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THE EFFECT OF SOUND ON CAPTIVE CHIMPANZEES (*PAN TROGLODYTES)*

A Thesis

Presented to

The Graduate Faculty

Central Washington University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

Primate Behavior

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by

Grace Meryl Coffman

May 2019

CENTRAL WASHINGTON UNIVERSITY

Graduate Studies

We hereby approve the thesis of

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ABSTRACT

THE EFFECT OF SOUND ON CAPTIVE CHIMPANZEES (*PAN TROGLODYTES*)

by

Grace Meryl Coffman

May 2019

Sound exposure can have detrimental physiological and psychological effects on humans, but effects on nonhuman primates are not as well understood. Captive chimpanzees are exposed to markedly different acoustic environments than their wild counterparts. This study assessed the organic soundscape of a chimpanzee sanctuary, the Fauna Foundation, in Carignan, Québec, Canada. Noninvasive, observational data collection assessed for frequency of behavior and correlations between chimpanzee behavioral categories, arousal level, and decibel level. Agonistic behavior occurred more frequently in the highest decibel level category. There was a positive correlation between decibel level and arousal level. These findings suggest the need for increased awareness of sound exposure within chimpanzee sanctuaries, as heightened acoustic environments induce stress. This study has implications for captive welfare regulations, enclosure construction, husbandry routines, and zoo environments.

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There are many people (human and nonhuman) I would like to thank for assisting me with this project. First- my advisor and committee chair, Dr. Mary Lee Jensvold, who has devoted countless hours to ensuring the success of this project. She has helped me turn my interest and passion for captive welfare into a research project that has real life impacts. This study truly would not have been possible without her support and input every step of the way- it is thanks to her that I stayed on track when I encountered roadblocks. Next, Dr. Blue and Dr. Sheeran, my wonderful committee members, have provided me invaluable support whenever I needed it, no matter what. Whether it be last minute changes or a quick pep talk, they have helped me throughout this process more than I think they know.

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Finally, to my family and friends who have always picked up the phone and lent me support and love- even from over 2,000 miles away. To my Primate Behavior Cohort, who are some of the most intelligent and wonderful humans I have ever met, I could not imagine going through this process with anyone else. Lastly, thank you to the Pete and Sandra Barlow Award Fund, Department of Anthropology and Museum Studies, CWU; Friends of Washoe; and Debra and Arlen Prentice for helping me fund this study. Hooray!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Sound levels are quite variable from construction sites, airports, and concerts to yoga studios and libraries. Sound exposure is an important factor in quality of life as it is becoming increasingly difficult to escape anthropogenic sound, which can vary in composition from brief, high-impact sound to constant, amorphous soundscapes (Slabbekoorn, Dooling, Popper, & Fay, 2018; Ricciardi, Delaitre, Lavandier, Torchia, & Aumond, 2015; Ziaran, 2005). Soundscapes also have the potential to affect nonhuman animals who rely on acoustic signals for survival and communication.

The decibel (dB) is one of the frequently used measures of sound. A dB is a numeric measurement that represents sound on a logarithmic scale (Chapman & Ellis, 1998). The dB is "used in environmental noise pollution (studies) as a measure of sound power level, sound intensity level and sound pressure level" (Ziaran, 2005, p. 178). A whisper is listed at 30 dB, conversational speech registers between 70 and 80 dB, and shouting is just below 90 dB. Automobiles on the highway are 110 dBs (Ziaran, 2005).

Acoustics play an important role in any organisms' day-to-day activity since sound and its corresponding vibrations can affect quality of life (Ziaran, 2005). Continuous exposure to sound levels higher than 85 dBs can lead to hearing loss in humans (Atmaca, Peker, & Altin, 2005; WHO, 2015). Noise induced hearing loss is also a concern for concert goers, as sound levels consistently exceed 100 dBs (Bogoch, House, & Kudla, 2005). Environmental sound exposure increases human reports of annoyance, sleep disturbance (e.g. increased number of times woken up), and impaired cognitive performance (Stansfeld & Matheson, 2003). Sound exposure is also concerning for patients hospitalized for psychiatric symptoms as environmental stress (e.g. sound) can increase psychological stress (Holmberg & Coon, 1999; Basner et al., 2014). Acoustic overstimulation can also cause detrimental psychological impacts. For example, prisons are noisy institutions where "omnipresent noise is more than an inconvenience" (Bryant, Davis, Haywood, Meikle, & Pierce, 2014, p. 105). Workers in industrial settings experience chronic exposure to high intensity sound and also report annoyance reactions, including anger (Stansfeld & Matheson, 2003; Cohen & Weinstein, 1981).

While the effects of sound on humans are well studied, they are less studied in nonhuman primates. Captive animals are subject to a markedly different soundscape than wild populations. Nonhuman primates in rainforest environments experience a range of 27 to 32 dBs of ambient sound (Waser & Brown, 1986). Comparatively, sound measurements during cleaning in a laboratory were over 80 dBs (Peterson, 1980). When vents opened for air exchange, dB levels were over 110 (Sales, Milligan, & Khirnykh, 1999), more than double that of the rainforest. Many species have auditory ranges that are more or less sensitive to sound levels than humans. Auditory sensitivity is measured in Hertz, or the frequency of a sound, while loudness is measured in dBs. Chimpanzees are more sensitive than humans to frequencies above 8 kHz (kilohertz) and are less sensitive to frequencies below 250 Hz (Kojima, 1990), but have similar ear structure and sound sensitivity (Prestrude, 1970).

