The Effects of Construction Activity on the Behavior of Captive Rhesus Monkeys (Macaca mulatta)

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The Effects of Construction Activity on the Behavior of Captive Rhesus Monkeys

(Macaca mulatta)

A Thesis Presented

By

COURTNEY A. BEGNOCHE

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE

February 2014

Neuroscience and Behavior Program
The Effects of Construction Activity on the Behavior of Captive Rhesus Monkeys

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Approved as to style and content by:

Melinda Novak, Chair

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Neuroscience and Behavior Program
ABSTRACT

THE EFFECTS OF CONSTRUCTION ACTIVITY ON THE BEHAVIOR OF CAPTIVE RHESUS MONKEYS (MACACA MULATTA)

FEBRUARY 2014

COURTNEY A. BEGNOCHE, B.S., UNIVERSITY OF MASSACHUSETTS AMHERST

M.S., UNIVERSITY OF MASSACHUSETTS AMHERST

Directed by: Dr. Melinda A. Novak

Previous studies have revealed insight into the effects of noises and vibrations on rodents, livestock, and zoo animals, but there is little information about such effects on non-human primates. This study aimed to assess the impact of construction activity on the behavior of animals in a non-human primate (rhesus macaque) facility. Construction activity and modified frequency behavioral data were divided into three phases: baseline (~3 months prior to construction), roof (construction on top of the animal facility), and honors (construction of 7 new buildings adjacent to the facility). We hypothesized that anxiety behaviors (scratch and yawn) would be increased during the construction as opposed to baseline but that overall behavioral activity would be decreased. Additionally, we predicted that these effects would be most prominent during the roof construction period. However, subjects actually exhibited a significant decrease in scratching behavior from the baseline to the honors phase (p=0.040). The average number of behaviors performed in a 15-sec interval (behavioral change) significantly decreased (p=0.034) between the baseline and honors construction periods. This same decrease was seen in the average number of different species typical behaviors performed per observation period (behavioral range; p=0.004). Both effects occurred from the baseline to honors period.
(p=0.015). Closer inspection of the honors construction period revealed levels of scratching, behavioral change, and behavioral range had returned to baseline during Honors 3 and 4 (All p>0.05). These data suggest that adaptation may be possible when monkeys are exposed to prolonged construction.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>viiii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>ix</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Background Information</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Effects of Construction Activity on Captive Animals</td>
<td>2</td>
</tr>
<tr>
<td>1.3 Experimental Manipulations of Vibration</td>
<td>4</td>
</tr>
<tr>
<td>1.4 Advantages of Our Study</td>
<td>5</td>
</tr>
<tr>
<td>1.5 Hypotheses and Predictions</td>
<td>6</td>
</tr>
<tr>
<td>2. MATERIALS AND METHODS</td>
<td>7</td>
</tr>
<tr>
<td>2.1 Subjects and Housing Conditions</td>
<td>7</td>
</tr>
<tr>
<td>2.2 Vibration and Noise Data Collection</td>
<td>8</td>
</tr>
<tr>
<td>2.3 Vibration and Noise Data Organization</td>
<td>9</td>
</tr>
<tr>
<td>2.4 Behavioral Data Collection</td>
<td>11</td>
</tr>
<tr>
<td>2.5 Data Analysis</td>
<td>12</td>
</tr>
<tr>
<td>2.5.1 Descriptive Vibration Data</td>
<td>13</td>
</tr>
<tr>
<td>2.5.1.1 Behavioral Data</td>
<td>13</td>
</tr>
</tbody>
</table>
2.5.1.1.1 Adaptation………………………………………………14
3. RESULTS……………………………………………………………………15
  3.1 Vibration Data as a Function of Three Main Construction Phases………………15
    3.1.1 Weekday, Saturday, and Sunday Vibration Data…………………16
  3.2 Behavioral Data as a Function of Three Main Construction Phases………17
    3.2.1 Global Behavioral Categories……………………………………17
      3.2.1.1 Anxiety-like Behaviors………………………………………19
      3.2.1.1.1 Activity Behaviors………………………………………19
      3.2.1.1.1.1 Aggressive Behaviors……………………………………20
      3.2.1.1.1.1.1 Social Behaviors………………………………………21
      3.2.1.1.1.1.1.1 Exploratory Behaviors……………………………22
  3.3 Adaptation……………………………………………………………………22
  3.4 Roof Early Versus Roof Late Behavioral Data Comparison…………………23
  3.5 Behavioral Data Comparison Across Four Honors Phases…………………24
    3.5.1 Global Behavioral Categories………………………………………24
      3.5.1.1 Anxiety-like Behaviors………………………………………25
      3.5.1.1.1 Activity Behaviors………………………………………26
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Segmented construction phases and corresponding dates</td>
<td>11</td>
</tr>
<tr>
<td>2. Species typical behaviors relevant for analysis</td>
<td>12</td>
</tr>
<tr>
<td>3. Weekday, Saturday, and Sunday vibration averages compared across construction phase and monitor location</td>
<td>16</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Design of colony rooms and their relation to the Acentech, Inc. monitors</td>
<td>9</td>
</tr>
<tr>
<td>2. Weekly vibration averages across construction phases in rooms A and D</td>
<td>15</td>
</tr>
<tr>
<td>3. Average behavioral change exhibited across construction phases</td>
<td>18</td>
</tr>
<tr>
<td>4. Average behavioral range exhibited across construction phases</td>
<td>18</td>
</tr>
<tr>
<td>5. Average scratching behavior exhibited across construction phases</td>
<td>19</td>
</tr>
<tr>
<td>6. Average locomotive behavior exhibited across construction phases</td>
<td>20</td>
</tr>
<tr>
<td>7. Average social grooming behavior exhibited across construction phases</td>
<td>21</td>
</tr>
<tr>
<td>8. Average visual exploratory behavior exhibited across construction phases</td>
<td>22</td>
</tr>
<tr>
<td>9. Weekly vibration averages split across seven phases in room 104A</td>
<td>23</td>
</tr>
<tr>
<td>10. Average behavioral change across honors construction phases</td>
<td>24</td>
</tr>
<tr>
<td>11. Average behavioral range across honors construction phases</td>
<td>25</td>
</tr>
<tr>
<td>12. Average scratching behavior across honors construction phases</td>
<td>26</td>
</tr>
<tr>
<td>13. Average social signaling behavior across honors construction phases</td>
<td>27</td>
</tr>
</tbody>
</table>
CHAPTER 1
INTRODUCTION

