise that the constructed concept map can be useful as it will highlight the key themes in self-management of hearing loss from the perspective of both the patients and clinicians. These key themes can then be used as tools to inform future decisions of healthcare research in relation to managing the effects of hearing loss on a day to day basis.

If patients are equipped with the right mind set and skill set to self-manage their hearing loss, this would decrease the pressure on the healthcare system, thus meaning decreasing the amount of appointments needed, which in turn benefits the health care system from a financial point of view. Not only does the introduction of self-management lead to better patient outcomes, it also leads to better financial savings for the health service.

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P31. A human variant of *PCDH15* affects hearing in the mouse.

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Following the out-of-Africa expansion, humans have adapted to a diverse range of new environments and selective pressures. Scanning genomes for genetic signatures of such adaptations in populations yields lists of thousands of genetic candidates. Their functional validation and investigation of their biological consequences is a roadblock in the field and modelling of non-pathological human variation has received limited attention to date. Linking mouse phenotype to fitness in humans is complex; nevertheless, animal models provide one of the few ways to test hypotheses regarding recent human evolution.

Using bioinformatics tools (FineMAV; Szpak et al. 2018), a list of ~100 high-priority candidates across different continental populations was compiled. This included *PCDH15*, encoding protocadherin-15, a crucial molecule for hearing function. A *PCDH15* allele has been highly selected in East Asia (A-allele; Grossman et al. 2010). We have used CRISPR/Cas9 technology to knock this variant into the mouse; an A>C variant confers a change from Aspartate, D, to Alanine, A, producing a D-allele and an A-allele. This D435A polymorphism is predicted to have no affect on the structure or dynamics of Pcdh15 protein (Powers et al. 2017).

We used auditory brainstem response (ABR) recordings in the mouse to assess auditory function from 4 weeks old to 1 year old. We noted an unexpected difference in auditory phenotype between mice carrying the D-allele or the A-allele. From as young as 4 weeks old, mice homozygous for the A-allele demonstrated 16-34dB elevations of ABR threshold for tone pips of 24kHz and higher compared to mice homozygous for the D-allele. These elevations became progressively more pronounced as the mice aged and extended as low as 12kHz in older mice.

To further investigate functional differences between the two alleles, we measured supra-threshold features of the ABR. Frequency tuning curves and responses to forward masking stimuli were comparable in the mice carrying the D-allele and A-allele. However, ABR wave 1 growth functions were impaired in mice carrying the A-allele, which may suggest altered coding of sound within the auditory nerve of these mice.

There is no reported difference in auditory function in humans carrying the two different alleles, but this requires further investigation.

Acknowledgments:
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P32. Time of day has no detectible influence on pure tone thresholds in normal hearing participants

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While auditory stimuli are thought to be weak *zeitgebers*, investigations into circadian influences on auditory evoked potentials, otoacoustic emissions and thresholds have produced conflicting evidence. This study tested the hypothesis that time of day influences auditory thresholds via pure tone audiometry. As humans are diurnal, it was hypothesised that there may be time of day differences in pure tone thresholds, related to chronotype, as assessed via Munich chronotype questionnaire (Roenneberg et al., 2003). In this within-subjects repeated measures study, 16 participants (10 females, 6 males, mean age 22.4 ±4.1) completed two air conduction pure tone audiometry assessments. Subjects were tested at 125, 250, 500, 1,000, 2,000 and 4,000Hz in the morning (9am) and late afternoon (4pm). Self-reported hearing loss was assessed using the hearing handicap inventory for adults (HHIA) (Newman et al., 1990). Monaural air conduction pure tone thresholds were recorded in a single walled sound attenuating room with a glass window, such that the participant could be seen by the experimenter at all times. Stimuli were always presented to the right ear first, via supra-aural headphones, with the non-stimulated ear plugged with a foam insert. Two participants self-reported mild hearing handicap via the HHIA and were removed from group analyses. Analysis on the 14 participants with no hearing handicap found no detectable effects via three way ANOVA, with ear of stimulation, sound frequency and time of day as factors, after adjusting for gender, age or chronotype covariates. Both participants with self-reported hearing loss had mild-moderate unilateral, right sided hearing loss. Interestingly, both had lowered right ear thresholds and raised left ear thresholds in the afternoon, relative to morning. This resulted in reduced hearing loss asymmetry in the afternoon, in both HHIA mild-moderate participants. Our findings suggest that in normal hearing participants, time of day effects do not have a detectible influence on pure tone auditory thresholds but potential differences in those with unilateral hearing loss requires further investigation.

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P33. The effect of age on auditory scene analysis - evidence from a change detection paradigm.

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The ability to detect a change in a complex scene, such as the appearance or the disappearance of a source, is essential in daily situations. For example, it allows to detect the arrival of a car out of our visual field when crossing a street. Change detection has been studied quite substantially in the young population but less is known about the effect of age on this ability.

Here, we used a change detection paradigm, originally developed by [1]. The listeners had to concurrently monitor six streams of tones - each characterised by a unique carrier frequency and temporal pattern - and listen out for the disappearance of one of them. Two age groups (40 listeners each), young (20-35) and older (60-82) with close to normal hearing, were tested. Additional profile measures targeting hearing acuity, speech perception, auditory and visual sustained attention were also collected. The study examined two aspects of scene analysis via the change detection paradigm.

First, sensitivity to temporal regularity was investigated by comparing performance on scenes which consisted of randomly patterned vs. regular streams. Whilst the older participants performed (d') significantly worse than the younger listeners in the "random" condition, there was no difference between groups in the "regular" condition. This suggests a relatively preserved sensitivity to regularity in the aging brain.
The second set of experiments investigated the effect of age on distraction by brief sounds. For this, "regular" scenes which included a distractor chord at the time of disappearance were presented to the participants. A condition without a distractor was also presented as a baseline. The distractor was detrimental to performance in both groups (d'). However, an increase in criterion was only observed for the older group, demonstrating an inhibitory effect of the distractor specific to older age.

An important question pertained to whether changes in auditory perception with age are correlated with audiometric and other profile measures. Overall, we found no correlations with major indicators used in the clinic including age, audiometric measures or speech-in-noise perception. However, change detection ability in the older listeners consistently correlated with measures of auditory sustained attention. These results demonstrate that good measures of attentive abilities are critical for understanding how hearing in crowded environments is affected by healthy aging.