Captive chimpanzees live in laboratories, zoos, and sanctuaries, environments with different potentials for sound. Visitors to zoos, caregiver activities, and conspecifics can all contribute to the soundscape (Davey, 2006). Cronin, Bethell, Jacobson, Egelkamp, Hopper, and Ross (2018) reported sound pressure levels exceeding 90 dBs in a zoo setting during a loud, annual event. Ogden, Lindburg, and Maple (1994) assessed the impact of ecologically relevant sounds on a group of zoo-living gorillas (*Gorilla gorilla gorilla*) in six conditions; quiet, ventilation, caregiver noises, bonobo *(Pan paniscus)* vocalization playbacks, and rainforest sounds on or off. Infant clinging increased during the caregiver noise condition and adults exhibited an increase in agitation during the rainforest sound condition. Koestler, Farrer, Pegram, and Krausman (1972) exposed two laboratory chimpanzees to "impulsive" or random sound pulses for 180 nights that reached up to 108 dBs. This resulted in poor performance on discrimination tasks during the day and permanent detriments in performance after sound exposure.

Quadros, Goulart, Passos, Vecci, and Young (2014) measured dB level and collected behavioral data when the zoo was open and closed to visitors. Sound levels were dependent on the presence or absence of visitors and could be predicted with a regression equation. The mean sound pressure level across all enclosures on days without visitors was 46.75 dBs and on days with visitors it was 60.42 dBs. Chimpanzee enclosures had an average sound level of 63.5 dBs, which was higher than the other exhibits. The adult and juvenile male chimpanzee showed increased vigilance and movement during times of increased visitor presence, which was correlated with higher dB level.

Birke (2002) measured the impact of visitor group size and group noise level on captive orangutans (*Pongo pygmaeus pygmaeus* and *Pongo pygmaeus abelii*). Visitors received instruction to remain silent or "make plenty of noise by talking or singing loudly" (p. 192). Once a group spent three minutes observing the orangutans in their loud or quiet condition, the group would exit and then return after 20 minutes in the other condition. Loud groups elicited an increase in vigilance and sitting for adults and were more likely to cause a change in behavior in the orangutans as compared to the quiet group condition.

Ruesto, Sheeran, Matheson, Li and Wagner (2010) measured tourist impacts, including sound, on habituated Tibetan macaques (*Macaca thibetana*) in a tourist park in China. Visitors observed the monkeys from platforms and dB levels ranged from 55 to 68. There was a positive correlation between the number of threat behaviors and higher dB levels. In white handed gibbons (*Hylobates lar*) at two zoos, the Metro Toronto Zoo and the Bowmanville Zoo, there was a correlation between higher dB levels and increased open mouth displays in males (Cooke & Schillaci, 2007). At the Chester Zoo in the United Kingdom, there was an increase in cortisol levels in spider monkeys (*Ateles geoffroyi rufiventris*) during times of increased visitor presence (Davis, Schaffner, & Smith, 2005).

Many chimpanzees in the United States are being moved to sanctuaries, due to the enactment of the Chimpanzee Health Improvement Maintenance Protection (CHIMP) Act and subsequent retirement of chimpanzees from biomedical research (Cong. 2752, 2000; National Institute of Health, 2013). Thus, sanctuaries are increasingly relevant to chimpanzee wellbeing. Sanctuary environments, with few to no visitors, are quite different than zoos, but the soundscape has not yet been assessed. This study addresses the relationship of sound levels on the behavior of sanctuary living chimpanzees.

Predictions

We predicted the following:

1) dB level would be significantly higher inside than outside the chimp house;

2) dB level would be significantly higher on full than partial cleaning days;

3) the average response rate of behavioral category would vary with sound level category and

4) a positive correlation between arousal level and dB level.

CHAPTER II

METHODS

Ethics Statement

The present study utilized non-invasive measures to analyze behavioral responses to sound in captive chimpanzees. There was no experimental manipulation of the sound environment at the sanctuary in this study. The study received approval from Central Washington University's Institutional Animal Care and Use Committee (IACUC) before beginning the study (protocol A051801).

Participants

There were 11 adult chimpanzee (*Pan troglodytes*) participants in this study. There were five males and seven females residing at the sanctuary at the time of the study. One chimpanzee, Sue Ellen, was excluded from the study because of health issues. Individual histories included cross-fostering, zoo life, and use in biomedical research. Table 1 details biographical information for each chimpanzee participant. The chimpanzees lived in semi-fluid, compatible sub-groups ranging in size from two to five individuals.

Study Site

Established in 1997 in Carignan, Québec, Canada, the Fauna Foundation (Fauna) is a sanctuary for chimpanzees, monkeys, farm animals, and other wildlife. Inside the chimp house there are six privacy rooms that open into two large multi-level backrooms, with each backroom (Back Room 1 and 2) opening onto an island. The south side is a multi-story area, the mezzanine, with access to an open-air terrace. The north side is a multi-room, 2-story area, Jeannie's Area, with access to an island. There are three outdoor tunnels that attach to the terrace, Jeannie's Area, and Back Room 1. Enclosures can be separated into sections via tunnels and doors.