1.1 Background Information

Non-human primates housed in laboratory settings are generally maintained in more predictable environments than those experienced by free-ranging monkeys. Captive monkeys are housed under constant day-night cycles and fed at the same times during the day. Cage cleaning and behavioral assessments also tend to occur according to a well-established schedule. However, events occasionally come along that may disrupt the normal routine of captive primates. One such event, about which little is known, is nearby construction activity. At the University of Massachusetts, Amherst, a large scale-construction project involving the erection of 7 large buildings occurred 50-100m from an animal research facility. Based on behavioral data and noise and vibration measurements taken before and during the construction process, the goal of this project was to examine the impact of unpredictable sounds and vibrations created from nearby construction on the behavior of captive rhesus monkeys (*Macaca mulatta*), particularly anxiety-related behaviors.

Little is known about the effects of vibration changes on rhesus monkey behavior. Furthermore, little perceptual information is available to indicate how rhesus macaques process vibrational stimuli and at what levels. This lack of information makes creating standards for captive nonhuman primates quite difficult. The Office of Research Facilities (ORF) suggests that vibration should not exceed 2,000 microinches/second in animal research facilities, a level thought to be unperceivable by humans (2008). Though
information on vibration perception in non-human primates is sparse, the auditory system of monkeys has been studied in detail. It has been well established that monkeys and humans have very similar auditory capabilities at low frequencies but monkeys, including macaques, have an increased sensitivity to high frequency sounds (Harris, 1943; Behar, Cronholm & Loeb, 1965; Fujita and Elliott, 1965, Stebbins, Green & Miller, 1966).

Again, we may be unable to hear sounds that could affect our research animals.

1.2 Effects of Construction Activity on Captive Animals

Construction equipment and associated activity creates measurable noises and vibrations that have been shown to produce behavioral and physiological changes in mammals. In rodents, construction activity can alter reproductive outcomes and stress hormone levels. In 2011, Raff et al. showed that male rats (WAG/Rij/MCW) exposed to a nearby construction project displayed about double the levels of three stress hormones (ACTH, corticosterone, and aldosterone) during construction compared to both before and after. These changes were not permanent in that hormone levels returned to baseline about one month post construction.

Nearby construction has also has been shown to alter the behavior of zoo-housed giant pandas and snow leopards in different ways. The noise associated with demolition next to the enclosure of two giant pandas (Ailuropoda melanoleuca) at the Smithsonian’s National Zoological Park was monitored over four construction phases from October 13, 2002 – February 28, 2003: 1) pre-construction, 2) short weeks (~2.8 days of construction per week), 3) long weeks (~5.3 days of work per week) and 4) post-construction. There was no baseline behavioral data during the pre-construction period but two hours of
instantaneous scan sampling were collected six days per week over the 17 week period. Extensive periods of construction (long weeks) was associated with increased activity as compared to the post-construction phase. Additionally, the giant pandas showed an increase in stress related behaviors on work days as compared to non-work days. Grooming and scent marking increased in the male, and urination and defecation increased in the female (Powell et al., 2006). In a separate study of three snow leopards (Uncia uncia) at the Basel Zoo in Switzerland, one hour instantaneous scan sampling data were collected two weeks before and during a construction project (January 12 – April 11, 1999). Though there were no specific noise or vibration measurements taken, the occurrence and type of noise were recorded during behavioral observation periods. In contrast to the giant pandas, the snow leopards showed reduced activity and social resting on noisy construction days (Sulser, Steck & Baur, 2008). It is possible that the conflicting results were due to the different species involved, amount of data collected (1 vs 2 hours), or frequency and severity of construction work over the demolition periods.

