Sample of Four Winning Project Narratives

The ASP Research and Development Committee are grateful to these winners of previous Small Research Grants for agreeing to have their proposals posted as exemplary examples for future applicants. Included here are projects from both the field and from captivity.

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Project Title: Vocal Communication and Dominance Rank in Male White-faced Capuchins.

Introduction: Sexual selection has profoundly shaped the evolution of sexually dimorphic traits in primates (Clutton-Brock, 2004). Although not mutually exclusive, intrasexual selection drives males to develop exaggerated traits (e.g., larger bodies, canine teeth) signaling a competitive advantage over other males, while intersexual selection drives males to develop physical adornments (e.g., manes, brilliant colors) that attract potential mates by signaling their quality (Bradbury & Andersson, 1987; Andersson, 1994; Delgado, 2006). Sexual selection can also act on behavioral traits, including vocal signals that indicate quality, competitive ability, or dominance (Snowdon, 2004; Bradbury & Vehrencamp 2011; Puts et al., 2016). In many primate species, including humans, more dominant individuals have been found to exhibit deeper-pitched calls, higher vocalization rates, and/or expanded repertoires. These differences are most pronounced in species where males experience intense intrasexual competition (baboons: Fischer et al., 2004; Kitchen et al., 2003; rhesus macaques: Highman et al., 2013; ring-tailed lemurs: Bolt 2013; vervet monkeys: Schad et al., 2023; crested macaques: Neumann et al., 2010; Geladas: Benitez et al., 2013; proboscis monkeys: Koda et al., 2018; Puts et al., 2016). Despite this, our understanding of how sexual selection shapes primate communication remains limited due to a lack of controlled experimental methodologies that examine the perspectives of both signaler and receiver (Snowdon, 2004). This limitation has hindered our comprehension of how primates incorporate vocal signals into their decision-making processes, such as dominance challenges and mate choice. Therefore, comprehensive studies examining vocal communication from both proximate and ultimate perspectives are essential.

White-faced capuchins (*Cebus imitator*) are an excellent model for exploring how sexual selection drives variation in vocal signals, due to the pronounced differences between males of varying dominance ranks (i.e., alpha vs subordinate). Male capuchins reside in multiple different social groups throughout their lives. These dispersal events can create unstable social environments characterized by intense intrasexual competition both within and between social groups as membership changes and individuals vie for dominance (Perry 1998 a,b; Gros-louis et al., 2003; Jack & Fedigan 2004 a,b; Jack & Fedigan 2006; Muniz et al., 2010). Intrasexual competition has, in turn, led to significant variation (behavioral, morphological, endocrinological) between alpha and subordinate males, such that alpha males even represent a distinct life history stage (Jack & Fedigan, 2018). Alpha males exhibit a suite of enhanced secondary sexual characteristics such as increased body size, mandibular girth, and scrotal size (Schoof & Jack 2013; Jack et al., 2014; Schaebs et al., 2017). Alpha males also sire most offspring within a social group (Jack & Fedigan 2006; Muniz et al., 2010) and display significantly higher androgen levels compared to subordinate males (Jack et al. 2014). These rank-based differences provide a robust framework for examining how vocal communication varies across dominance ranks and may be influenced by both inter and intrasexual selection.

Vocal communication is particularly important for male capuchins given their competitive social and ecological environments. Intrasexual competition, fueled by relatively short alpha male tenures (~3 years), high population densities with overlapping home ranges, and increased resource competition in the dry season, necessitates effective communication to maintain social cohesion and respond appropriately to challenges (Fragaszy et al. 2004; Jack & Fedigan 2018; Fedigan 2021). Intrasexual vocal communication that honestly signals male dominance status and competitive ability in these environments may function to avoid potentially costly physical confrontation between males, benefiting both parties by minimizing the risk of injury or death (Mitani, 1985; Fischer et al., 2004; Delgado, 2006; Puts et al., 2016). Additionally, intersexual vocal communication may convey a male's potential mate quality, thereby attracting females (Delgado, 2006). However, *<u>little is known about how white-faced capuchins use their vocal repertoire in reproductive decision-making</u>* throughout their lives, and *<u>it remains unclear if aspects of their vocal communication play a role in sexual signaling such that they function to attract mates or deter/intimidating rivals</u>*. There is, therefore, a need to quantify both the content (i.e., repertoire, properties of the vocalizations) and the function (i.e., the behavioral responses of receivers) of vocal signaling to evaluate the possible role of sexual selection in shaping these signals in wild C. imitator.

Project Aims: I will measure behavioral, acoustic, and hormonal variables to document the variation in vocal behavior among male white-faced capuchins across different life-history stages, including subadults, subordinate adults, alpha males, and former alphas. This approach will examine both the content (repertoire size, vocal rate, acoustic parameters) of the male who is vocalizing (signaler) and the behavioral reaction of his group members (receivers), addressing gaps in communication research that are often overlooked. *The aim of this project is to assess whether capuchin vocal signals demonstrate sexual selection in communication.* Following established criteria (Snowdon 2004), I will determine if the signals vary between same-sex individuals (Objective 1 & 2), elicit differential responses in recipients (i.e., preference or avoidance) (Objective 3), are expressed in a reproductive context (Objective 1), and are related to reproductive success (Objective 1 & 3).