Table 1

Detailed Biographical Information on the Chimpanzees

Individual	Date of Birth	Sex	Rearing History
Binky	April 10, 1989	M	Biomedical Lab
Blackie	April 14, 1969	F	Zoo
Chance	September 3, 1983	M	Biomedical Lab
Dolly	January 17, 1967	F	Zoo
Jethro	August 23, 1989	M	Biomedical Lab
Loulis	May 10, 1978	M	Research laboratory, chimp raised
Maya	July 8, 1977	F	Zoo/cross-fostered
Petra	February 24, 1988	F	Biomedical lab
Rachel	November 30, 1982	F	Biomedical research/hand-reared
Regis	December 28, 1988	M	Biomedical lab
Tatu	December 30, 1975	F	Cross-fostered

Caregivers are present in the chimp house from 0700 or 0800 to 1630 daily. Shifts sometimes begin with a single caregiver. Throughout the day one to ten caregivers, interns, and volunteers are present at any time. On average, six caregivers are in the chimp house at a single time. Caregivers and other staff are instructed to use quiet voices in the chimp house, although variation in anthropogenic sound generation occurs.

Mondays and Thursdays are full cleaning days and all enclosures are cleaned with a power washer. Cleaning begins at 0900 and continues until 1430 or until all enclosures are clean. Tuesdays, Wednesdays, and Fridays are partial cleaning days. This occurred between 0900 to 1030 and the privacy rooms, Jeannie's Area, and the apartment are cleaned with garden hoses. More staff members are present on full cleaning days than on partial cleaning days.

Procedure

Data was collected from July 24, 2018 to October 1, 2018. There was a total of 44 hours of data and 880 scans recorded, with 440 scans recorded on partial cleaning days and 440 on full cleaning days. Each focal individual was scanned 80 times. G.C. made all of the observations.

Observation Procedure

Data collection occurred four days a week in the chimp house, with a morning and afternoon session. Morning sessions began at approximately 1030 and afternoon sessions at 1330. Data collection occurred on two full cleaning days (Monday and Thursday) and two partial cleaning days (Tuesday, Wednesday, and/or Friday) each week. The schedule for data collection on partial cleaning days was randomized each week. During sessions, each chimpanzee was the focal for 3-min of observation (Altmann, 1974). After each observation, there was about a 1-min break to locate the next scheduled focal, and observations began as soon as that chimpanzee was located. The next scheduled chimpanzee was skipped if that individual could not be located within 1-min and was instead sampled at the end of the session. Focal individual selection was randomized without replacement to ensure equal sampling of each chimpanzee in each session.

Instantaneous scans occurred every 15 s for the 3-min session. During each scan, the data collector recorded the focal individual's behavioral category, arousal level, dB level, and location. The focal behavioral category was recorded according to the behavioral ethogram. For example, if an individual was exhibiting a play face and play walk, they would be coded as A.S., or Affiliative Social. The behavioral categories, abbreviations used for data collection, and definitions appear in Table 2. Active behaviors took precedence over any behavior received from another individual. For example, if the focal was being groomed while also grooming another, the behavior was recorded as grooming another (GGR). Arousal level was recorded on a Likert scale (1, 2, 3, 4, or 5). The number 1 indicated lowest level of arousal (e.g. apparent sleeping), 3 indicated medium arousal (some activity, no pilo erection) and 5 indicated the highest level of arousal (e.g. high activity level, vocalization). Decibel level was recorded with a Sper Scientific Sound Level Pen (model number 840018). The sound level meter was carried with the data collector on a clipboard and dB level was written down for each instantaneous scan. Finally, the focal's location was recorded as either inside or outside of the chimp house. For this study, an individual was recorded as being inside when they were inside the chimp house (including front rooms, back rooms, Jeannie's Area, and the Mezzanine) and outside (including the islands, the terrace, or the elevated skywalks). Data was collected with ZooMonitor (Ross et al., 2016) and dB level was transcribed at the end of data collection days.

Table 2

Ethogram of Behavioral Categories

Behavioral Category	Abbreviation	Description
Agonism	AG	Agonistic or threat behavior, highly aroused individual makes aggressive physical contact with another (contact aggression) or displays (Jensvold, Buckner, & Stadtner, 2010; McCarthy, Jensvold, & Fouts, 2012)
Atypical	AT	Atypical behaviors, including body rock, head rock, and rough scratch (Fritz, Nash, Alford, & Bowen, 1992; Walsh, Bramblett, & Alford, 1982)
Affiliative Social	AS	Affiliative social interactions between individuals that include grooming, reassurance, embraces, kisses, following, play, or soliciting an item (Jensvold, Buckner, & Stadtner, 2010)
Travel	TR	Individual travels from point A to point B (Nishida, Kano, Goodall, McGrew, & Nakamura, 1999)
Resting	RT	Individual rests, exhibiting little to no activity. Eyes may be closed (McCarthy, Jensvold, & Fouts, 2012)
Eating	ET	Individual eats, chews food, or forages
Other	OT	Individual exhibits behavior not listed in this ethogram
Not Visible	NV	Individual is not visible at time of the scan

Prior to data collection, G.C. and the second author M.L.J. obtained an interobserver reliability score of 95% for behavioral ethogram and 97% for arousal level during live observations. G.C. achieved a score of at least 85% on a written chimpanzee identification test.