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P34. Isolating the locus of informational interference during speech-in-noise perception

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Speech-in-noise research typically distinguishes between energetic masking (EM: interference between target and masker at the periphery) and informational masking (IM: interference higher in the auditory pathway). IM can be broken down into low-level and high-level IM. The term "informational interference" (inf-int) refers to high-level IM involving linguistic and cognitive factors, and which is influenced by long-term knowledge (e.g. familiarity with the language spoken by competing talkers; Van Engen & Bradlow, 2007). Unlike EM, inf-int is poorly understood, in part because it is extremely difficult to manipulate inf-int without altering EM or lower-level IM.

The current study aims to isolate one way in which inf-int may arise: awareness of a masker being speech as opposed to non-speech. In this study, inf-int was isolated by taking advantage of the perceptual properties of sinewave speech (SWS). SWS is produced by extracting the first few speech formants of a natural utterance and replacing them with time-varying sinusoids reproducing their frequency and amplitude variations. SWS is not usually initially perceived as speech, but through training can be made at least partially intelligible (Carrell & Opie, 1992).

Young normal-hearing listeners completed 3 tasks (pre-exposure, exposure, post-exposure). The pre- and post-exposure task was a speech-in-noise task, with target sentences presented in a masker of SWS and amplitude-modulated white noise. During the intervening exposure phase, one listener group was trained to understand similar SWS/white noise stimuli using the paradigm developed by Davis et al (2005). A second group listened to the same SWS stimuli, but were told that they were hearing randomly-generated machine noise, and performed a simple same/different task.

Using this method, all listeners hear the same stimuli (thus controlling for EM and lower-level IM), but only listeners in the trained group are aware of linguistic content in the masker, and only post-exposure. By comparing pre- and post-exposure performance across the two groups, it should therefore be possible to isolate effects on speech-in-noise perception arising specifically from an awareness of the masker being speech. Results will be interpreted in light of the literature on informational masking.

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P35. Using adaptation measurements to distinguish effects of noise exposure and hearing loss on the auditory brainstem response.

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Animal studies have shown that noise exposure can lead to a loss of synapses between inner hair cells and auditory nerve fibres (Kujawa & Liberman 2009). This ‘synaptopathy’ has been shown to occur in the absence of elevated hearing thresholds, leading to the suggestion that it mainly affects fibres that encode higher sound levels. Attempts at demonstrating synaptopathy in humans have mainly involved the auditory brainstem response (ABR). Because the ABR depends on the subject’s audiometric profile, and on other individual characteristics, such as age and gender, previous studies needed to carefully match these characteristics between test subjects and controls. Our aim is to devise recording methods for the ABR that will obviate the need for subject matching, and thus increase its viability for clinical application. Here, we evaluate an adaptation paradigm designed to isolate ABR contributions from auditory nerve fibre populations encoding low or high sound levels. We presented stimuli at both a lower and a higher level (20 and 60 dB SPL), and with a range of different inter-stimulus intervals (ISIs). We used a group of 26 young subjects with varying levels of noise exposure history, who were roughly matched for age, but not for gender or hearing loss. As a result, there were more males in the high- than low-exposed group (10/14 versus 3/12), and the high-exposed group had higher hearing thresholds, particularly, at higher frequencies (by ~11 dB between 12.5-16 kHz). We found a general reduction in the size of the ABR wave I across all ISIs in the high-exposed compared to low-exposed group. Contrary to expectations from the animal studies, this was the case for both the lower and higher stimulus levels. When we regrouped the subjects according to their high-frequency hearing thresholds, we found a similar reduction in wave I for the poorer-hearing group. In this case, however, the effect was limited to the lower stimulus level. Under the assumption that this was caused by degradation in OHC function, this suggests that comparing the size of the ABR wave I between lower and higher stimulus levels may help to disambiguate hearing damage that is audiometrically hidden (synaptopathy) from damage that underlies hearing loss (OHC damage).

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P36. Examining the relations between pupil response dynamics and subjective ratings of effort and tiredness from listening

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The mental effort associated with listening in adverse conditions may go unnoticed based on standard clinical testing procedures that measure speech intelligibility alone. However, repeated or sustained incidences of effortful listening may accumulate and result in fatigue and/or social withdrawal. Indeed, tiredness and fatigue from effortful listening are a common complaint from individuals with hearing loss. One way to measure effortful listening is by monitoring changes in pupil dilation during listening (known as 'pupillometry'). Previous research has demonstrated that the task-evoked pupil response (TEPR) increases as a function of listening demand, with larger dilations found in more adverse signal-to-noise ratios (SNRs) (Zekveld, Koelewijn, & Kramer, 2018). However, it is unclear to what extent the TEPR is related to the subjective experience of effort or tiredness from listening. Two experiments were conducted to examine associations between TEPR, subjective effort, subjective tiredness from listening, speech recognition performance, and subjective evaluation of performance. Participants performed a listening task with either two fixed SNRs: 'easy' and 'hard' and a listening break (Experiment One) or one fixed SNR and no listening break (Experiment Two). The listening task was speech recognition in the presence of a competing talker. During the listening task, participants were routinely asked to provide subjective ratings of effort, tiredness from listening, and performance evaluation. Results from Experiment One showed overall larger TEPRs and higher subjective ratings of effort and tiredness from listening in the 'hard' versus the 'easy' SNR condition. Both experiments revealed a negative association between changes in the TEPR and subjective ratings of tiredness from listening, but no relationship between TEPR and subjective effort. Relationships shown support a model of effortful listening and fatigue whereby TEPR decreases as the subjective experience of tiredness from listening increases. Within-task changes in TEPR appear to be more associated with perceived tiredness from listening than from perceived mental 'effort' exertion *per se.* Finally, changes in tiredness from listening ratings showed a negative relationship with performance evaluation, suggesting that tiredness from listening may also influence evaluation of one's own listening success.