Objective 1 will quantify the influence of dominance rank on vocal repertoire and vocalization rate. I will investigate how capuchins of differing dominance ranks utilize vocal communication strategies in various social contexts, such as intra-group competition, encounters with extragroup males, and immigration events, where reproductive decision processes are vital (avoiding or engaging males, securing mating opportunities, establishing dominance). **Objective 2** will evaluate the impact of dominance rank and physiology on the acoustic properties of calls. I will analyze variations in pitch, energy and individual signatures (e.g., fundamental frequency, formant frequency, dominant frequency band, peak frequency, frequency range) of vocalizations from different individuals and their relation to rank and hormone levels. **Objective 3** will test the ability of conspecifics, both male and female, to discriminate male rank status and individual identity based solely on vocal signals. I will conduct playback experiments by broadcasting specific vocalizations from known individuals and recording the behavioral and vocal reactions of group members.

Expected Outcomes: I predict that dominance rank status affects the vocal communication strategies of male capuchins. Specifically, alpha males will exhibit larger vocal repertoires (e.g., number of distinct calls) and higher rates of vocal communication (e.g., number of calls per bout, call interval, number of calls per hour) compared to subordinate males (Objective 1). I also expect that the acoustic properties of vocalizations will differ between males by rank and associated hormone concentrations, with alpha males producing lower-pitched calls corresponding to higher androgen levels (Objective 2). Additionally, I anticipate that capuchins can accurately identify rank and individual identity of males from their vocal signals alone, with alpha male calls eliciting stronger behavioral reactions (e.g., greater response rate, avoidance vs. approach) than those from subordinate males (Objective 3).

Methods: Study Site and Subjects: I will collect data on ~25 adult and subadult males from six social groups of wild white-faced capuchins in Santa Rosa Sector of the Área de Conservación Guanacaste (SSR), Costa Rica. This population has been studied continuously since 1983 (Fedigan & Jack, 2012) and is sufficiently habituated, allowing for the collection of high-quality audio recordings.

Procedure: I will record the vocalizations using a Sennheiser ME66 directional microphone and a Marantz PMD-661 handheld digital recorder, a technique applied in previous studies of this species (Boinski & Campbell 1995; Fichtel et al., 2005; Gros-louis 2006; Digweed et al., 2007; Gros-louis et al., 2008; Crofoot et al., 2011). For each vocal occurrence, I will record the identity and behavior of the calling male and any vocal respondents. Simultaneously, I will collect behavioral data using the established SSR ethogram via focal animal sampling (15-minute samples; Altman 1974). I will evaluate the effect of rank, age, and group on male vocal behavioral metrics using generalized linear mixed models (GLMM, Baayen et al., 2008) with individual ID and sample date as random effects.

To identify and quantify the differences in acoustic properties and their relationship to androgen levels, I will examine the recordings of male loud calls (e.g., alarm calls, lost calls, intergroup encounter calls, copulation calls). I will analyze the spectral properties (e.g., fundamental frequency, formant frequency, etc.) of vocalizations through an automated procedure I have developed and tested in a pilot study using OpenSmile software (Eyben et al., 2010). When automated extraction of acoustic properties is not feasible, I will manually analyze spectrograms using Praat (praat.org) software. To account for intra-individual variation in calls, I will analyze multiple high-quality recordings from each individual and use only recordings with a high signal-to-noise ratio to avoid interference from background noise (e.g., bird songs, humans talking or conflicting vocalizations from other individuals) (Highman et al., 2013; Fischer et al., 2013; Benitez et al., 2013; Leroux et al., 2023). I will then model the effect of male rank and age on acoustic variation, using individual ID and sample date as random effects. I will collect and assay fecal samples using the established protocol at SSR (Pappano et al., 2010; Schoof, 2014) and use a GLMM to identify effects of male rank status on androgen levels.

To quantify the behavioral and communicative reactions of group members to vocal signals from males of different dominance rank statuses, I will conduct playback experiments utilizing high-quality recordings of long-distance vocalizations. Due to the limited access to groups and individuals, I will implement a matched pairs design, randomly varying the types of trials in a predetermined manner (Zuberbühler & Wittig 2011). To account for the novelty factor of the experimental stimulus, I will use four different test conditions (lost call, intergroup encounter call, alarm call, copulation call), with each condition serving as a control for the others. As multiple group members are likely able to hear each experimental trail, I will only use each vocal stimulus one time per social group to minimize habituation and pseudo-replication (Zuberbühler & Wittig 2011; Candiotti et al., 2013; Fischer et al., 2013; Kroodsma et al., 2001). I plan to follow the experimental conditions outlined in Candiotti et al., 2013, which set six standard criteria that if not met, will result in aborting the trial. Using a Sony Handycam AX53 4K camcorder and the audio recording equipment, I will record the reaction of group members and document any relevant commentary throughout each experimental trial (Fischer et al., 2013).