Data Analysis

An Anderson-Darling test indicated that the null hypothesis of a normal distribution should be rejected ($p < .001$) and that dB level distribution violated the assumption of normality. Log, square-root, and cube root transformations were not successful in normalizing dB level. Residual plots indicated that dB level does not violate the assumption of homoscedasticity. A significance value of $\alpha < .05$ was set for all statistical analyses. Recognizing the non-normal distribution of the independent variable, non-parametric tests in RStudio (version 1.1.453) were utilized for arousal level and dB analysis (McDonald, 2014). The non-parametric Wilcoxon signed rank test assessed for differences in dB on location (in/out) and cleaning days (full/partial). A Spearman's Rank correlation assessed for a relationship between arousal level and dB level.

For behavior category analysis, dB level was categorized into an ordinal variable via three sound level categories (Cooke & Schillaci, 2007); low was 33.5 to 63 dBs, medium was 63.1-70 dBs, and high was 70.1 dBs or greater. The rate of each behavioral category was calculated for each sound level category. The Chi-Square test of independence with standardized residuals assessed for differences in rates of behaviors in low, medium, and high dB level categories on an overall and individual level.

CHAPTER III

RESULTS

The overall mean dB was 52.41 and the range was from 33.5 to 110.2.

Location and dB

A Wilcoxon signed-rank test showed a statistically significant difference in dB level inside (n=5,348) and outside (n=5,212) the chimp house ($p < .01$). Mean dB level inside the chimp house ($\bar{x}$ = 55.99) was higher than dB level outside ($\bar{x}$ =48.83) the chimp house. See Figure 1 for distribution of dB level inside and outside the chimp house.

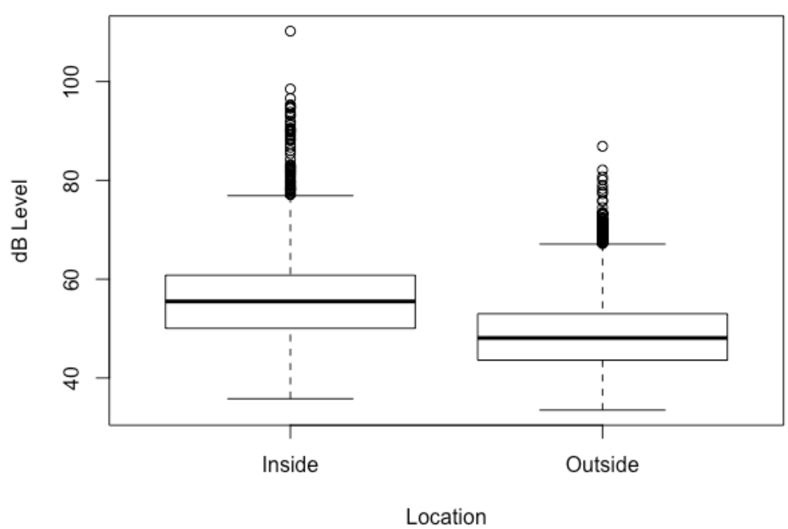

Figure 1. Boxplot comparing dB level inside and outside the chimp house.

Cleaning Day and dB

A Wilcoxon signed-rank test showed a statistically significant difference in dB level on full (n=5,280) and partial (n=5,280) cleaning days ($p < .01$). Decibel level was higher on full cleaning days ($\bar{x}$ = 53.12) than partial cleaning days ($\bar{x}$ = 51.79). See Figure 2 for distribution of dB level on partial and full cleaning days.

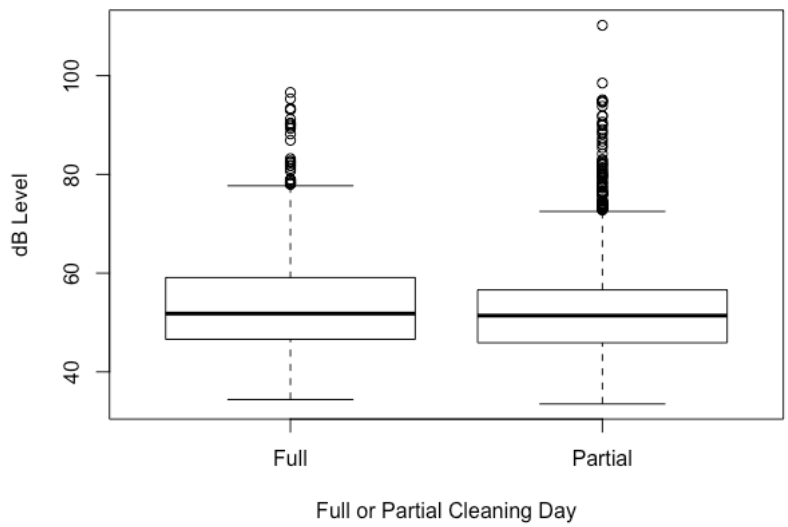

Figure 2. Boxplot comparing dB level on partial cleaning days and full cleaning days.