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P37. Tonic pupil response to predictable auditory sequences

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The brain is highly sensitive to auditory regularities. We exploit the predictable order of sounds in many scenarios, from parsing complex auditory scenes to the acquisition of language. However, it remains difficult to study incidental auditory sequence learning and to compare across verbal and non/pre-verbal populations.Pupillometry can be used across populations (e.g. infants and adults) and species (e.g. human and non-human primates); therefore, offering a potential technique to implicitly study sequence processing across different subject groups. However, it remains unclear exactly how sequence processing will be reflected in the pupil response. Abrupt changes to the sequential structure of auditory sounds elicit a phasic pupil dilation response that is thought to reflect an arousal-based spike in norepinephrine. However, slower changes to pupil dilation (tonic response) are also observed. These tonic changes have been linked to the release of acetylcholine and hypothesized to be associated with learning processes. Here we asses if the predictability of a rapid stream of auditory tone pips modulates pupil diameter. We manipulated predictability in two ways: 1) by presenting either regular (deterministic) or random sequences of tones and 2) by systematically varying the number of different tone frequencies in the sequence alphabet (5,10 or 15), e.g. random sequences of with a tone pool of 5 are more predictable than with a tone pool of 15. This created six conditions: Rand 5, Reg 5, Rand 10, Reg 10, Rand 15, Reg 15. Tone frequencies were matched across the regular and random sequences to isolate the effect of predictability from other acoustic factors.We tracked pupil diameter over nine second trials while subjects completed an auditory task unrelated to the sequence structure. We found that predictability modulated tonic pupil dilation. For all alphabet lengths random sequences produced a significantly larger response than their corresponding regular sequence. Moreover, with in both types of sequence alphabet size was reflected in the pupil response. Our findings demonstrate that predictability of an auditory sequence modulates tonic changes in pupil diameter and thus shows the potential of this technique for implicitly studying auditory regularities across cognition. It paves the way for future work to probe the underlying neurochemical drivers and cognitive processes implicated in sequence processing.

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P38. Effect of amplitude fluctuations on the loudness of low-frequency sounds

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The loudness of two-tone complexes (TTCs) with center frequencies (f_c) of 40, 63, 80, and 1000 Hz was matched with that of unmodulated tones (UTs). Frequency differences between the TTC components, corresponding to beat frequencies, f_b, were 1, 2, 5 and 12 Hz. To compensate for the steep decline in hearing sensitivity below 100 Hz, prior to the loudness match, subjects adjusted the relative levels (ΔL) of the TTC components to give maximum beat perception. Twenty-four normal-hearing subjects were tested. The values of ΔL giving best beats were well predicted from the transfer function of the middle ear and the estimated shapes of the auditory filters, assuming that the auditory filter whose output dominated the beat percept was centered somewhat above f_c. At the same root-mean-square level and independent of f_c, TTCs were perceived as louder than UTs for $f_b \leq 2$ Hz, had roughly equal loudness to UTs for $f_b = 5$ Hz, and were less loud than UTs for $f_b = 12$ Hz. The similar pattern observed across f_c suggests that the dependence of loudness on amplitude-fluctuation rate is determined by processes occurring at higher stages of the auditory system than the cochlea.

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P39. Pilot study to assess adjustment to electrical threshold (T) level and electrical stimulation rate on intensity discrimination and amplitude modulation detection at soft presentation level in adult CI users.

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Cochlear Implant (CI) users often show poorer speech perception at low intensity levels (Boyle et al. 2013). Very little is understood about the influence of sound processor fitting parameters on the discrimination of low intensity acoustic cues. Different implant systems use different approaches for setting T level e.g. Advanced Bionics T is set to 10% of M level, and for Cochlear Corporation T levels are measured. The effect of electrical stimulation rate on speech perception has typically shown that optimal stimulation rate varies on an individual basis, for speech presented between 60 to 70dBSPL (Arora et al. 2011). AM detection has been shown to correlate with speech perception and typically improves at lower stimulation rates (Green et al. 2012) when tested at moderate intensity, 60 to 70dBSPL.

The pilot study used amplitude modulation (AM) perception and intensity difference limens (IDL) to evaluated three methods for setting T level and three stimulation rates which span a commonly used range.

Thirteen experienced adult Advanced Bionics CI users were tested. The frequency of the acoustic sinusoidal stimuli was set to 1076Hz with the intention of stimulating electrode seven. Nine experimental maps were created with T levels set at: the perceptual threshold of audibility; perceptually equivalent to 'very soft' and 10% of the perceptual equivalent to 'most comfortable loudness'. Rates of electrical stimulation used were 900, 1800 and 2700 pulses-per-second.

An Adaptive 2I-2AFC IDL and AM discrimination tasks were presented via head-phones at soft presentation levels (48 and 54dBSPL for IDL and AM tasks respectively).

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

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P40. Using functional near infrared spectroscopy to map lateralization patterns of language networks in children.

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Structural and functional activation patterns of language networks become more specialized and progressively begin to span over both hemispheres during development reflecting increased linguistic proficiency. However, detailed lateralization profiles for the different aspects of language processing are still lacking. Therefore, we aim to investigate activation patterns and functional connectivity across language networks in relation to age and task performance and assess language system resting state connectivity.

To accomplish that 40 healthy native English speakers aged between 6 and 16 years old will be recruited. Functional lateralization profiles and neural connectivity will be acquired using functional near infrared spectroscopy, a neuroimaging technique which uses infrared light to measure levels of oxygenated and deoxygenated haemoglobin. Participants will also complete standardized behavioural and language assessments.

We expect that i) variability in lateralization profiles across tasks will be greater with increased age and linguistic performance, and ii) connectivity in language regions will increase as a function of language performance, after controlling for effects of age.

This research will inform future paradigms investigating functional lateralization and connectivity in children with developmental language disorder and will provide insight into how the typical language system matures.

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P41. Cortical remapping following acquired auditory deprivation – what can we learn from other senses?

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The brain contains orderly topographic maps of the peripheral sensory representations, and these are preserved up to the level of the cortex. It has been suggested that, when deprived of input from the peripheral receptors, the adult cortex can undergo large-scale plastic changes described as 'cortical remapping'.

Animal electrophysiological studies have provided evidence for cortical remapping across various species and modalities. They have consistently found that, following lesion of restricted sections of the receptor surface, the cortical territories representing these sections were invaded by an expansion of neighbouring representations. For instance, in the somatosensory domain, after amputation of the upper limb, the corresponding cortical area has been reported to be invaded by neighbouring representations of the face or lips (Pons et al., 1991). In the visual domain, it has been suggested that such cortical re-mapping can occur over very short time scales, with the earliest effects manifesting only minutes after the lesion (Gilbert & Wiesel, 1992). In the auditory domain, animal studies have suggested that remapping may not occur unless the contrast between intact and lesioned sections is both sufficiently steep and deep (Rajan & Irvine, 1996; Rajan, 1998).