Expected Results and Project Impact: This project will significantly enhance our knowledge of behavioral and morphological differences among male white-faced capuchins of different rank by exploring the interplay between vocal signals, endocrinology, and reproductive strategies. By identifying complex variation in capuchin vocal communication, this study will provide insight into how sexual selection shapes communication in wild primates, advancing the field of primatology as a whole

Education/Outreach (optional): Funding for this project will provide support for local conservation and research efforts in Área de Conservación Guanacaste (ACG). Through ongoing efforts, my team will participate in the “Quiero dejar una huella verde!” (Leave a green footprint!) campaign with the goal of reducing the ecological footprint of visitors in the region and educating local school groups on day trips to the ACG. Education and longstanding outreach partnerships will be key components in my work in New Orleans and at SSR. In Costa Rica, efforts will be made to employ local scientists at every level, and who will be trained in field primatology methods, including learning to identify >100 individual monkeys, the use of GPS technology, and methods for collecting a range of behavioral, biological, and vocal data. In New Orleans, I will continue to participate in the K-12 STEM education outreach through Tulane University, which provides positive mentoring and fosters interest in STEM fields by implementing educational activities. Through these primatology workshops, we encourage students to actively engage with multiple senses while participating, including activities such as using rocks to open rocks to illustrate the ways primates might access food resources in the wild. I hope to implement activities that highlight primate communication.

Anticipated Products and Indicators of Project Success: I will disseminate my results to American and international academics and the public through conference presentations, publications, and lectures. I plan to publish three papers, each addressing a different objective of this research. I will also submit to present this research at the ASP conference in 2025. Additionally, I will present my research as part of the Middle America Research Institute lecture series at Tulane University and at the Tulane Research, Innovation, and Creativity Summit.

Project Schedule and Timeline: I will collect data during the 2025 dry season (December 2024- May 2025) and again during the 2026 dry season. This schedule is designed to optimize the recording of vocalizations from all available individuals and allow for subsequent field experiments. Having already conducted extensive research at SSR, I am familiar with the individual identities and behavioral repertoire of the study subjects, which will allow me to begin data collection immediately.

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ASP Small Research Grant Proposal Form

Project Title: Foraging and Risk Avoidance Behavior of *Cercopithecus lowei* in a Human-dominated Landscape at the Boabeng-Fiema Monkey Sanctuary in Central Ghana.

1. Introduction and Relevant Background Information

Predation is a powerful force that affects animals' behavior. Prey adjust their behavior to reduce predation risk in high-risk areas, such as increasing vigilance, avoiding the area during high-risk periods, and decreasing group spread[1,2]. This leads to spatial patterns of responses known as the "landscape of fear"[1,3–5]. However, these behaviors may decrease foraging efficiency, and animals need to maintain a balance between avoiding predation and accessing food[6]. For example, *Cercopithecus mitis albogularis* were more likely to feed in high-risk areas, indicating that they only enter those areas for essential activities[2]. Predation risk and foraging strategies vary not only with location but also with age-sex class, reproductive status, and development[7,8]. This may lead to differences in flight distance (i.e., the distance to the predator that elicits the prey to flee). For instance*, Chlorocebus pygerythrus* have longer flight distances in rural areas than urban areas, and males have shorter flight distances than females and juveniles[7].

The trade-off between foraging and risk mitigation is likely important in shaping primate behavior in urban environments. These environments may provide high access to human-cultivated foods, while competition may also lead to conflicts between non-human primates (hereafter referred to as primates) and humans[2,7]. Humans are not a threat in all contexts. One example comes from the varied interactions between humans and *Cercopithecus lowei* in my home community at the Boabeng-Fiema Monkey Sanctuary in Ghana. *C. lowei* eat cultivated foods in the farmlands and from storage sheds in the communities. Although their behavior is often considered a nuisance[9,10], their presence at Boabeng and Fiema is not only important for cultural beliefs and the ecotourism project, but also for the local economy and biodiversity conservation. The people from these two communities do not directly interact with them in the forest, and they chase them from their property and food resources. Tourists actively feed the monkeys while researchers observe their behaviors without directly interacting with them[11]. To thrive in human-dominated environments, it is likely important to consider such contextual information to maximize foraging while reducing the likelihood of human conflicts. However, it is still unclear how primates respond to spatial, temporal, and contextual variation in food abundance and predation risk in these environments[4].

2. Project Aims and Novelty

The project studies how *Cercopithecus lowei* (Lowe's monkey) change their behaviors to optimize foraging and reduce risk at the Boabeng-Fiema Monkey Sanctuary in Ghana. This is a human-dominated landscape from which most other predators have been extirpated. Although the trade-off between foraging and predation has been examined in other primate species, it has not been studied in *C. lowei*. This study is a novelty because it explores the relatively unexplored area of how spatial and temporal variations in food availability and predation risk in a Human-dominated landscape impact primates. Examining this topic will enhance our understanding of primates' capabilities and limitations in adapting their behaviors to reduce risk while maximizing their foraging efforts.

3. Hypotheses and Predictions

H_1: Human encounters and negation interactions are associated with temporal and spatial variations and food access[8,12]. I predict encounters between the study group and humans will increase with proximity to the village, roads, and trails, increasing food abundance in those areas. They will be highest in the evenings and decrease with rain and hot temperatures. I predict negative interactions to be more likely to occur with community members than with tourists and researchers, especially in the presence of cultivated food items.

