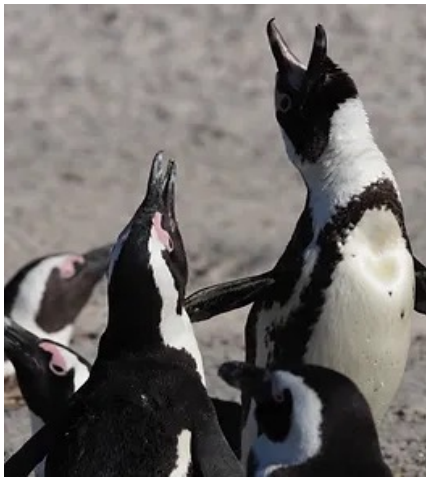
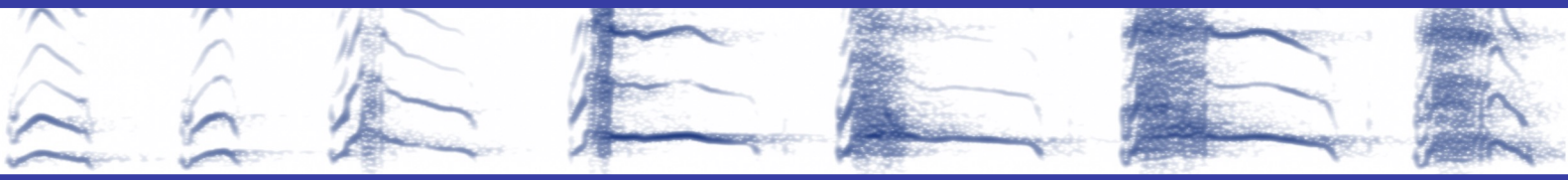


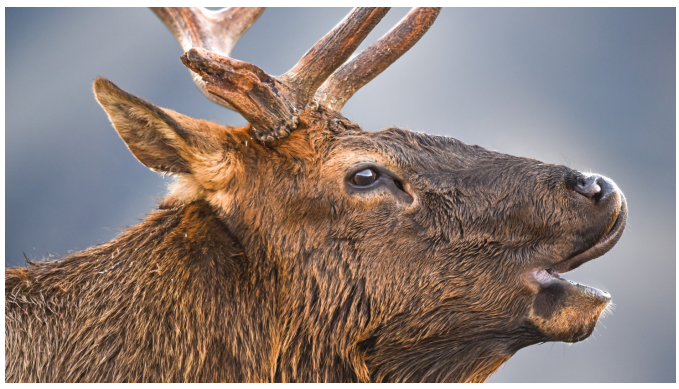


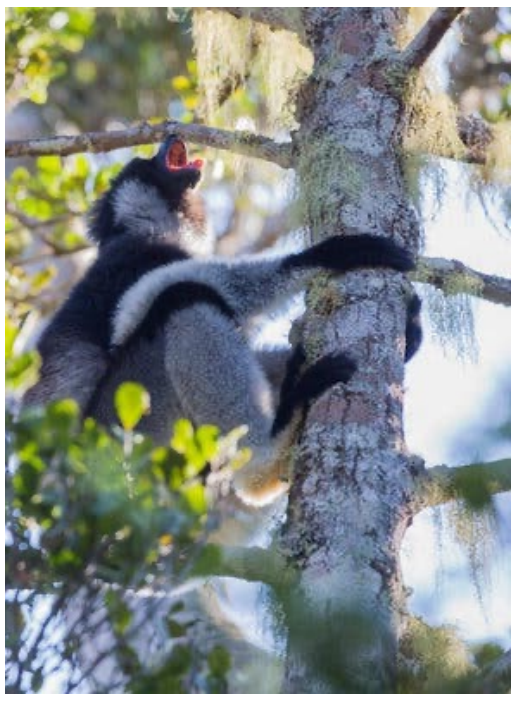

Nonlinear phenomena in vertebrate vocalisations: mechanisms and communicative functions



Symposium, June 14-16th 2023
Saint-Etienne, France

Organized by Mathilde Massenet, Nicolas Mathevon and David Reby (ENES lab)



ENES BIOACOUSTICS RESEARCH LAB
UNIVERSITÉ JEAN MONNET SAINT-ÉTIENNE
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LABEX CELYA UNIVERSITÉ DE LYON
FRANCE 2030

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Welcome!

Welcome to our beautiful city of Saint-Etienne ! ☺

This symposium is dedicated to current exciting and challenging research on nonlinear phenomena in animal and human vocalisations!

During these three days, we will discuss concepts and terminology, learn about cutting-edge methods and share our latest empirical research.
The symposium takes place at **Télécom Saint-Etienne** in the Manufacture campus.