Human neuroimaging, however, has challenged the animal results. In reassessing somatosensory remapping in amputees, Makin et al. (2015) found only partial invasion of the upper limb territories by the face representation. Similarly, in vision, Baseler et al. (2011), using a particularly carefully controlled paradigm, found very similar visual cortical responses in patients with acquired scotoma due to macular degeneration as in normal controls with simulated scotoma, effectively excluding any cortical remapping. In hearing, Langers et al. (2012), again found negative evidence for remapping, although this study tested tinnitus patients whose hearing thresholds were matched to controls.

In the present study, we develop a protocol for investigating the question of re-mapping in the auditory cortex based on a pilot data set involving cortical tonotopy measurements in normal control participants with simulated hearing loss.

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P42. Perceptual sensitivity to acoustic cues in mouse social communication

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Adult male mice produce complex courtship-related communication signals that are thought to be used by females for mate selection (Portfors & Perkel, 2014; Nomoto et al, 2018). For instance, "courtship songs" produced by male C57BL/6 mice in response to conspecific female cues consist of sequences of frequency-modulated ultrasonic calls emitted at a regular rate of ca 10 calls/second. However, which of these complex songs' acoustic features are socially informative to the listener and used during social goal-directed behaviour (e.g. judging male fitness and selecting a mating partner) is unclear. Here we assess the sensitivity of the listener's perceptual representation of communication sounds along several candidate acoustic dimensions. To achieve this, we use an ethologically-inspired behavioural paradigm in which female mice preferentially approach playbacks of male courtship songs (Hammerschmidt et al, 2009; Asaba et al, 2014; Chabout et al, 2015).

We found that females significantly preferred intact over rhythmically irregular versions of the songs. This suggests female listeners are highly sensitive to disruptions of the temporal regularity in courtship songs, which may represent a key acoustic cue for vocal-based mate selection. Initial results indicate that the females' behaviour is less consistently affected by other stimulus manipulations disrupting the spectrotemporal dynamics or sequential structure of the songs. Ongoing work is now investigating the neuronal substrates underlying the identified perceptual sensitivity to song regularity.

By assessing the acoustic dimensions along which natural acoustic sequences are encoded perceptually, this work helps pinpoint the sensory cues used during social communication in a mammalian species, which in turn may be candidate features for extraction and preferential encoding by auditory neurons.

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P43. Development of a method for predicting speech-in-noise performance using evoked responses to running speech

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A number of methods have recently been proposed for analysis of evoked responses to speech and speech-like stimuli. 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 severe dementia.

This study aims to produce a metric for the accurate prediction of speech-in-noise performance for both normal and hearing-impaired patients, by developing a protocol for the recording and analysis of EEG evoked-responses to continuous speech. The method presented builds on recently proposed techniques for analysing continuous, non-repeating stimuli (Lesenfants et al., 2019; Vanthornhout et al., 2018, Etard, 2019). By refining the stimulus and signal processing/machine learning techniques, the intention is to improve accuracy, reliability and practicality compared to previous methods. Preliminary results of the ongoing study are presented, comparing the performance of the method to results from a standard behavioral speech-in-noise measure (the Oldenberg Matrix speech test) in normal-hearing listeners. Results suggest that the prediction of behavioral test measures with a reasonable degree of accuracy is possible for normal-hearing listeners. However, further investigation is needed to confirm this and determine whether these results will translate to hearing-impaired patients.

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P44. Behavioural and neural measures of auditory regularity detection in ferrets

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To understand complex acoustic environments humans and animals are able to segregate and maintain auditory streams during auditory scene analysis (ASA). To perform efficient scene analysis, the brain is able to utilise stimulus statistics, ongoing context and temporal structure to extract regularities and predict future acoustic events. As a result, acoustic stimuli that transition from randomly occurring to regularly repeating pure tone sequences have recently been employed as an objective measure to investigate ASA (Barascud et al., 2016).

We trained ferrets (n=3) on a go/no-go task where the animals are required to detect the transition from a random sequence of tones (50ms duration) to a regularly repeating sequence (repeat length 3 tones, duration 150ms), and simultaneously in a visual task where a continuously lit LED transitions to a flashing LED (flash interval 150ms). During pilot experiments, all animals were able to perform significantly above chance (Monte-Carlo simulation) in each modality (Auditory: $p < 0.001$, d’ range across animals = 1.02 to 1.70; Visual: $p < 0.001$, d’ range across animals = 1.7 to 2.03). To test increasingly complex auditory patterns, repeat lengths were then varied in further experiments from 3 to 5 and 7 tones with most animals performing above chance in all pattern lengths with a decrease in performance with increasing pattern complexity (e.g. respective mean d’ across animals (n = 2): 1.44, 1.04, 0.85, $p < 0.01$).

With these data paving the way for investigating regularity detection, we aim to identify the neural correlates of this auditory process by recording local field potentials and spiking activity in the auditory cortex and hippocampus of trained animals engaged in this behavioural task, with comparison to neural activity in passive naïve animals.

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P45. Mandatory dichotic integration of second-formant information: Mismatched contralateral sine bleats have predictable effects on place judgments in consonant-vowel syllables

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Speech-on-speech informational masking may arise because the interferer disrupts processing of the target (e.g., capacity limitations) or corrupts it (e.g., intrusions into the target percept). Disrupting effects may be relatively non-specific but corrupting effects should produce predictable errors in phoneme identification (e.g., Porter & Whittaker, 1980). Listeners identified the consonant in three-formant buzz-excited analogues of approximant-vowel syllables, lying along a place-of-articulation continuum ([w]-[l]-[y]). There were two eleven-member continua; the vowel was either high-front or low-back. Continuum members shared F1 and F3 frequency contours; they were distinguished solely by the F2 contour prior to the steady portion. Continuum members also shared amplitude contours and fundamental frequency (130 Hz). When these tokens were presented alone, listeners produced clear and systematic patterns of place judgments. In the main experiment, target syllables were always presented in the left ear. For each continuum, the F2 frequency and amplitude contours were also used to generate contralateral interferers with radically different acoustic source properties—sine-wave analogues of F2 (sine bleats) RMS-matched to their buzz-excited counterparts. In the reference condition, each continuum member was accompanied in the right ear by the corresponding (i.e., matched) sine bleat; in the other conditions, each member was accompanied by a fixed mismatched bleat (1, 6, or 11). Relative to the matched-bleat case, each mismatched condition produced systematic and predictable effects on category judgments; these effects were reflected in changes in the centroid of, and area under, each of the three category functions. Overall, the largest effects were obtained from the /wi/ F2 bleat, which had the largest extent/rate of frequency change, and the smallest effects were from the /yi/ bleat, which had the smallest extent/rate of change. This may be another demonstration of the importance of the amount of frequency change in the interferer for the informational masking of speech (e.g., Roberts & Summers, 2015). Judgments of isolated sine bleats using the three place category labels were typically unsystematic or arbitrary (cf. Bailey & Hermann, 1993). In conclusion, informational masking by the sine-bleat interferers involved corruption of target processing as a result of mandatory dichotic integration of F2 information, despite the grouping cues disfavouring this integration.

