APAN Advances and Perspectives in Auditory Neuroscience

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Friday, October 16, 2015

8 AM – 6:30 PM

Abstract Book

(Arranged by last name of the Presenting Author)

Poster Board #	Notes	Name and affiliation index for ALL authors	Affiliation index and affiliations for all authors	Abstract title	Abstract text
12	Poster	Nicole Angenstein (1) André Brechmann (1)	(1) Leibniz Institute for Neurobiology Magdeburg	Effects of sequential comparison on the lateralization of processing of different fundamental acoustic parameters	The perception of complex acoustic stimuli requires the evaluation of basic acoustic parameters like frequency, duration and intensity. Usually, these parameters are not judged in an absolute manner but in relation to preceding sound segments e.g. the decision as to whether a given tone is soft or loud is made relative to a reference. As acoustic information of sound sequences unfolds over time, the evaluation of these sequences requires the storage of information of individual segments until the judgment is finished and it requires a sequential update of this information. Sequential processing is suggested to mainly involve the left hemisphere. With functional magnetic resonance imaging (fMRI) we investigated the effects of sequential comparison on the lateralization of processing in the human auditory cortex (AC) for direction of frequency modulations (FM), intensity and duration. For that we used a method that reveals differential hemispheric contribution to the processing based on an increase in activity by presenting additional noise contralateral to monaurally presented task-relevant stimuli. The categorization of FM tones according to their FM direction strongly involves the right AC. However, the pairwise sequential comparison of this parameter led to an additional involvement of the left AC. For intensity, left-lateralized processing in the AC was observed irrespective of the task (without or with sequential comparison) and irrespective of the stimulus type (tones with and without FM). The categorization of tones according to their duration stronger involved the right AC for FM tones and stronger involved the left AC for tones without FM. For both intensity and duration, additional sequential comparison of tones according to these parameters led to a stronger involvement of auditory areas and a network of brain areas outside the AC in contrast to the categorization of tones according to these parameters. Analogous to the results for FM direction, the stronger activity for comparison of duration compared to categorization was lateralized to the left AC. Together with previous studies on sequential comparison, the results suggests that the left AC is additionally involved when fundamental acoustic parameters have to be sequentially compared. The stronger involvement of the right AC during comparison in contrast to categorization probably has capacity reasons. During comparison areas outside the AC are probably stronger involved because it requires sequential update of information in memory. Supported by the German Research Foundation (DFG, AN 861/4-1).

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15	Poster	Gervasio Batista (1), Jennifer Johnson (2), Mauro Costa-Mattioli (2), Jose Pena (1)	(1) Albert Einstein College of Medicine (2) Baylor College of Medicine	Extension of the sensitive period for imprinting in chickens by manipulating experience-dependent translation initiation	The brain can be transiently sensitive to learning during short periods of time, known as sensitive periods (SP). Extending SPs may thus permit behavioral plasticity beyond early stages in life. Experience-dependent protein synthesis underlying long-term memory formation is a potential target for SPs extension. We tested this idea using imprinting in chickens as a learning task. We trained chickens to recognize an object paired to a sound on a computer screen, to test visual and auditory imprinting. Using Western Blotting and pharmacology we investigated whether eIF2α and mTORC1, which can independently regulate translation initiation, affect imprinting. Non-phophorylated eIF2α, which enhances translation initiation, was increased in the area involved in auditory imprinting but not in the site for visual imprinting. Accordingly, manipulation of this pathway either blocked or triggered consolidation of auditory, but not visual, memory. Notably, facilitating translation initiation through eIF2α also extended the critical period for auditory imprinting. The mTORC1 pathway was activated in both visual and auditory areas. However, blocking mTORC1 with Rapamycin only disrupted the formation of visual memories. In addition, we found that thyroid hormones, which can extend the critical period for visual imprinting, induced mTORC1 activation. Together, these data strongly suggest that the formation of auditory and visual long-term memory is mediated by two independent pathways that regulate translation initiation. Furthermore, manipulating these pathways can extend the SP for imprinting in each sensory modality.

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72	Poster	Robert B. Baudo (1), Beverly A. Wright (1)	(1) Northwestern University	Reactivation and anterograde disruption of recently encoded memories: A variant of reconsolidation	During learning, memories are transformed from a fragile to a stable state through a process of consolidation. There is growing evidence that when consolidated memories are accessed they re-enter a state of instability, during which they can be modified, and then must be consolidated again. This cycle of reactivation and reconsolidation is revealed by reports that consolidated memories are susceptible to retrograde interference following a reminder of the memory, even when the reminder occurs weeks to months after the initial training. Here we show behavioral evidence in humans of a mechanism similar to reconsolidation, but in which reactivated memories are susceptible to anterograde interference only within 24 hours of the initial training. Using a perceptual-learning paradigm, we first identified a case in which learning on a target task was disrupted in the anterograde, but not retrograde, direction. Learning across days on interaural-level-difference discrimination (L) (the target task) was disrupted by practicing interaural-time-difference discrimination (T) (the non-target task) before (TL; n=11), but not after (LT; n=10), daily practice on the target task. We then used a paradigm akin to that used to test for reconsolidation. Listeners practiced a bout of the target task in isolation (L) and 30 minutes later practiced the task order that elicited anterograde interference (TL) (L30minTL; n=14). This regimen yielded no improvement on the target task the day after training, suggesting that the initial bout of the target task was reactivated by the reminder and that both bouts were disrupted by the anterograde interferer. Learning returned when the reminder was removed (L30minT, n=10), confirming that the lack of learning in the L30minTL case was not due to retrograde interference of the non-target task (T) on the initial bout of the target task (L), and that the disruption of learning required the target-task reminder. Increasing the time between the initial and reminder bouts from 30 minutes to 24 hours (L24hrTL; n=14) yielded improvement on the target task from the initial bout to the test 48 hours later, but this learning occurred between the initial bout and the reminder, and not between the reminder and the test. Thus, after 24 hours, while the initial bout was no longer susceptible to anterograde interference, new bouts of training on the target task were. These data suggest that during an early stage of memory formation, recently acquired memories can be reactivated, but are susceptible to anterograde interference, while older memories are protected from such disruption.

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69	Poster	Michael V Beckert (1), Jose Luis Pena (1)	(1) Albert Einstein College of Medicine	Emergence of hemispheric spatial tuning in the owl's auditory forebrain	Previous work has shown that the auditory forebrain structure, Field L, which is homologous to mammalian primary auditory cortex (A1), and one of its downstream nuclei that is important for sound localization, the auditory archistriatum (AAr), which is homologous to the auditory portion of the mammalian frontal eye fields (FEF), lack a topographic representation of auditory space and are organized into clusters of similarly tuned neurons. This contrasts with the topographic distribution of spatial tuning observed in the avian superior colliculus. A similar difference is observed between the superior colliculus and auditory forebrain in mammals. Unlike in the midbrain, how auditory space in encoded in the forebrain is largely unknown. We are investigating this question in the auditory forebrain of the barn owl, Tyto alba. In particular, we are studying the transition from midbrain to Field L and from Field L to AAr. We improved upon previously used techniques by utilizing tetrode recordings to directly address the existence of these clusters and gather further insight into the organization of local populations in avian cortex. Tetrode recordings were performed in anesthetized barn owls. Sound stimuli were presented dichotically through custom made earphones, varying interaural time (ITD) and level difference (ILD), or from free-field speakers to obtain tuning profile of multiple single units within a single recording site. Tuning profiles of units within these local populations were then compared to one another to assess the similarity or difference in their composition. Our results in Field L are inconsistent with the clusters hypothesis and suggest a heterogeneous organization of neuronal tunings similar to mammalian A1. Groups of neighboring neurons can be tuned to very different combinations of binaural cues. In contrast, neighboring neurons in AAr, as well as neurons from different recording sites, have very similar tunings, suggesting that AAr is far more homogeneous than Field L. Additionally, AAr neurons show a stereotypic spatial tuning and a population response consistent with the emergence of a hemispheric population responding broadly to contralateral space, as proposed for mammals.

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9	Poster	Joel I Berger (1), Ben Coomber (1), Mark N Wallace (1), Alan R Palmer (1)	(1) MRC Institute of Hearing Research	Salicylate-induced changes in brain activity in awake guinea pigs	Tinnitus - the perception of phantom sounds - chronically affects an estimated 8-15% of people. Tinnitus is difficult to characterise and frequently intractable, and presents a significant burden to healthcare resources. Studies conducted in human subjects with tinnitus have shown altered patterns of resting-state oscillatory brain activity. However, to date this has not been extensively explored using animal models, which allow more invasive examination of changes in neural activity and their correlation with objective behavioural measures of tinnitus. Here, we describe the development of an awake preparation for examining tinnitus-related changes in resting-state and auditory-evoked brain activity. Guinea pigs were implanted with electrocorticography (ECoG) electrode arrays, with electrodes positioned on the surface of the dura over left and right auditory cortex and over the cerebellum, to monitor auditory brainstem responses. ECoG responses were subsequently compared before and two hours after tinnitus induction with sodium salicylate (350 mg kg-1; i.p.), a drug which reliably induces tinnitus in both humans and animals. Subtle salicylate-induced changes in oscillatory activity were observed in all animals recorded from electrodes over auditory cortex, predominantly at low frequencies, i.e. delta, beta, and alpha bands. Click-evoked cortical field potentials were dramatically enhanced (~100% increase) following salicylate treatment, compared with vehicle treatment, potentially indicating increased sensitivity to sound (hyperacusis). These salicylate-induced changes in spontaneous and auditory-evoked cortical potentials may be due to direct effects on neuronal excitability. Furthermore, small increases in neural gap detection thresholds were observed, suggestive of a slight worsening in temporal processing. Tinnitus induction with salicylate is widely used as an acute tinnitus model. The next stage will involve a chronic tinnitus model (induced by acoustic over-exposure), that will allow us to track neural changes throughout tinnitus development in an awake-behaving model.

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59	Poster	James Bigelow (1), Amy Poremba (2)	(1) University of California, San Francisco (2) University of Iowa	Audiovisual integration during short-term memory in primate prefrontal cortex	Among the brain regions thought to underlie audiovisual integration is the lateral prefrontal cortex (PFC), which is specialized for integrating and retaining sensory information in the service goal directed behaviors. Physiological investigations of audiovisual integration have traditionally employed passive exposure paradigms, leaving open the question of how circuits underlying audiovisual integration might interact with circuits enabling retention of information beyond periods of direct sensory stimulation. The current study investigated this question by recording neurophysiological activity within PFC during an audiovisual short-term memory task. Each trial included a sample and test stimulus separated by a retention interval, after which a second delay preceded a response window. Responses were rewarded following identical (match trials) but not nonidentical stimuli (nonmatch trials). Memoranda comprised sounds for auditory trials, images for visual trials, and sounds plus images for audiovisual trials. Audiovisual integration was evident within stimulus periods from units exhibiting significant evoked responses on both auditory and visual trials, and units with responses on audiovisual trials that differed significantly from the maximal unimodal response. Similar forms of audiovisual integration were observed during mnemonic-related responses, including delay activity and differential responses to matching versus nonmatching test stimuli. Additional analyses revealed a dissociation among delay types, wherein inhibitory activity was most likely during sample delays where a behaviorally relevant sensory cue was predicted, and excitatory activity was most likely during matching test delays where a motor response was predicted. The results reveal convergence of cross-modal and cross-temporal integration in individual units and local cell populations within PFC.

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58	Poster	Jennifer M Blackwell (1), Mark Aizenberg (1), Laetitia Mwilambwe-Tshiloo (1), Sara Jones (1), Ryan G Natan (1), Maria N Geffen (1)	(1) Otorhinolaryngology, University of Pennsylvania, Philadelphia, PA	Two types of interneurons differentially modulate toneevoked responses in the primary auditory cortex	The ability to discriminate between tones of different frequencies is fundamentally important for everyday hearing. Primary auditory cortex (A1) regulates behaviors that rely on frequency discrimination (Aizenberg and Geffen, 2013), but the underlying neural mechanisms are poorly understood. Frequency tuning of cortical excitatory neurons is shaped by the balance of excitatory and inhibitory inputs. In the cortex, the two most common classes of inhibitory interneurons are parvalbumin-positive (PV) interneurons and somatostatin-positive (SOM) interneurons. PV interneurons target the soma and initial axon segment, while SOM interneurons target distal dendrites. Therefore, these two classes may differentially affect responses of excitatory neurons. We found that photo-activation of parvalbumin-positive (PV) interneurons enhanced tone-evoked responses of excitatory neurons. By contrast, photo-activation of SOMs diminished tone-evoked responses in the excitatory neurons, by suppressing tone-evoked responses more than spontaneous activity. Furthermore, photo-activation of SOMs decreased the frequency tuning width of excitatory neurons. Combined, we find that different types of interneurons exert a differential effect on frequency responses of excitatory neurons. PVs and SOMs may therefore carry out functionally different roles in auditory processing.

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101	Poster	Vanessa Carels (1), Michael DeWeese (2)	(1) Helen Wills Neuroscience Institute, University of California, Berkeley (2) Helen Wills Neuroscience Institute, University of California, Berkeley; Department of Physics, University of California, Berkeley; Redwood Center for Theoretical Neuroscience, University of California, Berkeley	Signal-to-noise ratio impacts performance in a novel auditory stimulus selection task for rodents	Like humans and other primates, rats can learn to selectively respond to auditory features present in a mixture of sounds while ignoring others in a task that mimics many key features of the cocktail party problem. Previous work on selective attention in the primate visual system indicates that a change in the tuning properties of neurons in many sensory areas may be implicated in stimulus selection behavior (Motter 1993, Luck et al 1997). Previous work on auditory selective attention revealed a rule encoding signal for stimulus selection in both the medial prefrontal cortex (mPFC) and primary auditory cortex (A1), but the tuning properties of A1 neurons were surprisingly unaffected. It is possible that the stimulus mixtures were not low-contrast enough to require tuning changes in A1 to solve the task (Boudreau et al 2006). In the present study, we test whether rats can learn a similar task using mixtures of sounds with variable signal to noise ratio (SNR). We show that 1) rats can be trained to select stimulus features at low SNR and 2) changing the SNR impacts the behavioral response.

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73	Poster	V. C. CARUSO (1), A. F. EBIHARA (3), J.T.MOHL (1), J.LEE (1), D.S.PAGES (1), A. MILEWSKI (4), S. TOKDAR (2), W. A. FREIWALD (3), J. M. GROH (1);	(1) Ctr. For Cognitive Neurosci., Neurobiology, Psychology and Neurosci., Duke Univ., Durham, NC; (2) Statistical Science, Duke Univ., Durham, NC; (3) Lab. of Neural Systems, The Rockefeller Univ., New York, NY (4) Lab. of Sensory Neurosci., The Rockefeller Univ., New York, NY	Is multiplexing a general strategy for encoding multiple items in the brain? Evidence from a visual cortical face area and a subcortical auditory area	How the brain preserves information about multiple simultaneous items is poorly understood. We have previously reported that the monkey Inferior Colliculus is able to represent two sounds played simultaneously by interleaving the representation of each single sound in time, a strategy akin to time division multiplexing used in telecommunications (Caruso et al. SfN 2014). Specifically, while the monkey reported the location of the two sounds, the activity of some neurons in the IC alternated between the firing rates observed for each of the sound items presented singly. Fluctuation between activity patterns corresponding to each of multiple items may be a general strategy employed by the brain to enhance its processing capacity. Here, we tested this hypothesis in a different domain, face perception, and in a different brain region, the macaque middle face patch (MF). Neurons were recorded while monkeys viewed a face stimulus in the receptive field, a "distractor" face or object outside the receptive field, or both. We evaluated neural activity on dual-stimulus trials to determine if neurons switched back and forth between the two activity states the two component stimuli elicited in isolation. We focused on two time scales: whole trials and 50 ms time bins within trials. For the whole trial analysis, we were interested in whether the spike count distribution corresponded to (a) a mixture of the Poisson distributions observed on single stimulus trials, indicating whole-trial fluctuations; (b) a Poisson distribution with an intermediate rate (which might indicate within-trial fluctuations), or (c) several non-multiplexing possibilities (e.g. summation). We found evidence of both mixture and intermediate Poisson distributions, but not of the non-multiplexing possibilities. We then used a Hidden Markov Model to determine if the firing rate switched between different distributions during different 50 ms time bins. All of the cases with "intermediate" spike counts at the whole trial level showed switching behavior at this faster time scale. Overall, we found that roughly one fifth of the conditions tested (32/146) show evidence of either whole trial or within-trial multiplexing. The presence of multiplexing patters in both the MF and earlier IC results suggests that multiplexing may be a general mechanism that enhances capacity whenever neurons must code more than one stimulus at a time. Such a process may explain variability in neural activity and may be related to oscillations in LFP/EEG signals.

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	Talk	Fanny Cazettes (1), Brian J Fischer (2), José L Peña (1)	(1) Department of Neuroscience, Albert Einstein College of Medicine, Bronx, New York, 10461, USA (2) Department of Mathematics, Seattle University, Seattle, Washington, 98122, USA	The neural code biasing the owl's orienting behavior	How the brain, often a biased estimator, translates sensory information into adaptive behavioral responses is still a matter of debate. We study this question in the sound localization system of the barn owl. We have previously shown that neurons in the owl's midbrain map of auditory space are tuned to the most reliable auditory cue and that the degree to which a cue can be trusted is encoded in the shape of tuning curves. The next outstanding question is how the neural population is readout to capture cue reliability in the behavioral response. We tested the hypothesis that a population vector captures cue reliability and explains the biased orienting behavior of the owl in situation of uncertainty. We examined if a vector decoder can be computed by a population of neurons in the owl's midbrain tegmentum, which directly commands head orientation. We showed that convergence and normalization from the midbrain map leads to the emergence of a population vector in the tegmentum. We further demonstrated that manipulating the sensory input to modify specific response properties of the midbrain population can enhance or reduce the owl's behavioral bias in a manner predicted by the population vector and by the population response in the tegmentum. This is the first time a biased behavior has been explained at the encoding, decoding and behavioral levels.

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88	Poster	Nicolas Barascud (1), Ryszard Auksztulewicz (2), Theofilos Petsas(1), Sijia Zhao(1), Marcus Pearce(3), Karl Friston (2), Maria Chait (1)	(1)Ear Institute, University College London, London, UK (2) Wellcome Trust Centre for Neuroimaging, University College London, London (3) Queen Mary University of London, London	SENSITIVITY TO THE EMREGENCE OF PREDICTABLE STRUCTURE IN SOUND SEQUENCES	Patterns or regularities in on-going sound sequences are key cues to understanding complex auditory environments. The pattern of sound often conveys the identity and state of objects within the scene and also enables the listener to predict future events, supporting efficient interaction with the surrounding environment. This presentation will review recent behavioral and brain imaging findings in our lab that demonstrate just how sensitive we are to complex sound patterns, including those that we have never previously encountered and, indeed, maybe unlikely to encounter outside of the laboratory. Our findings suggest that the auditory brain is a remarkably well-tuned 'pattern seeker', continuously scanning the unfolding auditory input for regularities, even when listeners' attention is focused elsewhere. Brain responses reveal online processes of evidence accumulation - dynamic changes in tonic activity precisely correlate with the expected precision or predictability of ongoing auditory input –both in terms of deterministic (first-order) structure and the entropy of random sequences. Source analysis demonstrates an interaction between primary auditory cortex, the hippocampus and inferior frontal gyrus in the process of 'discovering' the regularity within the ongoing sound sequence. The results are consistent with precision based predictive coding accounts of perceptual inference and provide compelling neurophysiological evidence of the brain's capacity to encode high order temporal structure in sensory signals.

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21	Poster	K. K. Chong(1,2), K. N. Shepard(1), T. N. Ivanova(1), R. C. Liu(1)	(1)Emory University, Atlanta, GA (2)Georgia Institute of Technology, Atlanta, GA	Tolerance to acoustic variation within a natural vocal category increases between core and non-core auditory cortical fields	Recent years have seen mounting interest in the use of natural sounds (e.g., vocalizations) to investigate the neural basis of auditory memory formation. Such work has been particularly useful for characterizing plasticity in auditory functions such as sound detection and categorization. For example, our recent work (Shepard, Lin et al., 2015) established that a physiologically defined subset of single units in the core auditory cortex of the CBA/CaJ maternal mouse, but not the non-maternal female, is better able to separate two overlapping categories of ultrasonic vocalizations (USVs) - those of mouse pups, which carry sustained behavioral relevance to mothers, and those of adult males, which do not. This difference emerged in the absence of long-term tonotopic map expansion for USVs, in contrast to much prior work demonstrating that conditioned sounds gain increased auditory cortical territory. However, tonotopic map expansion might still occur transiently to support learning (Reed et al., 2011) and/or establish improved downstream processing of behaviorally important sounds in higher order areas. Hence, in the current study, we ask: 1) Does map expansion for USVs occur transiently in the maternal context? 2) How might learning of the pup USV category manifest in higher-order processing areas? We conducted electrophysiological mapping studies of 3 groups of maternal females (3-4, 9-10, or 21+ days post-parturition) and one group of non-maternal females. We found no evidence of tonotopic map plasticity at any maternal time point, suggesting that map plasticity is not involved in the formation of the maternal memory for pup USVs. Subsequent investigation of pup USV responses within individual auditory fields, however, revealed category-specific plasticity in the non-core field A2. Over the course of motherhood, multi-units in A2, but not core field UF, became increasingly likely to respond to both prototypical and non-prototypical pup USV exemplars. We then examined whether this principle derived from data in anesthetized mice can also be observed at the single unit level in awake mice. A preliminary analysis shows that when comparing single unit responses to prototypical vs. less prototypical pup USVs, A2 exhibits greater tolerance for variation in onset frequency modulation compared to core field UF. Thus, neural tolerance to natural acoustic variation within a behaviorally relevant category appears to increase between core and non-core processing stages, similar to hierarchical transformations of visual objects observed along the ventral stream of the visual pathway (Rust & DiCarlo, 2010).

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2	Poster Teaser	Kate L. CHRISTISON-LAGAY(1), Yale E. COHEN (2)	(1) Neuroscience Graduate Group, University of Pennsylvania, Perelman School of Medicine (2) Dept. of Otorhinolaryngology, University of Pennsylvania, Perelman School of Medicine	Contribution of primary auditory cortex to auditory-streaming behavior	A fundamental component of auditory perception is the grouping and segregation of auditory stimuli into distinct perceptual units—a process that is known as "auditory scene analysis". The auditory brain groups and segregates stimuli based on their spectral, temporal and spatial regularities (or differences). Once grouped, a single perceptual auditory unit is called an "auditory stream". One important psychophysical task that has illuminated many of the principles and mechanisms underlying a listener's ability to segregate and group acoustic stimuli is the "streaming" task, in which listeners report whether a sequence of tone bursts at two, alternating frequencies sounds like one "auditory stream" (i.e., "galloping" tones) or two auditory streams. The probability of a listener hearing one or two streams can be manipulated by changing certain parameters of the tone-burst sequences, including (1) the frequency separation between the tones, (2) the listening duration, and (3) the temporal overlap of the tones. Using this tone-burst sequence, we recently demonstrated directly, for the first time, that non-human primates segregate the auditory scene in a manner comparable to human listeners and, consequently, are a valid model of human stream-perception. Here, for the first time, we present findings from extracellular recordings from neurons in the primary auditory cortex (A1) while the animals performed this streaming task. We found that (1) A1 neurons are more broadly tuned during the streaming task than during a passive-listening condition and (2) the firing rate in response to the tone bursts habituates over time. We also find that (3) neural activity is modulated as a function of behavioral report. The degree of choice activity is comparable to that seen in other brain areas that contribute sensory evidence to the decision but do not code the decision itself. Further, unlike previous computational models, we find that choice behavior is not coded by neural habituation but, instead, can be explained by instantaneous firing rate. We discuss these finding in the context of the role of A1 and the hierarchical mechanisms of the ventral auditory pathway.

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10	Poster	Ben Coomber (1), Joel I Berger (1), Steve PH Alexander (2), Alan R Palmer (1), Mark N Wallace (1)	(1) MRC Institute of Hearing Research (2) School of Life Sciences, University of Nottingham	Manipulating endocannabinoid signalling in animal models of tinnitus	Animal models of tinnitus have revealed long-term hyperexcitability and altered neural synchrony, thought to arise from pathology affecting the balance between excitatory and inhibitory neurotransmitter systems. The release of all neurotransmitters is regulated by neuromodulators, such as endogenous cannabinoids (endocannabinoids). Endocannabinoids are produced on-demand in response to depolarisation and act to regulate presynaptic neurotransmitter release. Cannabinoid drugs are potent anti-nociceptive agents in models of chronic neuropathic pain, a condition that shares substantial parallels with tinnitus, i.e. phantom sensory percept in the absence of sensory input, initiated peripherally through deafferentation and subsequently involves central mechanisms. In the present study, tinnitus was induced by either (1) subjecting guinea pigs (GPs) to unilateral acoustic over-exposure (AOE) or (2) administering sodium salicylate. Both models involve central changes, i.e. they are not reliant solely on altered peripheral input. In animals subjected to AOE, tinnitus was objectively identified with the gap prepulse inhibition of acoustic startle (GPIAS) behavioural test, eight weeks after AOE. Hearing status was assessed using auditory brainstem responses. Animals were then retested on five occasions after being administered either the cannabinoid CB1 receptor agonist arachidonyl-2'-chloroethylamide (ACEA; 1 mg kg-1, i.p.) or drug vehicle. In the second group of animals, GPs were first implanted with electrocorticogra phy (ECoG) multi-electrode arrays, before being administered with sodium salicylate (350 mg kg-1; i.p.) to induce tinnitus, and either ACEA (1 mg kg-1, i.p.) or drug vehicle. Resting-state and auditory-evoked neural activity recorded in awake, freely-moving animals was compared between groups. Treatment with ACEA induced variable effects in animals with AOE-induced tinnitus, but neither augmented nor attenuated tinnitus behaviour. In the second group of animals, sodium salicylate altered resting-state activity and enhanced auditory-evoked responses. Preliminary data collected from animals co-administered ACEA and salicylate indicated a reduction in auditory oversensitivity (induced by salicylate). These data indicate that manipulating endocannabinoid signalling can affect tinnitus-related neural activity, but these changes may be too subtle to detect using the GPIAS behavioural approach.

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30	Poster Teaser	Jonathan Cote (1), Anthea F. Zeng (1), Etienne de Villers-Sidani (1)	(1) McGill University	Impact of adaptive spectral discrimination training on top-down influences in the auditory cortex of young and older adults	“Top-down” influences continuously modulate the sensitivity of sensory cortical fields to increase the salience of behaviourally relevant stimuli. In auditory pathways such context-dependent filtering improves ones ability to perceive sounds and speech presented in noisy or distracting conditions. With natural aging, this ”filter” however commonly fails resulting in difficulty understanding speech in noise. Interestingly, this impairment occurs even in the absence of peripheral hearing loss, suggesting that a central mechanism might be responsible. It remains largely unclear whether this hearing impairment could be due at least in part to abnormal top-down mechanisms involved in dynamically enhancing relevant sounds in primary or secondary auditory cortical fields. In a first step towards understanding how such filters might fail with aging we trained for 2 weeks young (20-40 years old, n=8) and healthy older adults (65-85 years old, n=4) on an adaptive auditory discrimination task involving arbitrary spectrally complex sounds and examined at several time points during the training the changes in activity and connectivity between auditory fields and putative brain areas involved in top-down sensory modulation using magneto-encephalography (MEG) We found that (1) training was associated in both groups with a significant reduction in A1 activation to non-target training sounds and that (2) this change was correlated with their improvement on the task. We also saw (3) that the pattern in connectivity between the auditory cortex and dorsolateral prefrontal cortex (DLFPC) changed over the two weeks of training. With improving performance we noted a progressive reduction in theta coherence but an inverse increase in gamma coherence between the two areas. We additionally found that older individuals had on average poorer performance on the task and that this difference was linked to reduced theta and gamma coherence between the auditory cortex and DLPFC. Moreover, we did not observe the training induced increase in gamma coherence in the older group. Finally, older participants also had relatively increased recruitment of auditory cortical fields during the task both at the beginning and end of training. We conclude that learning and dynamic sensory filtering changes with age and that dysregulation of connectivity in theta and gamma between the auditory and frontal cortical fields is associated with poorer auditory discrimination of complex sounds. Moreover the larger area of cortical activation in older participant throughout training suggests a lesser overall efficiency of cortical circuits in that groups.

