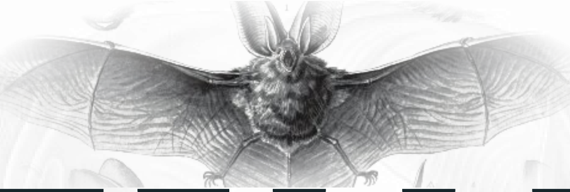

BATELLITE

Bats in Neuroethology

A Satellite Meeting of the International Congress of Neuroethology · ICN 2026

Sunday, July 26, 2026

University of British Columbia · Vancouver, BC, Canada

Brock Commons South · Room 1030

8:00 – 8:50	**Breakfast & Registration**		
8:50 – 9:00	**Welcome & Opening Remarks**		
9:00 – 10:30	**Session 1** — Trainee talks		
	• Satoki Michimoto	• Shane Seheult	• Zhongdan Cui
	• Zaria George	• Soshi Yoshida	• Simon Bauerle
10:30 – 11:00	*Coffee Break*		
11:00 – 12:30	**Session 2** — Trainee talks		
	• Shivani Hariharan	• Alexa Clarke	• Léo Demange-Hamel
	• Alberto Doimo	• Magdiel Jaroszewski	• Huan Ye
12:30 – 13:30	*Lunch & Poster Session*		
13:30 – 14:30	*Poster Session*		

PLENARY LECTURE

14:30 – 15:30 **Dr. Cindy Moss**
Johns Hopkins University

Finding the right research model to answer my scientific questions: The echolocating bat emerges again and again

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International Society for Neuroethology

BATELLITE · BATS IN NEUROETHOLOGY

Poster Presentations

On display during the lunch and poster sessions (12:30 – 14:30).

CONFIRMED POSTER PRESENTERS

- Tang Tang Guo
- Iñaky Marin
- Susanne Babl
- Jinhong Luo
- Eli Farber
- Jianan Ding
- Jiwon Lee
- Frithjof Küster
- Sophie Holtz

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Talks

Sessions 1 & 2 · Trainee talks

01 Maintained auditory function during aging in the Japanese house bat: Auditory brainstem response and hair cell analysis

Satoki Michimoto, Kazuki Yoshino-Hashizawa, Kazuki Tanaka-Shin'ya, Kohta I. Kobayasi, Shizuko Hiryu
Graduate School of Life and Medical Sciences, Doshisha University

Bats are known for their longevity despite their small body size, and rely on high-frequency sounds for navigation and foraging. Hearing is generally known to be susceptible to aging. Therefore, bats, which depend on hearing throughout life, may possess unique resistance mechanisms. In this study, we compared auditory function between young and old awake Japanese house bats (Pipistrellus abramus) by measuring auditory brainstem response (ABR) using 11 frequencies from 10 to 80 kHz. ABR were obtained by averaging evoked potentials in inferior colliculus. We evaluated latencies and hearing thresholds calculated from the ABR between age groups. As a result, no significant differences in thresholds were observed between the young and old groups, suggesting that bats may maintain auditory function despite aging, even though they are routinely exposed to intense echoes and vocalizations from conspecifics. To clarify the mechanism underlying the maintenance of auditory function, we additionally performed staining of cochlear hair cells and compared the results with C57BL/6 mice that exhibit age-related hearing loss. The cochleae of bats and mice were divided into three regions (apex, middle, and base) and stained separately. Bats exhibited the highest number of outer hair cells in the base, slightly higher than that observed in mice, while no interspecific differences were detected in the other regions. Since one known cause of age-related hearing loss is the loss of cochlear hair cells, particularly in the basal region, these findings suggest that the greater number of cells in the basal region of bats may make them less susceptible to age-related cell loss. Overall, our results suggest that Japanese house bats preserve auditory function with age, supported by a greater number of hair cells in the basal region as well as molecular-level mechanisms such as cellular morphology and specific protein expression.

