Title: Empowering Animals Through Technology: Enhancing Animal Agency in the sound environment

Abstract

As we learn more about how cognition, behaviour, health and welfare of animals can be impacted by sound, understanding how sound environments affect different species has become a topic of high importance. Many managed care environments for animals manipulate sound environments by presenting music, biologically relevant natural sounds or even low-level noise, in an attempt to improve animal welfare outcomes. However, there is very limited evidence about how these sound environments – and the acoustic variables within them – might improve or degrade conditions for most animals. Studies tend to view the sound environment as something 'beyond the control' of the animal, or as a variable that must be manipulated by humans while observing its impacts, often treating all animals in a population as equivalent. Moreover, specifics relating to the nature of the acoustic intervention are frequently lacking, such as the intensity of the audio and for what duration it is to be played, as well as fundamental information regarding frequencies, timbre, and quality of playback.

This in-person workshop will explore how innovative technologies can be designed to give animals some control over their sound environment for both research and tentatively, for managed scenarios. Participants will discuss advancements in acoustic technologies, its applications in different animal settings, animal-specific interface design, and practical methods for implementing and evaluating these solutions. The workshop will feature several case studies and discussions to deepen understanding and encourage collaborative solutions.

The outputs of this workshop will include designs for technological apparatus, evaluations or experiments that allow animals to control their sound environment. Such designs can then be the foundation for grant applications that fund their development, testing and/or implementation.

Introduction

Sound environments can profoundly affect cognition, behaviour, health and welfare of non-human animals (hereafter, animals). Rapid rates of human population growth, industrialization, and urbanization have led to pervasive and historically unprecedented levels of noise pollution worldwide that can have significant negative effects on wildlife and biodiversity [1]. Additionally, animals situated ex-situ or in domestic habitats such as farms, zoos and aquaria, laboratories,

shelters and domestic homes will also be exposed to unnatural sound environments (both intentionally e.g. music, and unintentionally e.g. road traffic, human voices, machine sounds) with potentially negative consequences on the animals such as increased stress levels, changes in behaviour and lower reproductive success [2–8].

Many studies on the effects of the sound environment have focused on inappropriate species-specific behaviours that incur costs when animals change their behaviour in response to anthropogenic sounds (reviewed in [9,10]). If a sound is perceived as stressful, it can activate physiological stress response systems that interact with and modulate the functioning of several other physiological processes such as neural plasticity, metabolism and immune function [11,12]. However, sound can also have stimulating effects on neural plasticity, arousal and attention [a,b]. A suitable sound environment therefore should avoid sounds that are perceived negatively by the animal but if possible include sounds that are stimulating. What constitutes a negatively or positively perceived sound under what circumstances and how to achieve a suitable species-specific sound environment are current challenges in designing acoustic enrichment.

The importance of ethical considerations of the welfare of animals exposed to an anthropogenically altered or controlled sound environment lies within the field of study focused on understanding animals' wants and needs, which is then translated to create rich living environments that optimise animal physical and cognitive health and wellbeing [13,14]. As noise reduction is not always feasible or cost-effective, nor is total silence necessarily beneficial to animals, research into ways of mitigating the effects of noise, or presenting different types of sound environments to animals, are required.

A popular intervention to improve sound environments is to add sounds assumed to be calming or biologically relevant to animals, such as music or 'nature' sounds. These acoustic additions are thought to be beneficial because they can mask stressful anthropogenic noise, provide beneficial sensory stimulation, encourage normal behaviour and/or induce positive emotional states [15–17]. In almost all studies on the effects of added sounds on captive animals, animals are passively exposed to sound environments and are unable to control even basic aspects of their listening experience such as intensity, duration, or timing of auditory exposure. Yet, there is growing evidence that being able to choose between meaningful alternatives is desirable, gives animals control over their environment and increases a sense of agency, and is integral to their wellbeing [18–22]. Being able to choose their sound environment may enable animals to determine their own priorities at that moment, weighing the potential cognitive, sensory, social, and/or hedonic costs and benefits of their existence in a particular sound environment.

On the other hand, the use of mediated sound environments specifically curated for animals also brings unique risks based on potentially unfulfilled 'expectations' and sensory dissonance. For example, the use of natural audio recording playback may contain signals from conspecifics or heterospecifics that would lead the animal to expect the presence of other animals, but not be able to sense them visually or through smell [23]. Additionally, beyond the type of sound played or the possibility for basic control by the animal, the lack of meaningful interactivity in the sounds, responding to the animal's vocalization or behavior for instance, might affect the

animal's reactivity and engagement towards the stimulus [24]. This, in turn, may deeply affect cognitive processes such as their sense of species identity, by shaping their theory of mind regarding what expectations form and interactions with conspecifics can look like.