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29	Poster	Da Costa S.(1,2), Crottaz-Herbette S.(1), van der Zwaag W.(3), Meuli R.(4), Rapin P.-A.(1,5), Clarke S(1)	(1) Lausanne University Hospital, Neuropsychology and Neurorehabilitation Service (2) Vanderbilt University Medical Center, Hearing and Speech (3) Centre D'imagerie Biomedicale, Ecole Polytechnique Federale de Lausanne (4) Lausanne University Hospital, Radiology (5) Lavigny Institution	Unilateral brain lesions modulate human tonotopic mappings	The primary auditory cortex (PAC) is essential to human auditory abilities. Previous fMRI studies have measured two large tonotopic primary subfields with mirror symmetric progressions of preferred frequency. In humans, brain lesions induce plasticity in brain regions belonging to the same network, a phenomenon defined as diaschisis. Here, we acquired fMRI tonotopic mappings in unilateral brain lesion patients and quantified how these lesions affected the contralesional tonotopic map. We hypothesised that diaschisis-like effects should cause functional reorganisation of PAC if the lesion site involved areas belonging to the auditory pathway. We scanned 12 healthy controls and 12 patients with unilateral lesion in the left hemisphere, right hemisphere and the right cerebellum. Each participant attended to progressive cycles of pure tone bursts (88 - 8000 Hz) presented in 32s-blocks during two 8min runs. PAC was functionally defined as the largest cluster containing the mirror-symmetric gradients in each individual hemisphere. Tonotopic maps were quantified as percentage of preferred frequency within the total amount of voxels in PAC – the frequency distribution– and as signal variations for each frequency bin within PAC – the percent signal change (PSC) distributions. Mirror-symmetric gradients were maintained in both hemispheres, despite variations in frequency representations depending on the lesion site. Frequency distributions and PSC variations in patients were outside normal range in contralesional and ipsilesional hemispheres, with lesion closer or within PAC inducing larger effects, such as an increased in low frequencies representations in contralesional PAC. Our results demonstrated that (1) tonotopic maps could be easily measured in stroke patients, (2) frequency mappings are preserved only if primary and non-primary auditory areas are not part of the lesion site, and (3) both contralesional and ipsilesional tonotopic maps are highly influenced by its own reciprocal maps, possibly reflecting some degrees of diaschisis-like effects.

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86	Poster	Oliver Barnstedt (1), Peter Keating (1), Yves Weissenberger (1), Andrew J King (1), Johannes C Dahmen (1)	(1) University of Oxford	Functional Micro-Architecture of the Mouse Dorsal Inferior Colliculus revealed through in vivo 2-Photon Calcium Imaging	The inferior colliculus (IC) is an obligatory relay for ascending auditory inputs from the brainstem and receives descending input from the auditory cortex. The IC comprises a central nucleus (CNIC), surrounded by several shell regions, but the internal organization of this midbrain nucleus remains incompletely understood. We used two-photon calcium imaging to study the functional organization of neurons in the mouse dorsal IC and corticocollicular axons that terminate there. In contrast to previous electrophysiological studies, our approach revealed a clear functional distinction between the CNIC and the dorsal cortex of the IC (DCIC) suggesting that the mouse midbrain is more similar to that of other mammals than previously thought. We found that the DCIC comprises a thin sheet of neurons, sometimes extending barely 100 μm below the pial surface. The sound frequency representation in the DCIC approximated the mouse's full hearing range, whereas dorsal CNIC neurons almost exclusively preferred low frequencies. The response properties of neurons in these two regions were otherwise surprisingly similar, and the frequency tuning of DCIC neurons was only slightly broader than that of CNIC neurons. In several animals, frequency gradients were observed in the DCIC, and a comparable tonotopic arrangement was observed across the boutons of the corticocollicular axons, which form a dense mesh beneath the dorsal surface of the IC. Nevertheless, acoustically-responsive corticocollicular boutons were sparse, produced unreliable responses and were more broadly tuned than DCIC neurons, suggesting that they have a largely modulatory rather than driving influence on auditory midbrain neurons.

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82	Poster	Ivar Thorson (1), Stephen David (1)	(1) Oregon Health and Science University	Spectral tuning of short-term plasticity in auditory cortex	Perception of behaviorally relevant signals (e.g., vocalizations) often requires integrating acoustic information over hundreds of milliseconds or longer, but the latency of sound-evoked activity in auditory cortex typically ranges over a much shorter duration. The ability of cortex to encode sounds in their broader spectro-temporal context has been attributed to modulatory phenomena, such as stimulus-specific adaption and contrast gain control. The current study tested whether short-term synaptic plasticity (STP) can provide a mechanism for such contextual influences on cortical responses to complex natural sounds. Single-unit activity was recorded from core (A1) and belt (dPEG) cortex of awake ferrets during presentation of a large battery of natural sounds. Encoding properties were first characterized using a standard linear-nonlinear spectro-temporal receptive field model (LN STRF). LN STRFs where then compared to variants of the STRF that incorporated a simple STP mechanism (depression and/or facilitation) prior to the linear filtering stage. In two model variants, STP was applied globally to all incoming spectral channels or locally to subsets of the inputs. For the majority of neurons, STRFs incorporating locally tuned STP predicted neural activity as well or better than the LN STRF and the global STP STRF. These results suggest that cortical neurons integrate inputs over multiple spectral channels, each in a different adaptation state determined by the preceding sensory context. The time course of STP varied across neurons, but was generally stronger for excitatory channels than inhibitory channels. STP effects typically recovered over 100-1000 ms, a timescale consistent with previously reported contextual phenomena. Spectrally and temporally heterogeneous adaptation, subserved by STP or a mechanism with similar dynamics, may support representation of the diversity of spectro-temporal patterns that occur in natural sounds on behaviorally relevant timescales.

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13	Poster	Joseph Dechery (1) (2), Jason N MacLean (1) (3)	(1) University of Chicago (2) Committee on Computational Neuroscience (3) Department of Neurobiology	Quantifying temporal structure of auditory cortex multineuronal patterns	The complexity of natural auditory stimuli is derived from the temporal features of one dimensional pressure fluctuations in atmospheric pressure. Multineuronal activity patterns in auditory neocortex can be similarly characterized by their temporal features. A fundamental step toward understanding the neural representations of sound is a quantitative description of the dynamics of these multineuronal patterns. This is especially true in neocortex where recurrent connectivity dominates and neurons must work in concert to encode behaviorally relevant stimulus features. Precision of spike timing is of particular interest, due to its potential for reliable information representation and its elusive mechanistic underpinnings. Here, we analyze temporal aspects of naturalistic network dynamics in A1 acute slices at the single cell, pairwise, and network level. Spiking activity is measured in populations as large as 1000 neurons with two photon calcium imaging. By comparing these recordings to simulated data that preserves firing rates but destroys pairwise temporal information, we statistically determine the temporal characteristics not driven solely by spike rate. Subsets of neurons have very reliable and temporally structured activation patterns relative to both intrinsic and extrinsic reference points in time. At the pairwise level, highly correlated neurons act as building blocks that together form reliable sequences of propagating network activity. Finally, we explored the dynamics underlying an observation that spike-time variability increases throughout a multineuronal pattern. This analysis acts to both describe the dynamics of neocortical neurons solely driven by local connectivity. Our results imply that activity in A1 can be described as sequences of reliable and structured multineuronal activity patterns. Characterizing the variance and stereotypy of activity propagating through a network will be key to understanding how the underlying synaptic inputs drive spiking and how the network itself encodes and transforms sensory input.

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52	Poster	Pradeep Dheerendra, Simon Baumann, Olivier Joly, Alexander Thiele, Timothy D. Griffiths	(1) Institute of Neuroscience, Newcastle University, United Kingdom	BOLD response to auditory object properties in the monkey auditory cortex	This work addresses how cues for auditory object perception are represented in the macaque auditory cortex. Previous work suggests that pitch cues are represented beyond the core area A1 in a region that overlaps multiple auditory core and belt fields [PMID 23015424]. Here we address how timbral cues are represented in the macaque auditory cortex: specifically the spectral flux dimension of timbre corresponding to the change in spectrum over time. Previous human work suggests differences in the representation of the timbral property of spectral flux in core and belt homologues [PMID 19052218]. Aims We sought differences in the relationship between BOLD and r in core and belt cortex. Methods Individual core and belt areas were defined on two subjects using tonotopic mapping and myelin mapping [PMID 25100930]. We measured the BOLD response corresponding to spectral flux using a synthetic stimulus that affords manipulation of flux independently of bandwidth [PMID 19052218]. Spectral flux was characterised in terms of the Pearson correlation (r) between amplitude spectra of adjacent timeframes. Sparse EPI images were acquired on a 4.7T upright scanner whilst subjects carried out visual fixation. We acquired 3 runs of stimuli with 5 different r values presented 45 times each in a randomized order. A generalized linear model analysis [SPM8] allowed single-subject inference to determine the relationship between BOLD and r in individual core and belt areas. Results In macaque core areas, BOLD activity decreased significantly as a function of increasing r (or decreasing spectral flux). In belt and parabelt, BOLD activity decreased as a function of increasing r with less negative slope than in core. Conclusions The data show a difference in the relationship between BOLD and spectral flux in macaque core and belt where the slope becomes more positive between core and belt areas. In the previous human study the slope changed from zero in core homologues to positive in belt homologues (as opposed to changing from negative in macaque core to less negative in belt). Whilst the perception of pitch by macaques appears similar to humans [PMID 25309477] we speculate that different timbre organisation might underlie differences in sounds that are relevant to the two species.

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100	Poster	Giovanni M. Di Liberto (1), Edmund C. Lalor (1)	(1) University of Dublin, Trinity College	Isolating neural indices of continuous speech processing at the phonetic level	It has been suggested that human speech perception is underpinned by a hierarchical cortical system that enables acoustically variable inputs to be perceived as categorical speech units. A method for indexing the neurophysiology of such hierarchical processing in the context of continuous speech has recently been introduced. Specifically, low-frequency EEG has been shown to be sensitive to phonemic-level processing and the relationship between continuous speech EEG responses was best described when that speech is represented using both its low-level spectrotemporal information and also the categorical labeling of its phonetic-features (Di Liberto et al., in review). Here we outline an experiment aimed disentangling low-level neural activity from that relating to phonetic-feature processing. The intelligibility of 10 s speech stimuli was degraded using noise vocoding. Each stimulus was then presented twice with an intervening presentation of the original clean speech version of that stimulus. As such, the second presentation of the vocoded version of the stimulus was primed by the clean speech and was found to be significantly more intelligible on a match-to-sample task. The responses to vocoded speech in both conditions were then studied both when the speech was represented as its envelope or spectrogram and when it was represented as a sequence of time-aligned phonetic features. This analysis provided a quantitative dependent measure of speech processing at the phonetic level.

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46	Poster	Frederic K. Dick (1) Matthew Lehet (2) Lori L. Holt (2)	(1) Birkbeck College, University of London (2) Carnegie Mellon University	Topographic representation of frequency-selective attention in human auditory cortex	Humans and other mammals are very sensitive to changes in the salience, task-relevance, and composition of the acoustic dimensions of complex and ecologically important sounds. Listeners appear to be able to shift attention across multiple simultaneously-present acoustic dimensions to home in on the ones that are diagnostic in guiding behavior. In particular, psychoacoustic experiments have shown that both endogenously and exogenously cued attention to a particular frequency or spectral band can enhance detection of auditory targets and sharpen sensitivity to multiple features within the attended band. Electrophysiological work in non-human animals has begun to uncover the mechanics of this process (Fritz et al., 2007; 2010) while a pair of fMRI studies in humans (da Costa et al., 2013; Paltoglou et al., 2009) have shown that attention to high or low frequency bands drives responses across auditory cortex in a way that is predicted by tonotopic mapping in the same participants. However, it is unclear how fine-grained this mapping is, how it differs across auditory fields, how it relates to the underlying myeloarchitecture of auditory cortex, and how other cortical regions drive or modulate 'attention-o-tonotopic' maps. In the current study, we use a novel fMRI paradigm to drive sustained attention to multiple frequency bands; in the same participants, we obtained quantitative MR data (to estimate cortical myelination) along with tonotopic mapping in order to localize auditory areas (Dick et al., 2012). Across participants, we found that multiple auditory fields showed 'attention-o-tonotopic' mapping that was closely aligned with tonotopic maps (which can be quite differently organized across participants and even over hemispheres). We also characterized the relationship of attention-o-tonotopic fields to putative the cortical myeloarchitectonic maps, both in the auditory core as well as non-core fields, and found interesting and reliable (cross-scan) patterns of individual variation. These results have implications for understanding how human listeners direct attention to behaviorally-relevant auditory dimensions in listening to complex sounds like speech and music and provide groundwork for understanding how experience may modulate these maps.

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92	Poster	Yue Ding (1), Yang Zhang (1), Juan Huang (4), Wenjing Zhou(2), Zhipei Lin (5), Bo Hong (1), Xiaoqin Wang (3,6)	(1) Department of Biomedical Engineering, Tsinghua University, Beijing 100084, P.R. China (2) Department of Neurosurgery, Yuquan Hospital, Tsinghua University, Beijing 100084, P.R. China (3) Department of Biomedical Engineering and Tsinghua-Johns Hopkins Joint Center for Biomedical Engineering Research, Tsinghua University, Beijing 100084, P.R. China (4) Zanvyl Krieger Mind/Brain Institution and Department of Biomedical Engineering, The Johns Hopkins University, Baltimore, Maryland 21205, USA (5) Department of Neurosurgery, General Hospital of People's Liberty Army, Beijing 100084, P.R. China (6) Department of Biomedical Engineering, The Johns Hopkins University, Baltimore, Maryland 21205, USA	An ECoG study of neural correlates of music listening and recall	Previous neural imaging studies have shown that the perception and retrieval of musical information are associated with activations of overlapped brain regions, including inferior frontal lobe, supplementary motor area, premotor cortex, superior temporal gyrus and supra-marginal areas. However, little is known about how the network of brain areas dynamically represents the time course of listening and recall of musical pieces and how the activations of specific brain areas are related to particular musical information. To explore cortical activity patterns associated with music listening and recall, we recorded electrocorticography (ECoG) from Chinese-speaking epilepsy patients with implanted subdural electrode arrays while they were listening to or imagining familiar musical melodies without lyrics. Subjects were asked to first listen to the initial segment of a familiar music piece and then complete the rest of the piece (2 or 5s) by auditory imagery. Subjects indicated the completion of the imagery by pressing a response button. We analyzed the neural activities of the onset phase (0-500ms) and the sustained phase (after 500ms) of music listening and recall separately. For the onset phase, we observed different sequential delay orders of neural activities between music listening and recall. Initialization of the onset cortical activity related to music listening first happened in posterior temporal lobe and supra-marginal area, followed by middle temporal and pre-central areas, and finally reached frontal lobe. In comparison, the cortical activity related to the onset of music recall first appeared in frontal lobe, followed by pre-central area and reached temporal lobe at last, showing a reversed sequential order. For cortical responses of the sustained phase, more brain regions were activated than during the onset phase, with dispersed brain regions activated in both music listening and recall including bilateral pre-central, supra-marginal area, left superior frontal lobe, and right anterior temporal lobe. During the sustained phase, the left temporal lobe and bilateral inferior frontal lobe were mainly involved in music listening, whereas the right superior frontal and superior temporal lobe were mainly involved in music recall. In addition, we found that high gamma band ECoG signal dynamically tracked the music intensity envelope in bilateral posterior superior temporal gyrus during music listening and in bilateral superior frontal lobe during music recall. [This research was supported by NSFC grants 61473169]

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80	Poster	Alex Dunlap (1), Geoff Adams (2, 3), Robert Liu (2, 3)	(1) Wallace H. Coulter Department of Biomedical Engineering, Georgia Institute of Technology, Atlanta, GA 30332, USA (2) Department of Biology, Emory University, Atlanta, GA 30322, USA (3) Center for Translational Social Neuroscience, Emory University, Atlanta, GA 30322, USA	An ethological paradigm for associating an auditory stimulus with a social reinforcer	The neural mechanisms within auditory cortex that support the learning of social communication sounds are not fully understood. Social interactions typically progress is a manner that does not easily allow for controlled sound delivery. This poses a major challenge for auditory neural characterization during such natural behaviors because of the need for repeatable playback of sounds. One possible solution to this problem is to exploit the stereotyped retrieval behavior female mice exhibit in response to isolated, vocalizing pups, an interaction that is presumed to be socially rewarding. By interacting with pups in their home cage, female mice can “learn” to preferentially approach distant speakers playing back ultrasonic models of pup calls over playback of other sounds with different acoustic properties, presumably because they recognize the calls as behaviorally relevant. This preference does not occur in “naive” virgin mice that have not had pup experience, and takes several days to emerge in such animals (Ehret, 2005). However, even once a preferred approach has developed, pup-experienced mice will typically habituate in as few as 6 trials to pure playback of pup call models if live pups are not present at the end of the approach apparatus (Haack 1982). Such a short duration complicates the ability to characterize neurons during social approach. To overcome this, we find that continual delivery of pups at the end of a 70 cm linear approach track produces a steady, stereotyped retrieval of over 100 pups in a 40 min time period, sufficient for characterizing neural activity in a realistic time-frame for holding single units. Additionally, mice exhibit little variability in their head position during the approach, reducing variation in forward sound delivery to only +/-3 dBspl for ultrasound frequencies, and less for lower frequencies. Head angle varies within +/-15 degrees from the approach axis, an angular difference that has been shown to be perceptually indiscriminable for mice (Heffner, 2001). Taking advantage of these results, we designed a paradigm for mice to learn to associate a new, exogenous sound cue to guide them to pups. We use a T-maze where mice are forced to make a decision at the split about which direction to go in order to retrieve a pup. With this paradigm mice can learn to approach a salient multimodal stimulus with >90% accuracy in 100 trials per mouse. When reduced to a purely auditory stimulus, mice still learn, though training takes longer. When combined with simultaneous neural recordings, this ethological paradigm will provide a useful tool for investigating how auditory representations change online when new sound cues that predict a social reward such as a pup are learned.

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67	Poster	Soraya L.S. Dunn (1) , Jennifer Bizley(1), Daniel Bendor(1)	(1) University College London	How generalizable is rodent hippocampal function across other species? Preliminary hippocampal recordings in the ferret (Mustela putorius)	In rodents, the hippocampus plays a fundamental role in spatial navigation. Lesions to the hippocampus disrupt spatial memory, while hippocampal neurons (place cells) are tuned to an animal's location in its environment. Furthermore, theta oscillations, a 5-12 Hz rhythmic component in the local field potential, are linked to locomotion and play a critical role in numerous hippocampal models of spatial navigation. However, neural coding principles of the hippocampus are based almost exclusively on rodent studies, and it remains an open question which principles can be generalized to other species. Rodents primarily rely on the proximal sensing strategies of sniffing and whisking. Therefore, their sensory world is tied very closely to their current location. In species where distal sensing is more dominant, activity in the hippocampus is not always consistent with the rodent data. For example, 'spatial-view cells' have been observed in non-human primates, and theta activity is more closely coupled with echolocation rather than locomotion in bats. To further investigate inter-species differences we have started to record hippocampal activity from the ferret: a predatory carnivore, which relies predominantly on the distal senses of audition and vision. Here we present a 3D reconstruction of the ferret hippocampus, which was used to guide electrode implantation, and preliminary data recorded from the ferret hippocampus during various behavioural paradigms.

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	Talk	Julia Erb (1), Marcelo Armendariz (2), Federico de Martino (1), Wim Vanduffel (2), Elia Formisano (1)	(1) Department of Cognitive Neuroscience, Maastricht University (2) Laboratorium voor Neuro- en Psychofysiologie, KU Leuven (3) MGH Martinos Center, Charlestown (4) Harvard Medical School, Boston	Homology and specificity of natural sound-encoding in human and monkey auditory cortex	How does the neural representation of natural sounds compare between human and non-human primate species? We used contrast-agent enhanced fMRI (Vanduffel et al., 2001) in awake macaque monkeys (0.7 mm isotropic voxel, using implanted phased-array coils, Janssens et al., 2012) to investigate the cortical encoding of natural sounds. We modelled fMRI responses in the auditory cortex as a function of the sounds' spectro-temporal content (fMRI encoding), and derived single- and multi-voxel modulation transfer functions as well as topographic maps of sensitivity to frequency, spectral and temporal modulations. Results are compared to human 7T fMRI data collected using identical stimuli and analyzed with the same modelling approach (Santoro et al., 2014). Topographic cortical maps of acoustic features in the macaque are similarly organized as in humans: Tonotopic maps showed typical alternating high-low frequency gradients across the primary core and surrounding belt areas (Moerel et al., 2014; Joly et al., 2014). Consistent with human results (Santoro et al., 2014), fast temporal and coarse spectral acoustic information was preferably encoded in posterior auditory regions, as opposed to slow temporal and fine spectral information in anterior-lateral auditory regions. As an important difference, however, the macaques' temporal modulation function showed a preference for faster modulation rates, with a peak at approximately 60 Hz, whereas the humans' preferred modulation rate was centered at 3-4 Hz. The latter modulation rate has been linked to the processing of syllables in speech (Luo and Poeppel, 2007). Supporting this hypothesis, sound representations in humans maximized the fine-grained discrimination of speech and other human vocal sounds, but not of sounds from other categories (Santoro et al., in revision). No such effect, however, could be observed in the macaque although identical sounds and methods were used. These findings suggest that tuning of the human auditory cortex to the syllabic rate is unique and might constitute a product of the evolution of speech and language.

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81	Poster	Jean-Pierre Falet (1), Jonathan Côté (2), Etienne de Villers-Sidani (3)	(1) McGill University, (2) McGill University, (3) McGill University	Generating a tonotopic map of the human primary auditory cortex using magnetoencephalography	Objective: To determine the feasibility of accurately mapping the tonotopy of the auditory cortex using magnetoencephalography (MEG) with human subjects, and to examine the changes that occur in this tonotopic orgination following auditory training. Methods: We used MEG recordings and generated spectro-temporal receptive fields (STRF) for dipoles in the postulated region of the primary auditory cortex. Using these STRFs, we were able to identify the preferred frequencies for each dipole as well as several other properties, including the response amplitude, bandwidth, latency, and modulation, and map them onto the cortex surface. Results/Conclusion: We were able to demonstrate a tonotopic organization of the postulated primary auditory cortex in humans subjects, using MEG. Moreover, our results show that auditory training alters several properties of the tonotopic organization, including response amplitude, bandwidth, and characteristic frequency.

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38	Poster	Lorenz Fiedler (1), Thomas Lunner (2,3), Alex Brandmeyer (1), Malte Wöstmann (1,4), Carina Graversen (2), Jonas Obleser (1,4)	(1) Max Planck Research Group "Auditory Cognition", Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany (2) Eriksholm Research Centre, Snekkersten, Denmark (3) Linnaeus Centre HEAD, Swedish Institute for Disability Research, Linköping University, Linköping, Sweden (4) Department of Psychology, University of Lübeck, Lübeck, Germany	In-Ear-EEG indicates neural signatures of effortful auditory processing	Hearing aids (HA) amplify, compress and further process incoming acoustic signals and are fitted to individual hearing impairment. However, HA thus far are unable to completely restore hearing in challenging listening situations, likely because HA operate uncoupled from the listeners' neural and cognitive processes. We here present data in a new approach to gather neural control signals for steering the HA. As a basis we took signals measured in N = 3 participants using Electroencephalography (EEG) recordings from three electrodes placed in the external ear canal ("in-ear-EEG") alongside with conventional 64 electrodes scalp EEG. The objective of this project was to detect reliable neural signatures of auditory cognitive processing in the in-ear-signals. To this end, we tested two established auditory paradigms: First, a concurrent dichotic oddball paradigm (with 1.4- and 1.8-Hz driving stimulus frequencies) to evaluate the detectability of auditory evoked potentials (AEP) in the in-ear-EEG and second, a cocktail-party, multi-talker scenario to extract neural responses to ongoing speech signals. First, our results show significant P1 and N1-equivalent ERP deflections in the in-ear-EEG on the single subject level in all participants. Second, spectral analysis disclosed evoked components at the two driving frequencies of the oddball paradigm and their higher harmonics. Furthermore, we found a prominent peak in the alpha frequency band for each participant. Third, using cross-correlation techniques, the cocktail-party scenario revealed significant neural phase-locking of in-ear-EEG to the speech envelope. Lastly, validating our approach, there was a significant and spatially distributed correlation of time-domain in-ear-EEG with simultaneously acquired conventional scalp EEG. In sum, by using established challenging-listening paradigms and data analyses, our results prove the feasibility of in-ear-EEG and the availability of neural signatures related to auditory processing. These findings thus provide a promising basis for further research using more real-life listening paradigms and brain-computer-interface (BCI)-geared analyses.

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43	Poster	Yonatan Fishman (1)	(1) Albert Einstein College of Medicine	The Mechanisms and Meaning of the Mismatch Negativity (MMN): Insights from Neural Population Recordings in Monkey Auditory Cortex	The mismatch negativity (MMN) is a pre-attentive, middle-to-long-latency auditory event-related response component recorded from the scalp in humans that is elicited by a change in a repetitive acoustic pattern. The MMN is typically investigated using an oddball stimulus paradigm in which infrequently occurring sounds ('deviants' or 'oddballs') are randomly interspersed among frequent, homogeneous sounds ('standards') that differ from the deviants along some acoustic dimension (e.g., frequency, intensity, duration) or abstract feature. The MMN has been attributed to neural generators within the temporal (auditory) and frontal cortices. While the MMN has been extensively studied for decades and used as a clinical diagnostic tool, its underlying neural mechanisms and meaning continue to be debated. Two dominant explanations for the MMN have been proposed. According to the "sensory memory" hypothesis and the related "predictive coding" interpretation, the MMN is a distinct 'non-obligatory' response component that reflects the brain's detection of a violation of a neural 'memory trace' or prediction generated by the regularity of the preceding standards. In contrast, according to the "neural adaptation" hypothesis, repeated presentation of the standard sounds results in adapted (i.e., attenuated) responses of feature-selective neurons in auditory cortex. Rare deviants activate neurons that are less adapted than those stimulated by the frequent standards, and thus elicit a larger 'obligatory' event-related response (e.g., N100), which yields the MMN upon subtracting the response to standards from the response to deviants. To help clarify the debate, here I present neurophysiological data from auditory cortex of alert and behaving macaque monkeys obtained using a variety of stimulus paradigms commonly tested in human MMN studies. Neural responses are recorded via multi-contact electrodes (laminar probes), and population techniques (local field potentials, multiunit activity, and current source density) are utilized to enhance translational relevance to noninvasive recordings in humans. We find that responses to violations of acoustic patterns can be largely explained by the "neural adaptation" hypothesis and provide no clear evidence for the "sensory memory" or "predictive coding" hypothesis, at least at the level of primary auditory cortex. I discuss implications of these results for the debate between proponents of the two competing models of the MMN and for the interpretation of noninvasively recorded event-related responses in humans.

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39	Poster	Juliane Krueger Fister1,2, LeAnne R. Kurela1,2, Aaron R. Nidiffer3, Troy A. Hackett2,3,4,6, Mark T. Wallace2,3,4,5,6	1Neuroscience Graduate Program, 2Vanderbilt Brain Institute, 3Dept. of Hearing and Speech Sciences, 4Dept. of Psychology, 5Dept. of Psychiatry, 6Vanderbilt Kennedy Center; Vanderbilt University, Nashville, TN.	Differential visual modulation of auditory activity in cat A1 between supra- and infragranular layers	Objects and events in our world are frequently specified by more than one sensory modality. Specialized regions within the brain are tasked with actively integrating these multisensory cues in order to facilitate behavior and perception. Traditional association regions in cortex receive convergent inputs from different thalamic and cortical sources and have been intensively studied for their multisensory processing capabilities. However, recent findings implicate that sensory-specific (i.e., unisensory) cortices can also be modulated by information from a different sensory modality. For example, neuronal responses within regions of auditory cortex are influenced by visual and somatosensory stimulation at the level of both spiking and local field potentials (LFP). Here we sought to expand upon these observations by examining visual influences on auditory responses in the primary auditory cortex of the cat (n = 3), with an emphasis on laminar differences that may provide important insights into multisensory modulatory networks. A 16 or 24 channel multilaminar electrode was advanced into primary auditory cortex (A1) and multi-unit (MUA) as well as LFP activity was recorded to visual only, auditory only, and combined audiovisual stimulation while stimulus location varied across azimuth and elevation. Although visual only MUA was rarely encountered, visual LFPs were robust and had similar activity onsets across all layers. Auditory and audiovisual LFPs were also stimulus location dependent and varied between cortical layers. When measuring peak activity, visual LFPs were maximum in infragranular (IG) layers while auditory and audiovisual LFPs peaked in supragranular (SG) and granular (G) layers. Multisensory interactions across the laminae strongly dependent on the magnitude (area under the curve) of the visual influences and the location of the stimuli. When collapsing across all tested elevations, stimuli at central locations elicited reduced audiovisual LFPs when compared to auditory LFPs in the SG layers, while audiovisual LFPs exceeded auditory LFPs in IG layers. With peripheral azimuths, the opposite held true. Findings when collapsing across all azimuths are less clear but suggest a general trend of decreased audiovisual LFPs in SG and increased audiovisual LFPs in IG laminae when contrasted to auditory LFPs. These results indicate that although visual influences into auditory cortex are broad across all layers, they have differential modulatory effects in SG and IG layers dependent upon stimulus location, hinting at potentially distinct processing strategies between networks involving cortical or thalamic loops.