Construction produces both noise and vibration, and seldom are these effects differentiated. In a unique study, cynomolgus macaques (Macaca fascicularis) were exposed to both real and fake dynamite explosions at the Swedish Institute for Infectious Disease Control (SMI) to determine if animals should be moved during a future construction project. In phase 1, macaques were exposed to six real dynamite explosions that became more intense with time. Both behavioral reactivity and plasma cortisol increased across the explosions. In phase 2, recorded dynamite explosions were used to examine the effects of construction noise while eliminating the vibration effects. An experimental group of monkeys heard a warning signal (30-second piano track) alerting
them to the impending noise but they did not differ behaviorally from the control group that did not receive the warning signal. However, the control group exhibited higher cortisol levels. This study attempted to parse out the differential effects of vibration and noise and the results suggest that a noise stimulus alone is not enough to alter monkey behavior. Alternatively, as the researchers suggest, making a stimulus predictable may decrease the stress response of an animal (Westlund et al., 2012).

1.3 Experimental Manipulations of Vibration

Though noise and vibration stimuli are closely linked, there are several well-established procedures for examining the effects of vibration alone on different species of animals in a laboratory setting. The shaker stress test has been shown to produce changes in cardiovascular and endocrine functioning in rats. Additionally, tests of transport simulation in livestock have been shown to alter behavior in pigs.

In rats, the shaker stress test exposes animals to controlled vibrations for a fixed amount of time. Rats exposed to this procedure for 14 weeks, showed an elevation in both heart rate and blood pressure from weeks 3-9 that returned to normal for weeks 10-14 (Bunag, Takeda and Riley, 1980). Hashiguchi et al. also used the shaker stress test to measure changes in behavior and hormone levels based on single or repeated exposures to a vibratory stimulus in Wistar rats. In one part of the study, there were four different groups of rats: two groups of rats that received either a 5 or 30 minute single exposure, and two groups that received a 5 or 30 min exposure ten times in one day. Both single and multiple exposures (at both time periods) of shaker stress raised levels of norepinephrine, epinephrine, and corticosterone significantly above baseline. Hormone
levels after a single exposure were generally higher than after the last repeated exposure. Researchers also recorded behavioral observations after the 5 or 30 min repeated shaker stress condition for a period of 11 days. The rats initially displayed high levels of freezing behavior in both time conditions then began to show habituation on the third day of repeated exposure trials (1997). One limitation of this procedure is that the shaker stress apparatus produces predictable vibrations that may not accurately reflect those experienced during an actual construction event.

Vibration also plays a role in transporting livestock in vehicles from one place to another. In one particular study, pigs were exposed to an apparatus that produced noises and vibrations mimicking those encountered during transport. An experimental group of animals learned to press a lever to turn the box off to a noise/vibration combination stimulus. A separate control group was only ever exposed to the noise stimulus and never learned to press the lever (Stephens et al., 1985). These data suggest that the noise stimulus alone was not enough to produce an aversive reaction in the pigs and that the vibratory component is necessary for this reaction.

1.4 Advantages of Our Study

The lack of information regarding effects of construction activity on monkeys highlights the importance of the University of Massachusetts study for understanding the impact of construction on captive primates. Unlike the giant panda, snow leopard, and macaque studies discussed above, this study differs in two significant ways. First, Acentech monitoring systems in colony areas were used to measure and differentiate ongoing noise and vibration, beginning with a baseline period and continuing through the
phase of the Honors College construction (April 1st, 2011 – October 31st, 2012). Second, monkeys at the UMass Primate Lab are routinely observed 5 days per week for most weeks throughout the year, and this has been the practice for the last 10 years. As a result, the expansive data set at our disposal made for a unique opportunity to compare these noise and vibration changes directly to monkey behavior. Additionally, we were able to utilize larger numbers of behavioral observations than most studies.

1.5 Hypotheses and Predictions

In this study, we hypothesized that nearby construction activity would be associated with behavioral changes in captive rhesus monkeys and that proximity of construction to the animals would make a difference. We predicted that these changes would be manifested as an increase in anxiety-like behaviors and a decrease in overall behavioral activity. Additionally, these changes would be most pronounced during the roof construction phase when the construction was in the animal facility compared to the honors construction phase which was 50-100 meters from the animal facility. Given the lack of information on noise and vibration, we made no specific prediction about the relative importance of these two stimuli in producing these changes.
CHAPTER 2
MATERIALS AND METHODS

2.1 Subjects and Housing Conditions

This study was conducted in the UMass Primate Laboratory at the University of Massachusetts Amherst. Subjects were nine rhesus macaques (*Macaca mulatta*) housed in three separate colony rooms. Six of the subjects were female (3 males) with ages between 5 and 27 years.

All animal rooms were on a 13 hour light-dark cycle in which lights came on automatically at 7:00 AM and turned off at 8:00 PM. Subjects were given Lab Diet Monkey Chow twice per day (8:00 AM and 2:00 PM) and had ad libidum access to water. The health and wellness of each animal was assessed every morning and at the same time, each animal received a small food item which varied each day as a part of introducing dietary variation (e.g., various nuts, fruits, vegetables, grains, and monkey dough). In addition, the UMass Primate Lab has a vigorous daily enrichment program which animals receive on a rotational basis. Enrichment items include ice cube treats, celery and other forms of browse, music, and television. This daily program is supplemented with pen enrichment that includes toys (both stationary and portable), furnishings (perches at various levels, hammocks) and a wood shaving floor substrate.

