THE EFFECTS OF HOUSING AND ENRICHMENT ON ZOO ELEPHANT BEHAVIOR

Beth Posta

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ABSTRACT

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Zoos today are concerned with providing for the physical and psychological welfare of captive animals. One of the greatest challenges for zoo managers is ensuring the good welfare of zoo elephants. Yet only a few scientific studies have comprehensively focused on activity and behavioral health of captive elephants or examined elephant behavior over a 24-hour period or throughout several seasons, making evaluation of diurnal and seasonal variations in behavior challenging. Elephants in the wild have been observed spending the majority of their day foraging and it is suggested that movement in the wild is based on the availability of food and water. Elephants in zoos are not subjected to food or water restrictions, and instead are more prone to obesity due to the high quality of feed and addition of enrichment foods. Thus the management of zoo elephants must consider the occupational needs of elephants to forage and to feed, while at the same time providing high quality diets.

This study examined the behavior of two zoo elephants over a 2-year period in an effort to determine factors that affect behavior. Results suggest that elephant activity is influenced by the type of housing, time of day, and season. Furthermore, a retrospective examination of the effectiveness of environmental enrichment showed that typical zoo keeper documentation techniques, while adequate for monitoring daily elephant care and well being, may not allow for a robust analysis of the effectiveness of enrichment in promoting specific behaviors.

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INTRODUCTION

Zoos today are concerned with providing for the physical and psychological welfare of captive animals. Industry-accepted standards for feeding, nutrition, exercise, social groupings, habitat use, and enrichment programs are commonly the targets of concern from critics of zoos whether they are, in fact, deficient or not. One of the greatest challenges for zoo managers is ensuring the good welfare of zoo elephants (Veasey, 2006), which are intelligent and charismatic flagship species. Numerous debates have focused on the welfare of captive elephants, especially related to foot health, walking, and stereotypic behavior. Yet only a few scientific studies have focused on the activity and behavioral health of captive elephants in a comprehensive way (Clubb and Mason, 2002; Stoinski et al., 2006; Rees, 2009). A number of critical opinions claim that the welfare of captive elephants may not be adequate (e.g., Clubb and Mason, 2002; Clubb et al., 2008; Mason & Veasey, 2010). Previous studies have commonly been limited to the daytime when staff can directly observe the animals, often for short periods of time (e.g. Gruber et al., 2000; Stoinksi et al., 2000; Wilson et al., 2004; Tresz and Wright, 2006; Rees, 2009) or during the night only (e.g. Brockett et al., 1999; Wilson et al., 2006). However, few have examined elephant behavior over a 24-hour period and throughout several seasons, making evaluation of diurnal and seasonal variations in behavior challenging (Rees, 2009). Harris et al (2008) studied the behavior and welfare of elephants in all 13 UK zoos over an 18-month period to determine the effects of various factors on elephant health and welfare. This study highlighted several negative indicators of welfare, such as lameness and obesity. Additional studies are needed to further examine indicators of positive welfare and factors that foster elephant well-being.

Elephants in the wild have been observed spending the majority of their day foraging, spending up to 16 hours per day feeding on a variety of grasses, twigs, bark, roots, and leaves (Wiedenmayer, 1998; Shepherdson, 1999; Hatt et al., 2006) and it is suggested that elephant movement in the wild is based on the availability of food and water. Elephants will typically travel farther during the dry season, when resources are depleted, to access food and water. (Viljoen, 1989; Whitehouse and Shoeman, 2003; Getz et al., 2007; Wittemyer et al., 2008). Elephants in zoos are not subjected to food or water restrictions, and instead are more prone to obesity due to the high quality of feed and addition of enrichment foods (Hatt and Clauss, 2006; Harris et al., 2008). Thus the management of zoo elephants must consider the occupational needs of elephants to forage and to feed, while at the same time providing high quality diets (Hediger, 1964; Hediger, 1968). With wild elephants spending between 60 and 80 percent of their time foraging for food (Clubb and Mason, 2002) it may be difficult for zoo managers to create environments in which elephant feeding behavior mimics that of their wild counterparts. According to Veasey (2006), the majority of a captive elephant's day should be consumed with feeding activities in which the animals must manipulate and work for food. If this is not accomplished, then much of the elephants' day may be left with few activities and choices, leading to a potential increase in behaviors, such as stereotypic swaying, that indicate decreased welfare. Husbandry practices and enrichment programming in the zoo should encourage elephants to explore different behaviors and to utilize different areas of their environment, with options to seek shelter and shade, avoid wind and rain, and seek or avoid social contact (Schulte, 2000; Veasey, 2006). Therefore, zoos should design exhibits to encourage appropriate behaviors that incorporate choice and control by the animals themselves.

An animal's captive surroundings should be dictated by the species' native habitat, natural history, and ethological considerations (Forthman Quick, 1984; Moore, 1987; Forthman and Ogden, 1992; Mellen and MacPhee, 2001). It is important to consider, however, that life in the wild may not represent optimal welfare, as wild animals are subject to stressors, such as predation, disease, lack of food or water, social pressures, and poaching (Hediger, 1969; Murphy and Iliff, 2004; Veasey, 2006; Grandin, 2009). Lacepede recognized this in the 1800s, noting the need for exhibit complexity through environmental elements, such as lakes, visual barriers, and night housing (see Murphy and Iliff, 2004). Hagenbeck reiterated this in the next century building exhibits that mimic wild habitats and encouraging animals to perform natural behaviors (Hagenbeck et al., 1909; Hosey et al., 2009**)**. However, until the recent past, many typical zoo exhibits were relatively barren. Constructed of concrete, these provided sterile environments for the animals in order to minimize health risks (Shettel-Neuber, 1988; Grandin, 2009) but did little to enhance their mental well-being. Today, zoo managers recognize the importance of encouraging species-typical behaviors and have constructed more realistic and enriching exhibits that resemble natural environments and provide greater opportunities for social interaction between conspecifics. Currently, many U.S. zoos are planning to upgrade or renovate their elephant exhibits (Lewis et al., 2010). With the design of these new facilities comes opportunities to investigate new concepts for enrichment that address a multitude of physical and psychological needs of the elephants as well as better twenty-four hour video monitoring. Thus, there are opportunities to develop and test broader concepts, such as changes in management or husbandry practices for elephants in ways that would provide enrichment opportunities and optimize their welfare.