Behavior and dB

A Chi-Square test of independence tested for a significant relationship between behavioral categories and sound level category (low, medium, and high). The distribution of behaviors across sound level categories were significantly different than expected ($\chi 2(14) = 310.321$, $p = .000$). Resting, affiliative social, travel, and eating occurred at higher average rates in the low sound level category. Agonism occurred at a slightly higher rate in the high sound level category (see Table 3). Individual expression of behavioral categories varied across sound level categories.

A Chi-Square test of independence assessed for a significant relationship between individual chimpanzee behavioral categories and sound level category (low, medium, and high). See Appendix for individual result tables. All four male chimpanzees exhibited agonism in the high dB level category more frequently. Four female chimpanzees exhibited affiliative social behaviors in the high dB level category more frequently. Resting and eating occurred less frequently in the high dB level category for individuals who had a significant standardized residual in the high dB level category. These results are supported by the overall average dB level for each individual within each behavioral category (see Table 4).

Table 3

Average Response Rate[a] of Behavioral Categories in Each Sound Level Category

	Sound Level			
Behavior	Low	Medium	High	P < .05
Resting	47.85	27.33	1.34	C_{11}
Atypical	1.59	.35	.11	Binky, Rachel, Jethro, Maya
Af. Social	8.24	.98	.54	C_{11}
Agonism	.13	.07	.15	-
Travel	8.41	.70	.28	C_{11}
Eating	14.93	1.01	.34	C_{11}
Other	2.18	.19	.00	Binky, Blackie, Rachel, Petra
Not Visible	6.09	.49	.18	Binky, Blackie, Chance, Dolly, Jethro, Tatu, Loulis, Maya

[a] Rate = (x/960) x 100, where x is the number of times the behavior was observed in the sound level category

Note: Significant behavioral category responses across each sound level category by all 11 chimpanzees indicated by C_{11}

Table 4

Mean dB Level for Each Behavioral Category for Each Chimpanzee

	Chimpanzee										
Behavior	Binky	Blackie	Chance	Dolly	Jethro	Loulis	Maya	Petra	Rachel	Regis	Tatu
Resting	50.27	49.95	52.47	50.25	51.48	53.786	52.21	54.37	52.12	52.57	54.28
Atypical	52.57	N/A	66.76	N/A	54.16	59.75	59.9	51.85	54.42	54.43	57.07
Af. Social	55.09	59.74	52.92	53.92	51.39	51.40	53.46	49	57.33	51.99	53.74
Agonism	69.05	46.50	N/A	90.2	69.02	81.9	N/A	N/A	N/A	67.16	N/A
Travel	53.21	50.25	54.07	52.65	52.28	53.56	53.38	51.3	53.03	52.66	52.71
Eating	53.64	51.53	53.22	51.79	51.98	50.38	51.18	54.92	54.89	49.96	50.52
Other	54.84	47.75	53.39	45.36	47.87	49.6	48.81	54.32	52.36	39.12	51.93
Not Visible	52.91	51.33	54.83	50.94	50.24	56.66	57.25	53.12	47.93	51.92	54.58

Arousal Level and dB

A Spearman's rank correlation showed a positive correlation between dB level and arousal level ($\rho = .19$, $n = 5$, $p < .001$). See Figure 3 for distribution of dB across arousal levels.

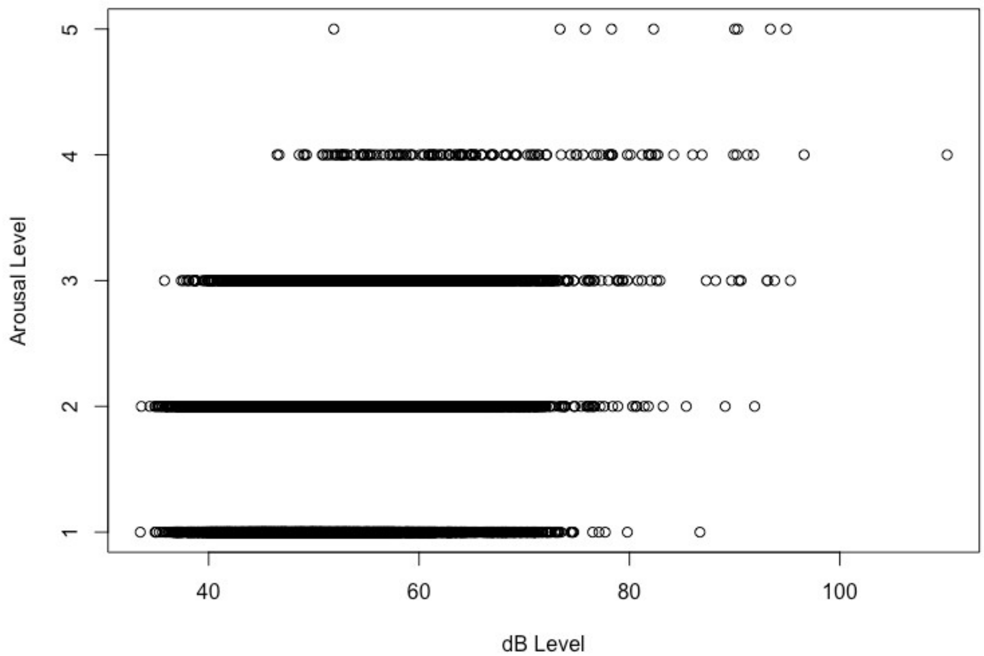

Figure 3. Scatterplot of dB level across arousal level categories.