The subjects were housed in three colony rooms with three animals per room (See Figure 1 for laboratory layout). Two females (ZA56 and ZA65) and one male (N03) occupied colony room B. N03 was housed alone in an Allentown cage while ZA56 and ZA65 were paired together in a second Allentown cage. Colony room C, contained two
females (V38 and 6NS) and one male (V27). V27 and V38 were housed in floor to ceiling pens adjacent to each other and could touch each other and groom each other through the mesh. 6NS was housed alone in an elevated quad cage. This was the only subject that did not have direct access to wood shavings but had shavings exposure during some of the daily enrichment periods. Subjects N02, V42, and V43 were all housed in colony room F. N02 and V43 were housed together in a large cage with two compartments. One side was a large floor to ceiling pen and the other side was a smaller sleep cage. V42 was housed alone in a floor to ceiling pen directly across from the two females.

2.2 Vibration and Noise Data Collection

Vibration and noise data were measured and recorded using a computer system set up by Acentech, Inc. There were two monitors set up in the laboratory, one in the food preparation area (Monitor A) and one in the student data analysis room (Monitor D; See Figure 1). The systems were configured to record both sound and vibration stimuli caused by the Honors College Construction Project next to our facility. Sound was measured in decibels (dB) and vibration in microinches per second (1 millionth of an inch). Vibration values were averaged and recorded over one minute intervals. Acentech, Inc. transformed these one minute averages into hourly averages for 24 hours per day both before and during the construction activity over the time period from April 1, 2011 – October 26, 2012.
Figure 1: Design of colony rooms and their relation to the Acentech, Inc. monitors.

2.3 Vibration and Noise Data Organization

Vibration and noise data collected from April 1, 2011 – October 26, 2012 were divided into three separate construction phases: baseline (4/1/11 – 6/24/11), roof construction (6/25/11 – 12/4/11), and honors construction (12/5/11 – 6/22/12). The baseline phase was the shortest because it was dependent upon when the monitoring devices were put in to place relative to the start of construction, which we had no control over. During the baseline phase, noise and vibration monitors were in place but no
construction activity had begun. This provides the baseline for noise and vibration levels in the facility. The roof phase was the first real exposure the animals had to the noises and vibrations of the construction project. Crews started by excavating the area outside of the building then put insulation and cement boards on the roof. After preparing the foundation for the new roof, the steel components were erected both on top of and around the building. Finally, insulation panels were installed along the walls and roof of the building. After this, the major construction project of the honors dormitories (honors phase) was begun and lasted until August of 2013.

Noise and vibration data were supplied by Acentech, Inc. in an Excel spreadsheet. Microsoft Excel was used to average the values from 7:00, 8:00, and 9:00 AM each day to provide a daily average. Construction began at 7:00 AM Monday-Saturday (usually no Sunday construction) and behavioral data collection occurred at 9:00 AM, so this average gives a complete representation of vibration activity before and during data collection. From the daily averages, the pivot table function in Excel was used to calculate weekly averages (Monday-Friday). Daily and weekly averages were calculated for the values obtained from both monitors (rooms A and D). Additionally, vibration values on Saturday and Sunday were averaged over the three construction phases listed above and compared to the weekday data. In addition to the three construction phases, we also looked at adaption to the noise and vibration. For these purposes, the roof phase was divided into early and late. The honors phase was extended to create 4 phases of equal length (See Table 1 below for dates). One week was eliminated from the end of both the original baseline and roof data to create seven phases, all eleven weeks long.
Table 1: Segmented construction phases and corresponding dates.

<table>
<thead>
<tr>
<th>Construction Phase</th>
<th>Baseline</th>
<th>Roof Early</th>
<th>Roof Late</th>
<th>Honors One</th>
<th>Honors Two</th>
<th>Honors Three</th>
<th>Honors Four</th>
</tr>
</thead>
</table>

2.4 Behavioral Data Collection

Modified frequency data were collected by undergraduate student observers (all at least 90% reliable using a conservative % agreement score) at 9:00 AM on every weekday before and during the construction periods (with few exceptions). Missing data for one subject resulted in deletion of that day from the data set. Each subject was observed for a 5-minute period with 15-second intervals in which behaviors were scored on a standardized sheet. These data were then entered into a protected computer database using Access. A two-fold error checking process was used. Other trained observers reviewed the paper records for calculation errors and reviewed the computer database for transcription errors and any detected errors were corrected.

The relevant behaviors for this particular study are listed in Table 2 below. Ten of the behaviors are frequently seen performed by the monkeys in our lab. We also created two new categories: 1) behavioral change, or the number of behaviors monkeys perform every 15-second interval during data collection and 2) behavioral range, or the number of different behavioral types the monkeys perform over the five minute collection time. In addition, certain behaviors were combined to create comprehensive categories that represent different phenomena. These categories included anxiety (scratch and yawn),...
activity (locomotion and pace), aggression (cageshake, crooktail and threat), social signaling (initiate/receive rump present, initiate/receive present, lipsmack, vocalization), social contact, and social groom. Social contact and groom were analyzed in a subset of monkeys (6 out of 9) based on those individuals that could directly interact with another conspecific (See Table 2 for behaviors).