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41	Poster	Darik Gamble (1) Xiaoqin Wang (1)	(1) Johns Hopkins University	Single-Unit Responses in Lateral Belt Auditory Cortex of the Behaving Marmoset Monkey	The current working model of primate auditory cortex comprises the hierarchical arrangement of a series of functionally distinct information processing stages: a primary 'core' region, a secondary 'belt' region, and a tertiary 'parabelt' region. Combined anatomical, physiological, and imaging data have subdivided core and belt into multiple tonotopic subfields (Kaas & Hackett 2000, Petkov et al. 2006). Previous reports have shown that lateral belt units prefer band-pass noise stimuli over pure tones (Rauschecker et al. 1995, Rauschecker and Tian 2004). We report here preliminary single-unit extracellular recording data from a region tentatively identified as the middle lateral belt region ML, based on tonotopic organization and distance from the lateral sulcus. The effects of arousal on firing rates were quantified by comparing responses in both behaving and passive conditions. Responses in the passive condition were further split into an ‘eyes open’ and ‘eyes closed’ state on the basis of an eye-tracker video camera. Analysis that revealed that while arousal could modulate firing rates either up or down, the eyes-open passive state was usually intermediate between the behaving and eyes-closed passive states. Consistent with previous findings, many units displayed restricted preferences for spectral bandwidth. However, two-noise stimulation revealed diverse significant nonlinear interactions extending outside of the single-noise receptive field, suggesting extensive spectral integration in lateral belt. We also found that most units preferred temporally modulated stimuli, with heterogeneous preferences for amplitude or frequency modulation.

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44	Poster	Phillip E. Gander (1), Sukhbinder Kumar (2,3), Kirill V. Nourski (1), Hiroyuki Oya (1), Hiroto Kawasaki (1), Matthew A. Howard (1), Timothy D. Griffiths (2,3)	(1) University of Iowa (2) Newcastle University (3) University College London	Direct recordings of oscillatory activity in the human brain during working memory for tones	Working memory is the capacity to hold and manipulate behaviourally relevant information in mind in the absence of ongoing sensory input. Here we explored the hypothesis that working memory for tones requires a network of oscillatory activity in auditory cortex, frontal cortex, and hippocampus [Kumar et al., 2015, SfN], and examined the form of such activity in neuronal ensembles. We recorded local field potentials from six human subjects undergoing invasive monitoring for pre-surgical localization of epileptic foci. The subjects were implanted with depth electrodes along the axis of Heschl's gyrus (HG) containing primary cortex in the medial part, and subdural electrodes over temporal and frontal cortex. Following a visual alert subjects were presented with a pair of tones (0.5 s duration, 750 ms ISI) belonging to two different categories ('Low': 300-570 Hz; 'High': 2000 -2800 Hz). A visual cue (750 ms) then informed the subjects which tone (first or second) to keep in mind. A 3 s retention period was followed by a tone which could be the same or different (frequency difference ±20%) from the tone held in mind. The subjects made a same/different decision by pressing a button. A total of 160 trials (80 each of 'Low' and 'High' tone retention) were presented. We measured average ERPs and carried out single-trial time-frequency analysis using a wavelet transform. During perception, both the magnitude of ERPs (~100 ms after stimulus onset) and gamma-band (60-120 Hz) power in electrodes located in HG and lateral superior temporal gyrus (STG) showed category-specific responses. High tones elicited stronger responses in medial HG and low tones in lateral HG. During retention, sustained induced low frequency power in the delta/theta-band (2-8 Hz) was observed in HG, frontal cortex (inferior and superior gyri), and hippocampus. Sustained low frequency activity was observed in all contacts that showed gamma-band responses during perception. Low-frequency power during retention also showed a recency effect: a greater response in HG electrodes was observed for the most recently presented (second) tone. On the STG, however, the opposite effect was observed: a greater 2-8 Hz power for retention of the first compared to the second tone. The data demonstrate: 1) a network of brain regions during auditory working memory that includes auditory, frontal, and hippocampal cortex 2) theta-band correlates of tone retention in auditory cortex in the same neural ensembles that are active in the gamma band during perception 3) neural bases in the auditory cortex for interference effects within tonal working memory.

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109	Talk	Lixia Gao and Xiaoqin Wang	Department of Biomedical Engineering, The Johns Hopkins University School of Medicine, Baltimore, MD 21205, USA	Neuronal Mechanisms Underlying the Temporal Coding Diversity in the Auditory Cortex of Awake Marmoset	How the central auditory system processes temporal information of sounds is an important question in auditory research, as it is crucial for our understanding of mechanisms underlying speech and vocal processing. Previous extracellular recording studies from our lab have shown neurons in primary auditory cortex (A1) of awake marmosets use two distinct response modes to encode temporal information: the stimulus-synchronized response where spiking is phased-locked to the sound envelope of slow time-varying stimuli and the non-synchronized response where firing rate co-varies with the temporal repetitions of time-varying stimuli (Lu et al. 2001, Bendor and Wang 2007). However, the cellular mechanisms underlying such synchronized and non-synchronized response modes are still largely unknown. Although intracellular recordings are the most widely used techniques in studying synaptic and intrinsic properties of neurons, few studies have been conducted in the auditory cortex of awake non-human primates, due to technical challenges. In the present study, we have developed a sharp electrode recording assembly which provides sufficient stability to allow repeat recordings of both subthreshold and spiking responses through the intact dura in auditory cortex of awake marmosets over many sessions. Using this novel technique, we were able to investigate the neuronal mechanisms underlying synchronized and non-synchronized response modes in A1 of awake marmosets. We observed several types of responses in A1 to click trains and sinusoidal amplitude-modulated tones (SAM): synchronized, non-synchronized (including both positive and negative monotonic responses) and mixed responses. At long inter-click intervals (ICIs) or slow modulation frequencies (MFs), the subthreshold responses of neurons with synchronized or mixed responses showed periodic depolarization which resulted in the stimulus-synchronized discharge. Moreover, the subthreshold depolarization exhibited entrainment to faster temporal repetitions of the stimuli than the spiking activity, suggesting a temporal-to-rate transformation of thalamic inputs in A1. At short ICIs, A1 neurons with positive monotonic non-synchronized responses exhibited pronounced sustained depolarization whose magnitude increased with decreasing ICIs, which corresponded to the increase in firing rate of these neurons with decreasing ICIs. In contrast, neurons with negative monotonic non-synchronized responses exhibited hyperpolarized responses instead of sustained depolarization at short ICIs. The magnitude of the hyperpolarization decreased with increasing ICIs, resulting in an increase in the firing rate. These results suggest distinct subthreshold mechanisms underlying positive and negative monotonic non-synchronized responses. In both of these cases, the membrane potential is transformed to firing rate by a power law, such that the firing rate is proportional to the voltage above the resting membrane potential. Furthermore, for both positive and negative monotonic non-synchronized responses, we observed no significant periodic subthreshold events at short ICIs, while there was weak periodicity in the subthreshold inputs at long ICIs, suggesting that neurons with non-synchronized responses may receive synchronized inputs at slowly changing time-varying stimuli through thalamocortical and/or intracortical inputs. Taken together, our results suggest distinct neuronal mechanisms underlying the diversity of temporal coding modes observed in auditory cortex of awake conditions. This diversity may serve as a necessary substrate for a wide range of A1 functions such as speech and vocal processing, sound stream segregation, objection recognition and multisensory integration.

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7	Poster	Adam Gifford (1), Michael Kahana (1), Yale Cohen (1)	(1) University of Pennsylvania	Characterizing the Dynamic Representation of Acoustic Spectral Regularity in Humans	Auditory perception depends on the auditory system's ability to detect and segregate or group the spectrotemporal regularities in the acoustic environment. In particular, the pattern of spectral progression over time is widely thought to be a signal that the auditory system can use to group and segregate acoustic events into distinct sounds. However, it is currently unclear how the auditory system tracks and reflects changes in spectral regularity over time in an ongoing, dynamic stimulus. Moreover, much of the previous work on the brain's representation of spectral regularity focused either explicitly on the contributions of the core auditory fields or was conducted with techniques that have poor spatial localization (such as electroencephalography). As a result, little is known about the extent to which aspects of spectral-regularity representation are specific to either the core or higher-order auditory fields, or general to the auditory system as a whole. The goals of this study were (1) to test how the human auditory system reflects local spectral regularities on short time scales in ongoing acoustic-tone sequences with pseudo-random structure and (2) localize these representations in cortex. Because neural oscillatory activity influences the timing of neural spiking and correlates with deviations in spectrotemporal regularities, we examined the contribution of oscillatory activity to dynamic spectral regularity representation by measuring electrocorticographic activity in human epileptic patients. Subjects listened passively to sequences of alternating tone bursts of two frequencies presented in a pseudorandom order. We analyzed oscillatory activity as a function of temporally local configurations of tones within the overall sequences (e.g., subsets of tone triplets). We found generally that, whereas analytic phase concentration was positively correlated with the degree of spectral regularity on local timescales, analytic amplitude was not. Additionally, we found that these phase-concentration effects were widespread across cortex, present not only in regions along the classical auditory pathways, but also other more multisensory regions. These findings support a role for oscillatory activity in dynamically tracking local spectral regularities and organizing the auditory scene.

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	Talk	Joshua R Gold (1), Fernando R Nodal (1), Andrew J King (1), Victoria M Bajo (1)	(1) Department of Physiology, Anatomy and Genetics, University of Oxford, UK	Optogenetic Silencing of the Ferret Primary Auditory Cortex in a Behaviorally- and Physiologically-Relevant Model of Lesion-Induced Tinnitus.	Tinnitus is the subjective perception of a sound in the absence of an environmental source. A key step to facilitate clinical progress is the development of animal models that capture relevant features of the condition in humans – in particular, the links between the patient's percept and the complex network of physiological changes correlated with the condition. Our aims were first to develop a model of trauma-induced tinnitus in the ferret, a species well known for its utility in auditory research, and to interrogate the animal model using longitudinal behavioral and physiological approaches. Second, we wished to investigate a possible causal role for the primary auditory cortex (A1) in tinnitus by optogenetically silencing A1 activity during gap-in-noise behavior (Gold et al., 2015, Behav. Neurosci.) in a mixed group of tinnitus (T) and non-tinnitus (NT) ferrets. In a cohort of ferrets (N=10), a partial, unilateral mechanical lesion of the spiral ganglion (SG) was performed that replicated certain aspects of the peripheral pathology noted in human tinnitus patients. Prior to and following this lesion, animals were tested on an auditory gap-in-noise detection task, to examine whether temporal processing was affected in a manner consistent with the presence of tinnitus. Mixed lesion-mediated effects were seen across the cohort, with a subset of animals showing reductions in psychometric gap detection threshold, slope and asymptote. Within the same (T & NT) cohort, pre- and post-lesion auditory brainstem responses (ABRs) were obtained using clicks, narrowband chirps and masked click stimuli. The data indicated complex lesion-mediated changes, with latency increases and shifts in amplitude-level functions, particularly in late-wave ABR components. Multi-unit recordings made bilaterally in A1 of a subset of animals showed tonotopic remapping, neural hyperactivity and hypersynchronicity following SG lesion. In a smaller mixed (T & NT) ferret cohort (N=6), the light-sensitive proton pump archaerhodopsin T (ArchT) was expressed in A1 neurons by bilateral viral vector injections (AAV8-CAG-ArchT-GFP), allowing suppression of neural excitability during behavior with 532 λ green laser light via fiber optic implants. Laser illumination modified gap detection behavior differentially according to side of illumination (bilateral, or ipsi/contralesional), acoustic stimulus type, and each ferret's tinnitus status. Our initial results suggest a possible approach to alleviating tinnitus through manipulation of mal-adaptively affected neural circuitry. Keywords: TINNITUS, AUDITORY CORTEX, OPTOGENETICS

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18	Poster	Pedro J. Goncalves (1), Jennifer F. Linden (2), Maneesh Sahani (1)	(1) Gatsby Computational Neuroscience Unit, University College London, UK (2) Ear Institute and Dept. Neuroscience, Physiology & Pharmacology, University College London, UK	Augmentation of A1 responses is reproduced by a recurrent circuit model combining strong excitation with synaptic depression	Cortical responses to dynamic stimuli display a temporal complexity reflecting the rich repertoire of recurrent cortical circuitry. For instance, primary auditory cortex (A1) responses to the second of a pair of tones are largely suppressed when the inter-tone interval is shorter than 500ms, even though most membrane currents are not sustained for that long (Wehr and Zador, Neuron 2005). This suppression may reflect thalamocortical or intracortical synaptic depression (Loebel et al., Front. Neurosci. 2007). However, in some cells the response to the second tone may be augmented, particularly at intermediate intervals around 300ms. Similarly, some cells in supragranular layers of A1 show augmented responses to the second and later stimuli within a regular train of noise bursts spaced by 300-400ms (Christianson et al., J. Neurosc. 2011) but not at lower or higher inter-burst intervals. In the same layers, an isolated noise burst leads to suppression of neural activity below spontaneous rates for about 300ms followed by a slight rebound above the spontaneous rate; this rebound was hypothesised to be related to the observed augmentation. How might this diversity of responses arise in the absence of long-lived membrane currents? We explored the hypothesis that suppression and augmentation both stem from intracortical synaptic depression. We characterized analytically the response of a network of excitatory and inhibitory neurons with depressing synapses between the excitatory cells, when stimulated by periodic drive of different frequencies, thus extending a study of Ledoux and Brunel (Front. Comp. Neurosci. 2011) on networks with static synapses. Although synaptic depression usually leads to suppressed responses, we found that networks with synaptic depression also exhibited a novel response regime in which low-frequency stimuli could be resonantly amplified. In this regime, with sufficiently strong excitatory recurrence, simulations of network activity showed a long-delay rebound following pulsed stimulation, in agreement with the A1 data. The same mechanism also led to an augmented response to a second input at intervals close to 300ms. This augmentation was driven entirely by network effects, without any mechanism for hyperpolarisation-induced membrane rebound or synaptic facilitation. In the augmentation parameter regime, a network with static and fully replenished synapses would be unstable. Thus the supragranular layers of A1 might operate in a regime where transient sensitivity to sound onsets is maximised, while runaway activity is prevented by the short-term depression of intracortical synapses.

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14	Poster	Boris Gourévitch (1,2), Florian Occelli (1,2), Jean-Marc Edeline (1,2)	Dept. Cognition & Behavior, Inst. De Neurosci. Paris-Saclay (NeuroPsi) UMR 9197 (1) CNRS, (2) Université Paris-Sud, Orsay, France	Is there an effect of long-lasting exposure to industrial noise in the adult auditory system of rats ?	Over the last decades, an increasing number of people have been exposed on a daily basis to important levels of noise. Short term damages induced by traumatic noise (>105 dB SPL) have been widely studied in the literature. Recent studies have shown that, even at a non-traumatic and legally authorized intensities (<85dB SPL), alterations of the auditory system occurred at the cortical (Noreña et al 2006) and peripheral levels in the absence of efferent feedback (Maison et al 2013). Only a few articles have tried to compare electrophysiology data and behavioral deficits after non-traumatic noise exposure after a 2-4 months exposure. Our whole project aims at evaluating the impact on the auditory system of adult rats after a long-lasting exposure (3-18month, starting at 2 months old) to a structured (industrial) non-traumatic noise (80dB SPL, 8h/day). Here, we assess on every single animal the consequences of such exposure on brainstem, behavioral and cortical response to noisy backgrounds and auditory contrasts. First, although auditory brainstem thresholds were affected by aging, they were not degraded by long-term exposure. Second, after very long-term exposure, exposed animals showed as good as or even better response features than control animals in the primary auditory cortex. If confirmed, these results might indicate that the type of noise (pure tone vs. dynamic noise) and/or the age at which animals started to be exposed are crucial factors that influence the impact of environmental noise.

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106	Poster	Manon Grube (1, 2), Catherine Davison (1), Sukhbinder Kumar (1), Faye Smith (1), Timothy D. Griffiths (1)	(1) Auditory Group, Institute Of Neuroscience, Medical School, Newcastle University, Framlington Place, NE2 4HH, UK. (2) Machine Learning Group, TU Berlin, Marchstr. 23, 10587 Berlin, Germany	Auditory sequence processing and language skill in mid-adolescence	The relationship between auditory processing and language skill has long been subject of debate. Recent evidence suggests a specific relevance for rhythm as a form of “temporal scaffolding” relevant to both music and language perception and production. Our previous school-based work in over 200 early-adolescent English speakers showed a moderate significant correlation between the perception of short isochronous sequences and language skill (Spearman’s rho correlation coefficients of > 0.3, robust against partialing out non-verbal IQ; Grube et al. 2012, 2013). In young adults in contrast, we found a strong and significant correlation with the processing of more complex rhythmic sequences with a roughly regular beat and to a lesser degree for those with a metrical beat (Spearman’s rho in the region of 0.6; Grube et al., 2014). The data suggest a developmental shift in the relationship between auditory and language skills toward an increased relevance of more abstract rhythm in older subjects. The present work assesses the correlation between rhythm analysis and language skill in mid-adolescence. Initial analyses (n = 212) reveal moderate but robust and significant correlations with measures of language skill (spelling, reading, non-word reading, rhyme decision, rapid automated naming, spoonerisms) for both the processing of short isochronous sequences and longer, more complex sequences with a roughly regular beat (Spearman’s rho correlation coefficients of about .3). No such robust correlations were seen between language skill and the processing of single time intervals or metrical rhythms. The data support the emergence of a developmental change in the relationship between auditory rhythm processing and language skill during adolescence, toward an increase in the relevance of higher-level sequence analysis. On-going work is investigating parallel development in pitch sequence processing.

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20	Poster	Yueqi Guo (1), Michael S. Osmanski (1), Xindong Song (1), Xiaoqin Wang (1)	(1) Johns Hopkins University	Measurement of acoustic frequency discrimination thresholds in common marmosets (Callithrix jacchus)	The common marmoset (callithrix jacchus), a New World non-human primate, has emerged as a promising animal model system in auditory neuroscience research. It is thus important to characterize the fundamental auditory perceptual abilities of this species, such as their capacity for frequency discrimination. We trained marmosets on a discrimination task using operant conditioning procedures and measured the minimum change in frequency (i.e., the frequency difference limen, or FDL) that marmosets could detect using pure tones at eight different frequencies. Stimuli spanned the entire hearing range of the marmoset from 220 Hz to 28.16 kHz with octave intervals. All stimuli were presented at a relatively constant sensation level. Sound level was also roved +/- 3dB to eliminate the possibility of using intensity fluctuation as a cue to perform the task. Our data show that (1) the absolute FDL increases as the testing frequency increases; (2) the relative FDL decreases from ~2.5 semitones (1 semitone equals ~6% of the testing frequency) until it reaches minimum value of ~0.5 semitones around 7kHz, then slightly increases as the testing frequency goes higher. The frequency range with lowest relative FDL overlaps with the most sensitive region in the marmoset audiogram, as well as with the fundamental frequency range of their typical vocalizations. We also tested marmosets' pitch discrimination abilities using harmonic complex tones with fundamental frequencies of 110 Hz, 220 Hz, 440 Hz and 880 Hz. It is shown that as the fundamental frequency increases from low to high, the relative difference limen first decreases and then increases, with a highest value of ~1.4 semitones at 110 Hz and a lowest value of ~0.4 semitones at 440 Hz. These results reveal auditory perceptual capacities of the marmoset and help guide further studies of auditory behaviors of this species. This research is supported by an NIH Grant (DC003180).

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111	Talk	Wei Guo (1,2), Amanda R. Clause (1,4), Asa N. Barth-Maron (1,3), Barbara G. Shinn-Cunningham (2), Daniel B. Polley (1,2,4)	(1) Eaton-Peabody Laboratories, Massachusetts Eye and Ear Infirmary (2) Center for Computational Neuroscience and Neural Technology, Boston University (3) Dept. Neurobiology, Harvard Medical School (4) Dept. Otology and Laryngology, Harvard Medical School	Layer 6 corticothalamic neurons modulate the gain and selectivity of columnar sound processing	The cortical column is the canonical unit of information processing in the cerebral cortex. Until recently, the neural circuitry that imposes real-time modulation on columnar sensory processing has remained obscure. Here, we characterized thalamocortical response dynamics induced by activation of layer 6 (L6) Ntsr1 neurons, which provide the dominant source of corticothalamic projections but also have abundant connections within the local column. We used a cre-dependent viral construct to selectively express channelrhodopsin-2 (ChR2) in L6 auditory cortex (ACtx) neurons of Ntsr1-cre transgenic mice. We explored the modulatory effects of L6 activation on thalamocortical sound processing by simultaneously recording from the ventral subdivision of the medial geniculate body (MGv) and all layers of ACtx in awake, head-fixed mice while optogenetically activating L6 Ntsr1 neurons. Photoactivating L6 neurons induced a robust gamma oscillation in deep layers (at 100 – 120 Hz) and superficial layers (at 40 – 50 Hz), immediately followed by a low frequency oscillation (1 – 4 Hz) that persisted for hundreds of milliseconds after the cessation of Ntsr1 neural activity. These data suggest that L6 Ntsr1 neurons engage distributed networks of excitatory and inhibitory neurons throughout the cortical column that could dynamically transform afferent sensory traces. We tested this hypothesis by quantifying changes in gain and selectivity of frequency tuning in single units when tone stimuli were presented at various delays relative to L6 Ntsr1 neural activation. Unlike recent reports in visual cortex, L6 activation imposed weak, additive gain on the tuning function rather than divisive suppression. Surprisingly, far stronger, bi-directional effects were observed following the cessation of L6 activation, when the network state was dominated by low frequency oscillations. We found that frequency selectivity in layer 4 and 2/3 units more than doubled 50ms after the offset of L6 activation, which was immediately followed by a substantial increase in response gain and reduced frequency selectivity just 100ms later. We observed a group of fast-spiking, putative inhibitory ACtx units that strongly responded at the offset of laser stimulation, coinciding with the greatest changes in tuning curve gain or selectivity and the beginning of low frequency oscillations in the network state. Bi-directional modulation of frequency tuning was also observed in MGv, but with different temporal dynamics and significantly lower amplitude, indicating a separate mechanism for the corticothalamic circuit. Overall, these data suggest that L6 Ntsr1 neurons modulate columnar sound processing directly in ACtx via local inhibitory circuits and indirectly via a cortico-thalamo-cortical loop. These findings suggest an elegant mechanism whereby columnar processing can be alternately biased towards selectivity or sensitivity depending entirely on the relative timing between sound and L6 Ntsr1 neural activity.

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54	Poster	Amy Hammond-Kenny (1), Victoria M Bajo (1), Andrew J King (1), Fernando R Nodal (1)	(1) University of Oxford	Neural correlates of multisensory behavior in the auditory cortex	Our perception of everyday events relies on the ability to integrate information obtained from different sensory modalities. Such integration often results in shorter detection times and greater accuracy or discriminability. Recent neural recording studies have shown that multisensory processing occurs even at the level of early sensory cortices. However, to date, these studies have mainly been performed under anesthesia and, therefore, the behavioral relevance of the cross-modal interactions observed remains to be determined. Here, we explore the multisensory nature of the ferret auditory cortex by recording neural activity while animals perform different tasks, thereby enabling correlation of neural and behavioral changes. Ferrets were trained by positive operant conditioning in two audio-visual tasks. Task 1 tested the performance accuracy of animals when localizing multisensory stimuli as compared to component unisensory stimuli, presented from 1 of 7 sites separated by 30° around the frontal hemifield of a circular arena. Task 2 tested the ability of ferrets to categorize multisensory stimuli according to the spatial congruency of their unisensory components. Once behavioural abilities were established and performance was stable, neural activity was recorded during task performance via bilaterally implanted electrode arrays. Behaviorally, animals showed an improvement in localization accuracy for multisensory versus component unisensory stimuli, with greatest gains observed at the shorter stimulus durations (<200 ms) and at more lateral locations. In addition, Race model inequality analysis of approach-to-target response times and head orienting reaction times showed that different mechanisms, multisensory integration and probability summation, respectively, were responsible for the multisensory facilitation observed in the two response modes. Recordings from cortical neurons showed that approximately 40% of units responded to both stimulus modalities, with the majority (>90%) of bisensory units displaying sub-additive interactions to spatially congruent audio-visual stimuli presentations. In addition, although ferrets can correctly identify spatially congruent multisensory stimuli, bisensory units exhibited higher firing rates to spatially incongruent than to congruent stimuli presentations. Together, our results suggest that multisensory activity is widespread in the auditory cortex and that the magnitude of the interactions between visual and auditory inputs changes when the stimuli are categorized behaviorally according to their relative locations.

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90	Poster	E. G. Hazlett (1, 2), J. M. Grimsley (1), N. Vallabh (1), S. Sheth (1), M. Latsko (3), A. Jasnow (3), J. J. Wenstrup (1)	(1) Northeast Ohio Medical University (NEOMED), Department of Anatomy and Neurobiology (2) Kent State University, School of Biomedical Sciences (3) Kent State University, Department of Psychological Sciences	Brief restraint in mice alters stress levels, vocal behavior and the neural representation of sound in the basolateral amygdala	Interpreting the meaning of a sound depends on contextual cues, including other sensory stimuli and the internal state of a listener. The basolateral amygdala contributes to the analysis of a sound's meaning by integrating information from several senses as well as internal state. The amygdala's analysis of internal state has the potential to modulate the primary auditory system via its direct and indirect projections to auditory cortex. We hypothesized that even brief restraint, such as normally occurs in auditory neurophysiological studies, will alter stress levels as well as responses to sounds in the BLA. This study assesses effects of restraint on neurophysiological responses in the BLA as well as behavioral, vocal, and hormonal measures of stress. Blood corticosterone levels were measured in 10 free¬moving and 10 restrained (2 hour) CBA/CaJ mice. In other mice, we measured the effect of brief restraint using a light/dark box, a marble bury test, and recorded vocalizations. Test mice were restrained for 2 hours on 3 consecutive days; control mice were placed in the test chamber without restraint. To assess effects on the auditory responses in the BLA, we recorded 160 repetitions of noise¬evoked local field potentials (LFPs) in 13 adult male mice. Auditory responses were recorded in two sets from free moving mice, followed immediately by two sets of recordings from the same animals during restraint. Signals were transmitted wirelessly from custom multi¬electrode implants using a wireless headstage. Several measures of stress were significantly higher in mice after restraint: corticosterone levels ($F(19) = 10$, $p = 0.006$), time in dark ($p = 0.002$), and number of buried marbles ($t(15) = 3.809$, $p = 0.002$). The frequency and duration of emitted syllables differed dramatically for mice during restraint compared to mating encounters or isolation in a novel chamber ($p < 0.001$). A one way ANOVA revealed a main effect of discriminatory information from comparisons of recording sets ($F(3,37) = 4.7$, $p = 0.007$); the free vs. restrained comparison had significantly higher levels of discriminatory information ($p<0.05$).

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23	Poster	Nathan C. Higgins (1), Susan A. McLaughlin (2), G. Christopher Stecker (1)	(1) Vanderbilt University (2) University of Washington	Temporal weighting of binaural cues in human auditory cortex: an fMRI study	When human listeners localize sounds in space, their judgments reflect weighted combinations of the available acoustic cues. For horizontal localization, the primary cues are the interaural time (ITD) and level differences (ILD). In real world listening, these cues fluctuate over time, yet perception remains stable. That stability reflects the perceptual dominance of cues occurring at particular times in the duration of a sound: the ITD at sound onset and the ILD at onset and offset. For both cues, the middle part of the sound appears remarkably ineffective, suggesting a dissociation between perception and the physical features of the stimulus. In order to determine whether spatial processing in the human auditory cortex (hAC) reflects the perceived versus physical features of sounds, functional magnetic resonance imaging (fMRI) was used to measure activity in response to 1 s trials which varied in ITD or ILD (nine values spanning left to right) in separate runs. Each trial presented trains of 16 narrowband clicks in which the binaural cue was applied equally to all clicks (referred to as “full-cue”) or only to the first click (“onset”), in which case clicks 2-16 carried zero ITD and ILD. Listeners performed a simple pitch-change detection task to ensure vigilance. Image acquisition employed a continuous event-related design (TR=2s, 3 Tesla, 2.75 x 2.75 x 3mm resolution). Data were analyzed using general linear modeling and parcellated into regions of interest corresponding to hAC using Freesurfer. Cortical responses to full-cue ILD stimuli in each hemisphere were larger for contralateral than ipsilateral ILDs, and exhibited a minimum around ILD=0. Onset ILD stimuli also elicited large responses to contralateral ILDs, but additional elevated responses near 0 dB ILD (i.e., when onset and post-onset ILDs matched) and conspicuous response minima at intermediate ILDs of +10 dB were also observed. Unlike ILD stimuli, but consistent with previous fMRI studies of ITD processing, the ITD response functions were relatively flat in both conditions, and displayed little contralateral dominance despite strong overall activation to sound. These results were used to evaluate competing models of AC population response, including topographic, opponent-channel, and three-channel models incorporating mechanisms of response adaptation, forward suppression, and lateral inhibition. Overall, the pattern of results for full-cue and onset ILD parallels the psychophysical results that perception is influenced by both stimulus onset and offset ILD cues, and provides evidence that hAC maintains sensitivity to ILD of the onset and later portions of the sound.