25 Rue Dr Rémy Annino

See the map on page 15 for information on how to get there by public transport, and where to have lunch.

We have also planned some social time in the evenings at **La Cempote** (14/06) and **L' Escargot d'Or** (15/05).

If you any questions please contact us:
Mathilde +33 6 32 85 39 98; massenet.mathilde@gmail.com
David +33 7 72 25 74 46; david.reby@gmail.com

We hope you will enjoy this meeting and your stay !

Schedule

Wednesday, June 14th		
9h	Welcome with Coffee	
9h30	Tecumseh Fitch	Applying nonlinear dynamics to the voice: A historical perspective
10h	Hanspeter Herzel	What are nonlinear phenomena ?
10h30	Christian Herbst	Bioacoustic signal analysis with Praat – lessons learned, and questions asked
11h	Coffee break	
11h30	Coen P. H. Elemans	Embodied motor control of the animal voice
12h	Jacob C. Dunn	The comparative anatomy of the primate larynx: implications for the production of nonlinear phenomena
12h30	Lunch	
14h	Tecumseh Fitch Hanspeter Herzel	**Workshop** Concepts, definitions and terminology
15h30	Coffee break	
16h	Christian Herbst	**Workshop** Mechanisms of production of nonlinear phenomena : from the vocal anatomy to biomechanical simulations
17h30	Free time	
19h30	Cocktail dinner (**La Cempote**)	

Have a drink & enjoy local food at La Cempote !

3 Avenue Grüner

Do not forget your voucher to get a free drink ☺

Schedule

Thursday, June 15th		
9h	Welcome with Coffee	
9h30	Romain Lefèvre	Equivocal: in-vivo and ex-vivo evidence for the production of two fundamental frequencies in horses' vocalisations
9h50	Livio Favaro	Occurrence of nonlinear vocal phenomena in begging calls of the African penguin
10h10	Marco Gamba	Nonlinear phenomena across behavioural contexts and age classes in the Asian colobines
10h30	Mathilde Massenet	Nonlinear phenomena in dog puppy whines: a possible cue to arousal?
10h50	Coffee break	
11h10	Daniel Blumstein	Nonlinear phenomena in marmot alarm calls
11h30	Anna Terrade	Nonlinear phenomena in mammalian alarm and distress calls reduce receiver's habituation
11h50	Camille Fauchon	Pain cries of human babies are characterized by acoustic roughness, which recruits the empathy brain network
12h10	Nicolas Mathevon	Crocodile perception of distress in Hominid baby cries
12h30	Lunch	
14h	Andrey Anikin	**Workshop** How to analyse nonlinear phenomena ?
15h30	Coffee break	
16h	Andrey Anikin	**Workshop** How to synthetise nonlinear phenomena ?
17h30	Free time	
20h	Dinner (**L'Escargot d'Or**)	

Enjoy French typical food at L'Escargot d'Or and try some snails (or not) !

5 Cours Victor Hugo

Schedule

Friday, June 16th		
9h	Welcome with Coffee	
9h30	Elodie Briefer	Biphonation in mammalian vocalizations: insights into production mechanisms, phylogeny, and communicative functions
9h50	Luc Arnal	The sound of salience: how rough sounds hijack exogenous attentional systems
10h10	Daria Valente	Vocal indices of extreme pain: production and perception of women's childbirth vocalisations
10h30	Romane Philippe	Effects of appeasing harness and synthetic pheromone on puppy whines *(Canis familiaris)*
10h50	Veronika C. Beeck	Non-linear phenomena in non-laryngeal calls of Asian elephants
11h10	Coffee break	
11h40	Florence Levréro	Non-linear phenomena in three non-human primate species: effect of ontogeny and emotional states on their occurrence
12h	David Reby	Beyond speech: exploring diversity in the human vocal space
12h20	Kasia Pisanski	Humans need auditory feedback to produce typical volitional nonverbal vocalizations
12h40	Greg Bryant	Nonlinear phenomena in musical cultural evolution
13h	Lunch	
14h30	Closing discussions	
16h	End ☺	

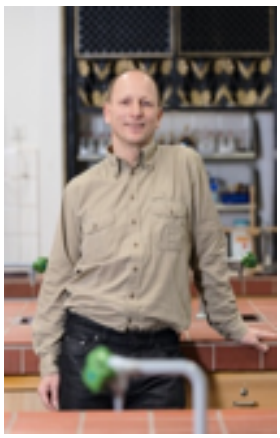
Speakers & Abstracts

Applying nonlinear dynamics to the voice: A historical perspective

Tecumseh Fitch
Department of Behavioral and Cognitive Biology, University of Vienna, Vienna, Austria