02 A Tale of Two Ears: Development of Binaural Auditory Processing in Big Brown Bats

Shane Seheult, Sophie Molina, Nita Chan, Paul A. Faure
McMaster University

Big brown bat (Eptesicus fuscus) pups are born naked, blind, and with closed external auditory canals that later open asymmetrically. It remains unclear whether this developmental asymmetry influences hearing. We visually examined the ears of newborn bat pups (n = 82; 42 female) and found a 1 ± 1 (mean ± SD) post-natal day difference between when both ears opened. After both ears opened, we recorded auditory brainstem response (ABR) waveforms in a subset of pups by placing subdermal needle electrodes near the base of the auditory bullae, repeatedly presenting broadband acoustic clicks and averaging the evoked response (bandwidth = 84 kHz; duration = 0.1 ms; n = 512 repetitions). We recorded ABRs at 2, 3, 4, 8, and 16 weeks of age plus 1 year of age and compared monaurally- and binaurally-evoked hearing thresholds. In pups <4 weeks old, monaural thresholds were lower in the ear that opened first compared to the opposite ear; however, by 16 weeks of age there was no longer a prominent threshold difference. Binaurally-evoked thresholds were lower (i.e. more sensitive) than monaurally-evoked thresholds in both juvenile and adult bats. Peak latencies were smaller and peak-to-peak amplitudes were larger in ABR waveforms evoked from stimulating the ear that opened first, indicating faster processing and more neurons recruited to respond. Across development, peak latencies got smaller and amplitudes got larger, whereas peak widths were consistent. Our data suggest that the initial asymmetry in ear opening and auditory processing may help pups localize sounds until their central circuits that compute interaural timing and level differences mature.

03 A predictive neural code for vocalization rate in the auditory midbrain

Zhongdan Cui, Huan Ye, Zhenxu Liu, Jinhong Luo
School of Life Sciences, Central China Normal University

Vocalization rate is a core temporal feature actively regulated by acoustically signaling mammals, including humans. However, the neural mechanisms by which the mammalian brain encodes this behaviorally relevant parameter remain largely unknown. By leveraging the highly dynamic vocal behavior of the echolocating bat, we demonstrate that the auditory midbrain (inferior colliculus, IC) is a critical brain region for encoding instantaneous vocalization rate. We found that most IC neurons preferentially encode vocalization rate via the reciprocal of the call interval, rather than the interval itself, a computational strategy that maximizes neural resolution for the rapid temporal demands of echolocation. Surprisingly, a subset of these neurons represented both the current and future vocalization rates. Using a simple population decoding model involving only a few cells, we could decode vocalization rate with an accuracy of approximately 3 Hz. Our finding of predictive rate representations in the midbrain identifies a core neural substrate supporting the precise echolocation control in bats.

04 Context-Driven Behavior Operates Independent of Physiological Responses in R. aegyptiacus

Zaria George, I. Marin, A. Salles
University of Illinois Chicago

The socio-emotional context of sound is essential to how we communicate throughout our day-to-day lives. However, how we as mammals contextually modulate those auditory cues and assign them social value remains largely unknown. A tractable mammalian model for investigating this knowledge gap is the bat Rousettus aegyptiacus. R. aegyptiacus, like most bats, is an auditory specialist that can emit echolocation calls used for navigation, as well as social communication calls used to convey their internal state. Using physiological methods, we investigate the distinct mechanisms underlying the perception of different calls from the repertoire of R. aegyptiacus. Heart rate monitoring during playback experiments was leveraged to identify the physiological valences of specific call types. We further employed in vivo electrophysiological recordings of the primary auditory cortex (A1) to investigate the neuronal mechanisms underlying the perception of these calls. Both physiological practices provided direct insight into how social sounds are processed independent of a social setting. The speaker test, a playback experiment, allowed us to determine the role of context on the behavioral valence of distress calls in this species. This work establishes foundational links between contextual modulation and auditory processing of social communication in mammals, with implications for understanding human disorders of social communication.