Environmental enrichment is viewed as "a dynamic process which structures and changes an animal's environment in a way that provides behavioral choices to animals and draws out their species-appropriate behaviors and abilities and enhances their welfare"(AZA, 1999). The effects of enrichment have been examined in numerous animals, with many studies focusing on the effectiveness of a particular enrichment device (e.g., Fishbacher and Schmid, 1999; Vick et al., 2000; Stringer, 2004; Wells and Irwin, 2009). Enrichment in zoos today is often based on specific behavioral goals for the animal (Mellen and MacPhee, 2001; Margulis et al., 2005; Tarou et al., 2007), and on items designed to achieve these goals, incorporating knowledge of the species in the wild as well as that of the individual animals.

The purpose of this study was to determine the activity budgets of a captive mother and calf elephant over a two year period. This study allowed for year-round, seasonal, and round-the-clock evaluation of behavior. Based on these data I aimed to address three specific questions (1) whether behavior was affected by indoor or outdoor housing contingent on season, (2) whether daytime activity is representative of a 24-hour activity budget, and (3) whether current levels of keeper documentation of enrichment practices provide a robust method of scientific analysis of the effectiveness of behavioral enrichment. For the latter, my working hypothesis is that current levels of documentation, while satisfying minimum requirements established by the USDA and the Association of Zoos and Aquariums (AZA), do not meet scientific evaluation needs. Using a retrospective review of keeper records, I examined the number of different types of enrichment offered per day, the goal behaviors addressed through this enrichment, and attempted to determine, by reviewing their daily documentation, whether one could assess whether the keepers were able to meet their goals for the animals.

MATERIALS AND METHODS

Subjects

The subjects for this study were a mother and calf African elephant (*Loxodonta africana*). The mother, Renee, a 27-year old, was wild born in Zimbabwe and brought to The Toledo Zoo in 1982 after she was orphaned as a calf. Her 3-year-old son, Louie, was born via artificial insemination at The Toledo Zoo in April, 2003. Renee and Louie were the zoo's only elephants during the study period and have lived together since Louie's birth.

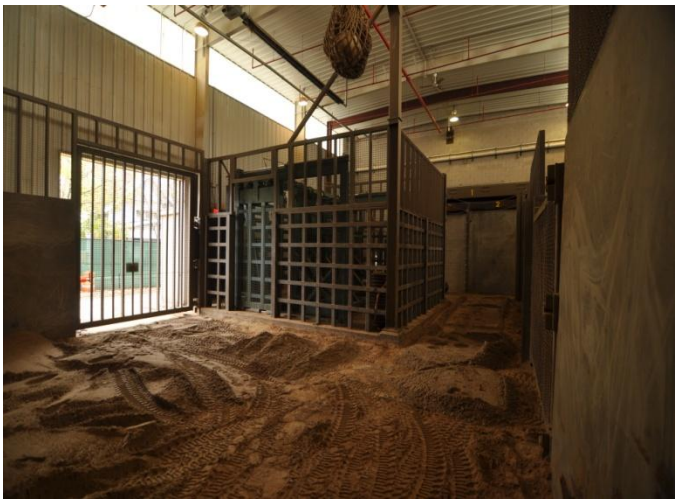
Housing and Management

The elephant facility includes both indoor and outdoor exhibits. The outdoor facility measures 916m^2 and includes a sand substrate, a deep water pool, and several trees and deadfall logs to which various enrichment items can be attached (Figure 1). The indoor facility (Figure 2) includes three animal areas: two heated stalls, including a main stall and a pool stall totaling 564 m^2, and a 244 m^2 sand floor addition that houses the elephant restraint device with a scale. The main stall includes various enrichment attachment points. The pool stall includes ground space with enrichment attachment points and a small pool. The indoor and outdoor enclosures are separated by a public pathway. In order to move the elephants from one enclosure to another, gates are opened across the public pathway, temporarily blocking visitor access and allowing the elephants to walk from the indoor enclosure to the outdoor enclosure and vice-versa. Once in the designated enclosure the gates are closed and the public pathway reopened. Thus, the elephants were provided access to either the indoor or outdoor facilities at one time but not both at the same time.

Figure 1. Outdoor elephant exhibit

a

b



c

Figure 2. Indoor elephant facility a) main stall with Renee (r) and Louie (l) using enrichment b) pool stall c) sand addition with the elephant restraint device.

The elephants were managed primarily in a free contact system where the keepers worked with the animals without a barrier between them. As Louie reaches sexual maturity he will be managed in a protected contact system where the keepers work with him through a barrier. To facilitate this change, Louie's behaviors were trained and maintained through both free contact and protected contact training systems.

During the warmer months the elephants were typically given a bath inside between 09:00 and 10:00, during which time they also participated in operant conditioning training sessions. At 10:00 they were given access to the outdoor exhibit where, weather permitting, they remained overnight. When inappropriate temperatures or storms were predicted, the elephants were brought inside before the keepers left for the night at 17:00. During the winter months the elephants were allowed outside when weather conditions permitted. When inside overnight the elephants had access to all three indoor stalls and were not chained or otherwise restrained. The elephants were fed several times per day, with piles of hay provided, as well as enrichment puzzle feeders that required manipulation to obtain the food.