The recognition that nonlinear phenomena including subharmonics, bifurcations and deterministic chaos are present in animal vocalizations is a relatively recent one. Most of the key concepts and mathematical principles of nonlinear dynamics were already well worked out by the early 1980s. In the early 1990s, Hanspeter Herzel in Berlin recognized in several landmark publications that these principles are applicable to the voice, initially to baby cries, but then he and his colleagues rapidly generalized this insight to animal vocalizations. Although such nonlinear phenomena play a relatively peripheral role in most human vocalizations beyond the first year of life, they are quite prevalent in many animal communication systems, and the physics and physiology underlying many of these nonlinear phenomena had remained mysterious up until then. Since that time, the broad recognition of the existence of nonlinear vocalizations, and the quantitative study of their production and perception, has fueled a small revolution in our understanding of animal communication. I will provide an abbreviated history of these historical developments, based on interviews with some of the key players and my personal experience. I concentrate on how the core concepts came into focus, and on some of the early attempts to apply them to an ever-wider circle of vocalizations. I end with a prospectus for the next thirty years of research on nonlinear phenomena in vocal production.

What are nonlinear phenomena?



Marta Del Olmo, Christoph Schmal, **Hanspeter Herzel (*)**

(*) Presenting author:
Institute for Theoretical Biology, Humboldt University and Charite, Berlin, Germany

Most animal vocalizations are based on self-sustained oscillations often termed “limit cycles”. Negative delayed feedback loops and nonlinearities are necessary conditions of limit cycle oscillations. We discuss the relation of delays with fundamental frequencies and sources of nonlinearities in acoustics. Strictly speaking, limit cycles could be termed “nonlinear phenomena”. However, in voice research and animal bioacoustics the term “nonlinear phenomena” is typically associated with more complex vocalizations including subharmonics, biphonation, and deterministic chaos. In order to understand the features of these nonlinear phenomena, the understanding of phase space dynamics and bifurcations is helpful. We introduce systematically basic features of nonlinear dynamics such as Hopf bifurcations, period-doubling, toroidal oscillations, and chaotic dynamics. In particular, we discuss bifurcation diagrams of coupled oscillators. Finally, we list representative of nonlinear phenome in animal bioacoustics.

Speakers & Abstracts

Bioacoustic signal analysis with Praat – lessons learned, and questions asked

Christian T. Herbst
Department of Behavioral and Cognitive Biology, University of Vienna, Vienna, Austria
Janette Ogg Voice Research Center, Shenandoah Conservatory, Winchester, VA, USA

The Praat framework (www.praat.org) is a state-of-the-art tool for sound analysis. Originally developed and intended for human speech analysis, it is now also widely used in bioacoustic research. Use cases cover qualitative (e.g., spectrogram assessment) and quantitative analysis (e.g., estimation of fundamental frequency). Notably, Praat is regularly used when describing non-linear phenomena (NLP) in vertebrate vocalizations. In this short presentation, the limitations of NLP analysis with Praat are discussed. I propose that the sound analysis methods provided by Praat – introduced and optimized to investigate nearly-periodic waveforms occurring in human speech – are not geared towards non-linear analysis. The lack of rigorously established thresholds and default values in some of Praat's algorithms possibly introduces anthropocentric and individual bias into the analysis process.

Embodied motor control of the animal voice

Coen P.H. Elemans
Department of Biology, University of Southern Denmark, Denmark

How the developing body and brain interact to produce vocal signals critically depends on the biophysical mechanisms that vertebrates employ to produce sounds. Over the last ten years, my lab has studied and elucidated sound production mechanisms across the vocal vertebrates. Next to remarkable adaptations, we have also shown that the myoelastic-aerodynamic theory for human sound production underlies sound generation in many vertebrates including birds, primates, bats, and most recently also toothed and baleen whales. This is crucial groundwork for defining and quantifying the parameters that modulate vocal signals to causally link motor control to sound in the major animal model systems.

The comparative anatomy of the primate larynx: implications for the production of non-linear phenomena

Jacob C. Dunn
Primate Evolution and Ecology Research Group, University of Anglia Ruskin, Cambridge, UK

Understanding the evolution and ecology of vocal communication requires detailed knowledge of sound production mechanisms. However, the anatomy and physiology of animal vocal production remains little-studied compared to that of the human voice, in part due to the challenges of acquiring suitable specimens. In mammals the larynx represents a key target for selection, particularly in species with highly developed auditory-vocal communication, such as primates. The larynx can be highly variable in form, and identifying adaptive modifications depends on our understanding of functional anatomy in a phylogenetic context. In this talk I will provide an overview of our research into the evolution of the primate larynx, considering implications for the production of non-linear phenomena. I will provide an overview of the primate larynx in a comparative mammalian context, showing that the primate larynx has evolved rapidly, resulting in a pattern of larger overall size and increased deviation from expected allometry with body size. I will then talk about the comparative morphology of the hyoid bone and its relationship with the presence of air sacs in a wide range of species, including the intriguing cases of howler monkeys and humans. Finally, I will talk about our recent research showing how, paradoxically, the increased complexity of human spoken language followed simplification of our laryngeal anatomy. All non-human primates retain at least two pairs of vibrating structures (vocal folds and vocal membranes), facilitating the regular production of nonlinear phenomena, common in many of their calls. Overall, our results imply that selective pressures on the mechanistic determinants of vocalization may be strong in primates and highlight the importance of non-linear phenomena in the evolution and ecology of primate communication.