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83	Poster Teaser	K. Jannis Hildebrandt (1), Pedro J. Gonçalves (2), Maneesh Sahani(2), Jennifer F. Linden(3)	(1) Cluster of Excellence "Hearing4all", Department of Neuroscience University of Oldenburg, Germany (2) Gatsby Computational Neuroscience Unit, University College London, London, UK; (3) Ear Institute and Department of Neuroscience, Physiology, and Pharmacology, University College London, UK	Activation of parvalbumin-positive interneurons enhances transient responses and changes tuning of offset responses in awake auditory cortex	Alterations of cortical inhibition have been proposed to play a crucial role in modulation of cortical activity. While optogenetic manipulation of different functional groups of interneurons has become an important tool to study the roles of different cells in sensory processing, the timing of light relative to sensory stimulation becomes a confounding factor, and the pattern of supra-threshold activation of inhibitory neurons may not be physiologically accurate. Here, we circumvent these limitations by using stable step-function opsin (SSFO), which can be rendered continuously active or inactive with short pulses of light. We expressed SSFO in parvalbumin-positive (PV+) interneurons in the primary auditory cortex of mice, and recorded both local field potentials (LFP) and spiking responses to tone pips of varying frequency in awake animals. Prolonged low-level activation of PV+ cells profoundly changed the dynamics of spike responses in several and diverse ways. While spontaneous activity and sustained responses to the tones were mostly suppressed during PV+ activation, onset and offset responses where either enhanced or reduced less than spontaneous responses, thus increasing signal-to-noise ratio. More consistently, we observed that best frequencies of offset responses shifted towards lower frequency by as much as an octave when SSFO was turned on. This shift was much less pronounced in sustained and onset responses. Additionally, PV+ activation resulted in finer tuning of offset responses in the majority of recorded cells. Intriguingly, tuning broadened for a small fraction of units whose spontaneous activity increased during activation. Possibly, theses units were PV+ cells directly activated by SSFO. Analysis of LFP data confirmed the contrary effect of PV+ activation on transient and sustained responses. Activation of SSFO caused a decrease of the power in the high-γ range (50-150Hz) during spontaneous and sustained tone-response phases. Both onset and offset responses were boosted compared to control, and offset responses increased more than onset response. Generally, SSFO activation increased power in the low-frequency range of the LFP (<50Hz) and decreased power in the high-frequency range (50-150Hz, high gamma).

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22	Poster Teaser	Tamara IVANOVA (1) Kelly K. CHONG (1,2) Robert. C. LIU (1)	(1) Emory University , Biology Department (2) University of Georgia Technology	Vocalization-induced Arc mRNA expression in core auditory cortex depends on the interaction of estrogen and social experience	.Studies in nonmammalian vertebrates have long indicated that hormones can modulate sensory processing in social contexts, but there is new interest in understanding whether and how this manifests in mammals. A maternal model of sensory learning has recently gained attention, and provides an ethologically relevant context to study how hormones may interact with social experience to alter the neural processing of sensory cues from infants. In mice, studies from several labs demonstrate that auditory cortical activity in response to pup ultrasound vocalizations (USV) is significantly altered in post-weaning mothers, which behaviorally recognize the calls, compared to naïve virgin females, which do not. Maternal hormones may facilitate this learning and long-term memory, since virgin co-caring females, which help mothers raise pups, do not show as long-lasting behavioral preferences or auditory cortical plasticity for pup USVs (Lin et al, 2013). In the current study, we explore the role of estrogen in modulating auditory cortical plasticity that could support learning USVs. We have previously used compartmental analysis of temporal fluorescent in situ hybridization (CATFISH) to reveal that the expression of the synaptic plasticity effector immediate early gene Arc in core auditory cortex is modulated by the familiarity of sound categories, including pup USVs (Ivanova et al, 2011; SfN 2011, 2013). Here, we manipulated both estrogen status and social experience with pups in ovariectomized, adult virgin females. We used silastic implants and placed animals either with a mother and its pups, or in an adjacent “yoked” compartment where females could hear and smell but not see or interact with pups. All animals thus heard USVs until pups were P5, after which subjects were isolated for play back of pre-recorded USVs and CATFISH analysis. Preliminary data indicates that estrogen and social experience interact to modulate Arc mRNA expression in core auditory cortex. Yoked/vehicle-implanted mice showed significantly fewer neurons with cytoplasmic-only expression, and more neurons with intranuclear-only expression than other groups, which were not different from each other. These data suggest that while estrogen itself without social experience can enhance the core auditory cortical molecular trace of the USV’s familiarity, social pup experience alone, with or without estrogen, can also achieve this enhancement, perhaps through parallel social hormonal mechanisms (Marlin et al, 2015). Our results establish a hitherto unknown role for systemic estrogen in modulating mouse auditory cortical responses to behaviorally relevant sounds.

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51	Poster	Gareth P. Jones (1), Stephen M. Town (1), Katherine C. Wood (1), Huriye H. Atilgan (1), Soraya Dunn (1), Jennifer K. Bizley (1)	(1) University College London	Exploring the role of synchrony in auditory-visual integration in ferrets	Animals and humans integrate sensory information over time, and combine this information across modalities in order to make accurate decisions in complex and noisy sensory environments. Little is known about the neural basis of this accumulation of information, nor the cortical circuitry that links the combination of information between the senses to perceptual decision-making and behaviour. Most previous examples of multisensory enhancement have relied on synchrony dependent mechanisms, but these mechanisms alone are unlikely to explain the entire scope of multisensory integration, particularly between senses such as vision and hearing, which process multidimensional stimuli and operate with different latency constraints. Presented here are behavioural and neural data from an audio-visual behavioural task (adapted from Raposo, et. al. 2012) conducted on ferrets implanted with chronic electrode arrays, allowing recording from auditory cortex while the animals performed the task. Subjects were required to accumulate evidence from one or both senses over time to estimate average rate of short auditory and/or visual events embedded in a noisy background (20 ms white noise bursts or flashes) over 1 second. Throughout the stimulus the instantaneous event rates varied using fixed “short” and “long” gap lengths (50/230 ms, respectively), meaning the accuracy with which the overall event rate could be estimated increased over time. Rate discrimination was assessed in both unisensory auditory and visual conditions as well as in synchronous and asynchronous multisensory conditions. Analysis will focus on how auditory and visual signals are integrated in auditory cortex during both synchronous and asynchronous multisensory conditions.

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76	Poster	Vladimir Jovanovic (1), Cory T. Miller (1)	(1) UC San Diego, La Jolla, CA	Responses of marmoset auditory and prefrontal cortex neurons to changes in natural categories during active vocal exchanges	Communication is vital to social interaction -- especially so within nonhuman primates like the common marmoset. Marmosets naturally engage in reciprocal vocal exchanges when visually occluded from conspecifics. This antiphonal calling behavior involves both a perceptual (identifying the speaker) and decision-making component (deciding if and when to produce a response). Previous work shows that neurons in marmoset prefrontal (PFC) and auditory (ACX) cortex are responsive to the sensory and motor aspects of vocal communication. However, it has not yet been tested how these areas may complement each other during natural communication by simultaneous recording neural activity in each of these neocortical substrates. Our aim here is to record neurons in marmoset PFC and ACX during experimentally controlled vocal exchanges in order to examine their complementary roles for social categorization and its effects on decision making during communication. To address these issues, we employ a novel interactive playback design in which subjects engage in vocal exchanges with a 'Virtual Monkey', whose vocal signals and vocal behavior can be parametrically manipulated. During bouts of vocal exchanges, we presented subjects with either vocalizations that differed in acoustic structure (Reversed) or social category (Different Caller). These manipulations are known to be perceptually salient in behavioral experiments. We are recording single and multi unit activity, as well as local field potentials, during these experiments in order to characterize facets of this behavior in PFC and ACX neurons.

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1	Poster Teaser	Alexander JE Kell (1,2), Daniel LK Yamins (1,2), Sam V Norman-Haignere (1), Josh H McDermott (1)	(1) MIT (2) AK and DY contributed equally to this work	Functional organization of auditory cortex revealed with neural networks optimized for auditory tasks	Despite many proposals, there is little consensus on the functional organization of non-primary auditory cortex. Here we probe functional organization by developing models that perform difficult auditory tasks at near-human levels and then comparing the model representations with responses measured in human auditory cortex. If the set of solutions to difficult auditory tasks is small, the models could plausibly converge on representations similar to those in the brain. Models that perform well on ecologically relevant tasks thus provide candidate hypotheses of auditory cortical computation. As a first step in this research program, we trained a hierarchical convolutional neural network (CNN) to recognize words in high levels of complex background noise. We used millions of examples of speech from labeled corpora, explicitly optimized network architecture (Yamins, Hong, et al., 2014), and trained filters with standard back-propagation. Crucially, the CNN was optimized only for the speech task; it was not optimized to predict neural responses of any sort. With training complete, we measured fMRI responses to 165 natural sounds (e.g., outdoor sounds, mechanical sounds, animal vocalizations, speech, music, etc.) in the auditory cortex of eight humans, and tested whether different layers of the speech-trained CNN could predict the voxel responses. We computed the response of each unit in the CNN to the 165 sounds, and measured the representational similarity between the neural and model responses using linear regression. Specifically, we modeled each voxel as a linear mixture of model units from a particular CNN layer, and predicted the response to left-out stimuli. We have three key findings. First, the CNN predicts neural responses better than a standard spectrotemporal filter model, and better than an untrained CNN with the same architecture (and thus same number of model units). Second, the CNN suggests a computational distinction between primary and non-primary auditory cortex: shallow and deep CNN layers both predict primary auditory responses well, but deep CNN layers predict responses in non-primary cortex substantially better than shallow layers. Third, within speech-selective cortex, the predictive advantage of deeper layers of the CNN increases along the medial-to-lateral axis, potentially suggesting a previously unreported hierarchical organization within speech-selective cortex. Overall, our results suggest that task-optimized models can both clarify known properties of auditory cortex and reveal previously unknown aspects of cortical organization.

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63	Poster	Bahar Khalighinejad (1), Minda Yang (2), James O’Sullivan (3), Nima Mesgarani (4)	(1) Columbia University (2) Columbia University (3) Columbia University (4) Columbia University	Determining the Joint Neural Encoding of Phonetic and Speaker Features with EEG	Humans possess the ability to simultaneously and continually perceive speech and speaker information. This perceptual ability requires the extraction of linguistic features such as consonants and vowels from a complex acoustic signal, and the linking of these features to the speaker that uttered them. Recent invasive and non-invasive studies have shown an acoustic phonetic feature representation of speech in human auditory cortex. However, how speaker specific variability affects the representation of phonetic features remains unknown. Here, we addressed this question by analyzing scalp electroencephalography (EEG) data recorded from subjects who listened to continuous stories with alternating sentences read by a male and female speaker. To ensure the attentional engagement of the participants, they were required to answer questions regarding the content of the stories. The stories were segmented into time-aligned sequences of phonemes, and the neural responses to all instances of each phoneme were obtained. We then grouped these responses into phonetic feature categories and found that the neural responses to different phonetic categories (e.g., consonant-vowel, manner of articulation) were discriminable. In order to determine the dependence of such a phonetic representation on speaker specific characteristics, we compared the average responses to each individual phoneme spoken by each speaker. We used the pairwise Euclidian distance between phoneme pairs as a measure of dissimilarity. We found a varying degree of overlap between the phonetic feature representations of the two speakers. Furthermore, by performing a similar analysis on the average spectrograms of each phoneme, we found that the joint acoustic similarity of speaker and phonetic features determined the organization of the neural responses. These results suggest a joint encoding of speaker information and phonetic features, which is a fundamental step towards determining the neural basis of the ability to attend to a single speaker in multi-talker and noisy environments.

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36	Poster	Fatemeh Khatami(1,2), Markus Wöhr(3), Heather L. Read(1,2), and Monty A Escabi(1,2,4)	(1)Department of Psychology, University of Connecticut (2) Department of Biomedical Engineering, University of Connecticut (3) Behavioral Neuroscience, Experimental and Physiological Psychology, Philipps-University of Marburg, Germany. (4) Department of Electrical Engineering, University of Connecticut	Acoustic features contributing to 1/f temporal modulation spectra of vocalization sequences and speech	In vision, natural scenes exhibit 1/f power spectrum where visual edges are main contributors and cortical neurons are tuned to effectively extract edge related information (Field, 1987). Similarly, in audition, temporal modulations in vocalized sounds exhibit 1/f modulation power spectrum (Voss and Clark, 1975) and neurons in the central auditory structures can respond efficiently to such statistics (see discussions, Escabi et al., 2003; Rodriguez et al., 2010). Numerous factors contribute to temporal fluctuations in vocalized sounds including articulatory gestures, vocal tract filtering, and vocal fold vibration. Yet how such factors contribute to 1/f structure is unclear. Vocalized sounds contain a variety of temporal cues, including rhythmic fluctuations (typically < 20 Hz), onsets and offsets at the beginning and end of transient vocalizations (e.g., isolated words, species specific calls), and periodic structure such as from vocal fold vibrations (e.g., periodicity pitch) and these vary extensively over several orders of magnitude (from a few Hz for rhythmic information to ~800 Hz for pitch). It is plausible that 1/f structure arises from the combined contribution of such physical cues. We used vocalization sequences from a variety of animals, including nonhuman primates, mice, birds, infant cries, and speech to evaluate the role of vocalization onset and offset timing, duration and amplitude variation in the sound temporal envelope. Envelopes from vocalization sequences were decomposed to isolated vocalization transients and compare temporal modulation spectra from full sequences versus isolated vocalizations. Synthetic vocalization sequences were generated based on statistics of the vocalization duration, timing, and amplitude variation of natural sequences and artificially perturbed to investigate contributing factors. In all instances examined, the presence of onsets and offsets at the beginning and end of isolated calls predicted the observed 1/f modulation spectrum observed in vocalization sequences. Though timing, duration, and amplitude variation shaped the temporal modulation power distribution these only accounted for a residual variation around the observed 1/f modulation spectrum. The results imply that acoustic "edges" (temporal onsets and offsets) are largely responsible for 1/f modulation structure found in vocalization sequences including speech. This is similar in principle to visual edges in images being main contributors to 1/f spectrum. Since central auditory neurons are exceptionally sensitive to temporal transients the 1/f structure in vocalizations sequences are likely to be represented by temporally sparse neural responses to auditory edges.

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37	Poster	Yukiko Kikuchi (1), Ariane E. Rhone (2), Kirill V. Nourski (2), Phillip E. Gander (2), Adam Attaheri1 (1), Benjamin Wilson (1), Christopher K. Kovach (2), Hiroto Kawasaki (2), Timothy D. Griffiths (1,2,3), Matthew A. Howard III (2) & Christopher I. Petkov (1)	(1) Institute of Neuroscience, Newcastle University, Newcastle upon Tyne, Tyne and Wear NE2 4HH, UK (2) Human Brain Research Laboratory, Department of Neurosurgery, The University of Iowa, Iowa City, IA 52242, USA (3) Wellcome Trust Centre for Neuroimaging, University College London, London WC1N 3BG, UK	Nonsense word sequences elicit comparable nested oscillations in intracranial recordings from human and monkey auditory cortex	Neuronal oscillations entrain to environmental events and are thought to play an important role in segmenting sensory input. For instance, a prominent model of speech segmentation based, in part, on human intracranial recordings from auditory cortex suggests that theta oscillations (4-7 Hz) entrain to speech content and couple with gamma (50-120 Hz) amplitude (Giraud & Poeppel, Nat Neurosci 15:511-7, 2012). The extent to which such processes are uniquely human or evolutionarily conserved remains unclear and require more direct comparisons between humans and animal models. Here we ask which auditory cortical oscillations respond to sequences of nonsense words in intracranial recordings from Rhesus macaques and human neurosurgical patients. We used an Artificial Grammar (AG) learning paradigm where the monkeys and humans were first exposed to representative rule-based sequences of nonsense words generated by the AG. In a subsequent testing phase, we presented the participants with sequences that were either consistent with the AG or contained violations of specific AG rules. This allowed us to study the cortical oscillations in response to the nonsense words (regardless of sequencing context) and also how rule-based sequencing relationships affect these responses. As the participants listened to the testing sequences, we recorded local field potentials from the auditory cortex in the monkeys and from depth electrodes along the axis of Heschl's gyrus (HG) in humans. In the two monkeys, we observed prominent nested oscillations in the form of theta phase coupling with gamma amplitude (recording sites with significant coupling, $P < 0.05$, Bonferroni corrected: 101/145, 70%). Violations of the AG ordering relationships further modulated the strength of the theta-gamma coupling over time (81/101, 80 %). Comparable results were observed in intracranial recordings from human HG with significant coupling between low-frequency phase and high-frequency (gamma) amplitude (10/16, 63% of contacts in the two patients). Furthermore, the nested oscillations in the majority of HG recording sites in the patients (6/10, 60%) were modulated by violations to the AG ordering relationships, as observed in the monkey auditory cortex. We provide evidence that monkey auditory neural responses show low-frequency coupling in response to sequences of nonsense words, in ways that are strikingly similar to results reported elsewhere (Canolty et al, Science 313:1626-8, 2006), and as seen in the results from our more direct comparisons with human intracranial recordings. The findings suggest that nested oscillations reflect general auditory processes that are unlikely to have, at least at this general level, uniquely specialised in humans. This opens the door for detailed study and manipulation of these processes in animal models, combined with more direct comparisons to human auditory neural processes.

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75	Poster	Julia King (1,2,3,4), Ina Shehu (1,2,3,4,5), Mario A. Svirsky (3), Robert C. Froemke (1,2,3,4)	(1) Skirball Institute of Biomolecular Medicine, (2) Neuroscience Institute, (3) Department of Otolaryngology, (4) Department of Neuroscience and Physiology, New York University School of Medicine; (5) Department of Biology, Hunter College	Neuroplasticity and Cochlear Implant Use in Rodents	Cochlear implants (CIs) are neuroprosthetic devices that can restore meaningful hearing to the profoundly deaf. However, outcomes can be highly variable -- many recipients require significant time and practice with the device to attain useful phoneme and speech recognition (Chang et al., 2010; Ruffin et al., 2007). The causes of delayed recognition abilities and outcome variability with CI use are poorly understood. Elucidating the mechanisms of neuroplasticity that underlie patient abilities to reinterpret the CI signals may provide insight into how central auditory circuits successfully adapt to the device or fail to do so. We are investigating these neuroplasticity mechanisms in a rat CI model we have developed. We first modified the surgical approach for rat CI insertion to minimize surgical time and post-surgical side effects. Our basal turn cochleostomy approach eliminates the need to cauterize the stapedial artery and increases insertion depth; application of steroids to the facial nerve eliminates potential nerve damage, speeding recovery and behavioral training. We then trained animals on a self-initiated auditory go/no-go sound detection and recognition task (Froemke et al., 2013). We deafened animals with bilateral sham CI surgery and assessed the degree of functional hearing loss and the changes in auditory brainstem responses (ABRs). In deafened animals, behavioral responses (d') dropped to from 1.8±0.1 to 0.18±0.1 ($p<0.0001$) while ABR thresholds rose >50 dB SPL ($p<0.005$). In an animal fitted with a two-channel CI, however, we found that while the animal was initially deaf, over a period of two weeks it regained hearing perception and behavioral performance improved, peaking at a hit rate of 99% and a d' of 4.02. In another implanted animal, the learning trend is also in the positive direction, with d' rising from -0.06 to 0.81 over just three days. When the CI was temporarily inactivated, behavioral performance fell back to chance, indicating that the perceptual gains were directly due to CI use. These results are promising and suggest that rats are a good model for examining how training and neural plasticity are important for CI use and recovery of hearing.

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104	Poster	Seth Koehler (1) and Xiaoqin Wang (2)	(1) Johns Hopkins University	Functional organization of sensorimotor interactions across primate auditory cortex during vocal production	Vocal communication relies on auditory sensation to interpret other's speech and to monitor, learn, and maintain one's own speech. Auditory feedback is crucial for maintaining normal vocal production in noisy acoustic environments. Understanding auditory-motor interactions in auditory cortex is essential to understanding the role of hearing in production and self-perception of vocalizations. In a phenomenon common to human and non-human primates, neural activity in auditory cortex is suppressed before and during vocalization. Human imaging and EEG studies have suggested that speaking suppresses cortical activity in restricted regions of human auditory cortex, primarily in superior temporal gyrus. Neurophysiological studies in the marmoset have shown vocalization-related suppression of neural activity in and near A1. While rostral regions of primate auditory cortex have been implicated for processing vocalization signals, it is unknown which regions are involved at the single neuron level in processing self-produced vocalizations. To study neural responses during vocal production, we recorded single-unit activity wirelessly from freely moving marmosets in naturalistic environments, including during antiphonal calling bouts and spontaneous vocal interactions in their housing environment. In order to compare neural responses to vocal production across auditory cortical regions, we recorded single-unit activity from 32 tungsten electrodes (AM Systems) chronically implanted in a Warp-32 array (Neuralynx) to target primary auditory cortex, caudal belt, rostral area (R), lateral belt, and lateral parabelt. An acoustic stimulus set containing 1300 stimuli delivered through an open-field speaker was used to characterize cortical responses to sound to provide physiological evidence for cortical regions. Individual electrodes were independently advanced to sample units across layers, as it has been shown that neurons in layers II/III are more likely to be suppressed during vocal production in marmosets. We identified whether neurons on each electrode exhibit suppressed or enhanced responses during vocal production to indicate which cortical regions preferentially process self-produced vocalizations.

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110	Talk	Kishore V. Kuchibhotla (1), Jonathan V. Gill (1), Robert C. Froemke (1)	(1) NYU School of Medicine, Skirball Institute for Biomolecular Medicine	Cholinergic modulation provides contextual information by controlling cortical inhibition	Animals adjust their behavior based on environmental context. How do neural circuits flexibly encode the same stimuli in different contexts? Here we dissect the activity patterns in mouse primary auditory cortex (A1) in response to the same auditory stimuli in different contexts using two-photon Ca2+ imaging and whole-cell recording in behaving head-fixed mice. We found that attentional demands of a behavioral task transformed the input-output function in auditory cortex via cholinergic modulation and local inhibition. Mice were trained to perform a go/no-go task in response to pure tones in an active context and listened to the same tones without behavioral responses in a passive context. In the active context, tone-evoked responses of most cortical neurons were broadly suppressed, but a specific sub-network of neurons rapidly and reliably increased their activity. Whole-cell voltage-clamp recordings in behaving mice showed larger context-dependent changes in inhibition than excitation, and the two sets of inputs sometimes changed in opposing directions, providing a parsimonious synaptic mechanism for ensemble-level control of brain state by behavioral context. Calcium-imaging of PV+ layer 2/3 interneurons showed that, in contrast to the overall A1 population, activity in PV+ interneurons was greatly increased during the active context, consonant with inhibitory control as a key mechanism for state-dependent cortical responses. While inhibition may govern cortical output, where does the global contextual signal arise? We measured activity of axons in A1 from the cholinergic nucleus basalis in behaving head-fixed mice using two-photon calcium imaging. After animals were conditioned in the active context, there was a substantial increase in the activity of nucleus basalis axons during the active context. We conducted voltage-clamp recordings in trained, behaving mice, and found that cholinergic receptor activation was required for context-dependent changes in cortical inhibition. Thus, local synaptic inhibition gates long-range cholinergic modulation from NB to rapidly alter auditory cortical output, temporarily removing the requirement of co-tuned excitatory and inhibitory inputs, and improving perceptual flexibility.

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48	Poster	Sukhbinder Kumar(1,2), Sabine Joseph(3,4), Phillip Gander(5), Nicolas Barascud(6), Andrea Halpern(7), Timothy D Griffiths(1,2)	(1) Auditory group, Institute of Neuroscience, Medical school, Newcastle University, Newcastle upon Tyne, NE2 4HH (UK) (2) Wellcome Trust Centre for Neuroimaging, 12 Queen Square, London, WC1N 3BG (3) Institute of Cognitive Neuroscience, 17 Queen Square, London, UK (4) Institute of Neurology, 33 Queen Square, London, UK (5) Human Brain Research Laboratory, Department of Neurosurgery, The University of Iowa, Iowa City, IA 52242, USA (6) UCL Ear Institute, 332 Grays Inn Road, London, WC1X 8EE (7) Department of Psychology, Bucknell University, Lewisburg, PA, 17837	A brain system for auditory working memory	We examined the human brain system for auditory working memory: the process of holding sounds in mind over seconds. Neural activity in 16 human subjects was measured using fMRI while subjects, after listening to a pair of tones, were cued to maintain either a low or high tone for 16s. During the maintenance period, when no sound is present sustained activation in individual voxels that are mostly confined to secondary auditory cortex (planum temporale) and lateral part of HG was observed. In addition to auditory cortex, sustained activity was also observed in hippocampus and frontal regions including inferior frontal gyrus. Application of multivoxel pattern analysis (MVPA) shows that although activity in most of the voxels in the Heschl's gyrus (HG) was subthreshold, patterns of activity in it could distinguish which of the two tones subjects were maintaining in memory. Above chance classification of maintained tones from patterns of neural activity is also observed in the Broca's area. Connectivity analysis using psycho-physiological interactions (PPI) shows long range connectivity of auditory cortex to both hippocampus and inferior frontal gyrus during the maintenance period. Our data suggest a system for auditory working memory in which content specific representations in the auditory cortex are kept active during the maintenance period by projections from the higher order areas that include hippocampus. This role of hippocampus in working memory is in accord with the emerging idea that its role in cognition may not be confined to supporting long term declarative memories alone.

Poster Board #	Notes	Name and affiliation index for ALL authors	Affiliation index and affiliations for all authors	Abstract title	Abstract text
94	Poster	Pawel Kusmierek, Josef P. Rauschecker	Georgetown University	Effect of altered auditory feedback on behavioral measures in the “monkey piano” audio-motor task	Two rhesus monkeys (D & R) were trained extensively to produce audio-motor sequences on a “monkey piano” behavioral apparatus. Four levers were associated with different musical tones each, and the monkeys were trained to produce a predefined sequence of eight lever-presses, generating an 8-note “melody”. Monkey R was trained more extensively than monkey D: R has played his sequence approx. 54,700 times while D played hers 21,900 times. We examined behavioral indicators of information flow from the auditory to the motor system in the “monkey piano” paradigm, using altered auditory feedback. Single notes produced by the apparatus after correct lever-presses or entire whole 8-note sequences were altered with a low probability (~5%) in one of 4 variants: changing pitch to another pitch of the sequence, changing to a novel pitch, changing to a novel timbre, silencing note(s). In case of single-note alterations, more variants resulted from making the change at various positions in the sequence. Response latencies and lever choices were analyzed in 4 subsequent lever-presses (single-note alteration), or in 8 lever-presses immediately following each note of the altered sequence (whole-note alteration) by comparing the monkeys' performance to their performance with unaltered sequences in the same experimental sessions. Significant differences in latencies (shifts or changes of distribution shape) of any lever-press after single-note alterations were found in 6/10 tested variants in D and in 7/14 in R. After entire-sequence alteration, the results were 3/4 (D) and 0/4 (R). Significant changes in the fraction of correct lever choices were found in 2/10 (D) & 3/14 (R) variants after single-note alterations. For whole-sequence alterations, the results were: 3/4 (D) & 1/4 (R). To identify the contribution of alteration types, another analysis was conducted with data combined across all experiments within a group of variants sharing a feature (e.g., all novel-pitch alterations). This revealed that, in monkey D, disruptions of behavior by altered auditory feedback were consistent between experiments, and were more reliably driven by change of timbre or change to a novel pitch than by change to another pitch of the sequence. In contrast, disruptions of R's behavior varied between experiments, leading to fewer significant differences when the experiments were grouped by feature. Interestingly, in some cases the same alteration produced opposite effects in the two monkeys: silencing all notes in the entire sequence caused D to slow down her presses, while R sped them up. In summary, altered auditory feedback has a significant effect on behavioral measures (mainly on response latencies) indicating that an active feedback loop exists between the auditory and motor systems in the “monkey piano” task. Supported by: R56 DC014350, R56 NS052494 and FiDiPro award (Academy of Finland) to JPR.