H_2: Perceived risk and foraging efficiency are associated with individual traits and characteristics, a group's social structures, and flight distance[1,7]. I predict a higher likelihood of foraging (i.e., behavior necessary for survival), increased vigilance, and decreased group spread (i.e., anti-predator behaviors) with proximity to the village, roads, and trails during evenings and decreased rainfall and temperatures and with the presence or abundance of cultivated foods, and with proximity to humans, particularly community members. Also, I predict *C. lowei* will show shorter flight distances during low food abundance, when feeding in areas with high food availability, closer to shelter (i.e., trees in the forest), higher vertical strata, proximity to group members, and when encountering tourists than community members.

4. Study Site(s)
The Boabeng-Fiema Monkey Sanctuary (BFMS) is a 1.9 km^2 protected forest in Ghana managed according to traditional beliefs[13,14]. Most predators have been extirpated from this area. The vegetation comprises patches of original forest, degraded forest, woodland, and derived savanna[14] but the study species (*Cercopithecus lowei*) also spends considerable time in the village and farmlands[15]. The people primarily rely on subsistence farming, with major crops like yams, cassava, and mango as food sources for *C. lowei*. People use the forest to collect resources like firewood, typically during the dry season. A major source of income is the ecotourism project, and a significant number of tourists come to view the monkeys each year [11,16].

5. Subjects (species, number, demographics, and housing, if applicable)
Cercopithecus lowei is omnivorous[9,15,17] and feeds on forest plants, insects, and human-cultivated food [17]. Although the locals do not actively hunt them, they chase them from their property and food resources, tourists feed and take pictures with the monkeys, and researchers observe the monkey's behavior [11]. A group of guenons (AK group) consisting of 18-20 individuals has been selected for observations because its home range includes forest, forest-village edge, and village habitat; they interact more with community members and tourists than other groups, and I was able to individually recognize 10 adult males and females during my 2023 preliminary data collection season. I will collect data from adult males and females using individual IDs, while data on juveniles and immatures will be recorded using their age-sex class.

6. Experimental Design
From August 2024 to August 2025, behavioral data collection from one social group will occur in different habitat types (forest, forest-village edge, and village). The behavioral observation blocks consist of five days, from 7:00 to 18:00 hours. I will do monthly phenology surveys to document food availability. I will record rainfall and temperature daily.

7. Data Collection Protocol (including animal handling, if applicable)
Every 30 minutes, I will record the group's location with a GPS unit, group spread, and conduct group scans[18] of as many group members as possible for 10 minutes to record individual state behaviors (rest, feed, travel, social, vigilant, other), habitat type, vertical level, number of conspecifics in 5 meters, and proximity to humans and predators. For feeding individuals, I will also record the food species and plant parts. I will use 5-minute focal samples of adults (who can be recognized individually) to continuously record interactions with humans and predators, including approaches, vigilance, alarm calls, social interactions, and flight distance. Alarm calls, any response or

interaction with other species, and context will also be recorded *ad libitum*. Humans interacting with the monkeys will be classified as community members, tourists, or primate researchers. I will create maps of food and predator encounters by dividing the encounter densities by usage densities using kernel density estimation in QGIS [1]. I will collect monthly phenology data from food trees and food storage sites in the village[19], combined with mapped locations of food trees/sites to calculate monthly food availability indices for the forest, edge, and village habitat within this group's home range. I will also collect monthly human spatial usage data by surveying the presence of humans in the forest, edge, village, roads, and trails to determine spatial overlap between guenons and humans in these habitat types.

8. Planned Data Analysis

I will examine whether encounters and negative interactions with humans are predicted by the usage density of the location, habitat type, food availability index of cultivated foods vs. other foods, time of day, rainfall, temperature, season, and human type (H_1). I will investigate whether group spread, feeding, and vigilance during group scans and flight distances (H_2) are predicted by individual age-sex class, the location's likelihood of human encounters, food availability index, vertical height, presence/absence of humans in 5m, number of group members in 5m, time of day, rainfall, temperature, and season, and human type. Analyses will be done using Generalized Linear Mixed Models in R with the random effects group scan ID or focal ID.

9. Expected Results and Project Impact

I anticipate obtaining 1,936 hours of observations, 10,120 group scans and location points, and 816 hours of focal samples that I will use to determine how spatial, temporal, and context of primate encounters with humans predict feeding, perceived predation risk and flight distances. Investigating these topics will help us understand primates' abilities and constraints in expressing behaviors to minimize predation risk while maximizing foraging in human-dominated landscapes. The research aims to contribute to the theoretical concept of the landscape of fear and the trade-off between predation risk and foraging, but I will also, in collaboration with my communities, apply the findings to develop population management plans for promoting co-existence between humans and primates.

10. Education/Outreach

I will present my findings to tour guides and tourists at BFMS and discuss with community members and other stakeholders how my findings can be incorporated into management plans to reduce human-primate conflicts and promote human support for the conservation project.

11. Anticipated Products and Indicators of Project Success

I will present my findings at the ASP conference and publish two articles ("Foraging and Risk Mitigation in a Human-Dominated Landscape" and "Human and Non-human Primates Interactions at the Boabeng-Fiema Monkey Sanctuary in Ghana") in AJP and Animal Behavior. This study will also be part of my PhD dissertation on human-primate interactions.