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P46. Development of a tool to balance loudness in bilateral cochlear-implant fittings using participatory design

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Poor communication in everyday environments, which are generally noisy, can negatively impact on the speech and language development, education, and social wellbeing of bilateral cochlear implantees. Loudness balance across ears, although not the only factor underlying the deficits in spatial listening (Fitzgerald et al., 2015; Kan & Litovsky, 2015), is optimised in the fitting process. An app was created to assist audiologists in achieving this aim. In a first stage of development, ten normal-hearing participants were presented with sounds via headphones. Participants controlled the sound level balance across ears using a wheel so that the sound is perceived in a central position. The feasibility of the task, the occurrence of learning or fatigue effects, and the outcomes expected for normal-hearing listeners were determined. The task was feasible and the average RMS error across sounds was small (2.51 dB across participants). Occasionally there were spurious results due to issues related to the use of the interface. There were no effects of level, type of sound, or number of run, although there was a trend for the RMS errors to be higher for the first and the last runs (run 10), and just before the break (run 5). Reliable outcomes can be obtained by averaging two runs after allowing a practice run. The critical difference between runs 2 and 3 was 6.55 dB on average across runs, and can inform any decisions about discarding/repeating runs. Changes to the App were made in order to avoid spurious readings. The second stage of the study is currently under development. In this phase, ten additional normal-hearing participants will perform the task in conditions of simulated asymmetric hearing in order to determine the sensitivity of the app. The frequency bands at which attenuations will be applied and the level of such attenuation will be systematically varied.

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P47. Investigating temporal-coherence driven auditory-visual binding

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Our perception of the objects present in the world depends on the ability of the brain to integrate the information arriving from the sensory systems distributed through the body. Multisensory integration has been shown to be pervasive in the brain. However, recent evidence demonstrates that the crossmodal interactions described in the early sensory cortices could be involved in multisensory binding (1). Binding has been described as a specific form of integration based on perceptual object formation (2), which conceptually involves an enhancement of both binding and non-binding features, changing the coding within a sensory modality.

Temporal coincidence has been largely discussed as a major promoter of multisensory integration in general. Evidence from behavioural and physiological studies have demonstrated that the manipulation of stimulus onset times across modalities alters the way in which observers and neurons respond to such stimuli. Previous work recording spiking and local field potential (LFP) activity in the auditory cortex (AC) of passive listening ferrets has shown that temporal coherence drives multisensory binding of audiovisual stimuli, inducing an enhancement of the auditory stream, in a mixture, that varied coherently with the concurrent visual stimulus (1). However, this study used an all or nothing approach in which crossmodal signals were either temporally synchronous or fully independent, which does not provide information of how temporal coherence links signals over time.

To address this problem, we constructed an experimental paradigm in which we recorded neural activity in the AC of passive listening ferrets while they were presented with correlated audiovisual stimuli with gradually shifted stimulus onsets. This way, we aimed to explore whether audiovisual stimuli are bound in a window of time as previously described in behavioural studies. Moreover, to investigate temporal coherence as a distinct from the learnt experience that linked features tend to change in magnitude together, we presented ferrets with audiovisual stimuli varying coherently in time but with an unnatural pairing, this is, an increase in the visual luminance was accompanied with a decrease in the auditory intensity and vice versa. Consistent with previous studies, preliminary data suggest that there is a range of onset asynchronies over which binding is robust.

Acknowledgments: Supported by a grant from La Caixa Foundation and the Wellcome Trust.

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P48. Hidden hearing loss impacts the neural representation of speech in background noise

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The ability to follow a conversation in high levels of background noise, referred to as 'cocktail party' listening, is critical to human communication. However, despite seemingly normal hearing abilities, many individuals struggle to understand speech in noisy backgrounds. Here, we investigated the representation of speech sounds by neurons in the auditory midbrain (inferior colliculus, IC) of gerbils subjected to a mild acoustic noise insult (octave-band noise, 2-4 kHz, 105 dB SPL) that only caused a temporary hearing threshold shift.

At high sound levels (75 dB SPL), neural discrimination performance of vowel-consonant-vowel (VCV) speech tokens was significantly lower for neurograms obtained from noise-exposed compared to control animals. Impaired performance was significant correlated with spectral characteristics of the different VCVs; discrimination was most impaired for VCVs with relatively greater spectral energy within or above the spectrum of the band of damaging noise. In contrast, at moderate sound levels (60 dB SPL), recordings from exposed animals yielded significantly better neurogram-based VCV discrimination than those from control animals, and this improvement was unrelated to relative spectral content. Human listeners, presented with representations of the VCVs sonified from the neural data, experienced a significant reduction in intelligibility of speech reconstructed from neurograms from noise-exposed animals compared to that from controls, and this reduction was greater at 75 than at 60 dB SPL. A computational model combining damage to high-threshold auditory nerve fibres with increased response gain of central auditory neurons could reproduce the level-specific effects. The data are consistent with the conclusion that noise-induced damage to high-threshold ANFs elicits a deficit in neural coding of speech-in-noise at high sound intensities, as well as a compensatory increase in response gain in the central auditory system that renders speech-in-noise more intelligible at moderate intensities.

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P49. Finite element model of the cochlea to explain and remedy post implantation acoustic hearing loss

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Electrode arrays are normally implanted in one cochlea only, and so they provide no directional hearing. It is prohibitively difficult to insert an electrode array long enough to reach into the apical turn of the cochlea, and so cochlea implants are not very effective at frequencies much below 500Hz. Severe hearing loss often occurs only at frequencies above this value, leaving lower frequency acoustic hearing to provide some directional discrimination and valuable clues for speech recognition.

The implant is normally inserted through the round window of the cochlea, which becomes stiffened as flexible area is reduced. The stiffening is exacerbated by the formation of callous tissue on the round window, around the implant. The function of the round window is to release pressure in the cochlear fluid, caused by the action of the stapes, including the oval window; the pressure release allows movement of the practically incompressible fluid from the stapes to the round window, via the basilar membrane where the acoustic nerve is stimulated. As a result, implantation often results in a significant loss (c20dB) of valuable mid and low frequency hearing.