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99	Poster	Michael Crosse (1), Edmund Lalor (1)	(1) Trinity College Dublin	Eye can hear clearly now: visual speech increases the sensitivity of auditory cortex to peri-threshold speech-in-noise.	It is well established that viewing a speakers' articulatory movements can improve comprehension of auditory speech, especially in noisy environments (Sumby and Pollack, 1954). It has been suggested that this effect is underpinned by an early integration mechanism where visual speech information increases the sensitivity of auditory cortex to acoustic information and a late integration stage that constrains the possible candidates in a spoken utterance based on visual information about a speaker's articulators (Peelle and Sommers, 2015). In this study, we examined the impact of visual speech on envelope entrainment for clean speech and speech-in-noise using electroencephalography (EEG). Stimuli consisted of audio-only (A), visual-only (V) and audiovisual (AV) continuous speech segments of ~60 s duration. For speech-in-noise, the audio was embedded in spectrally matched white noise at an SNR of−9 dB, a level where individual words could occasionally be discerned but where the semantic content was essentially unavailable. Word detection and self-reported intelligibility scores were significantly improved in the AV condition relative to the A condition. While only very low levels of cortical entrainment to the envelope were evident for auditory cortex in the A and V conditions, a substantial index of envelope tracking was apparent for the AV condition. These results suggest that, at SNRs where speech is largely unintelligible and cortical entrainment much diminished relative to clean speech, the addition of visual speech information improves speech comprehension by facilitating an increase in the sensitivity of auditory cortex to the acoustic speech information.

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6	Poster	Jaejin Lee(1), Yale E. Cohen(2), Yonatan I. Fishman(3)	(1) University of Pennsylvania (2) University of Pennsylvania (3) Albert Einstein College of Medicine	Combined effects of frequency and location differences on auditory streaming	A fundamental aspect of hearing is the perceptual organization of time-varying acoustic inputs to form auditory objects corresponding to sound sources in the environment (i.e., "auditory scene analysis"). One process contributing to auditory scene analysis involves the integration or segregation of sequential sound inputs based on acoustic cues such as frequency; this is a phenomenon known as auditory streaming. Another process utilizes spatial cues to infer auditory objects based on their location. Whereas many studies have separately examined auditory streaming and sound localization, few studies have tested how these two processes interact in auditory scene analysis. Here, we examined this issue by conducting a series of psychophysics experiments in human subjects aimed at identifying the relationship between auditory-streaming cues, sound localization, and auditory scene analysis. Specifically, we presented sequences of alternating tone bursts that varied in frequency, location, and sound level. Subjects were asked to report when they heard a deviant louder tone burst. We varied task difficulty by changing either the frequency difference between the tones, the spatial separation between the tones, or both. To our knowledge, this is the first human psychophysical study to examine the interactive effects on auditory streaming of three fundamental acoustic cues used in auditory scene analysis: differences in frequency, azimuth, and intensity.

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66	Poster	C. M. Lee (1), A. F. Osman (2), M. A. Escabi, (2, 3), H. L. Read (1, 2)	(1) University of Connecticut, Dept. of Psychology (2) University of Connecticut, Dept. of Biomedical Engineering (3) University of Connecticut, Dept. of Electrical and Comp. Engineering	Sustained spiking patterns discriminate sound envelope shape in ventral non-primary auditory cortices	Mammals, including humans and rats, have multiple auditory cortical fields with segregated thalamic pathways but it remains unclear if these cortices support distinct temporal sound cue processing (Storace et al., 2010; Hackett 2010). In many species, onset responses and first spike latencies change with the sound envelope shape in A1 providing one potential means for discriminating this cue (Heil, 2004). In rat, spike-timing precision (jitter) changes with sound envelope shape in A1, ventral (VAF) and caudal suprarhinal (cSRAF) auditory cortical fields providing another potential means for discriminating this cue (Lee et al., SFN 2014). Here we separate onset and sustained responses and examine whether the latter can discriminate sound shape cues in A1, VAF and cSRAF. First we characterize onset and sustained responses to each sound shape by quantifying the peak latency, peak magnitude, and half-amplitude duration of the sound cycle peri-stimulus time histogram (cPSTH) response. We find a rank order increase in PSTH peak delay with: A1 < VAF < cSRAF (means (standard error), A1: -41 (4), VAF: -32 (3), cSRAF: -17 (3) ms, p <0.001) and a rank order increase in duration with: A1 < VAF < cSRAF (logarithmic means and standard error, A1: 19 (1.01), VAF: 27 (1.02), cSRAF: 33 (1.05), p<0.001). In addition, the PSTH peak amplitude is greater in A1 than VAF or cSRAF (means A1: 53 (0.5), VAF: 54 (0.4), cSRAF: 40 (0.3) Hz, p<0.001). These findings suggest that A1 neurons have primarily a brief robust "onset" response; whereas, VAF and cSRAF neurons have an additional sustained spike response that follows the sound envelop shape. We developed a neurometric discrimination index based on a spike distance (van Rossum, 2001) between spike trains to periodic noise sequences of different shapes. To investigate the role of onset and sustained activity in shape discrimination, onset spikes were removed from the response spike trains. The perturbed spike trains yielded better shape discriminability in rank order with: A1 < VAF < cSRAF as compared to A1. Together, these findings indicate that sound shape is primarily encoded during the onset of the sound in A1; whereas, in ventral fields, shape is also encoded by the sustained response. These distinct primary and non-primary cortical forms of spike-timing response will have unique contributions to sound envelope shape coding at the next level of sound processing.

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74	Poster	Xiong XR(1), Liang F(1,2), Zingg B(1), Ji XY(1,2), Ibrahim LA(1), Tao HW(1), Zhang LI(1)	(1) University of Southern California (2) Southern Medical University	Auditory cortex controls sound-driven innate defense behaviour through corticofugal projections to inferior colliculus	Defense against environmental threats is essential for animal survival. However, the neural circuits responsible for transforming unconditioned sensory stimuli and generating defensive behaviours remain largely unclear. Here, we show that corticofugal neurons in the auditory cortex (ACx) targeting the inferior colliculus (IC) mediate an innate, sound-induced flight behaviour. Optogenetic activation of these neurons, or their projection terminals in the IC, is sufficient for initiating flight responses, while the inhibition of these projections reduces sound-induced flight responses. Corticocollicular axons monosynaptically innervate neurons in the cortex of the IC (ICx), and optogenetic activation of the projections from the ICx to the dorsal periaqueductal gray is sufficient for provoking flight behaviours. Our results suggest that ACx can both amplify innate acoustic-motor responses and directly drive flight behaviours in the absence of sound input through corticocollicular projections to ICx. Such corticofugal control may be a general feature of innate defense circuits across sensory modalities.

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89	Poster	Kai Yuen Lim (1) Luke Johnson (1) Charley Della Santina (1,2) Xiaoqin Wang (1)	(1) Department of Biomedical Engineering, Johns Hopkins School of Medicine (2) Department of Otolaryngology-Head & Neck Surgery, Johns Hopkins School of Medicine	Cortical Representations of Stimulus Intensity of Cochlear Implant Stimulation in Awake Marmosets	Electrical stimulation of the cochlear nerve via a cochlear implant (CI) is successful in restoring auditory sensation to individuals with profound hearing loss. However, many questions remain unanswered regarding how the central auditory system processes the electrical stimulation. Understanding how the brain processes CI stimulation should help guide improvement of CI technology, but techniques for studying human cortical processing have low spatial resolution, and the extent to which non-primate or anesthetized animal models represent the human case is unclear. We therefore developed an alert non-human primate CI model in the common marmoset (Callithrix jacchus) by implanting a multi-channel electrode array in one cochlea while leaving the other cochlea acoustically intact. This preparation allows us to directly compare a cortical neuron's responses to acoustic and CI stimulation in the awake condition. We found that acute, episodic CI stimulation was less effective in activating primary auditory cortex (A1) neurons compared to acoustic stimulation. This may be explained by broader cochlear excitation areas caused by electric stimulation compared to acoustic stimuli, because many cortical neurons exhibit narrow frequency tuning and sideband inhibition. For neurons driven by both CI and acoustic stimuli, we characterized responses as a function of current level and sound intensity. A majority of these neurons showed monotonic responses to CI stimuli; less than 35% had non-monotonic responses. This compares to acoustic responses which had 60% non-monotonic responses. We observed that ~50% of non-monotonic CI-driven neurons showed monotonic responses to acoustic stimuli, while ~40% of monotonic CI-driven neurons showed non-monotonic responses to acoustic stimuli. This change of response pattern in the same neuron suggested that CI and acoustic stimuli evoked different neural circuits. Consistent with clinical psychophysical data from CI users, dynamic ranges of A1 cortical neuron responses to CI stimuli were much smaller than those to acoustic stimuli (3.4 dB vs 32 dB in our experiments). For a given A1 neuron, thresholds of CI and acoustic stimuli were positively correlated, but their dynamic ranges were not significantly correlated. Response latencies were also positively correlated between the two stimulation types. In addition, acoustic stimuli usually evoked greater firing rates than CI stimuli. These findings suggest that the coding mechanism for stimulus intensity differs between the stimulation modes, and that CI stimulation is less efficient in driving A1 neurons.

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34	Poster	Jennifer F. Linden (1), Lucy A. Anderson (2)	(1) Ear Institute and Department of Neuroscience, Physiology & Pharmacology, University College London (2) Ear Institute, University College London	Mind the gap: two dissociable mechanisms of temporal processing in the auditory system	High temporal acuity of auditory processing underlies perception of speech and other rapidly varying sounds. A common measure of auditory temporal acuity in humans is the threshold for detection of brief gaps in noise. Gap-detection deficits, observed in developmental disorders, are considered evidence for "sluggish" auditory processing. Here we show, in an animal model of developmental disorder, that deficits in auditory brain sensitivity to brief gaps in noise do not imply a general loss of central auditory temporal acuity. Extracellular recordings in three different subdivisions of the auditory thalamus in anaesthetised BXSB/MpJ-Yaa mice revealed a stimulus-specific, subdivision-specific deficit in thalamic sensitivity to brief gaps in noise in experimental animals relative to controls. Neural responses to brief gaps in noise were reduced, but responses to other rapidly changing stimuli unaffected, in lemniscal and non-lemniscal (but not polysensory) subdivisions of the medial geniculate body. Through experiments and modelling, we demonstrate that the observed deficits in thalamic sensitivity to brief gaps in noise arise from reduced neural population activity following noise offsets, but not onsets. These results reveal dissociable sound-onset-sensitive and sound-offset-sensitive channels underlying auditory temporal processing, and suggest that developmental disorders specifically affect the sound-offset-sensitive channel.

Poster Board #	Notes	Name and affiliation index for ALL authors	Affiliation index and affiliations for all authors	Abstract title	Abstract text
70	Poster	David F Little (1), Henry Cheng (1), Beverly A Wright(1)	(1) Northwestern University	Learning on a musical-interval discrimination task through a combination of task practice and stimulus exposure alone	Introduction A fundamental component of musical skill is the ability to discriminate between and identify musical intervals, fixed ratios between pitches. Learning this skill is challenging because the same musical interval can be instantiated by multiple pairs of pitches, and even identification of a single instance of an interval is difficult. Here we asked whether a training regimen that combined periods of task practice with periods of stimulus-exposure alone facilitates musical-interval learning. Similar regimens have been particularly effective at inducing learning on basic discrimination tasks in audition and vision. These outcomes are of particular interest because the practice-plus-exposure combination can yield learning even when neither element does so in isolation. If this regimen yields musical-interval learning, it would indicate that it aids discrimination as well as category formation. Methods In four different 4-day training regimens, each day was divided into four ~8 minute blocks of either practice, stimulus exposure, or silence. During practice blocks, listeners discriminated multiple instances of perfect 4ths from major 3rds, perfect 5ths, and major 6ths, for 60 trials. During exposure blocks, listeners performed a written matching task while 60 examples of perfect 4ths were presented in the background. During silence blocks, listeners performed a mock musical-interval discrimination task in silence. On each day, listeners (n=7 per group) received either (1) 180 stimulus exposures (Exposure+Silence), (2) 180 practice trials (Practice+Silence), (3) 360 practice trials (All Practice) or (4) 180 trials + 180 exposures (Practice+Exposure). Results Discrimination accuracy improved by ~24 percentage points with the Practice+Exposure regimen, compared to ~11 to ~14 percentage points for the Exposure+Silence, Practice+Silence and All-Practice regimens. The improvement was greatest for the Practice+Exposure regimen (all $p < 0.001$), and did not differ significantly among the remaining three regimens ($p \geq 0.934$). The benefits conferred by the Exposure+Practice regimen generalized to untrained stimuli (triangle tones) for the trained task and to an untrained task (interval identification) for the trained musical interval (the 4th). Conclusions Pairing practice with stimulus-exposure alone yielded learning on a musical-interval discrimination task, extending the demonstrated benefits of this regimen beyond basic discrimination tasks to a challenging case requiring category formation that is of practical use. This result suggests that a similar mechanism drives the observed enhancements to learning in both cases.

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11	Poster	Xiaoyang Long (1), Rongrong Han (2), Dongqin Cai (1), Miaomiao Liu (1), Yi Zheng (1), Yang Liu (1), Limin Zhao (3), Jun Yao (1), Kexin Yuan (1)	(1)Tsinghua University (2)Weifang Medical University (3)Affiliated Hospital of Weifang Medical University	GABAB receptors mediate temporal processing plasticity in developing primary auditory cortex	Faithful tracking of rapidly successive acoustic signals in the primary auditory cortex (A1) is vital to cortical temporal information processing, and is central to the accurate perception of natural sounds such as human speech and animal vocalizations. However, how cortical stimulus-tracking capacity developmentally emerges remains poorly understood. Using in vivo whole-cell recordings immediately after hearing onset, we found that the temporal summation of inhibition and higher inhibition to excitation (I/E) ratio remarkably weakened the ability of developing rat A1 to track repeated stimuli. Surprisingly, brief exposure to sounds presented at ethologically high repetition rates rapidly and reliably improved cortical stimulus-tracking ability. This unexpected plasticity of spike responses resulted from the significant and long-lasting weakening of the summation of inhibitory inputs. Further pharmacological experiments revealed that GABAB rather than GABAA receptors took the responsibility for the rapid plasticity of the inhibitory time course in the developing cortex. Thus, our results demonstrated hypersensitivity of the developing sensory cortex to the temporal feature of stimulus events, and suggested that GABAB-medicated plasticity of inhibition played a critical role in experience-dependent maturation of cortical temporal processing.

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84	Poster	Matthew. MACDOUGALL (1,2), Shanna COOP (1), S. NUMMELA (1), J. MITCHELL (3), C. T. MILLER (1);	(1) Psychology, UCSD, San Diego, CA (2) Neurosurgery, UCSD, San Diego, CA (3) Brain and Cognitive Sci., Univ. of Rochester, Rochester, NY	Optogenetic control of marmoset cortical neurons	Marmosets offer several advantages for the application of modern molecular techniques in neuroscience, including relatively small brain and body size, high fecundity and a lissencephalic cortex. Optogenetic techniques have emerged as powerful methods to manipulate neuronal activity with precise temporal and spatial control. Here we developed an optogenetic preparation for awake marmosets. This project comprised two components. The aim of the first component was to determine which viral constructs were most suitable for use in marmosets. Using various adeno-associated viral (AAV) constructs containing channelrhodopsin genes with varying promoters, we examined methods for creating a marmoset optogenetic preparation. We investigated the utility of AAV 5, and 9, the promoters synapsin and CAMkII. The results demonstrate robust expression of channelrhodopsin with no signs of inflammation or gliosis. The aim of the second phase of the project was to characterize optical modulation of marmoset cortical neurons using these constructs. We demonstrate clear neuronal responses to light following transduction of channelrhodopsin. We observed robust increases or decreases in neuron firing rate entrained to laser pulses as brief as 20ms or sustained as long as 400ms. We found consistent laser-induced modulation of neurons from 6 weeks after transduction to 6 months with no observed decay in photomodulation yet. Our results here indicate that using optogenetic techniques in marmosets is a feasible and useful method of exploring neural activity in awake, behaving marmosets.

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45	Poster	Ido Maor (1) Adi Mizrahi (1)	Hebrew University	Functional microarchitecture of excitatory versus inhibitory neurons in layer 2/3 of mouse auditory cortex	Structure and function of neural circuits are inherently linked. In the auditory system, early neural stations like cochlea and brain stem are characterized by strict tonotopy, which is used to deconstruct sounds to their basic frequencies. But higher along the auditory hierarchy, as early as primary auditory cortex (A1), tonotopy starts breaking down at local circuits. This architecture is consistent with the argument that neurons in A1 show computations of complex sound features. However, whether and how the functional microarchitecture of A1 supports complex sound feature computations is not known. Moreover, cortical networks are composed of numerous cell types, which may show different architectures that could support different functions. Here, we studied the functional microarchitecture of excitatory versus inhibitory neurons in layer 2/3 of mouse A1 within 150□m3 cortical volumes. We used in vivo two photon targeted cell attached recordings from spatially and genetically identified inhibitory neurons (parvalbumin positive neurons, PVNS) and their excitatory neighbors intertwined within the local circuit. We tested both spontaneous and sound evoked responses of excitatory versus inhibitory neurons that were recorded and analyzed with respect to their relative distance from each other. We show that excitatory neurons have heterogeneous functional organization as characterized by a diversity of characteristic frequencies (upto 2 octaves apart) as well as highly diverse pairwise signal correlations (average correlation close to zero). These data support our previous mapping experiments using calcium imaging. Interestingly, and in marked contrast, PVNs exhibited highly homogenous functional organization. PVNs characteristic frequency distribution was narrow and their pairwise signal correlations strongly skewed to positive values (average 0.4) as compared to those of neighboring excitatory neuronal pairs. The distinct functional organization of excitatory and inhibitory cortical neurons reflect the connectivity differences among different cell types and has implications to how sensory information is processed by A1.

Poster Board #	Notes	Name and affiliation index for ALL authors	Affiliation index and affiliations for all authors	Abstract title	Abstract text
65	Poster	Jane Mattley[1], Lucy A. Anderson[1], and Jennifer F. Linden[1,2]	[1] Ear Institute, University College London, London, U.K. [2] Dept. Neuroscience, Physiology & Pharmacology, University College London, London, U.K.	In search of the origins of a central auditory deficit in gap-in-noise sensitivity	BXSB/MpJ-Yaa mice are a powerful animal model in which to study the neural mechanisms of auditory temporal processing and gap-detection deficits. These mice have long been used as an animal model for developmental disorders thought to affect auditory temporal processing in humans (Ramus, TINS 2004), such as dyslexia, specific language impairment, and central auditory processing disorder. Approximately 30–50% of BXSB/MpJ-Yaa mice have localised disruptions of neocortical lamination (ectopias) which are considered a hallmark of thalamocortical developmental abnormalities, and which resemble those observed in humans with auditory processing and developmental language disorders. Intriguingly, although the ectopias occur in frontal cortex and not in auditory cortex, ectopic BXSB/MpJ-Yaa mice have greater difficulty than their non-ectopic littermates with behavioural tasks involving detection of brief gaps in noise (Clark et al., Neuroreport 2000). Previous work has shown that neural responses to brief gaps in noise are abnormally weak in the auditory thalamus of ectopic mice (Anderson and Linden, SFN 2012), due to a reduction in the proportion of auditory thalamic neurons with sound-offset responses (Linden and Anderson, SFN 2015). To determine whether these thalamic deficits in gap-in-noise and sound-offset sensitivity arise “bottom-up” from abnormalities lower in the ascending auditory pathway, we recorded both auditory brainstem responses (ABRs) and extracellular responses from neurons in the inferior colliculus (IC) in ectopic and non-ectopic BXSB/MpJ-Yaa mice. Both types of recordings were obtained from urethane-anaesthetised mice. All recordings were conducted blind to the ectopic status of the animal, which was determined from post-mortem histology. In recordings from 8 ectopic mice (341 extracellular recording sites) and 7 non-ectopic mice (267 extracellular recording sites), we found no significant differences in IC responses to brief gaps in noise or noise offsets, even though responses to the same stimuli are abnormal in the auditory thalamus of ectopic animals. The median gap-detection threshold for both ectopic and non-ectopic mice within IC was 2.8284ms compared to 3ms for non-ectopic and 5ms for ectopic mice within auditory thalamus. Similarly, ABR recordings from 9 ectopic and 12 non-ectopic animals to clicks, tones and a click following a noise showed no difference in wave amplitude or latency for ABR waves I-V. Our results indicate that thalamic deficits in gap-in-noise and sound-offset sensitivity in ectopic BXSB/MpJ-Yaa mice arise purely within the forebrain, possibly in auditory thalamus or in auditory cortex. Putative mechanisms, currently under investigation in further experiments, include disruption of intracellular mechanisms for offset-response generation by nitric oxide. Supported by: Action on Hearing Loss 567:UEI:JL Action on Hearing Loss F44 Royal Society IE40709

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53	Poster	Matthew J. McGinley (1), Stephen V. David (2), David A. McCormick (1).	(1) Yale University (2) Oregon Health & Science University	Synaptic signature of optimal and suboptimal states for sensory signal detection	The cortical subthreshold membrane potential and synaptic dynamics underlying optimal sensory signal detection are not well known. Human and animal studies have reported that performance on signal detection tasks is highly state-dependent, exhibiting an inverted-U dependence on arousal and the activity of neuromodulatory pathways. This relationship, known as the Yerkes-Dodson curve, predicts that optimal performance occurs at intermediate levels of arousal (Yerkes and Dodson, 1908). But what are the synaptic and circuit mechanisms of this inverted-U dependence of optimal states for behavior and neural responses? To address this question, we recorded membrane potentials of auditory cortical neurons in mice trained on a challenging tone-in-noise detection task while assessing arousal with simultaneous pupillometry and hippocampal recordings. We find that the mouse's internal state fluctuates continuously and rapidly (in seconds or less), and arousal can be quantified simply as the diameter of the pupil. The pupil diameter closely tracks the rate of occurrence of hippocampal sharp waves. In addition, auditory cortical membrane potentials of layer 4 and 5 excitatory neurons exhibit: slowly fluctuating (1-10 Hz) rhythmic activity with low arousal; hyperpolarization and low variability at intermediate arousal; depolarization and variability with sustained hyper-arousal (with or without walking); and transient depolarization in synchrony with micro-arousal events. Optimal signal detection behavior and sound-evoked responses, at both sub-threshold and spiking levels, occurred at intermediate arousal when pre-decision membrane potentials were stably hyperpolarized. These results reveal a cortical physiological signature of the classically-observed inverted-U relationship between task performance and arousal, and that optimal detection exhibits enhanced sensory-evoked responses and reduced background synaptic activity. Furthermore, these results provide a framework with which to resolve apparent discrepancies between species and sensory systems in cortical membrane potential dynamics. Revealing the neural mechanisms by which the state of the brain and periphery is controlled on a moment-to-moment basis promises to clarify many interesting aspects of neural network function, including the neural basis of optimal performance, and may reveal a nervous system that is considerably more accurate and less variable than previously thought. Yerkes RM & Dodson DJ (1908). The relation of strength of stimulus to rapidity of habit formation. Journal of Comparative Neurology and Psychology 18, 459-82.

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62	Poster Teaser	Pierre Mégevand (1,2), Manuel R. Mercier (3,4), David M. Groppe (1), Charles E. Schroeder (5,6), Nima Mesgarani (7), Ashesh D. Mehta (1)	(1) Department of Neurosurgery, Hofstra North Shore LIJ School of Medicine, and Feinstein Institute for Medical Research, Manhasset, NY 11030, USA (2) Department of Neurology, Geneva University Hospitals, 1211 Geneva 14, Switzerland (3) Department of Neurology, Montefiore Medical Center, Bronx, NY 10467, USA (4) Department of Neuroscience, Albert Einstein College of Medicine, Bronx, NY 10461, USA (5) Cognitive Neuroscience Laboratory, Nathan S. Kline Institute, Orangeburg, NY 10962, USA (6) Department of Neurosurgery, Columbia University, New York, NY 10032, USA (7) Department of Electrical Engineering, Columbia University, New York, NY 10027, USA	The auditory cortex tracks the temporal dynamics of visual speech during silent lip-reading	Human speech is multisensory by nature: our lips, face and body are set into action when we speak; and being able to see our interlocutor complements and enriches our understanding of what is being said. How does visual speech affect the auditory cortex? According to an influential hypothesis, visual speech could induce phase reset of oscillatory activity in auditory cortex, thus modulating its excitability and optimizing the decoding of auditory speech (Schroeder et al., Trends Cogn Sci 2008). To explore this hypothesis, we recorded the responses of human cerebral cortex to naturalistic auditory and visual speech through intracranial EEG electrodes in patients with drug-resistant epilepsy. Electrodes were localized by co-registering pre- and post-implantation high-resolution MRI and CT scans. Participants watched and heard short (8-12 second) stories whose ending was cut off; after each story, they indicated whether a written word provided an appropriate ending. Each story was repeated several times, allowing us to measure the degree of phase-locking of the intracranial EEG across repeats of the same story (intertrial coherence, ITC) through time-frequency analysis. We defined auditory cortex as those electrodes that showed increased high-gamma power as well as delta- and theta-band phase-locking to auditory speech. We found that auditory cortex displayed significant phase-locking to visual speech (silent lip-reading) between 1 and 5 Hz, without any concomitant increase in power at these frequencies. We also observed a slight increase in high-gamma power. We then cross-correlated the ITC with mouth opening (approximated by the envelope of the auditory speech signal) and found positive correlations at the same frequencies, indicating that phase-locking in auditory cortex reflected specific characteristics of the visual speech signals. We also found a positive correlation between behavioral performance during silent lip-reading and the 1-to-5-Hz ITC to visual speech in auditory cortex. In order to examine how visual speech signals influence the processing of auditory speech, we compared the amount of phase-locking in auditory cortex when perceiving audiovisual vs. auditory speech and found higher phase-locking to audiovisual speech at 4 and 5 Hz. Our results indicate that oscillatory activity in auditory cortex reflects the slow dynamics of visual speech during silent lip-reading. They support the notion that visual speech gestures influence the oscillations, and hence the response of auditory cortex to speech sounds. More generally, they underscore the possible role of neuronal oscillations in multisensory integration and predictive coding.

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61	Poster	Anahita H. Mehta (1), Nori Jacoby (2), Ifat Yasin (3), Andrew J. Oxenham (1), Shihab Shamma (4,5)	1. University of Minnesota 2. Massachusetts Institute of Technology 3. University College London 4. University of Maryland 5. École Normale Supérieure	Neural correlates of attention and stream segregation in an auditory illusion	Natural auditory environments require listeners to parse out an acoustic signal of interest amidst auditory sources constantly overlapping or competing for salience. Listeners need to simultaneously use both sequential and synchronous sound segregation to focus on a target as most sounds both overlap and unfold over time. The present set of experiments use a stimulus, based on the "octave illusion" (Deutsch, 1974) to investigate the neural correlates of the effects of attention on the perceptual organization of competing sequential and simultaneous sounds. The illusion consists of alternating low and high tones in each ear being heard as a sequence of low tones in one ear and high tones in the other ear. The results suggest that the octave illusion is subserved by the same mechanisms that govern auditory streaming. Furthermore, directed attention can alter the percept of this stimulus and these changes can be observed in the corresponding EEG activity. Finally, results from both psychophysics and cortical EEG consistently suggest that the perceived illusory percept arises from a misattribution of time across perceptual streams, rather than a misattribution of location of sounds presented to one ear, as generally believed. We propose a simple account of the results using a model of auditory streaming based on the principles of temporal coherence.

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25	Poster	M Alex Meredith (1); Steven G Lomber (2); H Ruth Clemo (1)	(1) Virginia Commonwealth University School of Medicine (2) University of Western Ontario	Comparison of Dendritic Spine Density/Size for Primary Auditory Cortical Neurons from Early-deaf and Hearing Cats	Auditory cortex is reorganized by visual/somatosensory activity following early deafness. These crossmodal inputs arise essentially from the same regions that target the auditory cortices in hearing animals, indicating that crossmodal plasticity is subserved not by the ingrowth of new projections, but by local axonal branching and synapse formation. In areas with a high degree of crossmodal plasticity, concurrent increases in dendritic spine density and diameter have been observed. In contrast, the level of crossmodal plasticity demonstrated within A1 following early deafness remains unresolved. The present study measured dendritic spine features from A1 neurons in early-deaf cats (D; ototoxic administration within the first post-natal month, confirmed by flat ABR) and hearing (H) controls. The auditory cortex of adult cats (D= 3; H=3) was incubated for Golgi-Cox staining. Reactive neurons from A1 were visualized and their dendritic spine features assessed using a light microscope (100x; oil) controlled by Neuroludica software. The overall dendritic spine density (436 dendritic segments) did not vary significantly (D=0.81 spines/µm ± 0.02 se; H=0.82 spines/µm ± 0.005 se). However, spine density significantly decreased in the granular (thalamo-recipient) layers (D=0.42 spines/µm ± 0.02 se; H=0.58 spines/µm ± 0.02 se; $p<0.0001$) but was not changed in the supra- or infragranular layers. The diameter of dendritic spine heads was measured for 3448 spines, revealing that spine heads from early-deaf (D) animals were slightly but significantly larger (D avg. = 0.63 µm ± 0.005 se) than those of their hearing (H) counterparts (H avg. = 0.61 µm ± 0.004 se; $p<0.017$). This increase in spine diameter was exhibited by neurons in the supragranular (D = 0.65 ± 0.007; H= 0.59 ± 0.005; $p<0.001$) and infragranular layers (D = 0.69 ± 0.008; H= 0.63 ± 0.005; $p<0.001$) but not granular (D = 0.44 ± 0.01; H= 0.64 ± 0.01; $p<0.001$) layers, which showed a substantial decrease. These data indicate that dendritic spines in A1 react to early hearing loss in a lamina-dependent manner. Specifically, the presumed reduction of thalamic drive to granular layers corresponds with a large reduction in spine diameter (avg. decrease of 0.2 µm), while the preservation (or perhaps enhancement) of corticocortical inputs corresponds with increased spine diameters (avg. increase of 0.06 µm) in the cortical-recipient layers. When compared with other auditory areas following deafness, these data suggest that crossmodal plasticity employs different synaptic strategies for different regions. Supported by NIH Grant NS39460 and VCU PeRQ (MAM) and by CHIR (SGL).