CHAPTER IV

DISCUSSION

Arousal level in this study was indicated by pilo erect hair, vocalizations, and activity level. Arousal is associated with cortical neuron activity. For example, laboratory mice exhibited cortical activity in response to sounds, such as pages turning and books closing (Summerlee, 1992, p. 150). Arousal is indicated by elevated heart rate and high systolic and diastolic blood pressure. These physiological indicators of arousal are associated with higher levels of cortisol (Dabbs & Hopper, 1990). Cortisol, a glucocorticoid hormone excreted by the hypothalamus-pituitary-adrenal (HPA) axis, is associated with stressful events (Kirschbaum, Bartussek, & Strasburger, 1992; Gaab, Rohleder, Nater, & Ehlert, 2005). Chronic stress exposure and excessive cortisol release disrupts the body’s ability to maintain homeostasis and can lead to depression, cardiovascular problems, sleep problems, irritability, and increased susceptibility to diseases (Kudielka & Kirschbaum, 2005; Björntorp, 1996; Carroll, Curtis, & Mendes, 1976; Gold et al., 1984; Sachar, Hellhman, Fukushima, & Gallagher, 1970; Melamed et al., 1999). When high dB level and arousal level are correlated, cortisol is likely being released as well. Thus, dB levels are a factor in animal welfare. Future research could directly measure cortisol in relation to dB levels.

Agonistic behaviors were most associated with the higher dB level category. These behaviors are often accompanied by vocalizations, such as screams (Goodall, 1986). Additionally, chimpanzees often use objects in aggressive displays. Goodall (1986) describes a male rising in alpha status after repeated displays with empty gas cans, which made sound. Captive chimpanzees use objects and, in spaces with cement and metal, impacts are loud. This too can contribute to higher dB levels during high arousal.

The opportunity for wounding then increases with increasing sound. Anthropogenic factors that induce a potential for an increase in wounding are especially vital to study, address, and mitigate, due to the decreased retreat space captive nonhuman primates are offered in captive settings. Daily husbandry activities, for example, may cause sound. We found dB levels were significantly higher on full cleaning days. In another study, increases in human activity were correlated with increased rates of agonism and wounding in chimpanzees (Lambeth, Bloomsmith, & Alford, 1997). Jensvold, Field, Cranford, Fouts, and Fouts (2005) compared rates of aggression and wounding at the Chimpanzee Human and Communication Institute (CHCI) to those at the Yerkes Regional Primate Research Center in Georgia and the University of Texas M.D. Anderson Cancer Center Science Park (UTSP) (Baker, Seres, Aureli, & de Waal, 2000; Lambeth, Bloomsmith, & Alford, 1997). Average wounding rates at Yerkes and UTSP were 2.5 and 4.5 times higher than CHCI, respectively. Increased enclosure size at CHCI and ability for individuals to get away from stressful events, like acoustic overstimulation, could attribute to the lower rates of wounding.

Husbandry activities can also affect birth rates, with parturient captive chimpanzees exhibiting higher birth rates following the weekend and less husbandry activity (Alford, Nash, Fritz, & Bowen, 1992). Sounds associated with husbandry activities could contribute to this impact.

The analysis of behavioral categories in Table 4 shows some individual patterns as well. Chance, Tatu, and Maya exhibited atypical behaviors with a higher mean dB level. This behavioral context includes stress induced behaviors (Jacobson, Ross, & Bloomsmith, 2016) and may indicate stress induced by sound. All four male chimpanzees exhibited agonistic behaviors during times of higher dB level, increasing the potential for wounding.

Outside the chimp house dB levels ranged from 33.5 to 86.9 and inside the chimp house dB levels ranged from 35.8 to 110.2. Both ranges were higher than the 27 to 32 dB level range of a rainforest environment (Waser & Brown, 1986). The averages at Fauna, both inside and outside, were lower than recorded average dB levels in zoo settings (e.g. 65 dBs; Quadros, Goulart, Passos, Vecci, & Young, 2014). The acoustic environment within sanctuaries, therefore, better reflects a chimpanzee's natural environment when compared to a zoo and are within acceptable acoustic ranges for humans.

The chimpanzees could typically choose whether to spend time indoors or outdoors. This provides agency to move from a loud space to a quiet one, which at Fauna was the outdoor space. The outdoor space at Fauna included raised tunnels and island access, which provide areas for individuals to retreat from the main building with its sound and caregiver activities. It is recommended that chimpanzees across captive settings have access to outdoor and/or multiple indoor enclosures to remove themselves from loud, potentially stressful, events. This is especially important in zoo environments, where visitors contribute to a heightened acoustic environment (Quadros et al., 2014), and where captive individuals can be restricted to solely indoor or outdoor enclosures.