Another aspect of playback that may be overlooked is the aesthetic quality (or even overall sonic quality) of sounds that are selected by humans. As a case in point, research into the origins of human music shows that our appreciation of tones and harmonies is an evolutionary development linked to our ability to perceive and understand human vocal sounds [25]. Hearing and interpreting the underlying frequencies and harmonics in human voices enables us to distinguish people by voice, and to interpret emotions, facilitating sophisticated communication [26]. Equal loudness contours demonstrate that over the normal human hearing range, particular frequencies can be perceived at very low volume - with the lowest decibel level coinciding with the frequency of a human baby's cry [27]. This may explain why human-made music (based on our human aesthetic appreciation of acoustic signals) often holds little interest for other animals. Therefore, to find out what kinds of sounds other species might enjoy, we need to undertake more research into their species-specific audition. This can potentially be facilitated through offering animals control over the quality of the sounds in their environment, using technology to capture individual preferences.

Methods of giving animals choice and control over their exposure to sound environments must take into account species-specific predispositions, anatomy/morphologies, capabilities, and housing conditions. For example, a device that allows a group of small non-human primates in a zoo to voluntarily enter and listen to different sounds [28,29] will not work for larger animals that live in more dense social housing conditions such as commercially raised pigs. Knowing what acoustic characteristics animals perceive and respond to is also necessary for determining what options to present them with. Many species have poorly understood auditory perception and may require special consideration in what sounds to provide as alternatives and how to present them. It is in this space that animal-computer interfaces may provide novel solutions to the challenges surrounding the study of animal choice in varying sound environments as well as offer ideas for its adoption and application in a variety of contexts. The aim of this workshop is to develop or design technologies, experimental protocols or other solutions to allow animals - in varied contexts - control over their sound environment.

Intended Schedule

9:00 - 9:15   Welcome and Introduction
- Preface: sound environments and their significance for animals
- Group icebreaker/introduction activity

9:15 - 9:40   Introduction via keynote into technologies for Acoustic Control with Case Studies and Practical Applications of existing examples

9:45 - 10:45   Group Activity: Finding solutions

- Various case study 'scenarios' will be given, each focusing on a different taxon and setting (e.g. zoo, agricultural setting, laboratory, rescue shelter)
- Groups will focus on one of these scenarios each, and create a solution that allows the particular animal agency regarding their sound environment
- A brief outline of advantages and challenges will be set out for each
- Groups will then fill out a table or matrix outlining their approach to the scenario, technologies required, training needed and other considerations.

10:45 - 11:00 Break
11:00 - 11:30 Group Activity: Modifying Solutions for Individuals and Groups
11:30 - 12:30 Group Discussion and Future Goals
- Discussion and Brainstorming session on future technologies, research needs/questions and implementation

Case studies/scenarios

The case studies presented in this workshop aligned with the 'STRANGE' framework [30]. This framework allows the consideration of factors that may influence animals' inclusion in experimental (and especially behavioural) studies, standing for **S**ocial background, **T**rappability and self-selection, **R**earing history, **A**cclimation and habituation, **N**atural changes in responsiveness, **G**enetic make-up and **E**xperience. We have chosen taxa and settings that will enable comparisons between well-studied organisms (e.g. dogs) and those that are particularly understudied (e.g. reptiles), that would benefit highly from knowledge on how soundscapes affect welfare (e.g. meat industry), or that could allow some experimental freedom (e.g. zoos or aquaria). Groups will consider the STRANGE framework when brainstorming solutions for the scenarios. These case studies include:

Scenario 1: Snakes in a laboratory setting - how can we allow them to interface with sounds?
Scenario 2: Rescue Shelter dogs - Can each dog have power to control its own sound environment?
Scenario 3: Fish in an aquarium - How do we allow choice for underwater sound environments?
Scenario 4: Pigs in an agricultural facility - what kind of interface would allow interaction with sounds, and can this positively impact their welfare?

An email list of all participants will be gathered, allowing post-workshop debrief, including gauging interest in continuing with projects (see outcomes and outputs below) and obtaining feedback on the workshop itself.

Proposed Outcomes and Outputs

We anticipate that this workshop will generate some real-world, practical and implementable solutions for allowing animal agency in choosing and/or modifying their sound environment in captive scenarios. In particular, a focus will also be on how to meet animals as individual agents of their own lives. The output of the workshop will train participants to make best use of acoustic enrichment to enhance animal welfare and to investigate preferences around acoustic signals. In order to reach a wider audience, we will invite workshop participants to contribute towards a review paper on animal acoustics, the current knowledge gaps, lessons learned from the workshop, and with a focus on how to overcome current challenges in this space. In addition, we propose that the Acoustic Enrichment Interest Group, along with workshop attendees who are interested, will use the workshop as a foundation for one or more large grant applications to further collaborative research in this field, including the development of technologies that could be used worldwide to enhance the welfare of managed animals and their populations. Specific examples of outputs may include:

1. A design for engineering a computer interface mechanism and sound system set up for an animal to control their sound environment
2. An outline for an experimental protocol testing sound environment control options for captive or wild animals
3. A design for quiet 'refugia' that can be utilized by captive animals to escape current sound environments

These can then be put forward by members of the workshop as potential funding applications for design and testing.