<table>
<thead>
<tr>
<th>Behaviors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cageshake</td>
</tr>
<tr>
<td>Environmental Exploration</td>
</tr>
<tr>
<td>Crooktail</td>
</tr>
<tr>
<td>Behavioral Change</td>
</tr>
<tr>
<td>Locomotion</td>
</tr>
<tr>
<td>Behavioral Range</td>
</tr>
<tr>
<td>Active Stereotypy (Pace)</td>
</tr>
<tr>
<td>Visual Exploration</td>
</tr>
<tr>
<td>Aggression</td>
</tr>
<tr>
<td>Scratch</td>
</tr>
<tr>
<td>Social Contact</td>
</tr>
<tr>
<td>Threat</td>
</tr>
<tr>
<td>Social Groom</td>
</tr>
<tr>
<td>Yawn</td>
</tr>
<tr>
<td>Social Signaling</td>
</tr>
</tbody>
</table>

Table 2: Species typical behaviors relevant for analysis

These behavioral data were totaled per subject per day and from this, individual pivot tables were made for each behavior. The baseline phase was the shortest and only had 34 days of behavioral data collection while the roof phase had 86 days and the honors phase had 92 days, for a total of 212 days in which weekly averages were obtained per subject. Only weeks with at least three data points were included in the averages. These weekly averages were combined to get a weekly average for the group as whole.

2.5 Data Analysis

The noise data proved to be problematic in two ways: 1) the data were too variable to use for analysis and 2) the microphone, which was located inside the building,
selectively picked up the routine facility noises and not the exterior noise. As a result, the noise data were not analyzed (See Appendix Figure 1 for data).

2.5.1 Descriptive Vibration Data

Vibration data averaged across the three hours (7-9 am) were calculated across weeks and presented by monitor location. A paired t test was used to determine if the monitors differed in the vibration levels recorded. A Pearson correlation was used to assess whether the weekly fluctuations were correlated across the two monitors. Additionally, vibration levels were compared during the work week when there was also significant facility related activities, as compared to Saturdays when the construction was ongoing but facility related activities were low, as compared to Sundays where there was no construction and facility activities remained low. These data were analyzed with ANOVA where phase was the within subject variable. Pending significant results from the ANOVA, hypothesis tests with two contrasts were run: 1) weekday versus Saturday and Sunday and 2) weekday versus Saturday.

2.5.1.1 Behavioral Data

The behavioral data were analyzed using an ANOVA with phase (pre, roof, and honors) as a within subject variable. The baseline phase was the shortest and had 34 days of behavioral data collection while the roof phase had 86 days and the honors phase had 92 days. Analyses of Variance (ANOVAs) were performed for all behaviors to uncover any significant differences between the phases. If there were found to be significant differences across the three phases, subsequent hypothesis tests were performed. The
contrasts used were 1) baseline versus roof and honors construction periods combined and 2) baseline versus the honors construction period alone.

2.5.1.1.1 Adaptation

To determine whether monkeys showed adaptation during construction, behavioral data was split into the seven phases listed in Table 1. ANOVAS were performed across the two roof phases and across the four honors phases separately. Significant effects yielded the following contrasts: 1) roof early versus roof late, 2) honors one and two versus honors three and four, and 3) honors one versus honors four. There were a total of 286 data points that were used to calculate weekly averages across these phases. If any behaviors exhibited an effect that appeared to be adaptation, an ANOVA was performed for the averages of the behavior at baseline compared to the relevant construction phase. A p-value >0.05 would indicate that given behavior had returned to baseline levels similar to before the construction began.
CHAPTER 3

RESULTS

3.1 Vibration Data as a Function of Three Main Construction Phases

Weekly averages of the vibration data from the three main construction phases are reported below (Figure 2). The average vibration values for the baseline, roof, and honors phases in Room A were, 255.25, 758.94, and 639.67 microinches per second. Vibration averages in Room D were 182.71, 536.01, 506.29 microinches per second. The vibrations across all time points detected by monitor A were significantly higher than detected by monitor D ($t = 5.20, p< 0.01$, Means: Monitor A = 572.13 vs. Monitor D = 431.61). However, despite this difference, the vibration levels were correlated across monitors ($r = 0.68, p < 0.01$).

Figure 2: Weekly vibration averages across construction phases in rooms A and D.
3.1.1 Weekday, Saturday, and Sunday Vibration Data

Weekday vibration averages were compared to levels on Saturdays and Sundays during the three construction phases (See Table 3 below). On weekdays, there was construction and student activity in the lab. On Saturdays there was construction with minimal student activity and on Sunday there was no construction and minimal student activity. Monitor A and D were compared separately. There was a significant difference between average vibration values across the weekdays, Saturdays, and Sundays from Monitor A ($F(2, 118) = 21.05, p < 0.01$). There was also a significant difference when performing contrast 1, which compared the average vibration across weekdays to both Saturdays and Sundays ($F(1,59) = 38.74, p < 0.01$). When comparing weekdays to Saturdays alone there was also a significant difference ($F(1,59) = 18.87, p < 0.01$). In general, vibration levels on weekdays were greater than any other day. A similar effect was seen on Monitor D. There was a significant difference in vibration averages across weekdays, Saturdays, and Sundays from Monitor D ($F(2,118) = 53.72, p < 0.01$). Additionally, contrast 1 revealed that vibration was significantly higher on weekdays than Saturdays and Sundays combined ($F(1,59) = 74.25, p < 0.01$). Contrast 2 revealed that vibration across weekdays was higher than Saturdays alone ($F(1,59) = 43.41, p < 0.01$).