12. Project Schedule and Timeline

June-July 2023: Preliminary fieldwork to develop group scan and focal data collection protocols at Boabeng-Fiema, Ghana. August 2024 - July 2025: Data collection at Boabeng-Fiema, Ghana, data management, and preliminary data analysis. August – December 2025: Data Analysis. January - May 2026: Write-up of results and presentations. June – August 2026: Submit manuscripts for publication.

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Project Narrative

Abstract

The best experimental test of self-control in nonhuman primates, the hybrid-delay task, requires an involved experimental setup with a high degree of experimenter involvement. I propose a procedure to automate the hybrid-delay task with chimpanzees (*Pan troglodytes*) using a small, affordable sensor setup that detects the chimpanzees' movements throughout automated trials and automatically adjusts task contingencies according to chimpanzee behavior. With this novel setup, I will test chimpanzee decision-making and self-control in contexts in which it has not been feasible to test previously. More specifically, I will sample chimpanzee capacity for self-control across the course of the day and in naturally occurring variations in the chimpanzees' social environment.

Introduction

A. Specific Aims

a. Determine the effect of previously unexplored contributors to chimpanzee self-control - social influence of experimenter and conspecifics as well as biological rhythms - by automating the hybrid-delay task with a Kinect sensor.
b. Discover the utility of the Kinect sensor for use as apparatus for cognitive-behavioral testing of chimpanzees, automatic recognition of chimpanzee gestures, and response recognition for use with chimpanzees in any captive context.

B. Background & Significance

Studies of nonhuman primates' capacity for self-control have long offered a window into the primates' voluntary control over their behavior and their future-oriented thinking[1–3]. The hybrid-delay task (HDT) is the most comprehensive tool for estimating primate self-control[4–6]. First, the primate's capacity to *delay gratification* is tested by offering it a discrete choice between a smaller food reward now (smaller-sooner) and a larger food reward later (larger-later). If the smaller-sooner reward is chosen it is received immediately, whereas if the larger-later reward is chosen it is distributed incrementally across a period of time. Critically, distribution of larger-later rewards ends immediately if at any point the primate consumes one of the rewards. This tests the primate's capacity for *delay maintenance* - to continue to delay gratification beyond the initial choice. Taken together, the task simulates the challenging self-control decisions that humans make - to save or spend, to stick to a diet or cheat - in a way that is entirely nonverbal, suited to animal testing, extendible to other rewards, contexts, and delays, and readily analyzable.

A principal limitation of HDT is the high degree of experimenter involvement required. In classic HDT, experimenters isolate an animal, set-up trials, judge gestural communications of the animals, then deliver rewards according to strict timings. This procedure is demanding of the experimenter, and introduces some limitations. Experimenters may unknowingly cue animals' responses via Clever Hans effects, or unintentionally misrepresent choices during the subjective judgment of the animal's gestures[7]. Test sessions are made on the experimenter's schedule, typically testing animals' self-control during only a narrow window of time each day. And animals are often isolated for testing purposes, stripping deployment of individual self-control from the richly social context in which the animal's cognition developed.

An automated HDT would offer many advantages. How the animals evidence self-control would be studied on the animal's schedule, and in the animal's social environment, absent any biasing experimenter effects. Kinect hardware (Microsoft corporation) presents one plausible method of automating HDT. The Kinect includes multiples sensors - including infrared, an RGB camera, and a microphone - that combine to generate both a live video feed and a 20-point cloud of x, y, z coordinates representing the head, limbs, and joints of the primate. Because the Kinect is low-cost, mass-produced, and able to be interfaced with directly using drivers provided by the manufacturer, researchers have proposed use of Kinect sensors in diverse applications including K-12 education, physical therapy, and automatic detection of requests by older adults in long-term care facilities[8–10]. Because the Kinect is entirely noninvasive and represents primate heads, limbs, and joints in roughly the same way as humans', and these representations of normal primate anatomy and gesture can be mapped to arbitrary task contingencies like those of HDT, it is an ideal choice for automatic testing of chimpanzee behaviors[11]. Because it can represent multiple primates at once, it is also uniquely suited to quantifying the social context around an animal as it completes the task.

Use of Kinect hardware with a nonhuman primate would offer an exciting new apparatus for task designs in which conventional experimenter testing, joystick testing, or touchscreen testing are poor fits. Outside of cognitive-behavioral testing, a protocol for use of the Kinect sensor with chimpanzees would have many applications in studies of animal mobility, activity patterns, gesture use, and general welfare. The Kinect might be 1) used to allow captive animals to use gestures to control elements of their environment when human caregivers are not around, increasing overall welfare, or 2) incorporated into existing theoretical frameworks like automatically tracking foraging decisions as they are made. Extension of HDT beyond the relatively narrow range of testing situations in which it has been previously used would represent a much richer view of primate self-control abilities and the many factors that likely contribute to them.

Methods

A. Study Site

The University of Texas MD Anderson's Michale E. Keeling Center for Comparative Medicine and Research.

B. Subjects

A subset of the 47 chimpanzees housed at the Keeling Center will take part in this research. Chimpanzees are housed in social groups of 4-10 conspecifics and will never be separated for purposes of this research. Because testing will be automated, the specific number of chimpanzees tested will depend in part on chimpanzee enthusiasm for engagement with the apparatus.