05 Functional Roles of CF and FM Components in the Foraging Strategy of Horseshoe Bats

Soshi Yoshida, Haruhito Matsumoto, Apolline Wuhrlin-Damgé, Shizuko Hiryu
Doshisha University

Echolocation in horseshoe bats is based on a unique CF–FM signal design that combines a constant-frequency (CF) component with a frequency-modulated (FM) component. Whereas FM signals are widely used in many bat species and suited for object localization, CF signals are considered particularly suited for detecting fluttering prey. In this study, we investigated the respective roles of CF and FM components in prey localization. Pulse emission direction was recorded using a microphone array, while bat and prey positions were tracked with a motion capture system to quantify prey localization accuracy. During the attack sequence following prey detection, we applied band-limited noise targeting the CF component, the FM component, or a control frequency band, and analyzed the resulting changes in emission accuracy and capture behavior. Masking the CF component caused the pulse emission direction to deviate from the prey and resulted in the complete abandonment of capture attempts. In contrast, when the FM component was masked, bats continued to direct their pulses toward the prey and still attempted capture; however, flight speed decreased as bats approached the prey, hovering behavior increased, and capture time was prolonged. These results indicate that glint information reflected in the CF component functions not only as a detection cue but also as a directional localization cue during the approach phase, while during the final capture phase the FM component provides essential distance information. This functional dissociation demonstrates a complementary utilization strategy in which CF and FM components are adaptively engaged according to behavioral context.

06 Complex Social Vocalizations are Integrated into the Bat Wingbeat Cycle during Flight

Simon Bauerle, Leonie Reetz, Annette Denzinger
Animal Physiology, Institute for Neurobiology, University of Tübingen, Germany

Acoustic communication plays a central role in animal social behavior and exhibits remarkable complexity in various taxa. In bats, the emission of echolocation calls is known to be tightly coupled to wingbeat and respiratory rhythms. However, little is known about how complex social vocalizations are coordinated with the mechanics of powered flight. We therefore investigated how complex social calls are integrated into flight of wild Nathusius' pipistrelles (Pipistrellus nathusii). Using synchronized audio and video recordings, we quantified wingbeat dynamics and call timing during natural flight and reconstructed the temporal structure of complex social calls relative to the underlying wingbeat cycle. We found that social calls are seamlessly embedded within the ongoing echolocation behavior and consistently span three consecutive wingbeats. Within these social calls, motif durations scale with syllable number, whereas motif onsets are phase-locked to narrow, preferential phases of the wingbeat cycle. Our findings provide evidence that complex social calls in bats are integrated into the wingbeat during flight, demonstrating that vocal-locomotor coupling extends beyond echolocation to shape the structure of social communication. By mitigating the high energetic costs of vocalizing, biomechanical integration may have facilitated the evolution of complex vocal communication in bats.

07 Frontal Cortex Regulates Echolocation Under Acoustic Interference in Bats

Shivani Hariharan, Francisco Lopez, Susanne S. Babl, Nika Jurov, Jochen Triesch, Julio C. Hechavarria

Ernst Strüngmann Institute of Neuroscience & Freie Universität Berlin

Bats echolocate to navigate in silent and noisy environments, but how they adjust their vocal behaviour in noise remains debated. Here, we examined echolocation behaviour in fruit bats (Carollia perspicillata) swung in a pendulum under silence, continuous broadband noise, and rhythmic 4 Hz amplitude-modulated noise. We report that bats generally respond to broadband noise (whether continuous or rhythmic) by increasing call intensity, prolonging pulse duration, and lowering call pitch. Under rhythmic noise, they additionally adjust call timing, preferentially emitting echolocation pulses during low-amplitude ("dip") phases. The latter reveals a temporal strategy for dealing with acoustic interference, which we term dip-targeted echolocation. We show that dip-targeted echolocation is consistently present across individuals of both sexes and observed in both laboratory pendulum experiments and in freely flying wild bats. In addition, we describe that muscimol-induced frontal cortex inactivation impairs dip-targeted echolocation, implicating high-order cortical areas in echolocation timing.