Enrichment was offered to the elephants several times per day, beginning with the morning bath and included devices to encourage foraging, such as hanging hay nets designed to challenge the animals to work to obtain their food. A time-release feeder was developed and constructed by engineering students from the University of Toledo and was implemented in December 2005. This device was constructed with two steel trays that were held in place by electronic magnets that released on a programmable timer up to nine times per day. Hay, produce, and other food items could be placed on the trays to provide a variable diet in terms of food items offered and time of delivery. An additional automated deer feeder (Game Country model Day II) was hung from the ceiling and programmed to drop food items into a 55-gallon

plastic barrel at different times throughout the day and night. Holes were drilled in the barrel so the elephants could use their trunks to manipulate the barrel to obtain the food inside. The barrel was hung over the elephants' heads, creating an additional challenge.

Manipulable items, such as large barrels and tires, were hung from enrichment attachments on the indoor exhibit walls and outside from trees and poles, and several devices were added to encourage rubbing. The outdoor exhibit contained mostly sand and dirt substrate that allowed the animals to dust. Zoo keepers added sand on a regular basis and created mud wallows in various areas. The keepers generally interacted with the elephants during the afternoon for an additional training session, either with the animals on exhibit during a free contact training session or by requesting and rewarding behaviors from the public viewing area.

Equipment Setup

To facilitate nighttime monitoring video cameras were installed throughout the facility. Two cameras were installed in the indoor stalls. A camera with variable focal length (Sony CC25-BCCD) was mounted in the main stall and a high resolution vandal dome 12dc manual focus camera (480tvl, 3.6mm) was set up in the pool stall. Three additional cameras with variable focal length were mounted on the roof of the elephant building (Sony CC25-BCCD, Sony YK-217ZF Super HAD CCD, and Panasonic wv-bp334 color CCD), allowing full view of the outdoor facility. All cameras were linked to a Ganz video digital recorder (Model DR16ND-500 Digimaster) in the elephant keeper office that allowed all cameras to be viewed at once or individual cameras to be watched in full screen mode. Due to the set up of the addition, a small section of this area, approximately a few square meters in area, was difficult to see on video. Elephant activity was video recorded three nights per week on 8-hour videotapes at the SLP

setting. A video cassette recorder and video monitor were set up in the elephant keeper office where nighttime security staff could access and change videotapes.

To permit viewing at night, low wattage lights were mounted where necessary and were motion activated where feasible. A red film was used to cover the ceiling lights in the two inside stalls. The outdoor exhibit was fitted with four lighting zones, with each zone overlapping the adjacent one. Two flood lights with motion sensors were installed in each outdoor zone to allow enough light to observe video recordings of elephant behavior throughout most of the exhibit. The lights provided ambient light to allow for observations without disturbing the elephants.

Data Collection

A comprehensive ethogram was developed with input from the elephant keepers. Behavioral categories included daily maintenance behaviors, such as feeding and locomotion, as well as social, aggressive, mother-offspring, and stereotypic behaviors (Table 1). During data analysis, several behaviors were lumped together due to rare occurrences. Those behaviors are shown within the ethogram as sub-headings under the more general categories. Behaviors that were rarely observed were lumped with other similar behaviors or into the "Other" category to facilitate analysis. "Out of View" was also included with "Other" for analysis.

Table 1. African Elephant (*Loxodonta africana*) Ethogram. Behavioral categories are listed with subcategories of rarely occurring behaviors listed as sub headings.

Feed	Seeking or ingesting of food or water. Often involves gathering food with its trunk and lifting it into its mouth.
Nurse	One or a series of mouth on nipple incidents separated by less than sixty seconds.
Stand	Individual is stationary in an upright position. No other behaviors are occurring simultaneously.
Lie	Individual is in lateral recumbence. Weight is no longer supported by legs. No other behaviors are occurring simultaneously.
Walk	Animal takes 2 or more steps in any direction but not in a stereotypic pattern. Is not playing, feeding, or exhibiting any other overt behavior simultaneously.
Enrichment Use	Individual moves, pushes, tosses or picks up objects within its environment, such as grass, rocks, sticks, and dirt (not for purposes of dusting) or keeper-provided items. Does not include food items.
Self Directed	Individual touches, rubs on objects or exhibit furniture, or grooms own body. May use mouth, trunk, or appendages to contact any area of body. Does not include self-aggressive behavior or self-sucking behaviors. Includes digging and dusting.
Investigation	Exploring any area of the environment. Includes raising trunk to smell environment, using trunk on ground or exhibit furniture to explore substrate, bars, gates, locks, spices, or other objects (such as enrichment devices, ice, logs, etc.) without actually moving or picking the item up.
Social	Positive interactive behaviors such as play, trunk tangle, or caressing with a conspecific.
Aggression	Includes the following behaviors:
Drive	One animal follows closely behind another, the follower pushing the other animal from behind. Both animals must take more than two steps. The follower may make contact with the base of its trunk or put its trunk over the back of the first animal.
Social Aggression	Agonistic contact between conspecifics. Includes attacks with trunk, mouth, or legs, sparring, head butting, pushing and tusking. Does not include aggression toward keepers.
Threat/ Display	Agonistic behavior that indicates aggression between conspecifics but does not involve contact. May include mock charge or charge and threat display with ears erect and held outward. Does not include threats or displays directed toward keepers.
Submissive	Individual indicates submission through behaviors such as pawing, arched back, or foot swinging. Usually accompanied by ears flat against head and in conjunction with agonistic behavior from a conspecific.
Displace	Individual moves towards conspecific and overtakes the position of that individual. Other individual immediately moves away without any intervening behaviors.
Restrain	Calf attempts to move away from proximity of adult; adult prevents calf from moving away using her trunk or front foot.
Retrieve	Adult regains proximity with calf, bringing it toward her using her trunk; either the adult walks to within trunk distance of the calf or the calf moves toward the adult as a result of the trunk-calf contact; in both cases, the pair moves into proximity.
Push	One elephant contacts another and gradually forces or pushes against the other, often causing it to move. It may be body-to-body contact or the elephant may push with its forehead or base of the trunk.
Other	Animal is exhibiting any behavior not included in this ethogram
Work with Keepers	Animal is in a formal training session directed by the keepers or interacting with the keepers who are working in the yard or from outside of the exhibit.
Public	Elephants interact with or watch public.
Stereotypic Behavior	Any behavior that occurs in repetitive pattern, including pacing, swaying or head bobbing.
Out of View	Elephant is not visible or its behavior is not discernable