Speakers & Abstracts

Equivocal: in-vivo and ex-vivo evidence for the production of two fundamental frequencies in horses' vocalisations

Romain A. Lefèvre (*), Lucie Barluet de Beauchesne, Florent Sabarros, Sabrina Briefer Freymondd, Dominik Burger, Alessandra Ramseyer, Vinzenz Gerber, Matthieu Keller, David Reby, Tecumseh Fitch, Elodie F. Briefer
(*) Presenting author:
Behavioural Ecology Group, Section for Ecology & Evolution, Department of Biology, University of Copenhagen, Copenhagen, Denmark

Understanding the biomechanical processes underpinning vocal production is essential to determining functionally relevant acoustic parameters in animal communication. The "source-filter" theory has been foundational in exploring these mechanisms, explaining that vocal production is a two-step process involving the opening and closing of the vocal folds and subsequent filtering through the vocal tract. More recent research has explored nonlinear phenomena (NLP), such as biphonation, which involves two unrelated fundamental frequencies. Biphonic calls are the most prevalent types of calls in horses, where the lowest of these two frequencies ("*f0*") provides information about the emotional arousal (i.e., intensity), the highest fundamental frequencies ("*g0*") encodes its emotional valence (i.e., positive vs. negative). Despite growing interest in communicative functions of biphonic calls, the biomechanical processes involved during their production still need to be studied. In this project, we explored the structures involved in producing f0 and g0 frequencies at the level of the horse vocal apparatus through a unique combination of in vivo and ex vivo studies. To achieve this, we employed four complementary approaches: 1) endoscopic video recordings to visualise the functioning laryngeal structures during live vocal production; 2) analyses of vocalisations produced by horses suffering from recurrent laryngeal neuropathy; 3) excised larynx experiments to simulate sound production using air and helium ex vivo through the larynx in isolation; 4) CT scans on excised larynges to obtain high-resolution images of the vocal folds and surrounding structures. Our study suggests that recurrent laryngeal neuropathy mainly affects the sustainability of the fundamental frequency f0 during biphonation. In contrast, the secondary and higher-pitched frequency g0 likely arises from pressure fluctuations in the vocal tract, potentially due to a rotating air column within a laryngeal cavity, not tissue vibration. These results suggest that horses have evolved a unique way to concurrently convey multiple, independent pieces of information.

Occurrence of nonlinear vocal phenomena in begging calls of the African penguin

Ilaria Morandi, Chiara Tenneriello, Francesca Terranova, Melissa Cadman, Katta Ludynia, Anna Zanoli**, Livio Favaro (*)**

(*) Presenting author:
Department of Life Sciences and Systems Biology, University of Turin, Turin, Italy

Endangered African penguins (*Spheniscus demersus*) extensively use high-frequency food solicitation signals (begging calls) to request food from parents returning to the nest from a foraging trip at sea. During the 2022 breeding season, we studied the occurrence of nonlinear vocal phenomena (NLP) in food solicitation signals in 78 hand-reared penguin chicks at the Southern African Foundation for the Conservation of Costal Birds. For each chick, we recorded the begging calls daily, from the hatching of wild abandoned eggs to the release of the chicks into the wild approximately three months later. We recorded the chicks' age as an indicator of their growth and registered their health condition. We found that 30% of the begging calls exhibit subharmonics and/or deterministic chaos, and we investigated the effect of penguins' growth and arousal on the occurrence of these phenomena. Moreover, we found that sub-harmonics significantly increase in chicks contracting a respiratory disease (either avian malaria or aspergillosis). Our results suggest that NLPs are suitable indicators of the occurrence of respiratory ills in penguin chicks. Such information might also be useful for the timely diagnosis of penguins in need of veterinary treatment.