08 Exploring the role of FoxP2 in the auditory cortex of a vocal learning bat using transient transgenic models

Alexa C. Clarke, Nikita E. Groot, Benjamin Thompson, Ine Alvarez van Tussenbroek, Sonja C. Vernes

University of St Andrews

FoxP2 is a highly conserved transcription factor that is implicated in animal vocal learning and human speech development. In humans, heterozygous mutation of the FOXP2 gene results in childhood apraxia of speech. To better understand the role of FoxP2 in speech and language learning, we have developed targeted methods for manipulating FoxP2 expression in pale spear-nosed bats (Phyllostomus discolor). These bats are one of the rare mammals capable of vocal production learning (VPL), the ability to learn to produce new vocalizations by listening to those of other individuals. VPL is key to human speech development as well as bat, cetacean and elephant social vocalization development, and songbird song learning. In all cases, auditory input of external vocalizations and auditory feedback from produced vocalizations are important for successful VPL. Dynamic FoxP2 levels in regions of the songbird brain involved in VPL have been shown to impact the fidelity of song learning. We are exploring the role of FoxP2 in mammalian VPL using our transient transgenic bat model. Using a custom viral vector for transgene delivery, we unilaterally overexpressed FoxP2 in the P. discolor auditory cortex (AC), which lacks FoxP2 in adults. We are measuring single-unit neural activity in the AC in response to auditory stimuli, with a focus on conspecific social vocalizations, to assess the within-subjects effect of FoxP2 overexpression on auditory processing. This work aims to uncover how FoxP2 impacts the processing of auditory information required for successful VPL—both the initial external vocal input and the auditory feedback.

09 Neuronal Entrainment to Ecologically Relevant Rhythms in the Auditory Cortex of Frugivorous Bats

Léo Demange-Hamel, Susanne S. Babl, Julio C. Hechavarría

Freie Universität Berlin; Ernst Strüngmann Institute, Frankfurt am Main

The auditory specialist Carollia perspicillata, a frugivorous bat, lives in a rich acoustic environment, comprised of a multitude of simultaneously ongoing vocalizations in the colony. An important feature of this complex soundscape is its rhythmicity, which may be exploited by the bat's auditory system to predict upcoming stimuli and guide behavior. However, the way neuronal activity in the auditory system entrains to such rhythmic stimuli is incompletely understood. We presented head-fixed, awake bats with rhythmic acoustic click trains in several temporal frequencies naturally present in their environment, while recording firing rates in the auditory cortex. Neurons showed clear tracking of the stimulus phase at the single-cell level, especially at 6 Hz, a rate naturally present in bat vocalizations. Interestingly, some neurons responded to lower rate clicks (2 Hz) with additional excitation peaks, rendering a rhythmic response at around 4 Hz. A similar activity rhythm was also observed in some neurons in the absence of rhythmic stimuli, indicating intrinsic rhythmic activity. Taken together, this evidence puts the auditory cortex in a privileged position to follow and predict ecologically relevant rhythms in the bat's environment.

10 RO-BAT and SonoRo: bio-inspired swarm robotics platforms for audio-driven navigation

Alberto Doimo, Gabriele Baroli, Heiko Hamann, Andreagiovanni Reina, Thejasvi Beleyur
Max Planck Institute of Animal Behavior; University of Konstanz

Bats achieve agile flight and coordinated collective motion by relying on echolocation, even within dense swarms where numerous overlapping acoustic signals give rise to the so-called Cocktail Party Nightmare. Bats can detect the location of nearby individuals in two ways: either through active echolocation by emitting calls and listening for their echoes, or by passively listening to the calls and echoes produced by their neighbours. Inspired by these remarkable capabilities, we introduce RO-BAT and SonoRo, two bio-inspired robotic platforms designed to explore principles of echolocation and acoustic sensing. SonoRo is a passive sound-localisation platform that locates external sound sources by listening to external beacons. We equipped SonoRo with an array of microphones for sound localisation and a loudspeaker to broadcast beacon sounds, and demonstrated it in four acoustic navigation scenarios: collision avoidance with static sound sources, goal finding in a static environment, multi-agent aggregation, and multi-agent dispersion. Building on SonoRo, we then implemented active echolocation in the RO-BAT, developing a signal processing pipeline capable of extracting both range and directional information from returning echoes. Laboratory experiments demonstrated that the RO-BAT could autonomously detect and avoid obstacles using only self-generated acoustic cues, effectively reproducing the core principles of bat echolocation in a robotic platform. Our current research focuses on scaling up swarms of autonomous SonoRos and RO-BATs into fully decentralised collectives, hypothesising that strategies evolved by bats to cope with overlapping acoustic signals can inform scalable and resource-efficient sensing in robotics.