To simulate the effect of the implant on the acoustic velocity of the basilar membrane, a new finite element acoustic model of the cochlea has been developed that can accommodate significantly different physiology for the oval and round windows. The model has also simulated the effect of including a bubble within the implant, to act as a pressure-release, and hence a remedy for acoustic hearing loss.

The new model has been validated by comparing the simulation results with the average acoustic hearing loss measured by Verschuur et al (2016) in 105 patients; the simulated and measured results agree within 6db. When a cochlea with normal hearing is modelled, the results agree within 2db of those measured by von Békésy (1960). The ideal position for the bubble is as close as possible to the round window; however, precise proximity may not be achievable. The model shows that a bubble extending from 1-10mm from the round window and 0.3mm wide will restore acoustic hearing to its pre-implantation level.

Acknowledgements:

The help of supervisors Steve Elliott and Carl Verschuur is gratefully acknowledged.

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P50. The influence of hearing loss on the automatic recognition of neural responses to overlapping syllables

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A moderate hearing loss can pose major challenges for speech identification, principally in noisy environments. This is despite most features of speech remaining audible. It is not yet clear how the neural representation of speech changes following hearing loss. Here, in order to quantify this, we present a framework that integrates a Bayesian classifier with neural data gathered from animals with either normal hearing or noise induced hearing loss.

Neural responses to the presentation of vowel-consonants (VCs) overlapping one another, with onset asynchronies between 0 ms and ± 262.5 ms, were recorded from the inferior colliculus of anaesthetised guinea pigs. Animals either had normal hearing (NH) or were exposed to high intensity sound (8-10 kHz at 115 dB SPL for 1 hour; HL). A naïve Bayesian-inspired classifier was implemented to predict auditory perception. The classifier was trained and tested on neural data recorded from either NH or HL animals.

The classifier, trained on NH responses to VCs in quiet, was set to predict VCs in quiet with an accuracy of 95%. When presented NH neural responses from overlapping VC stimuli, this classifier's performance reduced to as low as 53%. When instead fed HL data, identification of overlapping VCs dropped by up to a further 20% at certain temporal overlaps. The classifier's identification of VCs in quiet only reduced by 2% with HL data. Despite predicted errors mainly resulting from consonant confusions it was vowel confusions that became more prominent following HL. When the classifier had prior knowledge of the interfering stimuli (i.e. the classifier was trained on overlapping VCs), overall performance improved. Notably, predictions made using HL data almost matched those using NH data at all temporal overlaps.

Overall, this work offers evidence for a degraded representation of speech in complex acoustic backgrounds at the midbrain level, following hearing loss. The qualitative changes to speech identification that were predicted are not solely attributable to a simple loss of auditory information in the frequencies most affected by hearing loss. Finally, the principle of applying a machine classifier to the neural coding of speech appears to be a promising method for understanding the real-world problems associated with hearing loss.

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P51. Informational masking of speech analogues by intelligible and unintelligible but acoustically similar interferers

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When target speech is heard in the presence of one or two interfering voices, the masking experienced is often primarily informational rather than energetic. Informational masking of target speech is generally greater when the interfering speech is intelligible than when it is not (e.g., speech from an unfamiliar language), but the relative contributions of acoustic-phonetic and linguistic interference are often difficult to assess owing to acoustic differences between interferers—e.g., the use of different talkers. Time reversal is often used to render interfering speech unintelligible because this manipulation does not change the spectral content of the stimulus; however, it does change the temporal-envelope characteristics (e.g., Rhebergen et al., 2005). This study used three-formant analogues (F1+F2+F3) of open-set natural sentences as targets and interferers. Target formants were presented monaurally (F0=120.3 Hz) either alone or accompanied in the contralateral ear by interfering formants from another sentence (F0=151.5 Hz); a target-to-masker ratio (TMR) between ears of 0, 6, or 12 dB was used. The dichotic stimulus configuration ensured that masking by the interferer was informational, not energetic (e.g., Roberts & Summers, 2015). Interferers were either intelligible or rendered unintelligible by delaying F2 and advancing F3 by 150 ms relative to F1 (cf. Remez et al., 2008), a manipulation designed to minimize acoustic differences between corresponding interferers by preserving the spectro-temporal properties of each individual formant. Target-sentence intelligibility (keywords correct) was 67% when presented alone, but fell considerably when an interferer was present, even though the interfering speech was on a different F0 (ΔF0=4 semitones) and presented contralateral to the target. Performance fell by 18% pts when unintelligible interferers were used (49% correct) and significantly further when interferers were intelligible (41%, extra fall = 8% pts). Changes in TMR over the range used produced neither a significant main effect nor an interaction with interferer type. Overall, the results suggest that interference with acoustic-phonetic processing of the target can explain much of the impact on intelligibility, but that linguistic factors such as lexical access also make an important contribution to informational masking.

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P52. Allocentric sound localization in ferrets

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The ability to localize sounds is critical for both human and non-human hearing. Humans can describe sound position within coordinate frames defined by the observer (head, eyes, etc.) or environment. Whether other animals perceive sound location in multiple reference frames is unclear and particularly if animals can report sound location in world-centered reference frames. Neurons within the ferret auditory system represent both head-centered and world-centered (allocentric) sound location, implying that world-centered auditory perception could exist in this species.

Here, we tested whether ferrets could perceive world-centered sound location within a two-choice allocentric sound localization task. Within the task, subjects reported the positions of one of two speakers located at opposite sides of a test arena. Trials were initiated and test sounds presented while the animal was at a central response platform located equidistant between sound sources so that the response ports and sound sources were not co-located. Across trials, the central platform was rotated to prevent use of sound location cues relative to the head or eyes.

Ferrets identified the location of sound sources at each platform rotation and thus reported sound location in the world independently of sound angle relative to the head. Generalization of sound location across head direction occurred immediately after platform rotations, indicating that ferrets did not rapidly re-learn head-centered cues to solve the task. Instead, our results show that ferrets developed a rule-based strategy based on the absolute position of sounds in the world, independent of head orientation. Finally, presentation of probe sounds at novel, untrained locations revealed that ferrets judged sound location on a continuum across space rather than as discrete spatial categories.