Speakers & Abstracts

Nonlinear phenomena across behavioural contexts and age classes in the Asian colobines

Marco Gamba (*), Niu Kefeng, Isidoro Riondato, Giovanni B. Di Panfilo, Olivier Friard, Daria Valente, Wu Ankang, Tianyou Yang, Chia L. Tan, Cristina Giacoma

(*) Presenting author:
Department of Life Sciences and Systems Biology, University of Turin, Turin, Italy

Asian colobines comprise nearly half of the Asian nonhuman primate species. These primates inhabit diverse, sometimes extreme, habitats and show highly specialized diets and communication signals. Therefore, studies about vocal behaviour can provide critical information for understanding behaviour ecology, representing a starting point for setting effective conservation policies. François' langurs (*Trachypithecus francoisi*) and Guizhou snub-nosed monkeys (*Rhinopithecus brelichi*) are perfect candidates for vocal behaviour and sensory ecology studies. They show anatomical modifications of the nasomaxillofrontal region and produce vocalizations showing a wide range of fundamental frequencies, including impressive nonlinear phenomena. This study aimed at understanding where, in the vocal repertoire of these species, there is a prominent occurrence of nonlinear phenomena and their distribution across sexes and age classes. All vocalisations exceeding a duration of 0.075 were subjected to Random Forest Classifier using 120 MFCC values. This approach allowed us to identify 11 vocal types for *R. brelichi* and 7 for *T. francoisi* with a correct classification rate ranging from 51% to 73% (exceeding the percentage predicted by chance of a minimum of 42%). While screening the vocalizations assigned to their putative vocal type, we found that, for both species, nonlinear phenomena primarily occurred in high-pitched calls, which serve as distress calls between adults and are given by immatures in response to separation or rejection from the mother.

Nonlinear phenomena in dog puppy whines: a possible cue to distress?

Mathilde Massenet (*), Katarzyna Pisanski, Karine Reyanud, Nicolas Mathevon, David Reby, Andrey Anikin

(*) Presenting author
ENES Bioacoustics Research Laboratory, ENES/CRNL, University of Saint-Etienne, CNRS, Inserm, Saint-Etienne, France

Animals often produce harsh-sounding vocalisations in high arousal distress contexts. These vocalisations typically contain nonlinear phenomena (NLP) including frequency jumps, subharmonics, chaos, and biphonation. While interest in the mechanistic origins and communicative functions of NLP is growing, how their production varies with caller's arousal state is poorly documented. Here, we describe NLP and their acoustic correlates in 13,346 natural whines given by puppies temporarily separated from their mother and littermates. Alongside an increase in whining, we show that the proportion of whines containing NLP, especially chaos, increases with time since separation. Within individual whines, all NLP types are usually produced during the first half of the whines' duration, typically corresponding to the steepest point of the rising phase in the average fundamental frequency (f_0) and amplitude contours. In psycho acoustic experiments, NLP and particularly chaos, experimentally added to synthetic whines also increased perceived distress by listeners. Our results are consistent with the hypothesis that NLP arise in calls as a product of instabilities in the vocal system of mammals, possibly communicating heightened level of distress.

Speakers & Abstracts

Nonlinear phenomena in marmot alarm calls

Daniel Blumstein
Department of Ecology and Evolutionary Biology, University of California, Los Angeles, CA, USA

In response to detecting predatory threats, yellow-bellied marmots (*Marmota flaviventer*) emit alarm calls. Prior work has shown that call production is associated with the degree of risk the caller experiences and that they are individually distinctive. Receivers respond to calls and are sensitive to variation in caller reliability. Calls also contain non-linear acoustic phenomena. Work has shown that socially isolated animals and those infected with Eimeria, an intestinal parasite, produced 'noisier' calls. However, animals that were likely under greater stress (as measured with fecal glucocorticoid metabolites) produced more structured and less noisy calls. The addition of nonlinear phenomena (NLP) increases responsiveness in receivers. Future work is examining the genetic basis of NLP production in marmots. Taken together, the study of NLP in marmots has enhanced our understanding of the potential information encoded in alarm calls and is consistent with the hypothesis that variation in NLP production communicates fear which stimulated work with humans resulting in the non-linearity and fear hypothesis.

Nonlinear phenomena in mammalian alarm and distress calls reduce receiver's habituation

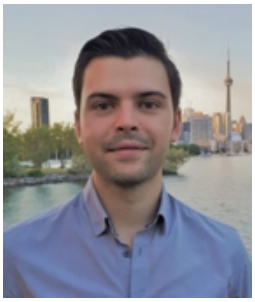
Anna Terrade (*), Bertille Tesson, Antoine Perricher, Mathilde Massenet, Andrey Anikin, Yann Locatelli, Nicolas Mathevon, David Reby

(*) Presenting author:
ENES Bioacoustics Research Laboratory, ENES/CRNL, University of Saint-Etienne, CNRS, Inserm, Saint-Etienne, France
Direction technologies innovation et projets groupe, SNCF, Saint-Denis, France

Nonlinear phenomena (i.e., deterministic chaos, sidebands, subharmonics, and frequency jumps) are widely present in mammalian vocal repertoires, especially in alarm or distress calls produced by highly aroused individuals. Here, we tested the key hypothesis that the unpredictability of nonlinear phenomena makes calls difficult to ignore and/or habituate to. To do this, we assessed the effect of different levels of deterministic chaos (none, middle, and strong) on receivers' habituation to series of conspecific calls in domestic dogs and red deer.