11 Cue-Guided Decision-Making in the Echolocating Bat

Magdiel Jaroszewski, Nikita Finger, Davi Drieskens, Keegan Eveland, Cynthia Moss
Johns Hopkins University

Goal-directed navigation requires flexible decision-making. Sensory cues acquired during navigation may guide decision-making strategies to assess potential outcomes. Bats, known for their reliance on sonar for 3D orientation, provide powerful research models for investigating decision-making during cue-guided navigation. Vicarious trial and error (VTE), a future-oriented decision-making process characterized by head-scanning in rodents, has been observed following navigational errors. While the cognitive processes underlying VTE remain debated, it is not known whether bats exhibit comparable overt decision-making behaviors during navigation. Here, we investigate whether big brown bats increase head-scanning and modulate sensory sampling via echolocation following navigational errors and under conditions that vary the temporal delay between cue onset and action. Four bats were trained to locate a landing perch in the dark and associate distinct sensory cues with the perch's physical location. We systematically varied the working memory demands required to maintain cue information prior to action by manipulating the delay between cue presentation and choice. We compared sonar beam direction, call rate, and head angular displacement between successful trials, those following invalid trials that misdirected the animal, and across delay conditions. The directional aim of the bat's sonar beam and head angular displacement at the choice point served as a metric for deliberative decision-making. This research offers insight into future-oriented decision-making behavior in echolocating bats and memory demands on adaptive navigation strategies.

12 Prevalent mismatch between behavioral and physiological audiograms across mammals

Huan Ye, Shiyu Zhou, Qianyu Wang, Jinhong Luo
Central China Normal University

Behavioral and physiological audiograms are widely used to assess auditory sensitivity in animals. Many studies have compared the differences between the two types of measurements, but they were often overlooked in practice, with physiological audiograms frequently used as direct proxies for perceptual hearing sensitivity. In this work, we measured behavioral audiograms in Pratt's roundleaf bat (Hipposideros pratti) using a two-alternative forced-choice (2AFC) paradigm, and obtained physiological audiograms using auditory brainstem responses (ABR) and inferior colliculus (IC) evoked potentials. We found striking mismatches between behavioral and physiological audiograms, particularly near the peak frequency of echolocation calls. We further examined the effect of body temperature on ABR audiograms in H. pratti, Hipposideros armiger, and Eptesicus serotinus, demonstrating that ambient temperature regulation is insufficient to stably maintain body temperature in anesthetized bats. Reduced body temperature significantly elevated ABR thresholds by up to ~20 dB near peak and end frequencies, consistently across species. Additionally, we compiled published audiograms from 10 bat species and 15 other mammalian species; comparative analysis revealed that mismatches between behavioral and physiological audiograms are widespread in mammals. Our findings highlight the importance of body temperature monitoring during physiological recordings and caution against directly equating physiological thresholds with perceptual sensitivity.