Data were collected by six animal behavior staff and interns with inter-observer reliability meeting a 90% requirement. Reliability was tested with each new observer and every several months with all observers using an index of concordance (Martin and Bateson, 1993). Behavioral data were collected using scan sampling with 90-second intervals during 30-minute observation periods (resulting in 20 data points per observation period). Data were collected in person during daytime hours and the animals were videotaped three nights per week to allow observations during times that personal observation was not possible. A total of twelve hours per week of data were collected per elephant for two years: six hours during the normal workday hours, (8:00 to 17:00), and six hours per week between the hours of 17:00 and 8:00. A total of 1787 observations per animal were conducted for a total of 893.2 hours of data per animal.

Additional data were collected regarding the distance each elephant walked during the nighttime hours. The exhibit was mapped and divided into several loops based on the elephants' typical travel patterns. The elephants were observed in person during daytime observations and via videotape at night. Distance walked was noted each time they were observed completing a quarter of one loop. At the end of each data session the distance was tallied and entered with the total number of hours in the observation period. Mileage was not recorded when the elephants walked less than one quarter of a loop. Therefore the distance recorded is an underestimate of the actual distance traveled.

Statistical Methods

Behavioral data were analyzed using a Replicated Goodness of Fit test (Sokal and Rohlf, 1994). The additive nature of this test and ability to detect heterogeneity within each analysis (Figure 3) permits comparison of behavior under different conditions. Frequency tables were

used to determine whether behavior was independent of location, time of day, or time of year. Seven sub-analyses were performed under one test to evaluate differences in behavior indoors versus outdoors, and within each location differences in behavior during the day and night, and among seasons. Expected values were calculated for each test using a null scenario. Freeman-Tukey deviates were then calculated for each test, allowing for cell-wise comparisons and examination of the degree of deviation of the observed frequencies of each behavior against these expected values.

The elephants were housed either indoors or outdoors primarily based on weather conditions. Therefore, the number of observations per location for each season varied based on the weather (Table 2). There were occasions when observation periods spanned times the keepers were moving the elephants either indoors or out, resulting in the animals being observed while both inside and outside. Those data were excluded from analysis since the data points were tallied for each observation period.

The behavior of the elephants when outside at night was analyzed for three seasons (spring, summer, and fall) because the elephants were not given outdoor access at night during the cold winter months. Fall and spring data for Renee were combined to eliminate zeros from the analysis.

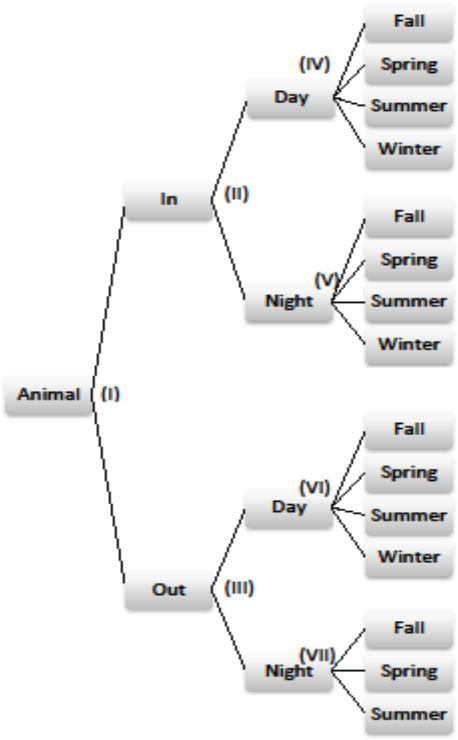


Figure 3. Flow chart for data analysis showing the various layers of comparison in a replicated goodness of fit analysis. Statistical tests (I-VII) are indicated at each node. Because the elephants were not given access outside during the winter nights, there are no data points and therefore no analysis of behavior for outside at night during the winter (node VII).

Table 2. Total number of days (a) data were collected and total number of observations for each location and throughout each season (b) for both elephants. The location of the elephants was often based on weather conditions. There were occasions when more than one observation was conducted on a given day, resulting in a greater number of actual observations than the number of days the animals were observed.

(a) Number of days the animals were observed during each season

Season	Inside	Outside
Winter	107	34
Spring	97	70
Summer	63	109
Fall	80	89

(b) Number of observations per season and location

Day In	Day Out	Night In	Night Out
196	47	145	0
150	105	108	21
63	214	53	116
94	158	179	71

Keeper Documentation of Enrichment Offered

Zoo keepers recorded enrichment offered to the elephants on a daily basis. Enrichment items included objects such as large hanging cargo nets and barrels with holes that were filled with food, aimed to increase feeding time and complexity. Food was also hidden throughout the exhibit, placed in paper mâché for the animals to open, or in boxes, bags or other items that encouraged manipulation or problem solving. Non-food enrichment was provided to encourage other appropriate elephant behaviors, including investigation, self maintenance behaviors such as digging and dusting, walking, and social interaction. Each type of enrichment had several variations. For example, 55-gallon barrels could be left intact within the enclosure for the elephants to manipulate and crush, or could be drilled with holes and hung or placed just outside of the enclosure to encourage the animals to reach inside to obtain food. Some barrels contained hard plastic balls, which the elephants had to manipulate to reach their food, while others were

attached to a timed feeder that at preset times released food into a barrel with holes for trunk access. However, all of these "barrel"-type enrichment items were recorded on the keeper enrichment documentation calendars as "barrel enrichment." In addition to daily enrichment records, the keepers noted major changes to enrichment or enclosure modifications, such as moving or adding sand to the yard, on their daily reports to the curators. These notations were intended to convey husbandry practices and not for future enrichment evaluation.