C. Procedures

a. Experimental Design

Chimpanzees will be tested throughout the week in their social groups. Testing apparatus will be positioned in indoor human areas 2-3 m away from chimpanzee enclosures (e.g., juice reservoirs, Kinect, computer setup) or affixed to the mesh of the chimpanzee enclosure (e.g., nozzle to receive juice rewards).

Pilot testing will reveal which chimpanzee positions, movements, or gestures are most reliably sampled and categorized by the Kinect. These will then be mapped to HDT contingencies. For example, a chimpanzee at a distance of 1 m from the mesh that is oriented perpendicular to the Kinect would be regarded as starting the trial. That chimpanzee approaching the mesh immediately would end the trial and dispense the smaller-sooner reward. That chimpanzee choosing to avoid approaching the mesh, and allowing rewards to dispense over time, would constitute choosing the larger-later reward. Alternatively, a request of the smaller-sooner reward could be made with one low-energy gesture (e.g., arm-above-head then return to neutral), whereas dispensing the larger-later reward could be contingent on maintaining the gesture across the course of the trial without exploiting the juice reward.

Other elements of experimental design will mirror previous HDT designs. A brief learning phase will be used to allow naive chimpanzees to sample both the smaller-sooner and larger-later task contingencies, and shape any specific gestural responses used in the HDT. To allow animals to sample both smaller-sooner and larger-later contingencies, some initial training trials will force animals into one of the alternatives rather than allowing the animal a choice. The specific reward quantities and delay durations used will vary continuously, within-subjects, between blocks of testing. To make the animals' choices more costly, and guarantee that the larger-later reward is indeed more efficient than the smaller-sooner reward in all trials, the intertrial interval will vary unpredictably such that the Kinect will not allow another choice for some dozens of minutes after a completed trial.

b. Data Collection

Videos of each trial will be recorded automatically by automating a screen-recording of the video feed from the Kinect. Kinect point clouds will be stored as series of timestamped xyz coordinates in .csv files. A summary of the Kinect movements that were detected, the choices these movements corresponded to, and the rewards dispensed will be stored in a separate .csv. All data will include contextual information like the time of day in which testing occurred and the number of individual chimpanzees that were in the Kinect sensor field of view during the trial. Data will be stored on external hard drives in separate locations and backed up according to data security best practices.

c. Data Analysis

HDT data will be represented both as the choice of smaller-sooner or larger-later reward on the initial delay-of-gratification decision, and as the number of larger-later rewards attained on any larger-later trial. Larger-later decisions in HDT tasks are transformed into an efficiency score metric that describes the efficiency of that choice, relative to the smaller-sooner decision, according to the quantity of rewards actually attained via the larger-later decision.

Kinect points will be eliminated where they are characteristic of a false-positive (no animal present) by the Kinect. Valid data will be algorithmically cleaned to remove a portion of the noise introduced by the Kinect sensor, akin to the algorithms used on eyetracking datasets (e.g., Tobii IVT algorithm). Previously reported or custom gesture-recognition tools will be used to evaluate the feasibility of using the Kinect to recognize chimp gestures of varying complexity.

Both sets of data, comprising the dependent variables in formal analyses, will be aggregated according to date, time, task contingencies, and social context (e.g., number or identity of individuals detected by the Kinect), comprising the independent variables in formal analyses. To determine the effect of independent variables on dependent variables, Bayesian multilevel models will be used. All analyses will be done using the pymc3 and pandas modules for Python3.

d. Animal Handling

Experimenters will not directly engage with animals during this research. Animals will be cared for at all times by a team of veterinarians and care staff.

Expected Results and Relevance

Chimpanzees will learn the task contingencies of a Kinect-automated HDT and make smaller-sooner and larger-later decisions. As in previous HDT designs, chimpanzees will be capable of effectively maintaining self-control throughout a delay period in order to maximize rewards. Unlike previous HDT designs, chimpanzee decisions and self-control will vary with trial context. Chimpanzees will be biased to more inefficient choices in the presence of conspecifics, and efficiency of self-control behaviors will vary systematically over the course of the day. These results complement ongoing research on chimpanzee self-control and the network of internal and external factors that affect it. Use of the Kinect will be an apparatus innovation that is well-suited to many other task designs in which crude recognition of primate positioning and gesture can be leveraged for the study of captive primate brains, behaviors, and welfare.

Education/Outreach (optional)

Results from these experiments, especially the Kinect representations of charismatic chimpanzees as they move and gesture in the task, will be used as a teaching tool during classroom outreach visits in-person in Central Texas and online via the Skype-a-Scientist program. I plan to do at least five of these outreach activities. I will also involve undergraduate research assistants via collaboration with Texas A&M University’s Evolutionary Ecology and Conservation Biology Dept, especially in exploring the reliability of the Kinect dataset and its potential for extensions to other research questions.