ABSTRACTS

Posters

On display during the lunch and poster sessions

01 Parent–Offspring Conflict and Sibling Competition in the Big Brown Bat

Tang Tang Guo, Joanna Zhu, Sigal Balshine, Paul Faure
McMaster University

Parent–offspring conflict occurs when there is a disagreement over parental resource allocation. Sibling competition occurs over allocated parental resources, such as food. Big brown bats (Eptesicus fuscus) are an interesting model to study both conflicts because in western North America they give birth to a single pup whereas in the east they give birth to twin pups. We assessed parent–offspring conflict and sibling competition in a captive breeding colony of E. fuscus by recording maternal care behaviours in mothers (n = 16) and solicitation behaviours in pups (n = 32)—first with one pup and then with a sibling—over the first 30 days of life. Mothers initiated fewer maternal interactions as pups aged, and pups required more attempts to attach to their mother's teat as they aged. Interestingly, moms initiated care more frequently when presented with both of their pups compared to a single pup. The presence of a sibling also made it more difficult for a pup to attach to its mother's teat, but only early in development. We then experimentally manipulated pup health status (n = 23) to determine how changes in body temperature or feeding status affected the temporal and spectral qualities of the isolation calls that pups emit to solicit maternal care. Pups in the cold arena emitted longer duration isolation calls compared to the warm arena. Consistent with parent–offspring conflict theory, our preliminary data reveal that parental investment declines over development, and that moms differentially allocate maternal care in the presence of one versus two pups.

02 Bats dynamically shift harmonic energy to counter acoustic interference

Jianan Ding, Meidi Yuan, Jinhong Luo
School of Life Sciences, Central China Normal University

Previous studies of noise-robust echolocation in bats have primarily focused on adjustments of the dominant harmonic, overlooking potential coordination among harmonics. Here, we test whether Hipposideros pratti flexibly regulate harmonic structure under broadband noise, narrowband noise, and heterospecific acoustic interference. Across conditions, all harmonic amplitudes increased with increasing noise levels. However, narrowband noise induced frequency-specific modulation: when noise overlapped with the second harmonic, amplitude increased for all harmonics, whereas overlap with the first harmonic only induced increases of the first harmonic, and overlap with the third harmonic produced no significant changes. Under heterospecific acoustic interference, amplitude modulation was generally coordinated across harmonics, except for Myotis pilosus calls that elicited disproportionately greater increases in the first and third harmonics. These amplitude changes also led to corresponding increases in the power ratios of H1 and H3. Specifically, bats showed a selective increase in the power ratio of H1, but not H3, in response to acoustic interference, indicating asymmetric redistribution of acoustic energy across harmonics. Together, our results reveal a previously underappreciated mechanism in which bats maintain echolocation robustness through flexible, coordinated control of harmonic amplitude.

03 Circadian Microbial Oscillations in Carollia perspicillata

Iñaky Marin, Kiersten Oderman, Jarrad Hampton-Marcell, Angeles Salles
University of Illinois at Chicago

Circadian oscillations in the gut microbiome contribute to host metabolic and immune regulation and are well characterized in laboratory rodents and humans. In these systems, microbial rhythmicity is closely linked to feeding cycles and host circadian gene expression, yet most evidence derives from mammals with slow gut transit and fermentation-rich digestive physiology. Whether comparable temporal organization occurs in mammals with rapid transit and reduced fermentation capacity remains unclear. Here, we characterized diel gut microbiome changes in Seba's short-tailed fruit bat (Carollia perspicillata), a species with streamlined digestive physiology associated with powered flight. Across two independent cohorts sampled repeatedly during inactive and active phases, we quantified microbial composition and functional potential alongside automated behavioral tracking. We identify pronounced phase-dependent restructuring of the microbiome, with distinct taxa enriched during resting and active periods. Several taxa commonly associated with pathogenicity in other mammals exhibit stable rhythmic abundance in bats, indicating that temporal organization is maintained within this rapid-transit, Proteobacteria-rich system. These findings extend circadian microbiome research to a physiologically distinct mammal and provide a foundation for future mechanistic investigation of host–microbe temporal dynamics.