Data from each month's enrichment calendar were tallied and the number of times each enrichment item was offered was noted. Each item had an associated enrichment category or behavioral goal, such as feeding, social interaction, or investigation, that allowed the keepers to plan enrichment based on the behavioral needs of the elephants each day. Many of the items fit several enrichment categories depending on how they were used. Information regarding enrichment changes was extrapolated from the keeper daily reports to determine whether these changes could be evaluated using the data collected on the elephants' activity budgets. Of the 91 keeper entries, only two types of enrichment changes were recorded such that a behavioral analysis could be attempted. These included adding or moving sand in the exhibit, and the introduction of automatic feeders that delivered food up to 9 times per day. All other entries were either too general to determine the exact nature of the enrichment, or one-of-a kind events. The analysis was conducted using data from Renee only, in an effort to determine if the current documentation met evaluation needs.

Data analysis included data collected two days prior to the enrichment event and two days following the day the enrichment was offered. The day of the enrichment offering was excluded from analysis because the time it was provided was not noted. Therefore, I was unable to determine whether data collected on the day of enrichment included the enrichment event.

Some occurrences were excluded from analysis due to a lack of data collected post enrichment. A total of five occurrences of sand pile creation and movement within the yard, and four occurrences of the automatic feeder were analyzed.

Due to the limited amount of data and inconsistent data collection, the data analysis was conducted using descriptive statistics, graphing the mean frequencies of each behavior for each phase of the enrichment. This allowed a comparison of elephant behavior prior to and after the enrichment was offered.

RESULTS

Renee

Figure 4 illustrates Renee's activity budget over the two year period. Overall, she spent 34% of the time feeding and 18% of her time walking. Other behaviors were observed less frequently, with standing and lying (i.e. resting behaviors) occurring 11% and 7% of the time respectively. Investigation and enrichment use were each observed 5% of the time, while interaction with Louie occurred less frequently.

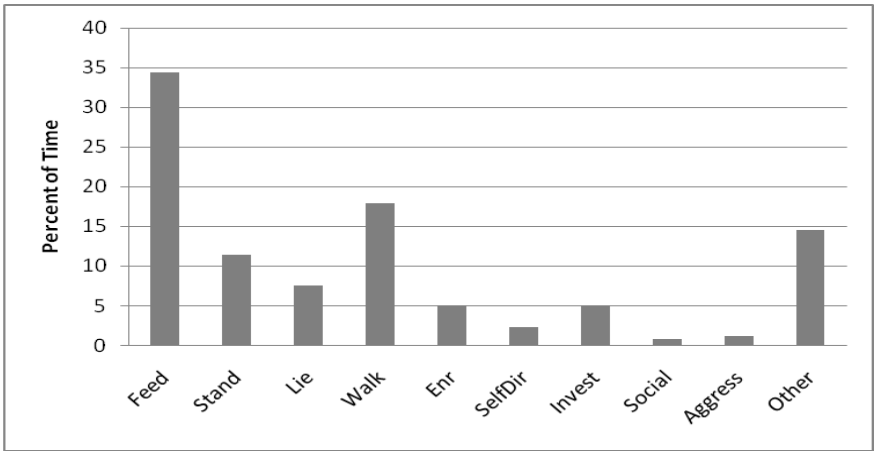


Figure 4. Renee's overall activity budget. She spent the majority of time feeding and walking.

Table 3 illustrates the frequencies and significance of behavior based on location, day or night, and season. It appears that each location lends itself to the performance of specific behaviors.

Table 3. Frequency data for replicated goodness of fit tests for Renee. Levels of analysis are indicated by indentations.