Speakers & Abstracts

Pain cries of human babies are characterized by acoustic roughness, which recruits the empathy brain network



Camille Fauchon (*), Siloé Corvin, Isabelle Faillenot, David Reby, Nicolas Mathevon, Roland Peyron

(*) Presenting author:
NeuroPain research Lab, CRNL, University of Saint-Etienne, INSERM U 1028, CNRS UMR 5292, UCBL, Saint-Etienne, France.

The acoustic structure of pain babies' cries is typically characterized by the presence of nonlinear phenomena, making these calls unpredictable, perceptually rough to likely increase caregivers' attention and elicit care. Adult listeners can identify pain in babies' cries, once they have experience in baby's care. Despite research indicating that this signal activates various cerebral networks, including those of vigilance and empathy processing, there is still limited understanding of the functional connectivity within and between these networks. Here, we investigate in an fMRI study how vocal roughness in cries modulate brain activity. The presence of vocal roughness (an acoustic marker of baby distress) was associated with stronger brain activity in the bilateral anterior insula and the inferior parietal cortex, and higher connectivity between empathy areas. The cry average pitch, a poor marker of pain, recruits mainly auditory areas (superior temporal gyrus) and leads to functional connectivity changes within the auditory network. Additionally, we investigated the impact of parenting experience and sex on brain network connectivity, and we found that parenthood-induced remodeling of brain connectivity that may facilitate an appropriate response to the information conveyed by a baby's cry.

Crocodile perception of distress in Hominid baby cries

Nicolas Mathevon (*), Nicolas Grimault, Florence Levréro, Julie Thévenet

(*) Presenting author:
ENES Bioacoustics Research Laboratory, ENES/CRNL, University of Saint-Etienne, CNRS, Inserm, Saint-Etienne, France

It is generally argued that distress vocalizations, a common modality for alerting conspecifics across a wide range of terrestrial vertebrates, share acoustic features that allow heterospecific communication. Yet studies suggest that the acoustic traits used to decode distress may vary between species, leading to decoding errors. Here we found through playback experiments that Nile crocodiles are attracted to infant hominid cries (bonobo, chimpanzee and human), and that the intensity of crocodile response depends critically on a set of specific acoustic features (mainly deterministic chaos, harmonicity, and spectral prominences). Our results suggest that crocodiles are sensitive to the degree of distress encoded in the vocalizations of phylogenetically very distant vertebrates. A comparison of these results with those obtained with human subjects confronted with the same stimuli further indicates that crocodiles and humans use different acoustic criteria to assess the distress encoded in infant cries. Interestingly, the acoustic features driving crocodile reaction are likely to be more reliable markers of distress than those used by humans.

Speakers & Abstracts

Biphonation in mammalian vocalizations: insights into production mechanisms, phylogeny, and communicative functions

Romain A. Lefèvre, Océane Amichaud, Doğa Özcan, **Elodie F. Briefer (*)**

(*) Presenting author:
Behavioural Ecology Group, Section for Ecology & Evolution, Department of Biology, University of Copenhagen, Copenhagen, Denmark

Biphonation refers to the production of two distinct fundamental frequencies (i.e., dual-source phonation), a complex phenomenon that has been observed in a wide range of mammals and has gathered significant attention due to its potential to provide insight into animal communication and vocal production. This review aims to investigate the various mechanisms behind biphonation that may vary across mammals and how these mechanisms may be influenced by phylogenetic relationships and communicative functions.