Together, our work suggests that like humans, other animals can also perceive sound location in allocentric coordinates. This opens the door for future recording of neurons in the auditory system to understand how neural circuits support coordinate frame transformation of sound space across the brain.

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P53. Electrophysiological and psychophysical measures of amplitude modulation discrimination interference in cochlear implant users.

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Cochlear implants (CIs) work by dividing the incoming acoustic signal into a limited number of frequency channels, extracting the slowly varying amplitude envelope in each channel, and using this to modulate the level of electrical pulses delivered to the auditory nerve fibres. The amplitude modulation (AM) cues that are transmitted are crucial for speech understanding. The use of AM cues can be affected by interference from adjacent channels caused by current spread, which can be further exacerbated if traumatic electrode placement or poor neural survival occurs.

We have tested twelve adult CI users with a measure of across-channel modulation interference (AMCI). The discrimination of different rates of AM in the presence of interfering AM on adjacent channels is measured behaviourally. In addition, an equivalent electrophysiological measure of modulation discrimination has been developed based on the electrically-evoked auditory change complex (eACC), a cortical potential that occurs in response to a change in an ongoing stimulus, AM-rate change in this case.

The ability to discriminate AM rate (based on behavioural measures and eACC) will be compared to speech perception scores. If the eACC to AM rate changes proves to be reliable, it can be used with children and also to identify poorly discriminated CI electrodes, to guide re-mapping.

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P54. Embedding beat in auditory streams suppresses auditory response: an MEG study

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When listening to a piece of music, listeners would automatically tap their toes to beat – the perceived rhythm. Beat is the basic temporal structure of music and serves as a fundamental framework for synchronization of movements to audition. Previous studies have revealed that beat perception is a complex brain function involving temporally-precise communication between auditory regions and motor planning regions of the cortex.

In the present study, we used magnetoencephalographic (MEG) recordings in combination with an adapted experiment paradigm (Benjamin Morillon and Sylvain Baillet, 2017) to investigate how beat information modulates and shapes the neuronal activities in time. In each trial, subjects were presented with 9 consecutive tones with different amplitude and frequencies, which were also temporally organized either in a periodic or an aperiodic manner. Using a time-resolved linear regression analysis on the MEG response for each tone stimuli, we estimated and separated brain response that was specifically modulated by amplitude, frequency, and beat. Our results（N=16）demonstrate that the sound amplitude showed a positive modulation on the auditory response, whereas the beat information exerted a negative influence at the latency of around 180 ms. Our findings suggest that the embedded rhythmic structure in auditory steams suppresses the neuronal response to sounds, consistent with predictive coding model, given that rhythm enables us to extract temporal regularities and efficiently anticipate upcoming events.

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P55. Low-frequency acoustical biasing of distortion product otoacoustic emissions in humans

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Introduction: Theoretical studies have demonstrated that the distinctive amplitude and phase patterns of DPOAEs can be sufficiently explained with a single saturating non-linearity[1], such as the mechanoelectrical tranduction (MET) transfer function of hair cells and can be approximated by a two-exponential Boltzmann function[2]. Studies have demonstrated that at low levels the magnitude of the cubic DPOAE (CDPOAE), 2f1-f2, is proportional to the absolute value of the third derivative of a sigmoidal transfer function. We present experimental data in humans to support such a model.

Methods: Distortion product otoacoustic emissions (DPOAEs) were recorded from humans over a range of primary tone levels in the presence of a low frequency biasing tone of 30 Hz at 120 dB SPL. Though non-linear fitting based on the Boltzmann model, the underlying transfer function and resting OP was derived.

Results: The results obtained suggest that for the parameters used in this study DPOAE generation can be predicted by a single saturating non-linearity that is spatially localised.

Conclusion: Through a combination of experimental investigation and modelling DPOAE amplitude growth functions can be predicted by third derivative of the output of a single saturating nonlinearity in humans.

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P56. Wnt signalling regulates the formation of inner ear sensory organs by antagonizing prosensory signals

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The inner ear is composed of the auditory organ responsible for sound detection and the vestibular system providing the sense of balance and acceleration. The mechanisms controlling their embryonic formation in the early otocyst remain unclear. Our recent work has shown that several of the sensory organs arise by progressive segregation from a common 'pan-sensory' domain[1], in which Notch signalling propagates prosensory identity by lateral induction. Wnt/β-catenin signalling is another pathway previously implicated in the development of the sensory organs[2], but its role in the sensory organ formation and whether it interacts with Notch in this context is unknown. Here, we show that in the developing inner ear Wnt signalling gradually expands in the dorsal part where it forms a gradient of Wnt activity. Our functional experiments in vivo revealed that Wnt signalling promotes non-sensory fate and the progression of Wnt activity coincides with the loss of neurosensory competence in the dorsal otocyst of chicken embryo. Furthermore, Wnt antagonises Notch signalling and restricts the spatial pattern of Notch activity in the otocyst. Blocking Wnt signalling in the developing inner ear leads to formation of ectopic sensory patches with hair cells in the dorsal part of the inner ear. These results suggest that Wnt signalling is part of the mechanism regulating formation and positioning of prosensory domains. RNA-Seq and bioinformatics analyses suggest that Wnt controls neurosensory specification by regulating the expression of proneural genes and inhibitors from bHLH and SRY-boxes families. Further investigation will show whether some of these genes are part of the mechanisms by which Wnt regulates prosensory organ formation in the otocyst.

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P57. Spatial release of masking in children with auditory processing disorder

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Auditory Processing Disorder (APD) is a developmental disorder leading to difficulties in listening to speech in noise despite normal audiometric thresholds. It is still poorly characterised and much disputed and there is a need for better diagnostic and intervention tools. Currently there is much interest in improving diagnosis in young children, not least because of suspicions that APD leads to learning difficulties in language and literacy, and hence to poor school performance.

One promising avenue of research is the claim that around 20% of children referred for APD have a spatial processing disorder (Cameron & Dillon, 2008) that manifests itself as an abnormally low spatial release of masking (SRM). Current clinical tests measure the SRM under headphones, virtualized by adult head-related transfer functions (HRTFs). Adults and children, however, can be very different in head dimensions. HRTFs in children have not been systematically measured so far and it is unclear if mismatched HRTFs impact speech reception thresholds (SRTs) and SRM, and whether children with APD are affected more due to their problems with processing auditory information.