AZA guidelines exist for several aspects of care such as ambient environment, habitat design, transport, and nutrition. The ambient environment guidelines address sound and vibration. The manual lists humans, both caregivers and visitors, as potential sources of sound, with only minimal guidelines to abate and control for sound generated by them (AZA Ape Tag, 2010). The manual suggests staff training and increased awareness of the sound generated throughout daily husbandry routines to limit sound production. However, unlike guidelines on other aspects of species welfare such as enrichment preparation, there lacks curriculum for any such sound sensitivity training. Similarly, GFAS has standards of care specific to large bodied apes. In the manual, sound requirements are “appropriate visual, olfactory, and acoustic barriers” (Standards for Great Ape Sanctuaries, p. 4, 2015). However, there lacks specification of what is an appropriate barrier. The United States Department of Agriculture Animal Welfare Act has no mention of sound (USDA AWA, 2017).

The present study analyzed the organic acoustic environment at Fauna without experimental manipulation. There was a correlation between dB level and arousal/behavioral indicators of stress, but it would be interesting to test for effects of different types of sound: human speech, conspecific vocalizations (Slocombe & Zuberbühler, 2007), or mechanical sound. Acoustic studies are especially important in settings that frequently have large groups of visitors, as they will inherently experience more of an anthropogenically modified acoustic environment. The acoustic environment of a sanctuary and a zoo are fundamentally different; average dB levels at a zoo enclosure are higher than the average dB level for a full cleaning day at Fauna (Quadros et al., 2014). While the presence of visitors at zoos is inevitable, steps can be taken to mitigate their sound levels. For example, enclosure design can provide captive individuals the ability to retreat from louder groups of people or stressful situations instead of pits or surrounded exhibits, where sound echoes from all sides. More acoustically absorbent materials can be utilized when remodeling and building enclosures to decrease sound transfer. Zoo visitors can be educated about sound effects and the importance of being quiet.

While anthropogenic sound drastically impacts captive soundscapes, the literature surrounding effects on wild populations has been growing in recent years. Noise pollution is pervasive throughout the world, permeating even the most protected of areas (Merchan, Diaz-Balteiro, & Solino, 2014; Buxton et al., 2017; Lynch, Joyce, & Fristrup, 2011). Marine environments are particularly at risk from overt sound exposure, as sound generated from commercial boats, ships, and aquatic military sound increases. Marine mammals have exhibited avoidance and other behavioral responses, as well as physiological stress responses (Tyack, 2008).

This study has implications for future captive welfare research, captive chimpanzee exhibit design, husbandry activities, and welfare regulations as it supports the hypothesis that sound has behavioral and arousal level effects on chimpanzees. This effect should be reflected in increased sound regulations within appropriate accrediting organizations. Current sound regulations in captivity vary with institution and accreditation, but a common theme is lack of acknowledgement of a damaging dB level threshold. This study provides evidence that the acoustic environment in sanctuaries, without a large number of visitors, has behavioral and arousal level correlates. Therefore, emphasis should be placed on sound regulations in captive settings where visitors play a large role in heightening the acoustic environment (e.g. zoos, laboratories) to work towards improving welfare standards for captive chimpanzees.

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APPENDIX
INDIVIDUAL CHIMPANZEE'S CHI-SQUARE AND STANDARDIZED RESIDUAL RESULTS

Binky

	Sound Level Category						
	Low		Medium		High		Total
Behavior	N	SR	N	SR	N	SR	
Resting	440	1.0	18	-1.8	3	-2.9*	461
Atypical	30	-.02	3	.07	1	.0	34
Af. Social	116	-.08	16	2.8*	5	.04	137
Agonism	0	-1.9	3	5.7*	1	2.5*	4
Travel	99	-.02	7	.02	5	.09	111
Eating	108	-.05	5	-.09	12	4.2*	125
Other	34	.01	2	-.01	1	-.01	37
Not visible	47	.01	3	.0	1	-.04	51

Note: N = 960, $\chi 2(14) = 83.940$, p = .000

Blackie

	Sound Level Category						
	Low		Medium		High		Total
Behavior	N	SR	N	SR	N	SR	
Resting	463	.3	21	-.03	8	-1.5	492
Atypical	-	-	-	-	-	-	-
Af. Social	38	-1.9	6	2.1*	12	8.5*	56
Agonism	1	.1	0	-.02	0	-.02	1
Travel	130	.03	3	-1.3	3	-.04	136
Eating	113	.03	5	-.02	1	-1.2	119
Other	33	-.01	3	1.1	0	-1.0	36
Not visible	112	.01	6	.02	2	-.07	120

Note: N = 960, $\chi 2(12) = 89.378$, p = .000

Chance

	Sound Level Category						
	Low		Medium		High		Total
Behavior	N	SR	N	SR	N	SR	
Resting	498	.07	25	-2.2*	7	-.04	530
Atypical	0	-2.1*	5	7.7*	0	-.03	5
Af. Social	35	-.02	2	-.05	3	3.0*	40
Agonism	-	-	-	-	-	-	-
Travel	37	-.09	8	2.5*	2	1.5	47
Eating	221	.0	20	.06	1	-1.4	242
Other	14	-.04	3	1.6	0	-.05	17
Not visible	70	-.02	7	.05	2	.07	79