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85	Poster	David Merry, Tobias Wells, Peyman Adjamian, Alan Palmer, Christian Sumner	MRC Institute of Hearing Research	Frequency selectivity of neurons in the ferret auditory cortex	Frequency selectivity describes the ability to resolve the individual frequency components in sound, and is a fundamental feature of hearing. It is crucial for most auditory tasks such as identifying sounds, separating auditory objects, and understanding speech. The ability of the auditory system as a whole can be measured through the behaviour of a subject, whereas the ability of neurons to be informative can be measured by observing their spiking activity when presented with an external stimulus. We examine the neural correlates of frequency selectivity using the power spectrum model. Although typically associated with behavioural measurements we instead utilised it to examine multi-unit neuronal response in the ferret's primary auditory cortex (A1). Neuronal responses to stimuli were recorded while the ferret was anaesthetised or awake, and results were compared to previous behavioural studies. In addition, these were compared to peripheral measurements of tuning in the auditory nerve (AN). Awake behaving neuronal tuning in A1 closely resembles behavioural results while the ferret undertakes a frequency specific sound localisation task. These are also broadly similar to prior results from anaesthetised recordings in AN, although AN bandwidths are more homogeneous across units of similar characteristic frequency (CF). These would suggest that frequency selectivity is established at the periphery, is maintained to the level of A1, and this ability is reflected in perception. However, units recorded in the ferret A1 under anaesthesia had better frequency selectivity, or sharper tuning, compared with units recorded under awake behaving conditions, and also behaviour and AN. This would imply that the ability to resolve frequency improves along the auditory system, but is then combined using sub-optimal coding to produce a perceptually poorer representation. Further study would be required to understand the factors behind these divergent results.

Poster Board #	Notes	Name and affiliation index for ALL authors	Affiliation index and affiliations for all authors	Abstract title	Abstract text
50	Poster	Arne F Meyer (1), Jennifer F Linden (2), Maneesh Sahani (1)	(1) Gatsby Computational Neuroscience Unit, University College London (2) Ear Institute and Dept. Neuroscience, Physiology & Pharmacology, University College London	Local sensory context modulates responses to complex sounds in multiple brain areas along the auditory pathway	Neurons in the auditory system are sensitive not only to the spectro-temporal pattern of a sound but also to the context in which that pattern occurs. Spectro-temporal sensitivities of neurons have been extensively studied using the spectro-temporal receptive field (STRF), a linear model relating a sound to the evoked response. However, little is known about the context-dependence of these sensitivities during stimulation with complex sounds. We characterized neuronal responses using the context model [1], a previously proposed form of multilinear model [2] which simultaneously characterizes both a linear "principal receptive field" (PRF) and a "contextual gain field" (CGF). The CGF describes how local gain at a particular point in the PRF is modulated by local stimulus context. We fit the context model to spiking data recorded in inferior colliculus, auditory thalamus and primary auditory cortex of rodents, as well as publicly available data sets [3] from homologous auditory areas in birds, all recorded during presentations of complex but stationary broadband sounds. In every case, the context model provided a more accurate description of neuronal responses than did the linear STRF model, yielding an increase in cross-validated predictive power by about 20%. Local facilitation in CGFs varied, but all areas shared a common pattern of reduction in input gain by preceding sound energy within about an octave range -- an input-frequency-specific, divisive form of forward suppression. The temporal structure of this suppression varied, with latencies ranging from 5-15 ms in birds up to 80 ms in rodents. Both latency and temporal extent increased from midbrain to forebrain. Using analytical results and simulations, we demonstrate that a cascaded context model can account for the increasing extent of contextual gain effects along the ascending auditory pathway. The results suggest that these nonlinear features of sensory neurons, which are not captured by linear STRFs, are transformed along the auditory pathway in a feed-forward manner. Further exploration of these mechanisms may help to elucidate the role of nonlinear integration in generating more complex sound representations in the auditory system.

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27	Poster	*LEE M. MILLER (1), BARTLETT D. MOORE (2), ANDREW S. KESSLER (1), CHRIS W. BISHOP (3)	(1) Univ. California, Davis, CA (2) Univ. Texas, Houston, TX (3) ViaSat, Carlsbad, CA	Frequency-multiplexed chirp-speech: rapid, simultaneous EEG characterization of the ascending speech processing hierarchy	Speech perception relies on multiple, simultaneously interacting levels of processing throughout the ascending auditory system. Indeed, successful perception correlates with activity at numerous levels, however this has usually been shown in separate studies using distinct, long-duration, mutually exclusive paradigms. Despite the clear scientific need – as well as a growing clinical appreciation for central factors in hearing loss – no method currently exists to rapidly and reliably assess the integrated functioning of the continuous speech system from brainstem to cortex. We developed a novel approach to create experimental speech stimuli that provide such a synoptic view into the functional health of the auditory system, including how different processing levels may interact. Although virtually any speech can be used, our stimuli were based on the Harvard/IEEE (1969) corpus. Sixteen subjects with healthy hearing and one with hearing loss participated. Sentences were first pitch-flattened to a constant glottal rate. Speech was then frequency-multiplexed with chirp trains. Chirps have been shown to compensate for the traveling wave velocity in the basilar membrane, resulting in a more synchronized neural response and larger auditory brainstem response (ABR). The chirp trains were isochronous 41Hz bursts, phase-synchronized with every other glottal pulse. This ensured that the chirps aligned acoustically and were thus perceptually bound with the speech. EEG was recorded from 16 channels at 16kHz sampling rate, located to maximize auditory and attentional (parieto-occipital alpha 8-12Hz) responses. This approach allowed the simultaneous measurement of speech evoked 1) auditory brainstem responses (ABR; especially Wave V, associated with “bottom-up” midbrain processing), 2) middle latency responses and auditory steady-state responses (MLR and ASSR), associated with signals reaching early auditory cortex, 3) long-latency responses from non-primary auditory cortex, particularly those representing syllabic-rate speech fluctuations (e.g. P1-N1 evoked potential waves), and 4) cognitive responses such as lateralized parieto-occipital alpha power. Among the advantages of our novel approach are that it is extremely fast (<5 minutes); one can use virtually any voiced speech and any naturalistic task, including established speech-in-noise corpuses and multiple talkers; it is simultaneous so one can assess intrasubject correlations across levels of processing, from brainstem to cognitive measures, e.g. reflecting spatial selective attention.

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93	Poster	Cory Miller (1) EunJung Hwang (1) Sirawaj Itthipuripat (1) John Serences (1) Takaki Komiyama (1)	(1) UC San Diego	2-Photon Calcium imagining in the auditory cortex of awake marmosets	Common marmosets have emerged as a valuable animal model in neuroscience. While neurophysiological methods have been well established in this primate model, particularly in the auditory system, their lissencephalic (smooth) cortex makes the species particularly amenable to various imaging techniques. 2-Photon calcium-imagining techniques allow the monitoring of population-based neuronal responses is one method that is particularly suitable for marmosets. Here we present progress on a preparation for calcium imaging in the awake marmoset auditory cortex. Data include work to optimize GCaMP6 viral expression, as well as preliminary neuronal responses in primary auditory cortex. We continue to examine evoked activity with simple tones of different frequency ranges, broadband noises, and sweep sounds. This preparation provides a foundation for further development of calcium imaging techniques in behaving marmosets in order to investigate how population-based neuronal activity in the auditory system contributes to auditory perception.

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95	Poster	Gen-ichi Tasaka, Ido Maor, Liqun Luo, and Adi Mizrahi	Hebrew University of jerusalem	Trapping of Cortical Plasticity in the Mouse Auditory Cortex	In the auditory system, early neural stations like cochlea and brain stem are characterized by strict tonotopy, which is used to deconstruct sounds to their basic frequencies. But higher along the auditory hierarchy, as early as primary auditory cortex (A1), tonotopy starts breaking down at local circuits. This more complex functional architecture is consistent with cortical physiology, suggesting that the cortex computes more complex sound features than pure tones. Moreover, cortical networks are well known to be sites of plasticity. The mechanisms of cortical plasticity remain only grossly defined; mainly at the level of tonotopical remapping. We exploited the power of mouse genetics to develop methods to genetically access specific neuronal populations in A1 based on their activity profile (a method called TRAP). I will describe our progress in trapping highly responsive neurons in A1 to reveal cortical micro-circuitry in A1, which we are able to achieve with good specificity but low efficiency. Interestingly, trapping works best for natural sounds but for pure tones. Further, we developed a new behavioral system (called the “Educage”) to train mice on a perceptual learning task. I will describe this powerful system and show preliminary data on combining trap with studies of cortical plasticity. Together, these techniques allow us new access to the heterogeneous cortical microcircuits underlying plasticity.

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55	Poster	Michelle Moerel (1), Federico De Martino (2), Kâmil Uğurbil (1), Essa Yacoub (1), Elia Formisano (2)	(1) Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, Minnesota, USA (2) Department of Psychology and Neuroscience, Maastricht University, Maastricht, The Netherlands	Cortical depth-dependent processing of natural sound features in human auditory cortex	Neuronal populations in the primary auditory cortex (PAC) are characterized by their acoustic feature preferences (e.g., frequency, spectrotemporal modulations). We use ultra-high field functional MRI (7 Tesla) to examine the cortical depth-dependent stability and variability of these preferences, in order to gain insight into the computations performed within the human PAC. We acquired high-resolution fMRI data (0.8 mm isotropic), while volunteers (N = 6) listened to 144 natural sounds. Cortical responses were analyzed with a computational model that defined the voxels' responses by their frequency-specific spectrotemporal modulation preference. The trained model predicted responses to novel sounds significantly above chance (mean prediction accuracy [SEM] = 0.69 [0.02]; chance = 0.5; p<0.001). Topographic feature maps were computed as the frequency, temporal modulation rate or spectral modulation scale with the highest model weight. We quantified the cortical depth-dependent stability of feature preference (i.e., "columnarity") as the ratio between the topographic maps' local gradient parallel and orthogonal to the cortical sheet. The majority of the PAC presented significantly columnar regions for at least one feature (p<0.05; permutation testing). While columnar regions for two out of three features were frequently observed as well, columnarity for all features was absent. Spectral modulation scale preference was significantly less stable across depths than frequency and temporal modulation rate, with lower spectral selectivity in superficial layers (p<0.05; paired t-test). Our results suggest a coding principle in human PAC in which tuning to a subset of features is kept stable, while tuning to another feature varies systematically. Cortical depth-dependent variations in spectral selectivity may reflect the integration of spectral information at PAC output compared to input layers.

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35	Poster	Jordan Moore (1) Sarah Woolley (1)	(1) Columbia University	Frequency tuning in the songbird auditory cortex: topographical distribution and relation to species-typical vocalizations	Tonotopy is a principle organizational feature of the vertebrate auditory system. Increasing evidence supports the hypothesis that avian and mammalian primary auditory cortices are homologous, but the extent to which their functional configurations are shared is unclear. Primary auditory cortex in mammals is mapped tonotopically with isofrequency columns traversing layers. A similar layout in avian primary auditory cortex has not been shown definitively. Moreover, in both birds and mammals, it is unknown how well tone-evoked cortical responses can explain spiking patterns in response to more complex stimuli, such as spectrotemporally modulated synthetic sounds or vocalizations. Here, we measured the frequency tuning of single neurons throughout the auditory cortex of two songbird species with acoustically distinct songs, the zebra finch (Taeniopygia guttata) and long-tailed finch (Poephila acuticauda). We presented pure tone stimuli and recorded physiological responses extracellularly in awake birds. High resolution mapping of best frequencies in Field L subdivision L2, the thalamo-recipient region, showed a systematic tuning gradient from low-to-high frequencies along the caudodorsal-to-rostroventral axis and along the lateral-to-medial axis. Isofrequency columns extended from L2 dorsally into subdivision L1 and caudal mesopallium and ventrally into subdivisions L and L3. Units in the lateral extents of these regions were heterogeneously tuned and not organized spatially. We also compared topographical patterns of response properties such as best frequency, excitatory and inhibitory bandwidths, and spectrotemporal modulation tuning to song acoustics. Species differences in tuning generally correlated with their disparities in song; some differences existed throughout the cortex while others emerged in specific subdivisions. These results suggest a shared functional architecture in the primary auditory cortex of birds and mammals.

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68	Poster	Todd Mowery (1) Vibhu Kotak (1) Dan Sanes (1)	(1) New York University	Developmental hearing loss leads to inhibitory synaptic deficits in the adult auditory striatum	Background Critical periods have been studied almost exclusively in the primary sensory pathways, including auditory cortex (Mowery et al. 2014). However, deprived animals often display behavioral deficits that are not solely attributable to sensory processing. Here, using a cortico-striatal brain slice preparation, we explored how transient hearing loss affects intrinsic firing properties and synaptic inhibition recorded from adult striatum that receives input from auditory cortex (ACx) . Methods Whole-cell voltage-clamp recordings were obtained from ACx-recipient putative medium spiny neurons (MSN) in a cortico-striatal brain slices from gerbils (Meriones unguiculatus) that experienced transient mild hearing loss. Earplugs were inserted bilaterally on postnatal day (P) 11 and removed on P35; thus the animals experienced hearing until P86. MSNs from earplugged animals (n=12) were compared to those recorded from age-matched controls (n= 15). Results In transiently earplugged animals, spontaneous postsynaptic inhibitory current (sIPSC) was significantly smaller [mean ± SEM: control; -25.1 ± 3.6 pA vs. transient earplug: -12.7 ± 1.0 pA; p < .05). The sIPSC time constant was also significantly longer [control: 22.2 ± 2.7 ms vs. transient earplug: 30.1 ± 3.3 ms, p < .05). Finally, the sIPSC rate was significantly lower [control: 15.2 ± 2.7 Hz vs. transient earplug 3.77 ± 1.3 Hz, p < .01]. Conclusion These results suggest that the striatum, a major non-sensory region downstream from sensory cortex, is sensitive to a brief period of acoustic deprivation. Furthermore, these effects persisted until adulthood, and this has implications concerning recovery from hearing loss in children.

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64	Poster	Ross S Muers (1), Mario J Bartolo (1), Timothy D Griffiths (1,2), Alexander Thiele (1), Christopher I Petkov (1)	(1) Newcastle University (2) Wellcome Trust Centre for Neuroimaging	Spatial influences on audio-visual interactions in the monkey brain	Multisensory signals that are in spatial and temporal register modulate a number of cortical areas. Many such regions, including those in caudal auditory cortex, belong to a dorsal, presumably spatial-processing pathway. However, brain imaging studies in nonhuman animals have not directly assessed the impact of spatial influences on audio-visual interactions. Thereby, an epistemic gap exists between human neuroimaging and nonhuman animal electrophysiological studies on spatial multisensory interactions. To advance our understanding, we used spatially moving audio-visual stimuli during functional MRI with two Rhesus macaques. Tonotopic maps for each animal were also obtained to approximate the location of auditory cortical fields. The monkeys were presented with unimodal (auditory or visual) and bimodal (audio-visual) stimuli moving in azimuth. Auditory stimuli were, virtual-acoustic space, moving broadband noises. Visual stimuli were moving black squares on a gray background. Bimodal stimuli either moved congruently or incongruently in spatial relation to each other. We analysed the fMRI data seeking to identify brain regions showing supra-additive multisensory interactions (modelled as: Bimodal (AV) > Unimodal (A+V)). Significant supra-additive interactions were observed in a number of brain areas (cluster corrected, $P < 0.01$) including areas VIP and LIP in the intra-parietal sulcus, area TPO in the superior-temporal sulcus, and visual area MT. Primary auditory and visual cortical areas also showed strong multisensory interactions. Stronger multisensory interactions were observed in posterior auditory cortical fields, including field A1 (RM-ANOVA, $P < 0.01$) and incongruent audio-visual stimuli preferentially modulated postero-medial auditory cortex. The multisensory effects in auditory cortex showed some interesting differences between the left and right hemispheres, although at the whole-brain level the effects were largely bilaterally distributed. In a control experiment with one of the macaques, we evaluated whether interactions were specific to moving stimuli. We observed that moving unimodal stimuli were more effective than stationary stimuli in activating caudal auditory fields and visual area MT. However, moving and stationary supra-additive multisensory interactions were comparable in these regions. Our results identify spatial influences on audio-visual interactions in the primate brain and serve as a bridge between human neuroimaging studies and those in animal models studying multisensory interactions at the neuronal level.

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98	Poster	Edmund Lalor	Trinity College Dublin	Classifying responses to music and speech using high-density EEG recordings	

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26	Poster	Ryan G. Natan (I), John J. Briguglio (1), Laetitia Mwilambwe-Tshilobo (1), Ethan M. Goldberg (II,III), Maria N. Geffen (I)	(I)Dept. of Otorhinolaryngology, (II) Dept. of Neurol., Univ. of Pennsylvania, Philadelphia, PA; (III) Div. of Neurol., The Children's Hosp. of Philadelphia, Philadelphia, PA	Multiple mechanisms for stimulus-specific adaptation in the primary auditory cortex	Adaptation to stimulus context is a ubiquitous property of cortical neurons and is thought to enhance efficiency of sensory coding. Yet the specific neuronal circuits that facilitate cortical adaptation remain unknown. In the primary auditory cortex (A1), the vast majority of neurons exhibit stimulus-specific adaptation (SSA), responding weakly to frequently repeated tones and strongly to rare tones in oddball stimuli. This form of history-dependent adaptation may increase cortical sensitivity to rare sounds. Here, we identify three distinct components shaping cortical SSA. The current source density sink amplitude profile across cortical layers in response to common and rare tones revealed that thalamo-cortical inputs to A1 exhibit SSA, albeit at lower levels than spiking responses. Furthermore, we found that two types of inhibitory interneurons contribute to SSA in a complementary fashion. Optogenetic suppression of parvalbumin-positive interneurons (PVs) led to an equal increase in the putative excitatory neuron firing rates to both common and rare tones (C). Suppression of somatostatin-positive interneurons (SOMs) led to an increase in neuronal responses to frequent, but not to rare tones. While the inhibitory effect of SOMs on excitatory neurons increased with successive tone repeats, PVs provided constant inhibition throughout the stimulus sequence. The effects of PVs and SOMs differed across cortical layers, consistent with their distribution across layers. Remarkably, both PVs and SOMs exhibited stimulus-specific adaptation. We constructed a firing rate model of a coupled excitatory-inhibitory neuronal population. Our simulation revealed how inhibitory neurons, despite exhibiting firing rate adaption themselves, increase adaptation in excitatory neurons. Taken together, our results demonstrate that SSA in the auditory cortex is a product of multiple adaptation mechanisms.

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31	Poster	Ruiye Ni(1), David A. Bender(2), Jeffrey R. Gamble(1), Dennis L. Barbour(1)	1. Department of Biomedical Engineering, Washington University in St. Louis, St. Louis, Missouri 63130, U.S.A. 2. Department of Biology, Washington University in St. Louis, St. Louis, Missouri 63130, U.S.A.	Single and population neural discrimination of vocalizations in noise	Robust sensory perception is critical for prompt behavior responses. Vocal communication in particular requires reliable auditory processing for both human and animals to interact with conspecifics. The nature of robust neural representation of vocalizations is incompletely understood. Recent research has revealed the existence of background-invariant neurons in higher auditory areas of songbirds, as well as site-dependence of the effect of masker type upon high-level neural representation. Auditory cortex contributes to the processing of complex natural sounds in primates, but relatively little is known about the impact of different noises on cortical encoding of vocalizations. Here we investigate the influence of two kinds of noises on the single and population neural discrimination of vocalizations in a highly vocal primate, the common marmoset monkey (Callithrix jacchus). Single-unit activities in auditory cortex were recorded from alert adult marmoset monkeys while animals passively listened to the playback of natural and modified conspecific vocalizations. White Gaussian noise (WGN) and 4-vocalization babble noise were mixed with five natural marmoset vocalizations at eight different signal-to-noise ratios. To quantify the influence of noise on individual neuron responses, we implemented spike-train distance-based discrimination analysis and further derived a robustness index for each neuron. An intensity invariant index corresponding to each vocalization was also developed in a similar way. We further trained diverse classifiers on pooled population response to assess the robustness of population encoding. Over the 224 primary auditory cortex neurons studied, the robustness indices of individual neurons against two noises are poorly correlated, revealing only a weak positive relationship. No significant correlation was shown between single units' intensity invariance and noise robustness under both noise cases. With regard to population coding, WGN leads to a lower detection threshold for the presence of target vocalizations than babble. Additionally, optimized subpopulation neurons outperformed the whole population for each of vocalization-noise pairs. Our results are consistent with our previous finding based upon correlation-based analysis and indicate individual neuron responses across different sound background are context-dependent in primate primary auditory cortex. The general influence of noise on cortical representation is revealed successfully by population coding and suggests that a variety of individual neuron responses is a prerequisite for robust coding across different conditions.

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71	Poster Teaser	Nidiffer, AR (1), Ramachandran R (2), Wallace, MT (3)	(1) Vanderbilt University (2) Vanderbilt University (3) Vanderbilt University	Multisensory temporal processing in the inferior colliculus	The presence of a cue in one sensory modality can enhance the detection of and the speed of reaction to cues in another modality. Furthermore, the magnitude of this behavioral enhancement has been shown to be dependent on both the intensity and the temporal relationship of the unisensory components of the multisensory stimulus complex. It is well established that these behavioral enhancements occur over a restricted range of stimulus onset asynchronies (SOAs), within the so-called “temporal window of multisensory integration.” Prior neurophysiological work has shown that multisensory enhancement in the superior colliculus is dependent on the temporal relationship between the component unisensory stimuli. Additionally, visual cues have been shown to modulate the responses of auditory signals in the inferior colliculus and even elicit responses when presented alone. Despite this growing evidence for multisensory processing in a traditional component of the ascending auditory pathway, numerous questions remain about the nature of the visual influences on auditory responses in the IC. One of these questions is whether similar temporal constraints exist for these audiovisual interactions in the IC as have been detailed for the SC. To begin to answer this question, monkeys were trained in a focused attention paradigm to report the detection of an auditory cue via lever release. Brief bursts of broadband white noise at varying intensity levels were presented alone and in the presence of an irrelevant, low-intensity visual stimulus at several different SOAs, and responses from IC neurons were recorded and related to behavioral performance. Behaviorally, monkeys showed speeded responses in the presence of the visual cue, but only for a restricted window of SOAs. Auditory neurometric thresholds were found to change in the presence of the visual stimulus, and were typically above concurrently measured psychometric thresholds. Furthermore, visual modulation of auditory responses was found to be dependent upon the temporal relationship of the irrelevant visual cue in a manner concordant with that found for the SC. Collectively, these results illustrate the relationship between neurometric and psychometric performance for IC neurons and auditory detection, and show that the temporal relationship between the auditory and visual signals in the IC is an important factor in how these signals are integrated.

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16	Poster	Sam V. Norman-Haignere (1) Josh H. McDermott (2)	(1) Department of Brain and Cognitive Sciences, MIT	fMRI Responses to Natural and Model-Matched Synthetic Sounds Reveals a Hierarchy of Auditory Cortical Computation	A central goal of auditory neuroscience is to understand the neural representation of natural sounds. One approach is to use “encoding models” to predict neural responses from stimulus features. However, there is no guarantee that features that predict neural responses are those that actually drive them, because distinct features are often correlated across natural stimuli. Here we introduce an alternative approach utilizing “model-matched stimuli” synthesized to evoke the same response as a natural sound in a model of neural computation. If the model provides a good description of the neural response, then the neural response to natural sounds and matched synthetic sounds should be similar even though the sounds may differ in many other respects. We used this approach to explore the sensitivity of different regions in human auditory cortex to standard acoustic features hypothesized to underlie their response. Using fMRI, we measured cortical responses to natural and synthetic sounds that were matched in average spectrotemporal modulation power, using a variant of existing texture synthesis methods. Crucially, the synthetic sounds were constrained only by their modulation power statistics, and as such were perceptually distinct from the natural sounds they were matched to (which exhibit additional higher-order statistical dependencies not made explicit by the spectrotemporal modulation model, and thus not replicated in the synthetic matches). Despite these perceptual differences, the natural and model-matched synthetic sounds produced nearly equivalent voxel responses in primary auditory cortex, suggesting that modulation power accounts for much of the neural response there. In contrast, voxel responses in non-primary regions differed markedly to the two sound sets, with many voxels producing little to no response for the synthetic sounds. This functional difference was much less pronounced using encoding models: modulation statistics were effective predictors of voxel responses in both primary and non-primary regions, presumably because they are correlated with higher-order features to which non-primary regions are tuned. Our approach reveals an increase in selectivity in non-primary regions of human auditory cortex and illustrates the use of model-matched stimuli in testing theories of cortical computation.

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57	Poster	Kirill Nourski(1), Mitchell Steinschneider (2), Ariane Rhone(1), Matthew Howard III(1)	(1) The University of Iowa (2) Albert Einstein College of Medicine	The “where” auditory processing pathway in the human: Insights from intracranial electrophysiology	Auditory cortical processing is envisioned to include a posterodorsal “where” pathway subserving sound localization (Rauschecker & Scott, Nat Neurosci 12:718-24, 2009). Originally described in Old World monkeys, it has been identified in the human primarily using non-invasive neuroimaging techniques. This model predicts that variations in sound location will maximally activate posterior regions of the auditory cortex of the superior temporal gyrus (STG) corresponding to monkey caudal belt and parabelt regions (e.g. area CL). We tested this prediction in humans using electrocorticographic (ECoG) recordings. Subjects were neurosurgical patients undergoing monitoring for medically intractable epilepsy. Studies were approved by the University of Iowa Institutional Review Board and NIH, and subjects could rescind their participation consent at any time. Speech syllables /ba/, /da/ and /ga/ were presented using one of three free-field speakers (-60, 0 +60 degrees azimuth, equidistant from the subject, eye level). Tasks included syllable detection, sound source detection or their combination. ECoG data were recorded simultaneously from Heschl’s gyrus (HG) and STG using multicontact depth electrodes and subdural grid arrays, respectively. Cortical activity was analyzed in the high gamma (70-150 Hz) frequency range. Syllables elicited robust responses throughout the auditory cortex. Interestingly, HG did not exhibit contralateral ear dominance, and short-latency responses to stimuli presented from all three locations were nearly identical. Target stimuli were associated with late increases in high gamma power that overlapped with behavioral responses. Within the most posterior portion of the STG, stimuli presented from the contralateral speaker elicited larger responses compared to ipsilateral or midline sources. These differences were enhanced in response to target stimuli. More anterior sites on STG had stronger responses to target than non-target stimuli, yet were not strongly modulated by sound location. The lack of contralateral ear dominance within HG is surprising given that monkey primary auditory cortex (A1) is generally more responsive to contralateral stimuli (Ahissar et al, J Neurophysiol 67:203-15, 1992). The finding that location sensitivity is greater on posterior STG parallels the greater sensitivity to sound location in area CL when compared to A1 in the monkey (Recanzone et al, J Neurophysiol 83:2723-39, 2000). Our findings provide the first human ECoG confirmation of the hierarchical model incorporating differential location sensitivity within relatively early stages of cortical sound processing. K.N. and M.S. contributed equally to this work. Supported by NIH R01-DC04290, UL1RR024979 and the Hoover Fund.

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19	Poster	Abigail L. Noyce (1) Samantha W. Michalka (1) Barbara G. Shinn-Cunningham (1) David C. Somers (1)	(1) Boston Unibersity	Auditory and Visual Biases in Multiple Demand Regions of Human Lateral Frontal Cortex	Lateral frontal cortex (LFC) is often characterized as domain general or multiple demand, due to its recruitment in a wide range of cognitive tasks (e.g. Duncan 2010; Fedorenko et al., 2013). We have previously used fMRI to identify discrete interleaved structures within LFC that show a preference for sensory modality in selective spatial attention (Michalka et al., in revisions). Here, we performed a replication test of that finding, and further investigated the sensory-biased versus multiple-demand nature of these regions. In our first experiment, we compared auditory to visual selective spatial attention. Subjects (n = 10) monitored one of two visual and two auditory stimulus streams for digits interspersed among letters. In our second, we compared auditory to visual nonspatial working memory. Subjects (n=14) performed visual 2-back (faces) and auditory 2-back (animal calls) tasks. In a direct contrast of auditory to visual task activations, both experiments identified four bilateral interleaved regions with significant sensory modality preferences in a majority of subjects. Visual-biased superior precentral sulcus (sPCS) and inferior precentral sulcus (iPCS) alternate with auditory-biased transverse gyrus intersecting precentral sulcus (tgPCS) and caudal inferior frontal sulcus (cIFS). In the subjects who participated in both experiments (n = 7), these regions were stable over the >1 year between scans. We defined a region that encompassed all eight of these structures as well as adjacent areas of LFC, and computed a continuous measure of sensory bias in the working memory task, ranging from exclusively auditory to exclusively visual. The mean sensory bias was very near zero, but the tails of the distribution extended to include strongly biased regions. Preliminary results suggest that areas showing stronger working memory recruitment are more tightly clustered around zero bias, while areas that are weakly recruited are more likely to show strong bias. LFC thus appears to be a multiple demand region that contains smaller areas with robust preferences for visual or auditory . This cortical area is likely multiplexing multiple sources of information, supporting flexible cognition in response to multisensory environmental input.