See Appendix Figure 2 for bar graph.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Roof</td>
</tr>
<tr>
<td>Weekdays</td>
<td>255.25</td>
<td>758.94</td>
</tr>
<tr>
<td>Saturday</td>
<td>212.57</td>
<td>435.02</td>
</tr>
<tr>
<td>Sunday</td>
<td>310.18</td>
<td>355.27</td>
</tr>
</tbody>
</table>

Table 3: Weekday, Saturday, and Sunday vibration averages compared across construction phase and monitor location.
3.2 Behavioral Data as a Function of Three Main Construction Phases

The behavioral data corresponding to the three construction phases listed above are shown below. All analyzed behaviors can be found listed in Table 2 in the methods section.

3.2.1 Global Behavioral Categories

Two global categories were calculated from all of the behavioral data: behavioral change and behavioral range. There was a marked decrease in behavioral change across the phases (F(2,16) = 5.10, p = 0.019). There was no difference seen when performing contrast 1 across baseline and roof/honors phases combined, but was particularly prominent in contrast 2 from the baseline to the honors construction phase (F(1,8) = 6.13, p = 0.038; Figure 3). In other words, monkeys showed a decrease in the average number of times they switched between behaviors. Similarly, there was also a significant decrease in behavioral range (F(2,16) = 7.83, p = 0.004). This difference was not significant using contrast 1. However, the decrease was pronounced in contrast 2 from the baseline to honors construction phase (F(1,8) = 9.27, p = 0.016; Figure 4). This indicates that the monkeys showed a decrease in the average number of different behaviors performed during an observation period.
Figure 3: Average behavioral change exhibited across construction phases.

Figure 4: Average behavioral range exhibited across construction phases.
3.2.1.1 Anxiety-Like Behaviors

Scratching behavior revealed a statistically significant result (F(2,16) = 4.78, p = 0.024). There was no significant effect of contrast 1, but contrast 2 revealed that scratching behavior decreased significantly from the baseline to honors construction phase (F(1,8) = 5.96, p = 0.040; Figure 5). Yawning behavior showed a marginally significant difference over the three phases (F(2,16) = 3.10, p = 0.073). See Appendix Figure 3 for data.

![Bar graph showing average scratching behavior across construction phases](image)

**Construction Phase**

Figure 5: Average scratching behavior exhibited across construction phases.

3.2.1.1.1 Activity Behaviors

There was no significant difference in motor stereotypic behavior across the three construction phases (See Appendix). However, there was a significant difference found between phases when looking at locomotive behavior (F(2,16) = 5.172, p = 0.019).
Specifically, contrast 1 revealed that locomotion increased significantly from the baseline to roof and honors phases combined (F(1,8) = 7.82, p = 0.023; Figure 6). There was no significant difference when performing contrast 2. The two above behaviors were combined to form an overall activity category and there was no significant difference found between the phases (See Appendix Figure 5).

![Locomotion Graph](image)

**Locomotion**

Figure 6: Average locomotive behavior exhibited across construction phases.

### 3.2.1.1.1 Aggressive Behaviors

Aggressive behaviors included cageshake, crooktail, and initiation of threat behavior. These behaviors were also combined to create an overall aggression category. There were no significant effects found for any of these behaviors or the category as a whole (See Appendix Figures 6, 7, 8, and 9).
3.2.1.1.1.1 Social Behaviors

Analyses were performed on the initiation and reception of social contact and social groom. Additionally, a global social category was created that included vocalization, receive rump present, initiate rump present, initiate present, receive present, and lipsmack. The only significant effect seen from all of the social behaviors was in social grooming (F(2,16) = 17.57, p = 0.001). Contrast 1 was not significant but contrast 2 revealed that social grooming behavior increased significantly from the baseline to honors construction phase (F(1,5) = 24.42, p = 0.014; Figure 7). See Appendix Figures 10 and 11 for social contact and social signaling data.

![Social Groom](image-url)

**Figure 7**: Average social grooming behavior exhibited across construction phases.
3.2.1.1.1.1 Exploratory Behaviors

There was no significant difference in environmental exploration across the construction phases (See Appendix Figure 12). However, there was a significant difference in visual exploration ($F(2,16) = 4.10, p = 0.036$). Specifically, contrast 1 showed that there was a marginal increase in visual scanning from the baseline phase to the roof and honors phases combined ($F(1,8) = 5.08, p = 0.054$; Figure 8). Contrast 2 did not reveal any significant effects.

Figure 8: Average visual exploratory behavior exhibited across construction phases.