	Feed	Stand	Lie	Walk	Enr	Self Dir	Invest	Social	Aggress	Other	Total	Treatment		df	G	P
Inside	7367	2462	2547	1394	1261	172	1208	114	182	3133	19840	Inside		9	18839.87	<0.0001
Outside	4507	1469	43	4816	471	610	515	183	229	1877	14720	Outside		9	17261.23	<0.0001
													Total	18	36101.10	<0.0001
Σ	11874	3931	2590	6210	1732	782	1723	297	411	5010	34560		Pooled	9	29504.64	<0.0001
													Heterogeneity	9	6596.47	<0.0001
Day vs. Night	4295	1057	66	769	625	115	965	73	154	2041	10160	Day		9	12351.60	<0.0001
Inside	3072	1405	2481	625	636	57	243	41	28	1092	9680	Night		9	10542.31	<0.0001
													Total	18	22893.91	<0.0001
Σ	7367	2462	2547	1394	1261	172	1208	114	182	3133	19840		Pooled	9	18839.87	<0.0001
													Heterogeneity	9	4054.04	<0.0001
Day vs. Night	3991	1095	29	2901	405	526	390	145	187	911	10580	Day		9	12527.93	<0.0001
Outside	516	374	14	1915	66	84	125	38	42	966	4140	Night		9	6376.03	<0.0001
													Total	18	18903.96	<0.0001
Σ	4507	1469	43	4816	471	610	515	183	229	1877	14720		Pooled	9	17261.23	<0.0001
													Heterogeneity	9	1642.73	<0.0001
Inside Day	718	134	12	151	149	17	187	18	41	433	1860	Fall		9	2101.275	<0.0001
	1285	412	2	212	144	31	276	25	42	571	3000	Spring		9	3880.276	<0.0001
	504	217	3	113	75	38	141	9	22	198	1320	Summer		9	1380.956	<0.0001
	1788	294	49	293	257	29	361	21	49	839	3980	Winter		9	3285.121	<0.0001
													Total	27	12647.628	<0.0001
Σ	4295	1057	66	769	625	115	965	73	154	2041	10160		Pooled	9	201.01	<0.0001
													Heterogeneity	36	12446.62	<0.0001
Inside Night	1137	481	1060	256	305	14	99	20	9	199	3580	Fall		9	4183.10	<0.0001
	780	464	432	103	87	14	54	5	7	214	2160	Spring		9	2684.73	<0.0001
	208	121	322	39	69	15	17	4	2	263	1060	Summer		9	1205.77	<0.0001
	947	339	667	227	175	14	73	12	10	416	2880	Winter		9	3080.37	<0.0001
													Total	27	11153.97	<0.0001
Σ	3072	1405	2481	625	636	57	243	41	28	1092	9680		Pooled	9	10542.31	<0.0001
													Heterogeneity	36	611.66	<0.0001
Outside Day	850	241	9	467	106	86	100	16	35	210	2120	Spring		9	2438.083	<0.0001
	1857	492	11	837	153	327	116	34	45	448	4320	Summer		9	5421.882	<0.0001
	1284	362	9	1597	146	113	174	95	107	253	4140	Fall Winter		9	5334.634	<0.0001
													Total	27	13194.598	<0.0001
Σ	3991	1095	29	2901	405	526	390	145	187	911	10580		Pooled	9	12527.93	<0.0001
													Heterogeneity	36	666.67	<0.0001
Outside Night	149	184	9	968	31	9	55	19	26	390	1840	Fall Spring		18	3197.476	<0.0001
	367	190	5	947	35	75	70	19	16	576	2300	Summer		9	<0.001	<0.0001
													Total	27	<0.001	<0.0001
Σ	516	374	14	1915	66	84	125	38	42	966	4140		Pooled	9	<0.001	<0.0001
													Heterogeneity	36	<0.001	<0.0001

Behavior Based on Location (Analysis Node I)

Significant differences in behavior were observed when Renee was inside versus outside (G= 36101, P<<0.0001). Renee's activity budget in each enclosure is shown in Figure 5. Feeding was a prevalent behavior in areas, occupying 37% of overall activity inside, and 31% outside. Walking was the dominant behavior outside where there is more area available, occupying 33% of Renee's activity in the outdoor yards, versus 7% inside. A similar trend was observed with self directed and social behaviors, although these behaviors occurred less frequently overall. Several behaviors were more common inside and less frequent outside than expected, including lying down especially, and feeding. Renee was rarely seen lying down outside, but would do so inside, often on sandy hills made by the keepers. Renee used enrichment less frequently inside and more frequently outside than expected.

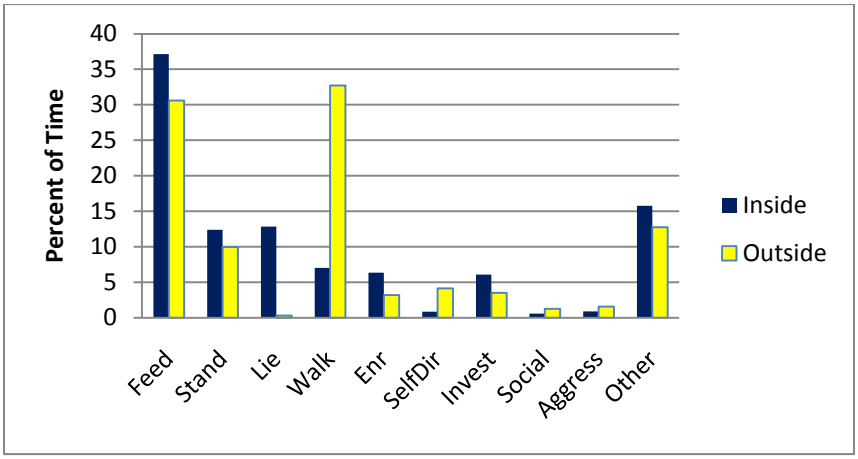
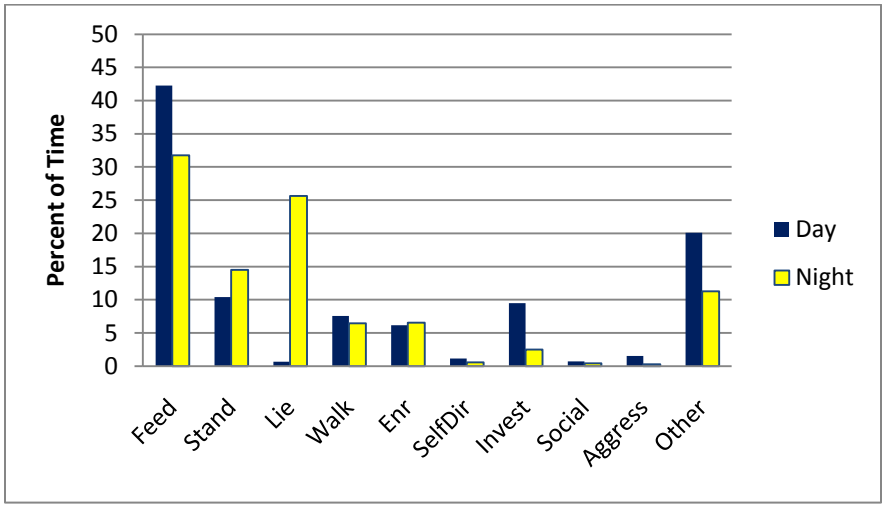