Timetable

Quarter 1 :: Acquire materials - build housing for apparatus - pilot different programs with different task contingencies - finalize experimental design - pre-register design and analyses with Open Science Foundation - begin data collection

Q2 :: Continue data collection - clean and aggregate data and algorithmically smooth Kinect data

Q3 :: Complete data collection - complete formal statistical analyses of data

Q4 :: Compile complete report of experiment

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Karaskiewicz: Sleep through the Social Lens

Introduction

Abstract. Sleep supports physical and mental functioning and is sensitive to social factors like partner presence. Specifically, partner absence leads to increased sleep disturbance, which is resolved upon reunion with the partner. Social sleep serves a variety of coregulatory functions from thermoregulation and postural support to stress buffering and affective regulation. Coppery titi monkeys (*Plecturocebus cupreus*) are socially monogamous primates that sleep socially and form enduring attachment relationships within a mating pair (but not from parents towards offspring). Research on sleep in titi monkeys is limited, but prior work identifies the common sleeping posture as bodily contact between pair mates and subadult offspring, most often with their tails intertwined. This posture is hypothesized to support thermo-conservation and balance, but no studies to date have examined the contributions of social others to sleep. The proposed work will manipulate the social setting in which titi monkeys sleep in order to discern the importance of social others and the unique contributions of the attachment figure during sleep. Ten pairs of adult titi monkeys will experience three experimental conditions on consecutive nights: sleep with the attachment figure (the pair mate), sleep with a non-attachment family member (subadult, independent offspring), and sleep alone without a social other. Comparing sleep across these conditions will allow us to draw conclusions about contributions of specific social partners to sleep—which inform not only our understanding of the unique social relationships between titi monkeys but contribute to our understand of attachment relationships in primates as a whole.

Specific Aims. The proposed work aims to identify the impact of the social environment on sleep, specifically how the presence and absence of the attachment figure during the night affects sleep in a co-sleeping species. This experiment will evaluate the role of a social other in sleep, namely whether the benefits of social sleep are conferred by any social other, or if there is a unique benefit of sleeping with one's attachment figure.

Background & Significance. Sleep is a fundamental biological process, which supports healthy physical (*humans*: Kuhn et al., 1969; Mullington et al., 2010; Sauvet et al., 2010; Ogawa et al., 2003; Zhong et al., 2005; Cappuccio et al., 2008; Miller & Cappuccio, 2007) and psychological functioning (*humans*: Haack et al., 2009; Kendall et al., 2006; Dawson & Reid, 1997; Drummond et al., 2000; Killgore, 2010; Drummond et al., 2006; Killgore et al., 2006; Mckenna et al., 2007; Kahn-Greene et al., 2006, 2007; Tempesta et al., 2010). Sleep is also sensitive to the social environment (*rhesus macaques*: Benca et al., 2000; *humans*: Diamond et al., 2008; Elek et al., 2002; Gay et al., 2004; Yamazaki et al., 2005), specifically to attachment style (*humans*: Carmichael & Reis, 2005; Troxel et al., 2007) and the presence of the attachment figure (*humans*: Diamond et al., 2008). Temporary partner absence leads to increased sleeping problems (i.e., longer latency to sleep, more disturbed sleep) and reunion resolves these issues (*humans*: Diamond et al., 2008). Among nonhuman primates, preparing for sleep and the consequences of sleep loss shape daily activity and behavior (Anderson, 1998, 2000). These findings indicate that sleep is sensitive to the social environment and that major changes to this environment are disruptive to an individual's sleep—which can have deleterious mental and physical health effects across even small amounts of time.

Titi monkeys (*Plecturocebus cupreus*) are socially monogamous primates that live in small family groups comprised of a single adult mating pair and their sub-adult offspring (Mason, 1966). They form strong, enduring attachments to their pair mates but not their offspring (Mason & Mendoza, 1998) and biparentally care for their young (Mason, 1966). Titi monkeys sleep socially in their family group, often huddled together with their tails intertwined (Mason, 1966; Moynihan, 1966). This posture is typically referred to as affiliative during the day (Fernandez-Duque et al., 2000), but some researchers hypothesize that at night contact between group members serves a thermo-conservative role and tail twining serves as postural support to maintain balance (Moynihan, 1966). Characterizations of sleeping posture and sleeping sites have been recorded in wild titi monkey populations but sleep in this species has never been directly quantified.

In addition to being the first to quantify titi monkey sleep through nighttime activity, this experiment will be the first examine the effect of the social environment on an individual's sleep in this species. Indeed, few studies have examined the impact of the social environment on nonhuman primate sleep at all. Prior studies in primates have chiefly identified the impact of altered social environments by isolating subjects for study and finding unusual patterns of extreme wakefulness (*rhesus*: Benca et al., 2000). In addition to pioneering sleep research in a new species, this research will provide insights for captive animal care and welfare. Understanding how separation from social others affects sleep will give captive primate care professionals necessary information about sleep in animals that are singly housed or isolated for healthcare treatment and recovery.

Methods

Study Site. This study will be conducted at the California National Primate Research Center (CNPRC) in Davis, CA. Animal husbandry and veterinary care will be provided by the CNPRC husbandry and veterinary staff. Data collection will be completed by the applicant (Chloe Karaskiewicz) with assistance from the research team of the Bales Laboratory for Comparative Neurobiology of Monogamy.

Subjects. Subjects for this study will be 10 pairs of coppery titi monkeys (*Plecturocebus cupreus*) that have been paired for over 1 year, have two behaviorally and nutritionally independent (> 6 months) offspring, and have no dependent (< 6 months) offspring.