The sound of salience: how rough sounds hijack exogenous attentional systems

Luc Arnal
Institut de l'Audition, Institut Pasteur, INSERM, Paris, France

Communication signals such as speech or music, are complex signals that exploit a large variety of acoustic features to trigger specific emotional and behavioral responses in the listener. However, the way we use some acoustic features to manipulate listeners' affective states and reactions remains mysterious. Hypothesizing that acoustic niches (or attributes such as roughness, pitch, etc.) are naturally selected to carry specific information (danger, gender, etc.) as a function of the fitness of the stimulus and inducible reactions to promote survival, I recently showed that alarm signals (e.g., screams, sirens, but not neutral sounds like speech) exploit a restricted acoustic regime, known as roughness. This feature is devoted to communicating danger, enhance negative affective responses and elicit faster reactions. Although they are scarcely present in the natural environment, rough sounds have considerable effects on perceptual, emotional and behavioral responses. Fast repetitive inputs such as strobe lights, phone vibrators or rough alarm signals induce temporally salient, annoying percepts that efficiently capture attention, even at low signal-to-noise ratio. These sounds are almost impossible to ignore or suppress perceptually, and long-term exposure to rough sounds like screams causes tremendous stress in the listener's brain 17, sometimes leading to maladaptive reactions (e.g., shaken baby syndrome).
Here, I will describe the neural underpinning of roughness in the human brain to illuminate how these sounds take over the control of our salience system by forcing exogenous attention in time. Measuring neural responses to click trains of varying rates during intracranial recordings in eleven epileptic patients, I show that sounds in the roughness [30–80 Hz] range are maximally aversive by synchronizing a widespread network of subcortical and cortico-limbic regions belonging to the Salience System. In a subsequent EEG experiment, I show that aversive and electrophysiological responses to rough sounds reliably probe this system and predict inter-individual anxiety. I will argue that these results are compatible with the notion that rough sounds target the Salience System via a primitive, non-classical subcortical system involved in sensory salience and arousal.

Speakers & Abstracts

Vocal indices of extreme pain: production and perception of women's childbirth vocalisations

Daria Valente (*), David Reby, Cécile Magnard, Alexis Koutseff, Katarzyna Pisanski

(*) Presenting author:
ENES Bioacoustics Research Laboratory, ENES/CRNL, University of Saint-Etienne, CNRS, Inserm, Saint-Etienne, France
Life Sciences and Systems Biology, University of Turin, Turin, Italy

Research on the vocal communication of pain entails many challenges, including obtaining vocal expressions of authentic pain, and directly testing which acoustic parameters encode for pain. Here, we combine acoustic analyses of pain vocalisations obtained during childbirth with perception experiments using resynthesized vocalisations to overcome these challenges. We audio recorded 15 adult women giving birth without the use of an epidural. Women self-assessed their pain levels throughout their labour, which increased from the first to the third and final expulsion stage. Acoustic analyses confirmed an analogous increase in the proportion of nonlinear phenomena, particularly deterministic chaos and sidebands, as women's labours progressed. This was accompanied by progressive increases in fundamental frequency (pitch) and its variability, call duration, amplitude, and perturbation parameters. Psychoacoustic experiments on naïve and experienced (e.g., midwives, obstetricians) listeners showed that both groups could reliably gauge pain levels from natural childbirth vocalisations and that their judgments could be largely predicted by the proportion of nonlinear phenomena in those vocalisations. These results were further verified using synthetic vocalisations with experimentally manipulated levels of nonlinear phenomena. This study provides converging evidence that nonlinear acoustic phenomena encode pain in human vocalisations that listeners can in turn decode, a capacity that aligns with the putative evolved function of pain vocalisations to elicit aid.

Effects of appeasing harness and synthetic pheromone on puppy whines (*Canis familiaris*)

Romane Philippe (*), Mathilde Massenet, David Reby, Anahita Le Bourdiec-Shaffi, Vassilios Kaltsatos

(*) Presenting author:
ENES Bioacoustics Research Laboratory, ENES/CRNL, University of Saint-Etienne, CNRS, Inserm, Saint-Etienne, France

In domesticated dogs, daily separations from their owners or conspecifics can be stressful and ultimately lead to behavioral disorders. To limit them, products such as Dog Appeasing Pheromone (DAP) and calming harness (Dog Anxiety) have been developed. In this study, we assessed the independent or combined effects of these products by investigating acoustic cues to emotional state, including the fundamental frequency (f_0) and the presence of nonlinear phenomena (NLP), in the distress whines produced by 35 puppies during a separation from their mother and littermates. We predict that whines given by puppies equipped with calming devices will be characterized by a lower f0 and lower levels of NLP.

Speakers & Abstracts

Non-linear phenomena in non-laryngeal calls of Asian elephants

Veronika C. Beeck (*), Evelyn Fuchs, Angela S. Stoeger, Gunnar Heilmann, Michael Kerscher, Martin Petz

(*) Presenting author:
Department of Behavioural and Cognitive Biology, University of Vienna

The repertoire of African elephants (Loxodonta Africana and Loxodonta cyclotis) and Asian elephants (Elephas maximus) spans from laryngeal calls — low-frequency rumbles (F0 < 20 Hz) and roars (F0 200-500 Hz) — to high-pitched nasal trumpets (F0 300-900). Only Asian elephants produce even higher pitched squeaks (F0 300-2300 Hz). I found that squeaks can be produced by two non-laryngeal mechanisms, one I suggest is by pressing air through tensed lips, the other by sucking air through the tensed nostril. Trumpets are produced by a blast of air through the trunk, the sound source is currently unknown but suggested to be laryngeal or vibrating nasal cartilages. In this talk, I will present two studies that quantified high percentages and variability of non-linear phenomena (NLP) in Asian elephants' squeaks and trumpets and discuss how they relate to their sound production mechanisms. Squeaks and trumpets are emitted only during contexts of arousal (social or external disturbance), which is congruent with high-frequency and modulated fundamental frequencies as well as non-linear phenomena commonly found in signals of arousal, appeasement, and fear across many species. These findings suggest that the hypothesis that these acoustic characteristics serve to exploit receivers' perceptual predispositions, hinder habituation and increase acoustic individuality, extends to calls produced through non-laryngeal mechanism.