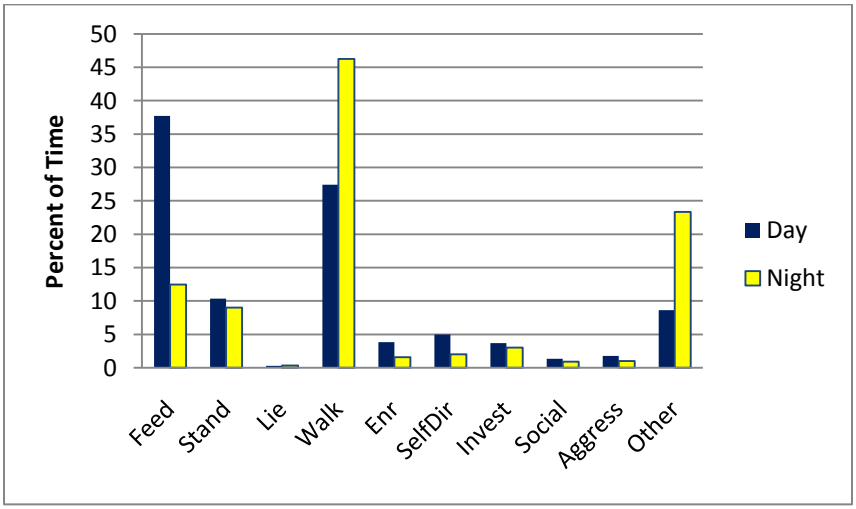
Figure 5. Overall activity budget in each location based on 1730 observations representing behavioral differences at test node I. Inside represents all three indoor locations. Outside represents the outdoor exhibit area. Predominant behaviors when housed inside include feeding, standing and lying down. Outdoor behavior was dominated by feeding and walking. Enrichment use and investigation, while occurring infrequently overall, were more often observed when Renee was inside, whereas self directed behaviors were more common outside. Renee was not observed lying down while inside.

Behavior Based on Location and Time of Day (Analysis Nodes II and III)

Several behavioral trends were observed based not only on location, but also on time of day. The keepers would leave the zoo at 17:00 each day, supplying the elephants with enrichment and food overnight until 08:00 the following day. Figure 6 summarizes the percent of time Renee spent involved in each behavior while inside and outside. Several trends were noted, with feeding occurring more during the day than night, and standing and walking showing opposite trends when inside versus outside. Standing was more common during the night when inside but more common during the day when outside. The opposite holds true for walking. Renee was observed lying down only when she was inside at night.



Inside



Outside

Figure 6. Activity budgets for indoor (node II) and outdoor activity (node III) based on time of day for 1730 observations. Daytime hours range from 08:00 to 17:00 and night time hours range from 17:01 to 07:59. Feeding was the most common behavior when inside during both day and night. Daytime activity inside was comprised mostly of feeding, investigation and standing, with little walking and enrichment use. Feeding was also the most frequently observed behavior when Renee was outside during the daytime, with walking the 2nd most common behavior. Outside nighttime activity was predominantly walking (46%), with feeding and standing occupying 12% and 9% of her activity.

Inside

While the elephants were inside, several trends were identified. Renee would feed more often during the day than during the night, even with the large amount of enrichment provided by the keepers overnight. Investigation was also higher during the day and less frequent at night than expected. Enrichment use was higher than expected for both daytime and night time, suggesting that the enrichment was effective throughout the 24-hour cycle. Renee walked less frequently than expected when inside regardless of day or night. Much of her nighttime behavior included lying down, leaving less time available for walking. She was rarely observed lying down inside during the day, but would lie down and rest at night. Social behavior and aggression were rarely seen at night and fell well below the expected frequencies, indicating less interaction between the elephants during the night than during the daytime hours.

Outside

Behavioral differences were also apparent between day and night in the outdoor exhibit. Renee fed less often than expected during the night and much less than during the daytime. Walking, however, was a much more prevalent behavior, with much higher than expected frequencies for both day and night. Self directed behaviors were more common during the daytime, when the animals were more exposed to the sun and heat and therefore more prone to dusting, digging, and rubbing on objects in the exhibit. Social interaction was also higher during the daytime while enrichment and investigation occurred less than would be expected both day and night.

Seasonal Effect on Behavior (Analysis Nodes IV-VII)

A significant seasonal effect on behavior was observed for both indoor and outdoor locations, as shown in the large total G and heterogeneity G values in Table 3. Behavioral patterns were evident among all seasons. For example, standing was more common during the spring in all scenarios than during other seasons. Feeding was the most frequently observed behavior in all scenarios except when the elephants were outside at night, when walking was the predominant behavior. Renee walked more often at night during the hot summer months than during other seasons. Seasonal trends can be seen in other behaviors, with feeding at its highest frequency inside during the winter, and at its lowest frequency during the summer when the elephants were outside during the day. Differences in walking were observed as well, with the frequency of walking outside during the winter days at twice that observed during other seasons. Seasonal trends and differences can be seen in less frequently occurring behaviors as well.

Inside during the day

Overall, a significant difference was observed in behavior based on season ($G = 12647.63$; $P<<0.0001$). Feeding occurred at its highest frequency in winter while standing was most common in the summer. Most behaviors differed among the seasons to varying degrees; however cell-wise comparisons indicate less of a seasonal effect on lying, investigation, social behaviors, and aggression.

Trends appeared among the seasons, with Renee standing inside less often in the fall and winter, but more often during spring and summer. Feeding inside occurred the least during the summer months when the elephants were outside much of the time, and most often during the winter months then the elephants spent more time inside. Renee walked less frequently inside

during the day, especially during the spring and winter months. Enrichment use and investigation, while occupying a small percentage of the activity budget, varied among the seasons, with more enrichment use occurring in the fall than during other seasons. During the summer, the animals spent little time inside; however, Renee spent more time engaged in certain behaviors when inside than during the other seasons. Only lying down and walking were observed less frequently than expected during the summer, while other behaviors were observed more often than expected.

