# How can Multi-Sensory Technologies in Zoos Shape the Relationship Between Non-human Primates and Humans

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Fig. 1. Left: Drawings of the device. Centre: Sensory stimuli device. Right: Image of the lemur engaging with the device.

Modern zoological institutions play a pivotal role in preserving endangered species and educating the public [6, 17]. However, zoos face three challenges: firstly, the limited range of animal activities, which can diminish their enrichment experience [8], the inadequate educational engagement for visitors often stemming from passive learning, which fails to foster engaging experiences [9, 12] and how to balance direct interactions between humans and zoo animals. The interactions between zoo animals and people are complex as excessive interaction can distress the animals [20], while too limited interaction fails to provide visitors with engaging educational experiences[22]. This PhD project aims to address these three challenges by utilising technology within the zoo context to foster appropriate human-animal interaction. This PhD will be conducted in three phases looking at 1) augmenting the red-ruffed lemur enclosure by providing multi-modal stimuli-based technology to see what stimuli attract lemurs to engage with technology and how to develop lemur technologies; 2) how animal technology can provide engagement educational experiences for zoo visitors via a human-animal system and 3) building on these results, how humans and animals can use these systems together.

## 1 INTRODUCTION

Modern zoos focus on four main objectives: conservation, education, research, and recreation [19, 31]. However, zoos encountered three challenges in pursuing their education and conservative objectives: First, while zoos protect animals, the limited space for captive animals to move will limit their experience [21]. Therefore, how to augment their enclosure to achieve a higher standard of animal welfare is a requirement for animal conservation in modern zoos [26, 35]. Secondly, how to provide engagement experience to enhance visitors' education is critical, as current methods like animal exhibits and zookeeper talks offer limited active engagement learning [9, 12, 23]. Thirdly, with over 700 million annual zoo visitors worldwide [16], creating appropriate interaction between humans and animals in zoo contexts is crucial, given the reduction in AZA recommendation for limited human-non-human primate contact. Direct visitor-animal interaction is a conflicting topic, as direct contact can let visitors gain a more engaging education [14]; still, equally, this can also cause stress to captive animals, especially in non-human primates [14, 15, 20, 21].

To address these, this PhD will investigate how to develop technologies with red-ruffed lemurs (Varecia rubra) at Blair Drummond Safari Park and Zoo. Red-ruffed lemurs are critically endangered primates that are kept in zoos to prevent their extinction, making it crucial to augment their captive enclosures [2, 3, 25]. The PhD research is structured into three distinct phases:

**Study One:** Augment the red-ruffed lemurs' enclosure with stimuli-based technology to investigate their modality and stimuli preference.

**Study Two:** Investigate how technology used within lemurs enclosures can be adapted to help the education experiences of zoo visitors.

**Study Three:** Investigate how lemurs and zoo visitors can use technologies together to improve the lemurs' enclosure and enhance visitors' engagement to elevate the education experience.

## 2 LITERATURE REVIEW

The increasing employment of animal-computer interaction (ACI) technologies in zoos has provided substantial literature, technology guidance, and methodologies for this PhD research. This section discusses the growing use of technologies in zoos, primarily aimed at (1) augmenting the enclosures for captive animals, (2) improving educational experiences for visitors, and (3) promoting appropriate animal-visitor interactions [5, 38, 39].

### 2.1 Augmenting the Enclosures for Captive Animals

Implementing zoo technologies for animal usage can significantly improve animal enclosures by enhancing their welfare [39]. Devices such as touch screens designed for rhesus monkeys [4] and drum kits for chimpanzees [30] are all technologies for animals. Studies on animals using technologies among non-human primates indicate that visual, auditory, and olfactory sensory technologies provide non-human primates in enclosures with varied enrichment experiences [40]. Yet, there is little research into how to augment a lemur enclosure, which is critical given their increasing vulnerability status worldwide and, thus, conservation efforts within zoos. This PhD research looks at how to meet a lemur's needs with technologies through multi-sensory stimuli-based devices to enrich lemurs' lives.

### 2.2 Improving Educational Experiences for Visitors

Zoos provide visitors with essential exposure to live animals and foundational knowledge in biological sciences and conservation, especially relevant to children t[23]. However, unlike museums and science centres, zoos often educate

through animal exhibits, demonstrations, and zookeeper talks. These forms often fall short of effectively engaging children in learning due to inadequate active engagement [23, 32, 41]. To enhance zoo education for child visitors, increasing their engagement is essential. In this PhD, we propose using empathy-building to improve children's engagement as empathy is a key element for children to understand other species [18, 33]. Empathy requires children to cognitively understand the world from others' perspectives and attempt to feel what others feel [18, 27]. In zoos, fostering empathy can educate children more profoundly, thus strengthening their conservation behaviours towards animals [13, 42]. For instance, Tokuoka et al. [37] designed a body-experience-based learning support system for visitors and animals. This system, using sensors to measure visitors' movements, provides an experience that simulates the animals' living environments, enhancing visitors' empathy towards the animals and thus was found to strengthen the educational effect.