3.3 Adaptation

In addition to the three construction phases above, the vibration data were further segmented and extended to observe any adaptation of the animals to the construction
activity. The same vibration data were used as in Figure 2 above and two additional honors phases were added on to this for a total of seven, 11-week long phases. The average vibration values for all phases (in chronological order as shown in Figure 9 below) in room 104A were 256.62, 564.10, 962.79, 622.96, 705.84, 505.61, 427.26 microinches per second. The averages in room 104D were 182.23, 405.57, 676.43, 535.31, 530.29, 334.28, 403.05 microinches/second.

![Monitor A and D Weekly Vibration Averages](image)

Figure 9: Weekly vibration averages across seven construction phases in rooms A and D.

3.4 Roof Early Versus Roof Late Behavioral Data Comparison

When comparing behavioral data between the roof early and roof late construction phases, there were very few significant differences found. There was a marginal decrease in scratching behavior (F(1,8) = 4.62, p = 0.064) and vocalization behavior (F(1,8) = 5.20, p = 0.052).
3.5 Behavioral Data Comparison Across Four Honors Phases

Analyses of Variance and two contrasts were performed across the honors phases: 1) honors one and two versus honors three and four 2) honors one versus honors four. The results of behavioral comparisons across the four honors phases are discussed below.

3.5.1 Global Behavioral Categories

There were significant differences in behavioral change \( (F(3,24) = 4.96, \ p = 0.008) \) and range \( (F(3,24) = 6.97, \ p = 0.002) \) across the honors phases. Both increased significantly from honors 1 and 2 to 3 and 4 \( (F(1,8) = 15.81, \ p = 0.004; \ F(1,8) = 19.53, \ p = 0.002, \) respectively). Also, levels of change and range returned to baseline in Honors 3 and 4 together \( (F(1,8) = 0.728, \ p>0.05; F(1,8) = 0.138, \ p>0.05; \) Figures 10 and 11).

![Behavioral Change](image)

Figure 10: Average behavioral change across honors construction phases.
3.5.1.1 Anxiety-like Behaviors

There was a significant difference in scratching behavior across the four honors construction phases (F(3,24) = 3.62, p = 0.027). Specifically, there was an increase in scratching behavior between honors 1 and 2 versus honors 3 and 4 (F(1,8) = 9.60, p = 0.015). There was no significant difference in yawning behavior across the honors phases (See Appendix Figure 13). Analysis across the baseline, Honors 3, and Honors 4 phases revealed a non-significant effect (p>0.05), indicating that scratching levels had returned to baseline by the end of the honors construction phase. Also, values of scratching behavior returned to baseline levels during Honors 3 and 4 (F(1,8) = 0.124, p>0.05; Figure 12).

Figure 11: Average behavioral range across honors construction phases.
Figure 12: Average scratching behavior across honors construction phases.

3.5.1.1 Activity Behaviors

There were no significant differences between the honors phases for either locomotion or stereotypic behavior. Additionally, there was no significant difference when combining these two activity behaviors into a separate category (See Appendix figures 14, 15, and 16).

3.5.1.1.1 Aggressive Behaviors

There were no significant differences across honors construction phases for cageshaking, crooktailing or threat behaviors (See Appendix figures 17, 18 and 19). The combined aggression category also did not yield any significant results (See Appendix Figure 20).
3.5.1.1.1.1 SOCIAL BEHAVIORS

There was a significant difference between the honors construction phases in social signaling behavior (F(3,24) = 6.64, p = 0.002). This difference was seen as an increase in these behaviors from Honors 1 and 2 to 3 and 4 (F(1,8) = 14.38, p = 0.005; Figure 13). There were no significant differences in either social grooming or social contact behaviors (See Appendix Figures 20 and 21).

![Social Signaling](image)

**Figure 13**: Average social signaling behavior across honors construction phases.

3.5.1.1.1.1.1 EXPLORATORY BEHAVIORS

When examining visual scanning and environmental exploration, there were no significant differences in behavior across the honors phases (See Appendix Figures 22 and 23).
3.6 Discussion

This study examined the effects of construction activity on the behavior of captive rhesus monkeys. The Acentech, Inc. monitoring system used to record vibrations did in fact measure the vibrations produced by the construction project. We tested this idea by comparing vibration levels during the week (full construction activity), with Saturday (partial construction activity) and Sunday (no construction activity). As expected, vibration levels were significantly higher on the weekdays compared to both Saturday and Sunday. Additionally, weekday vibration levels were also higher than Saturday alone. These results confirm that behavioral data was taken during times of peak construction activity. Vibration levels recorded on Monitor D were generally lower than those recorded on Monitor A although they were significantly correlated. A possible explanation for this difference could be that Monitor A was close to a hallway where movement of animal cages and foot traffic occurs on a daily basis. Monitor D was on the opposite side of the laboratory space and was fairly distant from this hallway (See Figure 1 for lab layout). The amount and type of construction relative to the two monitors could also have contributed to this effect but this possibility is harder to distinguish.