04 Comparing oxytocin and vasopressin receptor distribution in pregnant and non-pregnant bats

Jiwon Lee, Rosa Mendoza, Angeles Salles
University of Illinois Chicago

Oxytocin and arginine vasopressin have significant roles in regulating social behaviors. In rodents, oxytocin receptor expression shifts dynamically during the transition to motherhood, and cortical oxytocin signaling enables pup retrieval by enhancing responses to pup calls in the auditory cortex. Despite this growing understanding in rodents, comparatively minimal research has been done on oxytocin receptor (OXTR) and arginine vasopressin receptor (AVPR) distribution in the bat brain. The Seba's short-tailed bat, Carollia perspicillata, is a highly social mammal with complex social communication, making it a unique model for investigating the neuroendocrine regulation of maternal behaviors. Here, we examined OXTR and AVPR expression in pregnant and non-pregnant female bats across the auditory cortex (AC) and four brain regions involved in the social behavior network: the amygdala, prefrontal cortex, ventral pallidum, and nucleus accumbens. We found that OXTR and AVPR expression was broadly distributed throughout the five brain regions in pregnant females, whereas expression patterns were more variable in non-pregnant females. These findings provide the first characterization of OXTR and AVPR distribution in pregnant and non-pregnant C. perspicillata and establish a necessary foundation for understanding how oxytocin and vasopressin modulate maternal and socially relevant auditory behaviors in bats.

05 Foraging behavior of frugivorous bats using multisensory information

Susanne Babl, Julio Hechavarría
Freie Universität Berlin

Animals live in an environment cluttered with signals from multiple modalities. To obtain a full image of their surroundings and make adaptive decisions, these multisensory inputs must be constantly integrated and evaluated by the brain. The frugivorous bat Carollia perspicillata is a specialist in multimodal integration. Firstly, these animals heavily rely on acoustic information, not only sensing their environment through active echolocation, but also perceiving a multitude of social vocalizations from conspecifics. Secondly, they depend on olfactory cues to locate food sources such as fruiting trees. But how acoustic and olfactory information is integrated during a complex behavior such as foraging, and how this information is used to make adaptive decisions, is not understood. To address these questions, we investigated foraging behavior of wild Carollia in the tropical rainforest of Panama, when they were exposed to different olfactory and acoustic stimuli. We set up feeding stations close to several roosting sites. In pilot experiments, we presented odorants from ripe fruit, fermenting fruit, and plant secondary metabolites with repellent properties. Additionally, we presented playbacks of conspecific vocalizations, namely sequences of echolocation calls or distress calls, interleaved with silent periods from an ultrasound speaker. Approaches and feeding behavior of bats were monitored with high-speed infrared cameras and ultrasound microphones. Preliminary results reveal that bats approach feeding stations in groups of several individuals and that both olfactory cues and acoustic playbacks influence foraging behavior in a stimulus-specific manner.

06 A Multi-Sensor Approach for Characterizing Echolocating Bat Swarms

Frithjof Küster, Thejasvi Beleyur
University of Konstanz

Most species of bats heavily rely on their specialized ability to echolocate for sensing their environment. Whether hunting, navigating or just plainly avoiding obstacles, they are specialized to live in darkness, when their other sensory modalities simply cannot supply the necessary information to prevail. However, this system of active sensing comes with a drawback widely studied in engineering and signal processing: predisposition to noise, especially to “false” signals generated by other agents. Due to high similarity in signal frequencies and acoustic features, the faint echoes of a navigating bat can be overlaid with sounds virtually indistinguishable from the true signal and even be masked entirely by overlaying noise. So, how can bats coexist in large colonies, socialize in flight under complete darkness and even exhibit large swarm movements? In my doctoral project at the Active Sensing Collectives Lab, I use a field-based multi-sensor rig to record bat echolocation and behavior in groups and swarms of free-living bats. We use LiDAR scans of bat swarming sites to get a full 3D representation of the environment and align thermal footage trajectories into this simulated environment. Acoustic recordings are made with an extensive >60 microphone rig, mounted on the cave wall and calibrated spatially for accurate capturing of ultrasonic sound pressure levels. Together with collaborators from the Mathematics Department at the University of Lund, we aim to use the complex pattern of time-of-arrival differences to spot the identities of individual callers in the swarm. Combined, this yields an unprecedented 3D representation of every call and every movement of every bat in a swarm, offering a unique view into the struggles and strategies underlying the impossible feat of swarm echolocation.