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40	Poster	A. F. OSMAN(1), C. M. LEE(2), M. A. ESCABI(1),(3),(2), *H. L. READ(1),(2);	(1)Biomedical Engineering. Univ. of Connecticut, Storrs, CT; (2)Psychology, Behavioral Neuroscience. Univ. of Connecticut, Storrs, CT; (3)Electrical Engineering. Univ. of Connecticut, Storrs, CT;	Distinct timescales for neural discrimination of sound envelope shape in three auditory cortical fields	Changes in the sound envelope amplitude over time provide perceptual shape cues to identify and discriminate sounds (Iverson and Krumhansl 1993; Irino and Patterson 1996, Drullman, Festen et al., 1994; Geffen et al., 2011). Mammals need cortex to detect many temporal sound cues; however, the underlying cortical circuits and neural coding mechanisms for this ability remain unknown. Sound shapes can be represented with a shapespecific spike rate increase in primary (A1) auditory cortex (Wang et al., 2008). In addition, auditory cortical neurons can represent sound shape with variations in spiketiming (i.e. jitter, Lee et al., 2014). Here we ask whether spiketiming patterns can be used to discriminate sound shape in primary (A1), ventral (VAF) and caudal suprarhinal (cSRAF) auditory fields of the rat. To probe cortical single neuron sensitivities to sound shape, we generated a stimulus set with 55 unique shaped envelope noise sequences. Single neuron response spike trains were recorded from layer 4 neurons in A1, VAF and cSRAF where the physiology and corresponding thalamocortical pathways have been well described (Polley et al., 2007, Storace et al., 2010, 2011, 2012, Higgins et al., 2010). The spike train analysis temporal resolution was varied by convolving spike trains with an exponential kernel having a time constant, tc (van Rossum, 2001). The spike train distance between responses to different shapes was estimated using the sensitivity index (dprime; Green and Swets, 1966) for comparing responses across pairs of sounds in our stimulus set (Gai and Carney, 2008). For each pair of spike trains, the slope of time constant, tc, is varied between 1 and 256 ms to determine the tc yielding the maximal discrimination value, i.e. the “best dprime”. In all fields, we find a rank order increase in the response duration with A1 < VAF < cSRAF to any given sound shape (Lee et al., 2015). Similarly, here we find a rank order increase in tc yielding best dprime with: A1 < VAF < cSRAF (logarithmic means: A1: 33 ms (1.03), VAF: 39 ms (1.02), cSRAF: 44 ms (1.03), $p < 0.001$). A1 neurons discriminate small differences in sound envelope shape (e.g. 2Hz vs 4Hz). Whereas, VAF and SRAF outperform A1 for discrimination of large differences in sound envelope shape (e.g. 2Hz vs 64Hz). This data supports the notion that neural discrimination of shaped periodic sound sequences relies upon the temporal patterns of spiking. Furthermore,distinct response timescales allow for complementary shape discrimination abilities in primary and nonprimary auditory cortices.

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96	Poster	Michael S. Osmanski (1), Xiaoqin Wang (1)	(1) Johns Hopkins University	Perceptual categories for species-specific vocalizations in the common marmoset (Callithrix jacchus)	Animal acoustic communication systems provide particularly fertile ground for studying the perceptual grouping of complex, biologically relevant stimuli. Birds, for example, show evidence for the perceptual classification of species-specific vocal signals across a number of laboratory and field studies. The common marmoset (Callithrix jacchus) is a small, arboreal New World primate with a rich vocal repertoire. Several different classes of vocalizations have been described for this species. There is also evidence that many of these vocalizations may serve roles in diverse behaviors such as the maintenance of group cohesion, individual identification, and territorial defense. However, we know surprisingly little about how these vocalizations are actually perceived by these animals and even less about the primary acoustic features that define particular call types. We trained marmosets using operant conditioning techniques to discriminate among sets of complex sounds that included several variants of both natural and artificial vocalizations. We analyzed response latencies derived from this task using a multidimensional scaling (MDS) procedure, which arranges these complex sounds into a multidimensional space that reflects their underlying perceptual organization. We found that marmosets perceptually grouped certain stimuli together and that these groupings reflected previously defined call types for this species (e.g., marmoset twitter calls). We next sought to determine the primary spectral and/or temporal characteristics that the marmosets had used in discriminating among these different stimuli, and we describe several acoustic characteristics that were correlated with the monkeys' perceptual dimensions (e.g., frequency modulation rate, frequency bandwidth). The results of these experiments lay the groundwork for future studies examining the acoustic parameters most critical for marmosets' discrimination of different classes of vocal signals and what perceptual mechanisms are involved in the processing of species-specific vocalizations.

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49	Poster	Lasse Osterhagen (1), K. Jannis Hildebrandt (1)	(1) Cluster of Excellence "Hearing4all", Department of Neuroscience, University of Oldenburg	The role of parvalbumin-positive interneurons in auditory gap detection	Age-related hearing deficits often include impairment of the processing of temporal fine structure, which may be due to deterioration of cortical processing. Age-related structural and functional changes of the auditory cortex have been found within the inhibitory interneuron (IIN) system: The levels of IIN- targeting neurotransmitters are decreased in older mammals. Besides, a decrease of parvalbumin-positive (PV+) IINs, one main group of IINs, had been shown. PV+ IIN in the auditory cortex have been proposed to play an important role for temporal sound processing. We hypothesize that impairments of processing temporal fine structure, which affect primarily older people/mammals, are related to decreased activity in PV+ IIN and that it is possible to enhance the detection of short gaps in noise by artificially activating those neurons. In order to test for the effect of altered PV+ activity, we choose to use optogenetic activation of PV+ cells and test for both physiological and perceptual consequences. We circumvent the interactions of timing of light and sensory stimulus by using stable step-function opsin (SSFO), which can be rendered continuously active and inactive with short pulses of light. By using SSFO, we were able to examine the effects of prolonged low-level and probably more physiologically accurate activation on both neural and behavioral gap detection thresholds. In a first step, we performed electrophysiological recordings in awake, passively listening mice with and without optical activation of PV+ cells. Neural gap detection thresholds for gaps in noise were significantly enhanced both in local field potentials and spiking responses. Units that displayed a significant change in gap detection thresholds also showed increased offset responses at the end of noise stimuli, possibly suggesting a role of cortical offset responses in gap detection. In a second step, we developed an acoustic gap detection task that is embedded in a Go/No-Go paradigm in order to test for perceptual consequences of PV+ manipulation. During the task, continuous noise is presented to the animal. When, a gap of varying length is inserted into the noise stream the mouse has to leave a platform in order to gain a reward. Mice reached performance level > 80% within 20 training sessions. Behavioral gap detection matched neural detection thresholds (~ 2 ms). Currently, we are testing behavioral performance with, the activity of PV+ cells either manipulated through optical stimulation or left untouched. We expect detection performance to be increased in trials in which PV+ IINs are artificially activated by light stimulation as compared to trials without stimulation.

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107	Poster Teaser	Bethany Plakke (1), Lizabeth M. Romanski (1)	(1) University of Rochester School of Medicine, Dept of Neurobiology & Anatomy, Rochester, NY 14642	Involvement of medial prefrontal and striatal neurons during the decision process in an audiovisual working memory task.	The medial prefrontal cortex (mPFC) is involved in detecting conflict, decision-making, audio-vocal control and motor processing. It also receives input from temporal lobe auditory and multisensory regions, however few studies have examined its response to naturalistic auditory or audiovisual stimuli. Our previous work has shown that ventrolateral prefrontal cortex (VLPFC) integrates face and vocal information and is necessary for audiovisual working memory. Here, we asked whether mPFC might also play a role in audiovisual processing. We recorded from mPFC and the striatum in macaques while they performed an audiovisual nonmatch-to-sample task. Subjects attended an audiovisual movie clip of a face-vocalization as the Sample and detected the occurrence of a Nonmatch (when the face or vocalization differed from the Sample movie). Preliminary data showed mPFC and striatal cells are active during several task epochs including the sample (55%), the delay (65%), the match (41%) and the nonmatch (32%) period. In contrast to previous findings from VLPFC, a larger percentage of units were responsive during the Match, when the animal correctly withheld a response. Additionally, there was a subset of neurons active during the correct detection of both Nonmatch and Match stimuli, indicative of decision related activity. These decision related units were more commonly found in mPFC compared to previous results from VLPFC. This data suggests that both VLPFC and mPFC are part of a neuronal circuit underlying audiovisual working memory in the primate brain.

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60	Poster	Amy Poremba (1) James Bigelow (2)	(1) University of Iowa (2) University of California, San Francisco	Audiovisual integration in primate dorsolateral prefrontal cortex	Audiovisual integration underlies a wide range of adaptive behaviors in humans and other primates, including language and communication, recognizing individual conspecifics, and social decision-making. Among the brain regions thought to underlie audiovisual integration is the lateral prefrontal cortex (PFC), which may be particularly important for selecting appropriate actions in response to audiovisual cues. Neurophysiological studies have concentrated on audiovisual integrative functions within the ventrolateral division of PFC, largely because of its purported role in the ventral object-processing stream. Comparatively little is known about audiovisual integration within dorsolateral PFC, which is believed to form part of the dorsal spatial-processing stream. Motivated by neuroimaging data suggesting auditory-visual overlap in dorsolateral PFC, as well as anatomical findings revealing connections between ventrolateral and dorsolateral PFC, the current study investigated audiovisual integration in single units and local cell populations within dorsolateral PFC. Three rhesus macaques (Macaca mulatta) performed a fixation task in which pseudorandomly-shuffled trials presented visual stimuli alone (visual trials), sounds alone (auditory trials), or visual stimuli and sounds together (audiovisual trials). Stimuli included monkey faces and vocalizations, human faces and vocalizations, animal faces and vocalizations, and synthetic visual events and sounds. Evidence of audiovisual integration within dorsolateral PFC was obtained from units exhibiting significant evoked responses to both auditory and visual stimuli, as well as units with responses to audiovisual stimuli that differed significantly from the maximal unimodal response. The results support an expanded view of the cortical network underlying audiovisual integration, which includes both ventrolateral and dorsolateral divisions of the PFC.

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47	Poster	Sebastian Puschmann (1), René J. Huster (2), Christiane M. Thiel (1)	(1) University of Oldenburg, Germany (2) University of Oslo, Norway	Temporal dynamics of processing task-relevant and irrelevant sound feature changes	Previous functional MRI studies demonstrated deviance-related activations in human auditory cortex but also in frontal and parietal brain regions. Due to its low temporal resolution, fMRI cannot capture the temporal dynamics of the activation spread across the different brain regions. The interplay of auditory sensory regions with fronto-parietal brain regions during deviance processing has therefore not been investigated in detail. We aimed to solve this issue by concurrently measuring fMRI and EEG during an auditory stimulus categorization task, in which participants had to sort sounds either depending on the fundamental frequency or the duration. The fMRI data revealed feature change-related activity in a widespread cortical network, including secondary auditory cortex and large parts of the ventral and dorsal fronto-parietal attention networks. Complementing previous data on auditory and visual attention re-allocation, an EEG source analysis of neural activity within these brain regions demonstrated that deviance-related activity propagated from auditory sensory regions and the insula to inferior and superior parietal lobe, and, subsequently, to medial and inferior frontal lobe, before re-activating auditory cortex and parietal regions. The insula as well as frontal and parietal regions, but not auditory cortex, showed differing fMRI response amplitudes for task-relevant and irrelevant sound feature changes. Within EEG source time courses, first relevance-related differences in deviance processing were observed at the level of the insula, supporting the view that this structure is involved in evaluating the behavioral relevance of sensory input.

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4	Poster	Melissa Runfeldt (1), Ralph Beitel (1), Marc Heiser (2), Christoph Schreiner (3), Brian Malone (1)	(1) Coleman Memorial Laboratory, Department of Otolaryngology-Head and Neck Surgery, University of California, San Francisco, California 94143 (2) Department of Psychiatry, Child and Adolescent Division, University of California Semel Institute for Neuroscience and Behavior, Los Angeles, California 90024. (3) Coleman Memorial Laboratory, Center for Integrative Neuroscience, and Department of Otolaryngology-Head and Neck Surgery, University of California, San Francisco, California 94143.	Encoding and decoding of amplitude modulated signals amongst populations in auditory core of awake squirrel monkeys	Neurons in primary auditory cortex simultaneously encode information about multiple stimulus dimensions, including the envelope and fine structure of modulated signals. Individual neurons can exhibit carrier-bandwidth, carrier-frequency, and carrier level-specific modulation tuning, which can be expressed in the neuron's firing rate and/or the timing of spikes relative to the phase of the modulating waveform. It is unclear how the response properties of individual neurons shape the information available to downstream 'read-out' neurons that receive multiple simultaneous inputs. Using simultaneous multichannel recordings from awake squirrel monkey cortex, we analyzed the responses of local neural populations to sinusoidal amplitude modulation (4 to 512 Hz) applied to pure tone and noise carriers. We focus our analyses on how network- and stimulus-driven spiking correlations, temporal coherence, and diversity within single neuron tuning properties impact population decoding of signal modulation frequency. In a simple convergent model based on spike summation, pooling the activity of multiple neurons can either increase or decrease decoding performance depending on the interplay between spiking patterns among neurons comprising the encoding population. For example, pooling across neurons that fire at different phases with respect to the modulation envelope will limit the synchrony of the pooled response, and decrease information about the envelope carried by spike timing. Analyzing multi-unit activity, we found that increasing the number of simultaneously-recorded channels that contribute to a summed population response is detrimental to the decoding of modulation frequency on average. When intertrial correlations were removed by shuffling responses across trials, however, adding more channels almost always improved performance. We explore whether this reflects loss of information due to signal averaging and/or redundancy in local populations. Additionally, using single-unit activity from spike-sorted data, we identify optimal encoding populations and characterize the features that contribute to their performance.

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32	Poster Teaser	David M. Schneider (1), Richard Mooney (1)	(1) Duke University	Neural coding of self-generated sounds in mouse auditory cortex	Sounds generated by our own movements (reafferent sounds) often co-occur with sounds emanating from the environment (exafferent sounds), and distinguishing between these two sound classes is critical to many forms of auditory-guided motor learning, such as speech and musicianship. To distinguish between environmental and self-generated sounds, the brain may take advantage of the fact that self-generated sounds can be anticipated, since they are time-locked to our movements and their acoustic features are often predictable. One strategy for exploiting this predictability is through copies of motor-related commands that are sent to the auditory system, where they may suppress or otherwise modulate predictable self-generated sounds. A corollary discharge circuit connecting the motor cortex to the auditory cortex in the mouse is active during movement and suppresses auditory cortical pyramidal neurons, providing a potential substrate for such a mechanism. However, it is not known whether motor-related signals acting at the level of the auditory cortex specifically modulate self-generated sounds. To address this question, we developed a novel acoustic virtual reality paradigm in which we can precisely control and manipulate the timing, spectral features and predictability of the sounds produced by a mouse's movements. Mice ran on a quiet, non-motorized treadmill, the rotational velocity of which was monitored in real time, and brief tone pips of a fixed pitch were presented through a speaker at a rate proportional to the treadmill's velocity. Over several days of acclimation, mice ran the equivalent of many hundreds of meters and heard several thousand reafferent tone pips. Following acclimation, we made extracellular recordings from multiple auditory cortical neurons while mice ran and rested on the treadmill and listened to reafferent sounds that either matched or deviated from the predicted pitch. Neural responses to tone pips that matched the anticipated pitch were selectively suppressed during locomotion, whereas tone pips with unexpected pitch were only weakly suppressed, indicating that motor-related suppression of mouse auditory cortex is specific for the expected acoustic consequences of movement. Ongoing experiments aim to identify synaptic, cellular and circuit mechanisms through which neural responses to self-generated sounds may be selectively suppressed.

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105	Poster	Tim Schoof (1, 2), Stuart Rosen (1)	(1) UCL (2) Currently at Northwestern University	Neural origins of the Frequency Following Response to resolved and unresolved modulated tones	The frequency following response (FFR), which reflects sustained synchronous neural firing at the brainstem in response to periodic sounds, has gained much popularity in recent years. However, the exact origins of the response properties of the FFR are not clearly understood. It has been suggested that the FFR primarily stems from neurons at basal sites along the cochlea, rather than more apical sites tuned to the stimulus components, especially for stimuli presented at high intensities. To explore this hypothesis, FFRs were recorded to tones of 402 and 2010 Hz sinusoidally amplitude-modulated (SAM) at 100 Hz. Note that the components of the low-frequency SAM tone would be resolved in the periphery, while the components of the high-frequency SAM tone would not. The stimuli were presented in quiet, broadband uniformly exciting noise (UEN), and UEN high-pass filtered at various cut-off frequencies ranging from just above the target stimulus to about 7 kHz. These high-pass maskers ruled out contributions to the FFR from neurons at basal areas along the cochlea. The relative involvement of neurons at different regions along the cochlea could thus be assessed. The target stimuli were presented at both 60 and 70 dB SPL. Preliminary data analysis supports the idea that the FFR in part originates from neurons at more basal sites along the cochlea (i.e. neurons tuned to frequencies above that of the stimulus). Neurons along a larger section of the cochlea were involved in the response to the stimuli presented at 70 compared to 60 dB SPL. Differences between responses to resolved and unresolved components will also be discussed.

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103	Poster	Ashley Schormans (1), Marei Typlt (1) and Brian L. Allman (1)	(1) Department of Anatomy and Cell Biology, Schulich School of Medicine and Dentistry, Western University	Cortical Crossmodal Plasticity Following Adult-Onset Partial Hearing Loss in Multisensory and Auditory Areas	Hearing impairment results in crossmodal plasticity, which is characterized by an increased responsiveness of neurons to non-auditory stimuli. It is relatively unknown how adult-onset partial hearing loss affects areas of the cortex that are already capable of integrating multisensory information. Thus, we investigated the effect of noise-induced hearing loss on neurons in the dorsal auditory area (AuD) of the rat, and the neighboring lateral extrastriate visual cortex (V2L). Two weeks after a bilateral noise exposure, adult rats underwent an acute electrophysiological recording experiment. A 32-channel electrode was used to record local field potentials across the cortical layers or single neuron activity within the cortical areas. Computer-generated auditory, visual and combined audiovisual stimuli were delivered, and the associated activity was recorded. Noise exposure increased ABR threshold by 14.3 ± 4 dB. Compared to age-matched controls, noise-exposed rats showed an increased proportion of visual neurons in V2L, and a decreased proportion of multisensory neurons, despite the sound level of the auditory stimulus having been increased to adjust for their hearing loss. In contrast, the proportion of multisensory neurons nearly doubled in AuD following noise exposure. Current source density analysis revealed altered laminar processing in AuD; sink amplitudes increased in response to auditory and audiovisual stimuli in most cortical layers. Overall, noise-induced hearing loss resulted in an increase in the proportion of visually-responsive neurons. However, crossmodal plasticity differed across cortical areas; V2L showed a decrease in multisensory processing, whereas the neighboring area, AuD, showed an increased proportion of neurons capable of integrating audiovisual information.

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17	Poster	Brian H. Scott (1), Pingbo Yin (2), Laura H. Lee (1), Anna Leigh Brown (1), Mortimer Mishkin (1)	(1) National Institute of Mental Health (2) University of Maryland	Activity of neurons in dorsolateral prefrontal cortex during performance of an auditory short-term memory task	Short-term memory (STM) for visual stimuli has been shown to engage both prefrontal cortex (PFC) and the modality-specific cortical areas that support visual perception. Although monkeys can perform auditory STM tasks, their ability is limited relative to that in vision and appears to depend on passive retention of a stimulus trace. Neurons in rostral superior temporal cortex (rSTC) carry a potential correlate of this sensory trace, but the contribution of the dorsolateral PFC (dlPFC) to this process is unresolved. We recorded single-unit activity in dlPFC (the caudal portion of the principal sulcus, predominantly its dorsal bank) while a monkey performed a serial delayed-match-to-sample (DMS) task. On each trial, the monkey grasped a bar to initiate the presentation of a sample sound (~300 ms duration), followed by 0-2 nonmatch sounds (delay interval ~1 s), before the sample was presented again as a match; the monkey released the bar to indicate a match. Of 101 recorded units, 39 responded to sound, some at a surprisingly short onset latency (median 44 ms, minimum 22 ms). Firing rate was stimulus-selective in 30% of responsive units. Two classes of task-related effects were identified: First, the auditory response was modulated by task context in one-third of units, with 10/39 showing match suppression (relative to the sample presentation), and 3/39 showing match enhancement. However, suppression and enhancement were equally prevalent for match or nonmatch sounds, indicating that these effects were not stimulus-specific. Second, activity during the first delay period was shifted from baseline in one-half of units, with delay suppression (14/39) being more common than delay enhancement (4/39). Delay suppression was typically sustained throughout the trial duration, and could possibly drive the same effect previously observed in rSTC. Other forms of delay activity were qualitatively different and more variable in dlPFC than in rSTC. As in rSTC, there was little evidence for a sustained, stimulus-specific sensory trace in the delay activity of dlPFC neurons. Unlike rSTC, suppression and enhancement of match responses in dlPFC were not stimulus-specific, but seemed to reflect a generalized modulation of responses following the sample. Responses in some units were strongly dependent on task engagement. In addition, firing rate in dlPFC was often modulated around the time of the motor response, which was rarely seen in rSTC. These observations confirm that dlPFC receives short-latency auditory inputs, but suggest that activity in this region also encodes domain-general aspects of the serial DMS task.

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3	Poster	William Sedley (1), Phillip E Gander (2), Sukhbinder Kumar (3), Hiroyuki Oya (2), Hiroto Kawasaki (2), Matthew A Howard III (2), Timothy D Griffiths (1)	(1) Newcastle University (2) University of Iowa (3) University College London	Neural signatures of predictive coding in cortical pitch processing	Accumulating evidence suggests that perception is not simply the consequence of serially processed input from sensory organs, but results from a weighted combination of this information with prior expectations based on a generative model of the environment. In predictive coding (1,2), prior expectations take the form of predictions, represented by their mean and precision (inverse variance), and sensory information in violation of these is called prediction error, which is related to surprise (the negative log probability of a sensory event occurring). Theoretical models based on cortical microarchitecture (3) propose that predictions are represented by local field potential oscillations in the beta band (~20 Hz), and prediction errors in the gamma band (> 40 Hz), though empirical evidence is limited and mainly relates to gamma band activity. In the present study of cortical pitch processing, we varied the fundamental frequency of an otherwise constant pitch stimulus in order to explicitly manipulate and dissociate prediction error, surprise, prediction mean and precision. Recordings were made from primary and non-primary auditory cortex (in Heschl's gyrus and superior temporal gyrus) from awake patients undergoing invasive monitoring for epilepsy localisation. We found that the amplitude of gamma correlated with surprise (rather than prediction error), beta with changes to prediction mean, and theta (~6 Hz) with precision of predictions. The findings relating to beta and gamma lend strong support to existing hypotheses, and for the first time demonstrate quantitative relationships between the relevant neuronal and computational processes. Theta oscillations are of fundamental importance to a wide range of cognitive and perceptual processes, and have been shown to have an organising and modulatory effect on higher-frequency oscillations. The present results suggest that one such role may be to encode the precision of predictions passed from higher centres, which could be achieved through dynamic modulation of higher frequency prediction and error signals. 1.Rao, R. P. & Ballard, D. H. Predictive coding in the visual cortex: a functional interpretation of some extra-classical receptive-field effects. Nat. Neurosci. 2, 79–87 (1999). 2.Friston, K. A theory of cortical responses. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 360, 815–36 (2005). 3.Bastos, A. M. et al. Canonical microcircuits for predictive coding. Neuron 76, 695–711 (2012).

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	Talk	Li Shen(1), Yili Yan(1), Ning Guo(1), Bo Hong(1)	(1) Tsinghua University	Functional connectivity for spectrotemporal processing of neighboring neurons in rat inferior colliculus	Natural sounds are rich in spectrotemporal attributes and their processing is important for auditory perception. Inferior colliculus (IC) is sensitive to specific spectrotemporal features and is the first site emerging frequency sweep direction selectivity and envelope periodicity rate-tuning (Kuo and Wu, 2012; Langner, 1983). However, it is still unclear how the neighboring neurons are functionally connected with each other and how this connectivity play roles in spectrotemporal processing. Here, we used tetrodes (inter-tetrode separation < 100 μm) to simultaneously record the responses of neighboring neurons in rat IC to dynamic moving ripple which had structurally rich time varying spectrum (Escabí and Schreiner, 2002). Spectrotemporal receptive field (STRF) was obtained using reverse correlation (Dayan and Abbott, 2001). We analyzed the cross covariance function between simultaneously recorded neuron pairs and only pairs with significant correlation with 10 ms delays ($p<0.01$) with respect to an independent Poisson assumption were analyzed further (Atencio and Schreiner, 2013). We found that the activities of many neighboring neurons were temporally correlated. We separated the causal spikes from the activities of the source neuron and the target neuron to obtain causal spikes evoked STRF (causal STRF). We found that the neighboring neurons exhibited three types of functional connectivity: feature integrating, feature extracting and time-delay. In the first case, the target neuron integrated several simple spectrotemporal patterns to shape a complex feature selectivity and the causal STRF resembled the source STRF rather than the target STRF. The function role of this kind of connectivity approximated the “OR” operation. In the second case, only the spikes triggered by certain spectrotemporal features of the source neuron could drive the target neuron and the similarity between the causal STRF and the target STRF was higher. And the function role of this kind of connectivity approximated the “AND” operation. In the last case, the target neuron generally inherited the spectrotemporal properties of the source neuron except with various time delay. Accordingly, the causal STRF was almost equally similar with the source STRF and the target STRF if the delay was wiped out. These results suggest that the spectrotemporal feature selectivity of IC neurons can be developed and refined via functional connectivity within local circuits.

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87	Poster	Chen Song (1) Rui Xu (1) Wenjing Zhou (2) Zhipei Ling (3) Bo Hong (1)	(1) Department of Biomedical engineering, Tsinghua University, Beijing, China (2) Department of Neurosurgery, Tsinghua Yuquan Hospital, Beijing, China (3) Department of Neurosurgery, Tsinghua Yuquan Hospital, Beijing, China	Revealing the representational units in continuous speech by intracranial EEG	An important procedure in human speech recognition is to recognize the segmental units, e.g. phonemes and syllables, from the continuous speech sound stream. But what are the basic speech units and how the speech unit inventory is stored in human brain is still not fully understood. In this study, we used intracranial EEG signal from both surface and depth electrodes on human cortex to reveal the representation of segmental units, especially phonemes and combination of phonemes (Chinese diphthongs and triphthongs), which are supposed to be fundamental units in previous phonological studies. Subjects were instructed to listen to short stories. Chinese rhymes, which are defined to be composed of 3 phonemes named glide, nucleus and coda in phonology (Lee, 2003; Duanmu, 2000), were manually segmented from the stories. High gamma responses showed clear selectivity to Chinese rhymes on some electrodes, which were mainly located in bilateral STG and STS. The maximum of selectivity was reached at approximately 150ms after Chinese rhyme onset. However, high gamma responses on most electrodes were not selective to a single part of Chinese rhymes. Besides, nucleus, which is proposed to be the most important part in Chinese rhymes, accounted for most part of selectivity in the electrodes. Their selectivity was organized by place of articulation. To further determine the underlying dimensions describing the representation of Chinese rhymes, principal component analysis were performed on the features collected from all electrodes showing selectivity. The principle components showed selectivity to glide and nucleus, but not for coda, which resembles the selectivity defined by phonological categories. In short, the representation of speech units clearly exists in continuous speech perception. Moreover, when multiple segmental units were combined into a larger unit, the neural representation are dominated by the selectivity of prominent segmental unit, e.g. nucleus in a Chinese rhyme, and are less affected by other composing parts of a Chinese rhyme, indicating the auditory cortex may contains neural populations that process 'key units' in continuous speech to perform speech recognition more efficiently.