Non-linear phenomena in three non-human primate species: effect of ontogeny and emotional states on their occurrence

Florence Levréro (*) and Floriane Fournier

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Non-linear phenomena (NLP) are frequently observed in the vocalizations of the great apes, especially bonobo (*Pan paniscus*) and chimpanzee (*Pan troglodytes schweinfurthii*), but to our knowledge, NLP have been largely ignored by researchers studying their vocal communication. We propose here a qualitative and quantitative approach to characterize the production of NLP in these two great ape species and in addition in a monkey species, the mandrill (*Mandrillus sphinx*). For each species, we investigated which types of NLP (deterministic chaos, sidebands, subharmonics, vibrato, and frequency jumps) are produced, where they are located, and what proportion they occupy in their vocalizations. We also investigated whether these features change across the vocal repertoire and with ontogeny. Our preliminary results show that in mandrills (which have a discrete vocal repertoire), NLP are present in only one type of vocalization, in contexts of high arousal, and are age-dependent. In great apes, an effect of age is again strongly suspected, but NLP are widely distributed across their graded vocal repertoires. The effect of NLP on receiver responsiveness remains to be tested.

Speakers & Abstracts

Beyond speech: Exploring diversity in the human vocal space

Andrey Anikin, Valentina Canessa-Pollard, Katarzyna Pisanski, Mathilde Massenet, **David Reby (*)**

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It has been suggested that human speech has led to the complexification of filter-related articulation (formants) at the expense of source-related modulation (pitch, intonation, NLP). Our data show that while speech indeed uses only a fraction of available source modulation, humans extensively modulate the source to produce a wide range of nonverbal vocal signals in everyday communication, singing, hunting, etc. Thus, speech production has not evolved at the expense of nonverbal vocal production.

Humans need auditory feedback to produce typical volitional nonverbal vocalizations

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The acoustic forms of human nonverbal vocalizations such as screams and cries often reflect their evolved functions. Although the universality of these putatively primordial vocal sounds and their phylogenetic roots in animal calls suggest they may have a strong reflexive foundation, many of the emotive vocalizations that we humans produce are under our voluntary control, suggesting that, like speech, non-linguistic vocal sounds may require auditory input to develop typically. In support of this hypothesis, we show that profoundly deaf adults produce acoustically atypical and homogenous volitional vocalizations of aggression, pain, and fear that all sound similar: high-pitched with uniform vocal tract resonances and extremely few nonlinear phenomena, compared to hearing controls. In perception experiments, listeners often failed to gauge the intended emotions of these vocalizations, especially aggression, and perceived them as relatively inauthentic. These results suggest that vocal learning is required not only for speech acquisition, but also for the acquisition of volitional non-linguistic vocalizations.

Nonlinear phenomena in musical cultural evolution

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The sound of music is shaped by interactions between auditory perception and cultural evolution. Among the many influences of our sound perception is a sensitivity to nonlinear phenomena (NLP) in the vocal signals of humans and other animals, in large part due to selection for the rapid communication of vocal affect. Musical traditions around the world incorporate nonlinear phenomena in affective vocal performances, and even more extensively in instrumental sound creation. One possibility is that an auditory preference for NLP has formed the basis of a cultural attractor space, resulting in a co-evolutionary arms race shaping musical sound features (i.e., ritualization). NLP are also created electronically through both analog and digital manipulations of sound waves. For example, the advent of overdrive and distortion in blues and early rock evolved over decades into highly specialized genres of noise, to the exclusion of all other features ordinarily understood as music. NLP are vital components in vocal communication systems, and play an ever-increasing role in music communication worldwide.

Map with important places

Public transport (STAS)

Get to the symposium in ~ 30 min

- **Tram T2** from Chateaucreux to Cité du Design
- **Bus L13** from Chateaucreux to Carnot Nôtre

More information: https://www.reseau-stas.fr

Lunch

We suggest different options (in orange) at less than 10min walking from the symposium

City centre

Saint-Etienne city centre is quite small, and easily visited by foot. We recommend "terrasses" place Jean Jaurès or rue des Martyrs de Vingré in the old town.

Les Halles Mazerat (across l'Escargot d'Or) have been voted one of the 50 most influential food places in the world ! Go and check for yourself ;-)