Call for Participation

This in-person workshop will explore how innovative technologies can be designed to give managed animals some control over their sound environment. As we learn more about how cognition, behaviour, health and welfare of animals can be impacted by sound, understanding how sound environments affect different species has become a topic of high importance. Historically, studies tended to view the sound environment as something 'beyond the control' of a non-human animal, or as a variable that must be manipulated by humans while observing its impacts, often treating all animals in a population as equivalent. Moreover, specifics relating to the nature of the acoustic intervention are frequently lacking, such as the intensity of the audio and for what duration it is to be played, as well as fundamental information regarding frequencies, timbre, and quality of playback. However, with the support of technology, it has become possible to engage animals in projects that offer them control over their auditory

environment, allowing researchers to investigate ecoacoustics and perception from an animal-centred perspective.

During the workshop, participants will discuss advancements in acoustic technologies, their applications in different animal settings, animal-specific interface design, and practical methods for implementing and evaluating these solutions. The workshop will feature several case studies and discussions to deepen understanding and encourage collaborative solutions.

Outputs will include designs for technological apparatus, evaluations or experiments that allow animals to control their sound environments. Such designs can then be the foundation for grant applications that fund their development, testing and/or implementation.

Workshop Committee

The workshop committee involves interdisciplinary international researchers from animal ecology, physiology and aging, agricultural and computer science.

Dominique A Potvin is a Senior Lecturer in Animal Ecology at the University of the Sunshine Coast. She studies behavioural ecology in birds and herptiles, and is especially interested in how anthropogenic noise affects free-ranging animals.

Neil Evans is a professor of Integrative Physiology at the University of Glasgow. His research interests focus on how an animal's environment can affect health and welfare, with a particular interest in the stress axis. He and colleagues explore environmental effects on stress in domestic, companion and wild animals.

Fiona French is an Associate Professor at London Metropolitan University, where she teaches games programming and design, and established the Multispecies Interaction Design research group. Her research focuses on Animal-Computer Interaction, investigating how technology can support and enhance welfare and enrichment across a range of species. She is currently working on projects that involve non-human animal signaling mechanisms and engagement with their environment, particularly using modalities outside human perception.

Ilyena Hirskyj-Douglas is a Lecturer at The University of Glasgow. She directs the Animal-Computer Interaction group which researches how animals can use technologies to control their home and the animal internet, with publications in how non-human primates can control the audio sound environment of their home.

Azadeh Jalali (DVM) is a Veterinarian interested in animal welfare and behavior. She is experienced in Companion animal and commercial farm veterinary care service from Iran.

Rébecca Kleinberger is an Assistant Professor at Northeastern University. She directs the INTERACT Animal lab which focussed on leveraging technology to increase animals' agency

and welfare. Kleinberger's research explores the design, deployment, and evaluation of new voice and sound-based technologies for musical applications, assistive technology, and interspecies connection.

Ruedi Nager is a Senior Lecturer in Physiology Aging and Welfare at the University of Glasgow. His research interests focus on how organisms cope with the environment in which they live. He and colleagues explore the use of infrared thermal imaging on assessing animals' response to positive and negative stimuli both in the wild and in captivity.

Oluwaseun Serah Iyasere is an Associate Professor at the Federal University of Agriculture Abeokuta Nigeria (FUNAAB). She is a specialist in farm animal behaviour and welfare with a focus on chickens and goats.

Saeed Shafiei Sabet is an Assistant Professor in Animal Behaviour, at University of Guilan. He is a behavioural biologist and underwater bioacoustician with a current focus on sound impact assessments and predicting the potential effects of anthropogenic sound on aquatic animals across taxa (aquatic invertebrates, fishes and marine mammals).

Michelle Spierings is an Assistant Professor in Animal Sciences at Leiden University. Her research focuses on complex patterns both in acoustic production as well as perception of zebra finches, budgerigars and primates, and shared underlying cognitive capacities related to music and language perception.

Pralle Kriengwatana is a postdoctoral researcher at the M3-BIORES group in the Department of Biosystems at KU Leuven. She specialises in bioacoustics and the effects of early-life experiences on animal behaviour and health, with the aim of understanding the relationship between sounds and health.

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