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97	Poster	Xindong Song, Yueqi Guo, Xingde Li, Xiaoqin Wang	Dept. of Biomedical Engineering, School of Medicine, Johns Hopkins University	Flexible, nimble, and quiet two-photon microscope platform for auditory functional imaging of awake marmosets	Two-photon laser scanning microscopy (TPLSM) has been widely employed to study neuronal population functions in vivo. The standard implementation of TPLSM utilizes a pair of galvanometer mirrors to scan the imaging beam. However, this mechanical oscillation introduces a remarkable acoustic noise bearing a distinct pitch. This unwanted noise as well as the cooling noises from a Ti:Sapphire laser system, introduces potential auditory artifacts which haven't been carefully investigated in previous studies. Alternatively, a beam scanner based on acousto-optical deflector (AOD) enables fast, silent and random-access scanning; yet a pure random-access scanning mode might be vulnerable to movement artifacts and thus limits its imaging use in awake animals. We have designed and built a system capable of flexible and nimble two-photon AOD scanning imaging in awake animals (FANTASIA). We isolated the laser cooling system outside a double-walled acoustic testing chamber. Such a system can perform (1) 2D random-access scanning at a speed of 50,000 points per second; or (2) 2D raster scanning at video rate, or (3) even 3D multi-layer scanning without moving the objective. To test the system, we injected adeno-associated virus carrying GCaMP and GFP into the cortex of a marmoset monkey (callithrix jacchus), a highly vocal non-human primate species, which was implanted with an artificial dura based optical window and imaged under awake condition. Clear cellular structures could be resolved. Repeatable fluorescence traces of auditory response were seen. Both scanning flexibility and nimbleness were achieved without generating noticeable acoustic noise. This research is supported by an NIH grant (DC-03180).

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42	Poster	Mitchell Steinschneider (1), Kirill Nourski (2)	(1) Albert Einstein College of Medicine (2) University of Iowa	Electrocorticographic activation within and beyond auditory cortex during dialogue-based language and cognitive testing	Authors have contributed equally to this work The ventral pathway for language processing is envisioned to encode ever more complex and abstract features of speech (Rauschecker & Scott, Nat Neurosci 12:718-24, 2009; Poeppel et al, Philos Trans R Soc Lond B Biol Sci 363:1071-86, 2008). For instance, superior temporal gyrus (STG) is thought to be engaged in acoustic-phonetic mapping, while middle temporal gyrus (MTG) represents a sound-meaning interface. We examined this model using a dialogue-based paradigm, wherein subjects performed the Mini Mental Status Examination and other neuropsychological tests that assessed language and memory functions. Subjects were neurosurgical patients undergoing chronic invasive monitoring for medically refractory epilepsy. Studies were approved by the University of Iowa Institutional Review Board and NIH, and subjects could rescind their consent for participation at any time without affecting their clinical evaluation. Electrocorticography (ECoG) recordings were made simultaneously from auditory and auditory-related temporal cortex of Heschl's gyrus (HG), STG, MTG, superior temporal sulcus (STS), supramarginal gyrus (SMG), and mesial temporal structures including parahippocampal gyrus (PHG). High gamma (70-150 Hz) ECoG power was calculated using an FIR filter implemented in MATLAB. Responses were related to listening to the instructions of the interviewer and to the subject's verbal responses. As expected, posteromedial HG was activated during both listening and speaking regardless of the task. In contrast, STG was differentially affected by the tasks, with areas adjacent to the transverse temporal sulcus generally suppressed during self-initiated speech. STS and MTG were strongly activated during tasks involving lexical retrieval. While SMG is envisioned to be a major auditory-motor hub within the dorsal processing pathway, its anterior portion was generally activated during listening and suppressed during speaking. PHG was strongly activated during memory-based tasks. The amygdala was maximally activated in tasks possessing an emotional valence to the subjects. We conclude that models of speech and language processing need to incorporate brain regions outside classically defined auditory and auditory-related areas that subserve more general cognitive processes (e.g., memory retrieval, emotional valence) that are actively engaged in real-life conversations. These patterns of cortical activation observed during performance of neuropsychological tests will need to be further characterized using more structured experimental paradigms. Supported by NIH R01-DC04290, UL1RR024979 and the Hoover Fund.

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56	Poster	Wensheng Sun (1), Dennis L. Barbour (1)	Washington University in Saint Louis	Neural dynamics for encoding stationary sound stimuli in the primary auditory cortex of marmoset monkeys	Neural systems usually respond to external stimuli with rich dynamics, even when the stimulus itself is stationary. In primary auditory cortex, responses to stationary sounds contain two dynamic components. The onset component occurs immediately following stimulus onset, which spreads across a wide range of neurons at high population activity level. As the stimulus proceeds, responses of many neurons fade away, leaving only a small subset of neurons firing sustainably throughout the stimulus duration. This sustained response is the second component. Previous studies showed higher response selectivity for sustained responses and proposed distinct functions for the two response components, where onset responses encode the occurrence of a sound onset and sustained responses convey stimulus-specific information. To quantitatively investigate sound encoding properties of the two components, we recorded neural spiking activities from the primary auditory cortex of awake marmoset monkeys in response to pure tones. Through population decoding methods, we found that both response components contained stimulus-specific information. Moreover, to achieve a particular decoding accuracy, the required window length for onset responses was shorter. Along the entire stimulus interval, analysis windows with the same number of spikes showed the same decoding accuracy. Thus, the higher-rate onset responses can perform encoding at a faster speed. Finally, we showed that the observed relationship between activity level and decoding speed can be explained by the inherent properties of Poisson neurons, in which higher rates result in more reliable rate estimation and thus a shorter encoding interval. In contrast to onset responses, sustained responses were more energy efficient with their lower spiking rates. Instead of uniformly lowering the activity level of each neuron, however, a large number of neuron responses faded away while only a small subset remained active. This sparseness potentially helps maintain the statistical power of the system in the sustained low activity level regime, and improves code orthogonality, thereby preserving encoding capacity for new stimuli. The trade off, however, is a slower encoding speed. This unified theory accounts for the existence of primary-like neuronal responses that can rapidly encode sensory changes in the environment when they occur while also efficiently maintain that representation in face of no additional stimulus changes. These complementary strategies arise out of constraints from behavior, neuronal biophysics and metabolic factors.

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108	Poster	Tobias Teichert (1)	(1) University of Pittsburgh	Contextual auditory processing in the rhesus	Brain responses to sound strongly depend on the immediate auditory context, defined here as the identity and time of occurrence of previous sounds. Contextual effects are typically studied in predictable auditory environments by using long sequences of regularly repeating sounds. It is a matter of ongoing debate to what degree the observed contextual effects in this setting reflect (a) the detection of, and response to, the regularity (‘cognitive’ account), or (b) the depletion and gradual recovery of a limited physiological resource (‘refractory’ account). It is important to resolve this distinction in order to understand auditory contextual deficits that are a common, treatment-resistant symptom in patients with schizophrenia. To address this issue we studied contextual processing using extracranial EEG recordings in macaque monkeys – an important ‘bridge-method’ that links intracranial recordings in animals and non-invasive EEG recordings in humans. Four macaques passively listened to alternating 10 minute-long blocks of sounds whose identity and timing was either repetitive (regular environment), or not repetitive (random environment). In both environments, the inter-stimulus interval (ISI) ranged between 0.2 and 18 sec, thus encompassing the clinically relevant time-scale. Using high channel-count EEG grids we identified 6 distinct ERP components with consistent timing and topography across all 4 animals. Most components were strongly modulated by the time since the last sound, while the identity of the past sound had a weaker effect. Importantly, our results show highly similar contextual effects in the regular and random environment. In both environments, the contextual effects were convincingly explained by a model assuming depletion and exponential recovery of a limited resource.

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8	Poster	Antonia Thelen (1), Micah M. Murray (2, 3), Mark T. Wallace (1)	(1) Multisensory Research Lab, Vanderbilt Brain Institute, Vanderbilt University, TN, USA (2)The Laboratory for Investigative Neurophysiology (The LINE), Department of Clinical Neurosciences and Department of Radiology, Vaudois University Hospital center of Lausanne, Lausanne, Switzerland (3) Electroencephalography Brain Mapping Core, Center for Biomedical Imaging (CIBM) of Lausanne and Geneva, Switzerland	Electrophysiological correlates of performance variability in multisensory detection	Multisensory facilitation of neuronal and perceptual responses has been extensively demonstrated over the past decades. Generally, these studies report averaged responses derived from a group of participants, which can conceal substantial between- and within-subject variability in the processing of audiovisual information. Little work has focused on better understanding the brain bases for trial-by-trial differences in audiovisual perception. In the current study, we investigated the neural correlates of trial-by-trial perceptual variation, within the context of a detection task. Participants were asked to detect visual targets (presented alone or in combination with a tone), and to indicate their location (i.e., central vs. peripheral visual field). Response accuracy and reaction times were collected for each trial. Concurrently, high-density EEG recordings were carried out, in order to identify differences in both response strength (i.e., global field power) and neural generator configuration (i.e., topography) of the electrophysiological signals. Analyses focused on identifying differences associated with trials exhibiting multisensory perceptual facilitation compared to identical trials where no perceptual enhancement occurred, as well as detailing how this is affected by target location and stimulus structure (i.e., auditory vs. audiovisual). Preliminary findings suggest that audiovisual interactions within the peripheral visual field are dependent on visual target contrast polarity (i.e., bright vs. dark), leading to differential gains in the efficacy of stimulus processing (quantified as smaller speed-accuracy tradeoffs). EEG data analyses aim at understanding the neural network changes involved in the early, perceptual processing stages of multisensory events that determine the trial-by-trial speed-accuracy tradeoff observed at the behavioral level.

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5	Poster	Maryse Thomas (1,2,3), Miguel Cisneros-Franco (1,2,3), Lydia Ouellet (2), Etienne de Villers-Sidani (1,2,3)	(1) McGill University (2) Montreal Neurological Institute (3) Centre for Research on the Brain, Language, and Music	Modulating auditory cortical plasticity through passive exposure to amplitude-modulated noise	Cortical representations of the external world are shaped by sensory experience at a young age and preserved through the stabilization of inhibitory networks. These representations are largely thought to remain stable throughout the lifetime, but recent work has shown that sensory deprivation in adulthood, such as dark-rearing, is capable of returning sensory cortices to an immature and disinhibited state. Here, we draw a parallel between sensory deprivation and exposure to continuous white noise. Housing adult rats in white noise, which masks normal environmental sounds without damaging the auditory system, has been found to have a profound disinhibitory effect on the auditory cortex, however the mechanisms behind this effect remain unclear. We argue that similar to sensory deprivation, the prolonged absence of salient auditory signals in noise exposure is the trigger for disinhibition and subsequent induction of cortical plasticity. In the following experiments, we tested this hypothesis by passively exposing adult Long-Evans rats to white noise of different degrees of amplitude modulation. In this manner, we were able to vary the signal-to-noise ratio of the exposure from 0% (no modulation) to 100% (strong modulation). Specifically, we exposed four groups of rats to two weeks of 70 dB broadband noise modulated at a rate of 3 Hz and a depth of 0%, 25%, 50% or 100%. A fifth group of naive rats was housed under standard conditions. At the end of this period, we recorded auditory neuronal responses from the anesthetized rats using multi-electrode arrays and performed immunohistochemical staining on post-mortem tissue slices of the primary auditory cortex. For rats exposed to 0% modulated noise, we observed an increase in cortical plasticity in accordance with previous studies. Evidence of neural disinhibition included a higher spontaneous firing rate, a shorter response latency to pure tones, and sensitization to trains of repeated tones. These variations were significantly less profound in rats exposed to modulated noise, with the magnitude of these changes decreasing with greater depth of modulation. Immunohistochemistry results showed a pronounced increase in excitatory cellular activity as measured by c-fos expression for rats exposed to 0% modulated noise, along with a step-wise decrease in expression for 25%, 50%, and 100% noise-exposed rats. Our results suggest that the absence of sensory signals is a key factor in plasticity following chronic noise exposure. This is an important step in understanding how sensory deprivation leads to cortical disinhibition and will underlie future studies on therapeutic applications of induced sensory plasticity.

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102	Poster	Douglas J. Totten(1), William DeBello(1)	(1) University of California, Davis	Bimodal Integration and Noise Correlations in the Barn Owl Optic Tectum	The deep layers of the optic tectum integrate information across modalities to generate a topographic map of space. In the barn owl optic tectum the spatial tuning of single units and the effect of competing stimuli on response magnitudes have been well characterized; however the simultaneous responses in populations of neurons have not been described. We have used multi-electrode recordings in awake barn owls to explore how simultaneously recorded neurons change their firing rates, response variance and noise correlations when presenting unimodal (visual or auditory) or bimodal (audiovisual) competing stimuli. When we played stimuli in the overlapping portion of neurons' receptive fields their noise correlations were comparable regardless of stimulus modality, while the response magnitudes and fano factors of the responses were modality dependent. When the same stimuli were presented with a synchronous competing stimulus 20 degrees away, response magnitudes decreased regardless of the modalities of the driving stimulus and the competing stimulus. Interestingly, the noise correlations and the fano factor decreased when the competing stimulus and the driving stimulus were of different modalities, but not when they were the same modality. These changes in noise correlation cannot be accounted for by changes in response magnitudes. This suggests that the optic tectum may have different mechanisms for processing unimodal and bimodal stimulus competition. This has interesting implications for multimodal salience mapping and instructive learning in the auditory pathway, which is known to be driven by audio-visual spatial disparity.

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28	Poster	Joji Tsunada (1), Andrew S.K. Liu (1), Joshua I. Gold (2), Yale E. Cohen(1)	(1) Department of Otorhinolaryngology, University of Pennsylvania School of Medicine (2) Department of Neuroscience, University of Pennsylvania School of Medicine	Dissociation between spiking activity and local field potentials in the auditory cortex during auditory decision-making	Auditory decision-making requires the conversion of incoming auditory information into a categorical judgment. For a decision regarding the frequency content of an auditory stimulus, spiking neural activity in the middle-lateral belt region (ML) and the anterolateral belt region (AL) of the auditory cortex represents relevant frequency information, but only in AL does this activity directly and causally provide evidence for this decision. However, it is unknown the degree to which ML and AL activity reflects inputs from other brain regions or how it is shaped by local neural processing. To begin to address these questions, we recorded spiking activity, which provides the output signals from a given brain region, and local field potentials (LFPs), which reflect a combination of input, local, and output signals, from ML and AL, while monkeys performed an auditory frequency-discrimination task. For this task, the monkeys reported whether a sequence of tone bursts contained more high-frequency tone bursts (>1.75 kHz) or low-frequency (<1.75 kHz) tone bursts. The monkeys could report their choice at any time during the presentation of tone bursts. We manipulated task difficulty by systematically changing the proportion of high-frequency and low-frequency tone bursts. The monkeys' choice accuracy and response times depended systematically on the proportion of high- and low-frequency tone bursts, with faster and more accurate responses for stronger stimuli (i.e., a relatively high proportion of either high-frequency or low-frequency tone bursts). We obtained 79 pairs of spiking activity and LFPs (ML: 35 pairs, AL: 44 pairs) from two monkeys performing the task. Both ML and AL spiking activity was modulated comparably by the frequency content of the tone bursts: spiking activity increased as the proportion of tone bursts with frequencies matching the neuron's best frequency increased. However, ML LFPs had stronger frequency-dependent modulations than those in AL. Furthermore, a modulation index indicated that ML spiking activity and LFPs had similar frequency selectivity; whereas AL LFPs were less selective than AL spiking activity. Consistent with this observation, the spike-field coherence was stronger in ML than in AL. Together, these results suggest that there is dissociation between spiking activity and LFPs in AL, but not in ML. Based on these findings, we discuss a hypothesis that ML relays sensory inputs to other brain regions, including possibly AL, and AL transforms sensory inputs to a systematically organized representation of sensory evidence used to form the decision.

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77	Poster	Ross S. Williamson (1,3), Charles-Henri P. Villa (1,2), Kenneth E. Hancock (1,4), Daniel B. Polley (1,3,4)	(1) Eaton-Peabody Laboratory, Massachusetts Eye and Ear Infirmary (2) Section of Life Science and Technologies, Ecole Polytechnique Federale de Lausanne (3) Center for Computational Neuroscience and Neural Technology, Boston University (4) Dept. of Otology and Laryngology, Harvard Medical School	The Role of Cortical Feedback in Modulating Sensory Representations in the Midbrain	Neurons in layers V and VI of the auditory cortex form part of a massive projection system, innervating all levels of the central auditory pathway in addition to brain areas outside of the classic central pathway, such as the striatum and basal ganglia. Little is known about what these projections contribute to the representation and transformation of auditory signals in subcortical brain areas, and how these projections are able to influence sound encoding in real time. We directed our focus to the auditory midbrain (the inferior colliculus [IC]; a structure that receives a large number of layer V/VI cortical projections), and asked how activation of these projections might affect the ongoing processing of sound. To address this, we manipulated the corticocollicular pathway while recording unit activity from the IC of head-fixed awake mice as we presented simple broadband noise stimuli. An adeno associated viral construct that drove expression of 'Chronos' (an ultra-fast channelrhodopsin) under the synapsin promoter was injected into the primary auditory cortex (A1). Following ~3 weeks of incubation time, a fiber optic was implanted over A1 and a small craniotomy was performed over the IC. We interleaved trials in which a 250ms broadband noise burst was either presented in isolation or combined with A1 laser activation of the same duration. Such an approach yielded relatively weak effects, with less than 20% of IC recording sites being significantly enhanced by cortical stimulation, and an average increase in sound-evoked firing of only 6%. Because of this, we used a real time spike feedback optimization algorithm (Chambers et al., 2014) to identify A1 activation patterns that could alternately enhance or suppress sound-evoked activity in the IC. When the algorithm was tasked with finding a stimulation pattern to optimally enhance IC firing, the number of responsive sites more than doubled, and average sound-evoked firing was increased by 42%. The algorithm was also able to learn to maximally suppress IC firing (rather than enhance it) in a specific sub-region of the central nucleus, suggesting that the net effect of cortical output in this midbrain region is bi-directional, alternating between gain and attenuation depending on the temporal patterning of A1 stimulation. Our current work is now focused on isolating cortical projection neurons and establishing whether these mechanisms could be employed in active listening, where sound plays a crucial role in behavior.

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79	Poster	Daniel E. Winkowski (1), Saurav Seshadri (2), Dietmar Plenz (2), Patrick Kanold (1)	(1) University of Maryland, College Park, MD (2) NIMH, Bethesda, MD	Avalanche dynamics of population activity in the auditory cortex	The layered organization of cortex fundamentally organizes how information is processed in the brain. Sensory input enters layer 4 (L4) from which activity quickly spreads to superficial layers 2/3 (L2/3), deep layers 5/6 (L5/6) as well as to other cortical areas. In primary auditory cortex (A1), our recent in vivo 2-photon experiments revealed a homogeneous frequency (tonotopic) organization in L4, which is more heterogeneous in the next layer, L2/3. The organization of stimulus preference in L2/3 is currently not well understood, yet, numerous studies have shown that L2/3 incorporates ongoing cortical activity, usually in the form of reverberating activity from within or distant cortical regions, that reflect the state and behavioral context of the animal. A promising candidate dynamics are neuronal avalanches which emerge in L2/3 and provide a scale-invariant organization of activity patterns that correlate distant cortical sites in a highly selective manner, a prerequisite to form perceptual categories. Towards understanding the spatiotemporal properties of population activity in A1 and the functional relationship of neurons participating in neuronal avalanches we investigate the presence of neuronal avalanches in A1. We use in vivo 2-photon imaging of spontaneous and sound evoked activity of A1 in awake mice using GCaMP6. We deconvolve the signal from ROIs to derive the instantaneous neuronal firing rates. Non-zero firing rates from local clusters were calculated and the cluster size distributions were examined for power law behavior to identify avalanche dynamics. We then compare avalanche dynamics of ongoing and evoked activity in different lamina in the anesthetized and awake state. Together our experiments characterize the spatiotemporal population activity in the auditory cortex.

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24	Poster	Oscar Woolnough, Joel I. Berger, Ben Coomber, Mark N. Wallace, Alan R. Palmer, Chris J. Sumner	MRC Institute of Hearing Research, University Park, Nottingham, NG7 2RD, UK	Differential effects of multiple anaesthetic regimes on spontaneous, sensory and multisensory recordings from guinea pig sensory cortex	Anaesthesia is widely used in in vivo studies of sensory neural processing. Previous studies of the effects of systemic general anaesthesia on neurons in the auditory cortex have shown significant changes to frequency tuning and responses to basic features within the stimulus such as onsets and offsets. Studies of this nature have typically used a single anaesthetic agent, comparing awake and anaesthetised states, and it remains unclear to what extent the choice of anaesthetic agent will affect basic response properties of neurons to sensory stimulation. EEG is a widely used technique in humans and as it is a relatively simple protocol to implement in animals could provide an important methodological bridge between species. However, the effects of anaesthesia on EEG are relatively poorly characterised in animals. Electrophysiological recordings were made with chronically implanted, extradural electrodes, positioned over auditory and visual cortices. Recordings were made both while awake and under a range of anaesthetic regimes including opiates, NMDA antagonists and GABA potentiators. Recordings of spontaneous oscillations replicate the results of previous human studies, showing a rapid increase in power of low-frequency (<10Hz) oscillations at loss of consciousness, most prominently in the visual regions, and suppression of high frequency activity - effects which appear mostly independent of anaesthetic regime. Responses to a range of basic sensory stimuli such as auditory clicks, visual flashes and sequences of adapting stimuli were also recorded. Unlike spontaneous activity, we observed substantive differences in processing of even basic sensory stimuli between anaesthetic regimes. For example, the cortical auditory evoked potential in response to a broadband click shows an early (~25ms) and late (~50ms) deflection. Under ketamine anaesthesia both potentials were suppressed, diazepam suppressed the early potential but enhanced the later one and fentanyl and urethane both increased the size of the early potential but abolished the later one. We have also observed significant changes between anaesthetics in response latencies and, under all anaesthetic regimes tested, auditory-visual interactions were substantially suppressed. In conclusion, we have demonstrated that anaesthesia has significant effects on systems level sensory processing and that the choice of anaesthetic used for recording can have grossly different effects on the response to even simple sensory stimuli.

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78	Poster	Pingbo Yin, Shihab A. Shamma, Jonathan B. Fritz	Neural System Lab, Institute for System Research, University of Maryland, College Park.	Primacy of Frequency over Amplitude Modulation Rate in Retrieval of Auditory Memory	In order to explore the representation of sound features in auditory memory and the role of dorsolateral frontal cortex (dlFC) in auditory long-term memory, we developed an auditory task that requires information retrieval from an auditory long-term memory (LTM) store. Two ferrets were each trained on two versions of a 3-zone classification task based upon the acoustic features of either: 1) tone frequency (TN-task), or 2) amplitude modulation rate with white noise carrier (AM-task). While tone frequency and AM rate form a continuous distribution, in the LTM tasks both TN and AM sounds were divided into three distinct zones (Low, Middle and High) with clear boundaries. The animals were trained with a positive reinforcement Go/No-Go paradigm, with one stimulus presented in each trial. They learned to approach a waterspout for reward (Go-response) when a sound from the Middle zone was presented, and to avoid a time-out by not licking the waterspout (No-Go response) after a sound from either the Low or High zone was presented. Animals were initially trained on the TN-task, and after reaching behavioral criterion, were then trained on the AM-task. After learning both tasks to criterion, acoustic probes (unrewarded) were presented during task performances. Four sets of probe testing were conducted, in which animals were engaged in: A) the TN-task with AM noise as probe sound, B) the AM-task with the TN as probe sound, C) the TN-task or D) the AM-task with a hybrid combination of AM and TN as probe sounds (i.e. AM modulated tones). The ferrets showed no influence of task-set on probe trial performance i.e. displayed similar discrimination behavioral response to sounds whether they were presented in a probe-free task, or if the same sounds were played as probes while the animals engaged in different task (testing-A,B). Our results show that animals were able to simultaneously activate both classification systems during a session with mixed stimuli. However, when the AM-TN combination (hybrid) probes were used, we found that the frequency feature dominated behavioral choice - no matter whether the animals were engaged in either the TN-task or AM-task (testing-C,D). These results suggest that the frequency feature has primacy over the AM feature during retrieval of the auditory LTM. We recorded from single units in the dlFC in the different task and test conditions in order to gain insight into the neural basis of these behavioral results and to explore how the frontal cortex encodes, represents, classifies and retrieves the associative meaning of different sensory stimuli during passive stimulus presentation and during performance of multiple tasks.

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91	Poster	Yang Zhang (1), Yue Ding (1), Juan Huang (3), Wenjing Zhou (2), Zhipei Lin (5), Bo Hong (1), Xiaoqin Wang (4,1)	(1)Department of Biomedical Engineering and Tsinghua-Johns Hopkins Joint Center for Biomedical Engineering Research, Tsinghua University, Beijing 100084, P.R. China (2) Department of Neurosurgery, Yuquan Hospital, Tsinghua University, Beijing 100084, P.R. China (3) Zanvyl Krieger Mind/Brain Institute and Dept. of Biomedical Engineering, The Johns Hopkins University, Baltimore, Maryland 21205, USA (4) Department of Biomedical Engineering, The Johns Hopkins University, Baltimore, Maryland 21205, USA (5) Department of Neurosurgery, PLA General Hospital, Beijing 100084, P.R. China	Hierarchical neuronal representations of sound categories in human brain	The discrimination and recognition of different categories of sounds are assumed to be processed by functionally specialized cortical areas. However, the specific locations of these areas and the neural mechanisms underlying sound discrimination and recognition are largely unknown. We used both electrocorticographic (ECoG) and functional magnetic resonance imaging (fMRI) techniques for brain activity recording. Five different categories of voice and non-voice complex sounds (including voiced speech, scrambled voiced speech, non-speech voice sounds, animal vocalizations and natural sounds) were used to investigate the roles of various cortical areas in processing sound categories. Our results revealed potential hierarchical organizations of sound category processing. Neural signals recorded from individual ECoG electrodes in five epilepsy patients showed different selectivity to distinct sound categories. After mapping the ECoG signals (60-140Hz) onto the average brain surface, we identified four responsive sites in the left hemisphere (anterior STG, middle STG, posterior STG and middle pre-central areas) and three responsive sites in the right hemisphere (anterior STG, middle STG, posterior STG) that exhibited sound category selectivity. Furthermore, using peak latency and Granger causal connectivity analysis (GCCA), we observed a progression of cortical activity corresponding to sound category from middle STG to anterior STG and from middle STG to posterior STG, respectively. More specifically, we found anterior STG of the left hemisphere only responded to Chinese voiced speech, which may indicate its involvement in the processing of lexical information. We also found the activation of middle pre-central areas in the left hemisphere, which may indicate the implicit transformation of acoustic representation to sensorimotor representation. These findings suggest a potential hierarchical processing of sound category in the human brain.

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33	Poster	Nathaniel Zuk (1) Bertrand Delgutte (2)	(1,2) Eaton-Peabody Laboratories, Massachusetts Eye and Ear Infirmary, Boston, MA (1,2) Harvard-MIT Division of Health Sciences and Technology, Cambridge, MA (1,2) Program in Speech and Hearing Bioscience and Technology, Harvard University, Cambridge, MA (2) Research Laboratory of Electronics, MIT, Cambridge, MA	Rate and temporal coding of dynamic ITD and amplitude modulation in the inferior colliculus may explain differences in psychophysical detection limits	Humans cannot detect temporal variations in binaural cues such as interaural correlation or interaural time differences (ITD) at frequencies above 20-50 Hz where they can still detect monaural amplitude modulation, suggesting that binaural processing is "sluggish" compared to monaural processing (Grantham & Wightman, J. Acoust. Soc. Am. 63:511; Grantham, J. Acoust. Soc. Am. 72:1178). Even so, broadband noise with a time-varying ITD remains discriminable from spatially-static noise at frequencies above 50 Hz. In the inferior colliculus (IC) of the auditory midbrain, many neurons exhibit tuning to the frequency of both time-varying ITD and amplitude modulation in their average firing rate and phase-locking strength. Very few studies, however, have compared these in the same neurons. Here, we compared the neural coding of dynamic ITDs and sinusoidal amplitude modulation (SAM) by the same single units in the IC of unanesthetized rabbits. Both the frequency of maximum phase-locking and the upper frequency limit of phase-locking were lower on average for dynamic ITD than for SAM. This finding may be a neural correlate of binaural sluggishness. Additionally, firing rates for dynamic ITDs above 64 Hz deviated significantly from firing rates to an unmodulated stimulus presented at the center of the range of dynamic ITDs. This could allow dynamic ITDs to remain discriminable from spatially-static sounds at high modulation frequencies. Overall, our results suggest that the mechanisms underlying sensitivity to time-varying binaural and monaural features are at least partly distinct and that these differences may explain the differences in psychophysical detection limits observed in humans. Supported by NIH Grants R01 DC002258, P30 DC005209 and T32 DC000038, and by an Amelia-Peabody Scholarship from the Massachusetts Eye and Ear Infirmary.