### 2.3 Promoting Appropriate Animal-Visitor Interactions

Studies have shown that interactions between visitors and animals can augment the animals' experiences in enclosures [7, 10, 35]. For instance, Baker et al.'s study at Chester Zoo found that chimpanzees with more human interaction exhibited more positive behaviours [1]. Although interactions with visitors can enrich the animals' enclosure environments, negative effects are prevalent in modern zoos. For example, an increase in visitors will lead to an increase in the time that gorillas, kangaroos, and sika deer remain wary of visitors. [14, 20, 21, 35]. This is often due to visitors attempting to interact with animals through shouting or exaggerated gestures [10, 28, 29]. Behaviours like loud noises and rapid movements stress non-human primates in zoos [10]. However, limited or no interaction fails to provide visitors with in-depth education about animals, often falling short of what visitors expect in zoos [14, 22, 24]. Finding the right balance of interaction between visitors and animals to safeguard them from stress and enrich their captive experiences while providing educational opportunities for visitors is a contentious topic [14]. Addressing this issue, Webber et al. webber2017interactive designed a series of interventions, such as educator screens, volunteer iPads, and primate apps to help facilitate the space between education and interaction. These designs have been shown to enhance non-human primates' enclosures, simultaneously stimulate visitor engagement, and improve their education effects [39]. This PhD project will use the empathy approach to build interactions between visitors and animals.

## 3 STUDY ONE: HOW TO AUGMENT THE RED-RUFFED LEMURS' ENCLOSURE WITH STIMULI-BASED TECHNOLOGY?

In the first year, a research study (Study One) was conducted to address the issue of limited space impacting the enclosure experiences of red-ruffed zoo lemurs. Six red-ruffed lemurs from Blair Drummond Safari Park and Zoo were selected as participants. The subjects include two males and four females, with a diverse age range. Considering the keen olfactory, visual, and auditory senses of red-ruffed lemurs [11, 34], we developed a sensory stimuli-based technology tailored to their enclosure. The device incorporates three types of stimuli: (1) visual – three videos titled 'Abstract Colour', 'Colourful Rose Garden', and 'Colourful Fruits'; (2) auditory – three audio tracks including 'Waterfall Sounds with Birdsong', 'Traffic Noise', and 'African Music'; and (3) olfactory – three scents: blueberry, fig, and rose. This study will observe whether and how these stimuli augment lemurs' enclosures. Three infrared ranging sensors installed on the device effectively monitor lemur approaches. Upon activation, the device randomly presents a sensory stimulus—sound, scent, video, or a combination. This 63-day study consisted of a 7-day baseline research phase, a 49-day stimuli phase, and a 7-day post-stimuli phase. By observing their behavioural responses – regarding response number, frequency, and duration – before, during, and after the intervention, we could gauge a lemur's engagement with the device and infer

what attracts them. The study aims to understand how and what stimuli attract red-ruffed lemurs by analysing their engagement (number, frequency, and duration) with the device. Our research question focuses on the following aspects:

**RQ 1:** Does sensory stimuli affect the engagement of lemurs who use the specific space?

**RQ 2:** Does sensory stimulation have a lasting impact on red-ruffed lemurs' engagement afterremoval and throughout the study?

**RQ 3:** To what extent do single-sensory and multi-sensory affect lemur engagement?

**RQ 4:** Which sensory stimulation triggers the most engagement in red-ruffed lemurs?

## 4 STUDY TWO: HOW CAN ANIMALS USING TECHNOLOGIES HELP EDUCATE CHILDREN

Study 2 focuses on children, who are principal zoo visitors, as indicated by millions of annual visits for educational purposes [23, 36]. To enhance zoo education for child visitors, increasing their engagement is essential. Thus, We plan to implement two multi-sensory devices at the lemur enclosure, one for the lemurs and a similar one for the children, to allow them both to use the same system in a shared space and for the children to learn about what sensory stimuli the lemurs are triggering and why this might be. This approach will aim to build the children's empathy and foster a deeper understanding of the lemurs' world, bridging the gap between children's and red-ruffed lemurs' perceptions. Our primary research question in the study 2 is as follows:

**RQ1:** Does animals having access/using technology enhance visitors engagement within the red-ruffed lemur exhibit area vs the traditional approach?

**RQ2:** How effective is this engagement method in educating children and adult visitors on red-ruffed lemurs and wider conservation efforts?

## 5 STUDY THREE: HOW CAN LEMURS AND ZOO VISITORS USE TECHNOLOGIES TOGETHER?

To foster appropriate interactions between children and red-ruffed lemurs, reducing stress on lemurs and increasing children's engagement for enhancing education experience, We plan to develop an interactive system based on the previous two studies to allow lemurs and children to influence each other directly through the technology as a mediator. This system augments two sensory devices from previous studies for lemurs and children. We aim to determine if this mutual influence approach can benefit both, we will explore the following research questions:

**RQ1:** How can lemurs and humans use the same technology to influence each other?

**RQ2:** DDoes humans and lemurs influencing each other through technologies improve lemurs' welfare and human engagement and education?

## 6 CONCLUSION

This research, grounded in Animal-Computer Interaction (ACI) principles, aims to simultaneously contribute to the conservation of red-ruffed lemurs and the education of zoo visitors through technologies systems. This approach seeks to demonstrate that this technology system can have a positive impact on both animal welfare and visitor learning experiences.

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