Experimental Design. Subjects will move from their home enclosure to a private room where they will habituate to the novel cage and environment for 2 days (Bales et al., 2007) before experiencing three overnight conditions (Figure 1). During habituation, the family will sleep together as they would in their home enclosure. In the attachment condition, subjects will sleep with their pair mate (the attachment figure) while the offspring are separated from the parents by a visual and tactile barrier. In the social non-attachment condition, subjects will sleep with one of their offspring (nonattachment family member), separated from their pair mate and other offspring by a visual and tactile barrier. In the alone condition, the subject will sleep alone, separated from their pair mate and offspring by a visual and tactile barrier. Each family will undergo the testing procedure 3 times and the order of the testing conditions will be counterbalanced across pairs and across repetitions of the procedure. Separations between family members will occur during the dark period (18:00-06:00) and families will be reunited during the light period (06:00-18:00). All animals will have continuous access to *ad libitum* food and water during both separations and reunions.

Data Collection. On the same day the family is moved to the testing room, both adults will be fitted with collar-mounted accelerometers. The habituation period to the novel environment will also serve as the habituation period to the collar-mounted accelerometers. The accelerometers will continuously record each adult's activity for the duration of the experiment. Accelerometers will be removed as the family is returned to their home cage. Use of accelerometry to estimate activity is a well-validated tool by which to assess nighttime behavioral sleep among diurnal nonhuman primates (Qui et al., 2020). All testing sessions will be video recorded using an infrared video camera and supplemental infrared floodlight.

Data Analysis. This project will compare subjects' nighttime activity in the three experimental conditions described above. Overall nighttime activity will be compared, as well as more specific variables of sleep perturbance: sleep latency and sleep disruption. Sleep latency will be calculated as the amount of time after the onset of the dark period that it takes an individual to achieve 5 minutes of uninterrupted inactivity. Sleep disruption will be calculated as the frequency and duration of time an individual is active during the dark period after the first period of uninterrupted inactivity. Accelerometry data will be compared with behavioral scoring of activity from infrared video recordings by trained scorers.

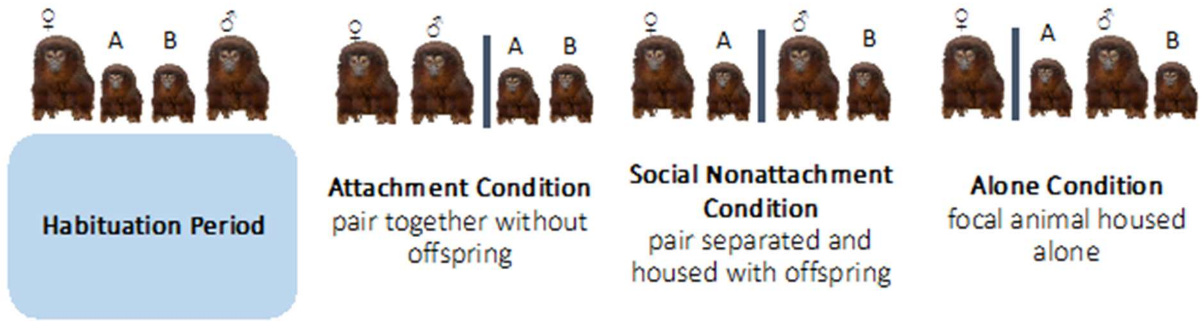

Figure 1. Proposed experimental design. For the Social Nonattachment and Alone conditions, the female is the focal animal in this example.

Animal Handling. This study will require minimal animal handling as all data collection is noninvasive. Husbandry professionals at the CNPRC will transfer families between their home cage and the testing room. Animals will be handled for collar placement by Chloe Karaskiewicz and another trained colleague from the laboratory research team using practices approved by the UC Davis IACUC and CNPRC.

Timetable. The testing procedure will take 3 weeks to complete for each subject family. Each week, the family will experience 2 days of habituation/rest, 1 day of attachment condition, 2 days of social non-attachment conditions (1 for each adult), and 2 days of alone conditions (1 for each adult). This process is repeated 3 times, for a timeline of 3 weeks per family. With a goal to enroll 10 families in this study and 2 separate testing rooms in which to run subjects concurrently, it will take 15 weeks to complete this study.

Expected Results and Relevance. I predict that subjects will be less active, have shorter sleep latencies, and have less disruptions to sleep in the attachment condition compared to both the social non-attachment and alone conditions. I predict that subjects will be the most active, have the longest sleep latencies, and the most frequent sleep disruptions in the alone condition compared to both the attachment and social non-attachment conditions. I predict a sex difference only in the social non-attachment condition: males will have less disrupted sleep in the social non-attachment condition compared to females because offspring sleeping with their fathers (their attachment figure) will be less disruptive than when sleeping with their mother (their non-attachment family member). The connection between sleep and attachment is not well understood, in part due to the bidirectional nature of the relationship. Results from this study will add to the sparse literature on this relationship as well as establish a unique nonhuman primate model in which to pursue future research on the socioecological aspects of primate sleep.

Education/Outreach. This project will present opportunities for undergraduate mentees to learn behavioral scoring techniques to quantify titi monkey activity throughout the night and data analytic techniques for cross-validating different measures (accelerometry and behavior) of the same outcome variable (activity). The applicant currently advises 3 undergraduates, all of whom will conduct independent senior practicums in Animal Biology under the guidance of the applicant.

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