Note: N = 960, $\chi2(12) = 93.567$, p = .000

Dolly

	Sound Level Category						
	Low		Medium		High		Total
Behavior	N	SR	N	SR	N	SR	
Resting	464	.05	15	-1.5	18	-.07	497
Atypical	-	-	-	-	-	-	-
Af. Social	40	-.08	3	.05	7	3.3*	50
Agonism	0	-1.0	0	-.02	1	4.6*	1
Travel	125	-.04	11	1.8	6	.0	142
Eating	135	-.01	14	2.8*	0	-2.5*	149
Other	27	.05	0	-1.1	0	-1.1	27
Not visible	85	-.01	0	-2.1*	9	2.5*	94

Note: N = 960, $\chi2(12) = 68.506$, p = .000

Jethro

	Sound Level Category						
	Low		Medium		High		Total
Behavior	N	SR	N	SR	N	SR	
Resting	456	.08	9	-2.2*	2	-2.6*	467
Atypical	28	-.04	3	1.5	1	.04	32
Af. Social	109	-.03	6	.06	5	1.5	120
Agonism	7	-2.6*	2	1.4	10	14.9*	19
Travel	131	.0	6	.02	2	-.06	139
Eating	93	-.04	10	2.9*	0	-1.5	103
Other	9	.02	0	-.06	0	-.04	9
Not visible	68	.02	2	-.05	1	-.04	71

Note: N = 960, $\chi 2(14) = 259.538$, p = .000

Loulis

	Sound Level Category						
	Low		Medium		High		Total
Behavior	N	SR	N	SR	N	SR	
Resting	467	-.05	65	1.2	19	.04	551
Atypical	2	.02	0	-.05	0	-.02	2
Af. Social	116	-.02	16	.06	4	-.01	136
Agonism	0	-.09	0	-.03	1	5.5*	1
Travel	41	-.01	4	-.04	3	1.2	48
Eating	132	1.4	2	-3.2*	1	-1.6	135
Other	1	.01	0	-.03	0	-.02	1
Not visible	73	-.02	11	.07	2	-.04	86

Note: N = 960, $\chi 2(14) = 50.500$, p= .000

Maya

	Sound Level Category						
	Low		Medium		High		Total
Behavior	N	SR	N	SR	N	SR	
Resting	455	-.01	53	.09	12	-1.2	520
Atypical	9	-.02	2	1.0	0	-.06	11
Af. Social	38	-.08	8	1.7	3	1.1	49
Agonism	-	-	-	-	-	-	-
Travel	66	.0	7	.01	2	-.03	75
Eating	217	.05	10	-2.5*	12	1.5	239
Other	38	.08	0	-1.8	0	-1.1	38
Not visible	20	-.09	6	2.2*	2	1.2	28

Note: N = 960, $\chi 2(12) = 29.633$, p = .003

Petra

	Sound Level Category						
	Low		Medium		High		Total
Behavior	N	SR	N	SR	N	SR	
Resting	477	-.08	85	1.8	14	.06	576
Atypical	2	.02	0	-.05	0	-.02	2
Af. Social	107	1.1	3	-2.9*	2	-.02	112
Agonism	-	-	-	-	-	-	-
Travel	26	-.01	4	.01	1	.04	31
Eating	167	.05	18	-1.0	3	-.05	188
Other	34	-.02	7	.09	0	-.09	41
Not visible	10	.05	0	-1.1	0	-.05	10

Note: N = 960, $\chi 2(12) =19.029$, p = .088

Rachel

Behavior	Low N	Low SR	Medium N	Medium SR	High N	High SR	Total
Resting	379	.04	31	-1.2	8	.01	418
Atypical	86	-1.4	23	3.9*	4	1.3	113
Af. Social	66	-.06	10	.09	4	2.0*	80
Agonism	-	-	-	-	-	-	-
Travel	76	.0	9	.04	1	-.05	86
Eating	141	.04	11	-.08	1	-1.1	153
Other	20	-.05	5	1.8	0	-.07	25
Not visible	85	1.1	0	-2.8*	0	-1.3	85

Sound Level Category

Note: N = 960, $\chi 2(12)$ =42.792, p = .000

Regis

Behavior	Low N	Low SR	Medium N	Medium SR	High N	High SR	Total
Resting	488	-.04	34	.01	32	1.7	554
Atypical	3	.02	0	-.04	0	-.04	3
Af. Social	95	.0	7	.02	4	-.02	106
Agonism	6	-1.2	2	1.6	3	3.7*	11
Travel	97	.01	9	1.0	1	-1.7	107
Eating	133	.07	6	-.08	1	-2.0*	140
Other	10	.03	0	-.08	0	-.07	10
Not visible	29	.06	0	-1.3	0	-1.1	29

Sound Level Category

Note: N = 960, $\chi 2(14)$ =34.973, p = .001

Tatu

	Sound Level Category						
	Low		Medium		High		Total
Behavior	N	SR	N	SR	N	SR	
Resting	466	.02	59	-.06	19	-.01	544
Atypical	5	.0	1	.03	0	-.05	6
Af. Social	110	-1.2	27	2.4*	8	1.3	145
Agonism	-	-	-	-	-	-	-
Travel	60	.01	6	-.08	4	1.0	70
Eating	117	1.0	6	-2.3*	3	-.07	126
Other	10	.05	0	-1.1	0	-.06	10
Not visible	45	-.07	14	2.7*	0	-1.4	59

Note: N = 960, $\chi 2$ (12) = 29.348, p = .003