Therefore, in our current study we measure HRTFs in children with and without APD, and compare the SRM achieved with these HRTFs to the same listening situation in a real anechoic environment or virtualized with HRTFs from an artificial adult head. In order to assess the influence of spectral pinna cues, we also measure SRTs for HRTFs gained from a spherical head model that only contains interaural time and level differences. Preliminary findings suggest differences in SRTs for the different listening conditions but with similar amounts of SRM. We hope our results will determine the relevance of individualized HRTFs for SRM and therefore the suitability of this test in the clinic and help to further clarify the nature of spatial processing disorder in APD.

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P58. Eye metrics as a measure of auditory salience

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Despite the prevalent use of alerting sounds in alarms and human-machine interface systems and the long-hypothesized role of the auditory system as the brain's 'early warning system', we have only a rudimentary understanding of what determines auditory salience—the automatic attraction of attention by sound—and which brain mechanisms underlie this process. A major roadblock has been the lack of a robust, objective means of quantifying sound-driven attentional capture.

Here we demonstrate that: (1) a reliable salience scale can be obtained from a large number of participants in an online experiment (N=911), (2) acoustic roughness appears to be a driving feature behind this scaling, consistent with previous reports which implicate roughness in the perceptual distinctiveness of sounds, and (3) crowdsourced auditory salience correlates with objective autonomic measures.

Specifically, we find that the salience ranking obtained from online raters correlated robustly with microsaccadic inhibition (MSI). Microsaccades are small, rapid, fixational eye movements, measurable with sensitive eye-tracking equipment. Within 300 ms of sound onset, the eyes of naïve, passively listening participants demonstrate different microsaccade patterns as a function of the sound's crowdsourced salience. More salient sounds evoked earlier MSI, consistent with a faster orienting response.

These results are in line with the hypothesis that MSI reflects a general re-orienting response which is evoked by potentially behaviourally important events irrespective of their modality. They also position the superior colliculus (hypothesized to underlie microsaccade generation) as an important brain area to investigate in the context of a putative multimodal salience-hub and demonstrate an objective means for quantifying auditory salience.

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DELEGATE LIST

NAME	POSTER/TALK NUMBER	PAGE
Ablett, Lewis	P01	30
Afif, Ahmed Bin	P02	31
Akeroyd, Michael	T02, T11, P03, P17	16, 25, 32, 46 46
Ali, Fatima	P04	33
Archer-Boyd, Alan	P05	34
Ashcroft, Caitlin	P06	35
Banafshe, Navid	T13	27
Beierholm, Ulrik	P07	36
Bianco, Roberta	P08	37
Billig, Alexander	T08	22
Biswas, Roshni	T11	25
Bizley, Jennifer	P44, P47, P52	73, 76, 81
Bleeck, Stefan	P09	38
de Boer, Jessica	P10, P35	39, 64
Brochier, Tim	P19	48
Brook, Rhiannon	T02	15
Bullen, Anwen	P11	40
Calcus, Axelle		
Caprini, Francesco		
Carlyon, Bob	T06, P05/19/21/22/23/27	20, 34, 48, 50-52, 56
Chait, Maria	T08, P08, P33, P37, P58	22, 37, 62, 66, 87
Clarke, Nathan		
Culling, John	P01, P03, P12, P26	30, 32, 41, 55
Dheerendra, Pradeep	P13	42
Dietz, Mathias	P14	43
Doleschal, Florian	P15	44
Drexl, Markus	P16, P55	45, 84
Firth, Jennifer	P17	46
Fletcher, Mark	P02	31
Forge, Andrew	P11	
Füllgrabe, Christian	P18	47
Gale, Jonathan	P24	53
Garcia, Charlotte	P19	48
Gartside, Sasha	T01, T12	15, 26
Gaultier, Clément		

NAME	POSTER/TALK NUMBER	PAGE
Genitsaridi, Eleni	P20	49
Gockel, Hedwig	P21	50
Goehring, Tobias	T06, P19, P22, P23	20, 48, 51, 52
Goncalves, Claudia	P24	53
Goodman, Dan	P25	54
Grange, Jacques	P12, P26	41, 55
Griffiths, Timothy	T03, T08, P13, P28	17, 22, 42, 57
Guérit, Francois	P27	56
Halliday, Lorna		
Harland, Andrew	P27	56
Holmes, Emma	P28	57
Hunt, Robyn	P29	58
Hussein, W	P30	59
Ingham, Neil	T13, P31	27, 60
Jacobo, A	T09	23
Kalsoom, M	P32	61
Keating, Peter		
de Kerangal, Mathilde	P33	62
Keshavarzi, Mahmoud	P23	52
Kharytaniuk, Natallia		
Knight, Sarah	P34	63
Koifman, Shiran		
Krumbholz, Katrin	P10, P35, P41	39, 64, 70
Lamping, Wiebke	T06	20
Linden, Jennifer	P04	33
Marquardt, Torsten		
Maxwell, Hannah	T12	26
McGarrigle, Ronan	P36	65
Milne, Alice	P37	66
Moore, Brian	P23, P38, P53	52, 67, 82
Nolan, Lisa		
Nunn, Terry	P39	68
Olthof, Bas	T01, T12	15, 26
Palmer, Alan		
Papoutselou, E	P40	69

NAME	POSTER/TALK NUMBER	PAGE
Pelekanos, Vassilis	P41	70
Perrodin, Catherine	P42	71
Perry, Samuel	P02, P43	31, 72
Perugia, Emanuele	T05	19
Poole, Katarina	P44	73
Rees, Adrian	T01, T12	15, 26
Roberts, Brian	P45, P51	74, 80
Salorio-Corbetto, Marina	P46	75
Sánchez-Jiménez, Ana Isabel	P47	76
Schaette, Roland	P48	77
Schneider, Felix	T03	17
Slater, David	P49	78
Smith, Katie	T04	18
Smith, Samuel	P50	79
Sollini, Joseph		
Steel, Karen	T.E. Talk, T13, P31	14, 27, 60
Summers, Robert	P45, P51	74, 80
Švent, Masa	T07	21
Town, Stephen	P52	81
Vickers, Deborah	P33, P39, P46, P53	62, 68, 75, 82
Walker, Kerry	T10, P06	24, 35
Wang, Yuanye	P54	83
Weddell, Thomas	P55	84
Williges, Ben		
Winter, Ian		
Żak, Magdalena	P56	85
Zenke, Katharina	P57	86
Zhao, Sijia	P37, P58	66, 87

Notes

Notes

Notes

Notes

Notes

Notes