07 Old-world Leaf-nosed Bats as a Mammalian Model for Studying Vocal Frequency Control of Mammals

Jinhong Luo, Nina Ma, Zhongdan Cui, Zhenxu Liu, Huan Ye
Central China Normal University

Much of the information in human speech is encoded by modulating the energy distribution of spectral content. Similarly, a growing number of animals demonstrate flexible control over the spectral parameters of their vocalizations. Some echolocating bats, in particular, achieve extremely rapid and highly precise frequency control—a capability unparalleled by most other species. In this presentation, I introduce Old World leaf-nosed (roundleaf) bats (Hipposideridae) as a model for understanding the neurobiological mechanisms of precise frequency control in mammals. We first demonstrate that Pratt's roundleaf bats dynamically adjust their frequency precision while pursuing insect prey, achieving a best average precision of 0.15% of the echo frequency. This is approximately 5–10 times more precise than the pitch control of professionally trained human singers. Using a high-speed FPGA system to provide frequency-shifted playback to vocalizing bats, we found that these animals rely on sensory prediction errors to fine-tune call frequency, a process computationally equivalent to the mechanisms governing human speech. Finally, we established a chronic electrophysiological setup to record extracellular single-unit activity in the auditory midbrain (inferior colliculus) of freely vocalizing bats, and show that many midbrain neurons encode the peak frequency of both self-emitted calls and acoustic playbacks. Interestingly, a specific population of neurons exhibited distinct frequency tuning profiles when responding to self-emitted calls versus calls from conspecifics or pure tones. Together, these data suggest that roundleaf bats represent a promising model for understanding vocal production control in mammals.

08 Striosome-matrix dissociation during distinct vocal behaviours in bats

Sophie Holtz, Julio Hechavarria, Mirjam Knörnschild, Constance Scharff
Freie Universität Berlin; Museum für Naturkunde Berlin

Vocal communication requires flexible neural control integrating sensory, motor, and internal state information to produce context-appropriate vocal signals. Bats provide a powerful model to study such flexibility because they produce two functionally distinct vocalisation types: self-directed echolocation calls for spatial orientation and socially directed vocalisations for communication. However, the neural mechanisms enabling context-dependent switching between these vocal behaviours remain poorly understood. Here we mapped brain-wide expression of the immediate early gene Egr1 associated with context-dependent vocal behaviour in the bat Carollia perspicillata using in situ hybridisation. Adult males were recorded during echolocation, courtship behaviour, or quiet resting. Both vocal behaviours induced widespread neural activation relative to quiet controls across cortical, limbic, and midbrain vocal-motor networks. Across analytical approaches, however, the striatum emerged as a robust discriminator of vocalisation context. Echolocation strongly increased Egr1 expression in both the matrix and striosomal compartments of the caudate nucleus, whereas courtship only elevated expression in the striosomes. These findings parallel social-context-dependent basal ganglia dynamics described in songbirds. In line with known mammalian basal ganglia circuitry, we propose a striosome–substantia nigra pars compacta–matrix gating framework, in which striosomes may influence striatal dopaminergic tone and thereby bias matrix-mediated sensorimotor processing according to behavioural context. Together, our findings highlight compartment-specific basal ganglia dynamics as a potential neural mechanism for context-dependent vocal control in bats.

09 Hierarchical coding of categories and identities in the bat hippocampus

Eli Farber, Saikat Ray, Or Spiegel, Shaked Palgi, Liora Las, Nachum Ulanovsky
Weizmann Institute of Science

The hippocampus plays a key role in navigation and contains place cells, neurons that encode an individual's self-location. Natural navigation occurs in complex environments that contain various categories of agents, including animals of the same or different species, and objects. However, little is known about how the hippocampus encodes these diverse categories during navigation. Here, we performed wireless neural recordings from dorsal-CA1 hippocampal neurons of wild-caught bats, as they were flying toward conspecifics (other bats), heterospecifics (humans), or objects. Hippocampal neurons encoded the category (humans/bats/objects) and identity (e.g. human1 or human2), via a mechanism of gain-modulation of place-fields ('rate-remapping'), thus preserving the spatial tuning. The hippocampal neural population enabled excellent decoding of category and identity, and formed a hierarchical code, with identity nested within the representation of category. Thus, the hippocampus forms a structured neural code of categories and identities in parallel to the classical spatial code.