Construction activity was associated with behavioral changes. From the baseline to the honors phase, monkeys showed both a decrease in the average number of times they switched between behaviors (behavioral change) and a decrease in the average amount of different behaviors exhibited (behavioral range). These data suggest a sort of behavioral
suppression, which we initially predicted. This same behavioral response has been seen in zoo-housed snow leopards (Sulser, Steck & Baur, 2008) and Wistar rats exposed to the shaker stress test (Hasiguchi, 1997). Also similar to the Hasiguchi results, our animals exhibited adaptation to the construction activity because both behavioral change and range showed a trend towards recovery from honors 1 and 2 to honors 3 and 4. Though our study dealt with a long term exposure to noise and vibration, the behavioral response appears similar to other species of animals.

Our prediction about anxiety-like behaviors increasing during the construction period was not supported. On the contrary, there was no difference in yawning across the phases and a decrease in scratching from the baseline to the honors phase. Similarly to the behavioral range and change, scratching behavior also showed an effect of adaptation. Rates increased to baseline levels in the second half of the honors college construction as shown by the comparison honors phases 1 and 2 versus 3 and 4. The initial decrease in scratching behavior may in part be explained by the overall decrease in behavioral activity.

Although there was an overall decrease in behavioral activity, there were increases in a few select behaviors. Locomotive behavior increased from the baseline to the roof and honors phases. Based on the data, this change appears to be driven mostly by a sharp increase during the roof construction phase that steadied off during the honors phase. The roof construction took place right above the animal rooms, and this close proximity could account for the temporary increase in locomotion. However, this increase is not necessarily an indication of anxiety because when locomotive and motor
stereotypic (pace) behaviors were combined into one category, there was no difference across the construction phases. There was also a marginal increase in visual scanning behavior across the construction phases suggesting increased vigilance while construction was directly overhead. There was also an increase in social grooming from the baseline to the honors phase. It has been previously suggested that social grooming may be a method of tension reduction in primates (Terry, 1970). There have been instances of decreased self-directed displacement behaviors after grooming sessions both in the monkey receiving and initiating the grooming (Schino, Scucchi, Maestripieri, & Turillazzi, 1988; Aureli & Yates, 2010). Though there was no difference in social signaling behaviors across the baseline, roof, and honors phases, there was an increase in these behaviors from honors 1 and 2 to honors 3 and 4. Snow leopards exposed to construction activity showed a similar increase in social activity. These data suggest that animals were predominantly performing these few behaviors which caused a decrease in the overall behavioral change and range as a result.

Our final prediction about proximity of the construction activity causing pronounced behavioral effects was only partially supported by these data. While it was true that locomotion increased from the baseline to the roof and honors phases, no other behaviors were significantly altered in this same pattern. Also, when analyzing behaviors within the roof phase (roof early versus roof late), there were no significant changes in behavior. Behavioral changes mostly occurred from the baseline to the honors phase, and there were also multiple significant changes within the four honors phases as mentioned above. This may be because the roof phase was too short to produce immediate behavioral changes within it and instead these changes were manifested during the
prolonged honors phase. Additionally, the honors phase exposed the monkeys to greater amounts of construction than the roof phase and this may have also contributed to the behavioral changes.

Overall, there is a general trend of decreased behavioral activity in the construction period compared to before construction began. However, the animals do seem to be exhibiting signs of adaptation as the honors period comes to an end. These data suggest that unpredictable construction activity may initially cause some changes in monkey behavior some of which seems to be related to decreased activity. However, because many of these changes are reversed over time, they appear to habituate to prolonged exposure to vibrations.
APPENDIX

DATA AND GRAPHS

Figure 1: Monitor A and D weekly noise averages.

Figure 2: Monitor A and D vibration averages across weekdays, Saturdays and Sundays.
Figure 3: Average yawning behavior exhibited across construction phases.

Figure 4: Average active stereotypic behavior exhibited across construction phases.
Figure 5: Average activity behaviors exhibited across construction phases.

Figure 6: Average cageshaking behavior exhibited across construction phases.
Figure 7: Average crooktail behavior exhibited across construction phases.

Figure 8: Average threat behavior exhibited across construction phases.
Figure 9: Average aggressive behaviors exhibited across construction phases.

Figure 10: Average social contact behavior exhibited across construction phases.
Figure 11: Average social signaling behavior exhibited across construction phases.

Figure 12: Average environmental exploration exhibited across construction phases.
Figure 13: Average yawning behavior exhibited across honors construction phases.

Figure 14: Average locomotive behavior exhibited across honors construction phases.
Figure 15: Average stereotypic behavior exhibited across honors construction phases.

Figure 16: Average combined activity exhibited across honors construction phases.
Figure 17: Average cageshaking behavior exhibited across honors construction phases.

Figure 18: Average crooktailing behavior exhibited across honors construction phases.
Figure 19: Average threat behavior across honors construction phases.

Figure 20: Average aggressive behavior exhibited across honors construction phases.
Figure 21: Average social grooming behavior exhibited across honors construction phases.

Figure 22: Average social contact behavior exhibited across honors construction phases.
Figure 23: Average visual scanning behavior exhibited across honors construction phases.

Figure 24: Average environmental exploration exhibited across honors construction phases.
BIBLIOGRAPHY