Inside during the night

When inside at night variability was observed in several of Renee's behaviors ($G= 10542.31$, $P<<0.0001$), with standing at its highest frequency during the spring, and lying down lowest during the same season. Enrichment use and walking were varied as well, but to a lesser extent. Feeding behavior varied among the seasons, with the least amount of feeding occurring in the summer when the animals were outside the most. Renee would lie down inside during all seasons but less often in the spring than during the remainder of the year. Walking and enrichment use occupied less than 10% of her activity budget, yet variations were also observed during each season.

Outside during the day

Data for Renee were combined into three seasons, with fall and winter behaviors combined due to rare occurrences of some behaviors. When she was outside during the day ($G= 13194.598$, $P<<0.0001$), Renee walked more frequently than expected and especially during the winter months when feeding was at its lowest. Several trends were observed, with lying

occurring much below expected values and investigation below expected values as well. Self directed behaviors occurred more frequently than would be expected, especially during the summer. Differences noted among the seasons included feeding more often in the spring and summer than fall and winter. Enrichment use was observed less than would be expected in all seasons except spring and social behaviors occurred at higher frequencies during the winter months.

Outside during the night

Walking was the predominant behavior outside at night, occupying at least 40% of Renee's time. During the fall and spring, this increased to more than 50%. Other behaviors, including feeding, walking, and self directed behaviors, occurred with less frequency but showed significant variation among the seasons ($G= 6521.093$, $P<<0.0001$).

Walking

Overall, when outside, Renee walked consistently throughout much of the year, with the exception of the summer days, and averaged 0.24 km/hour. She often walked more than 16 km and up to 31 km during the summer nights. During other seasons, both day and night her walking distance ranged from 1.2 km/hour to 1.75 km/hour. Typical distances walked inside were 0.18 to 0.27 km per hour, considerably less than outside.

Louie

Louie's activity throughout the two-year study is shown in Figure 7. He spent 20% of the time feeding and slightly less time lying down. Walking and enrichment use were also dominant behaviors at 11% and 12% respectively. Lying was his main form of resting, with Louie standing only 5% of the time. The remaining behaviors occupied 5% or less of his time.

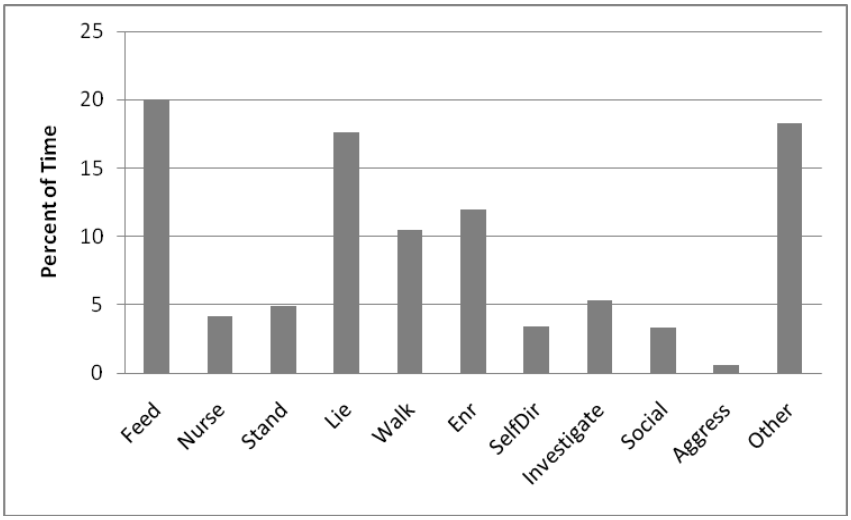


Figure 7. Louie's activity budget over the two year study show feeding and lying occupying much of his time. Walking and enrichment use were also frequent behaviors.

Behavior Based on Location (Analysis Node I)

Behavioral patterns were different for Louie in each location (Figure 8). When inside, Louie spent most of his time feeding and lying, investing more than 20% of his time in each activity. Outside, he would feed, walk, and use enrichment. Many of the enrichment items were food based and out of Louie's reach in the indoor facility but were more accessible to him in the outdoor exhibit. Self directed behaviors, such as digging and dusting, were more common outside as well.

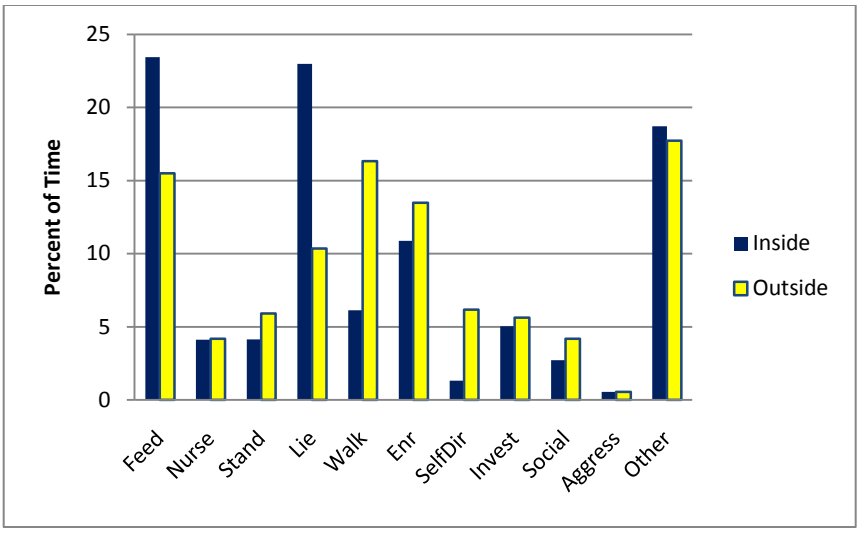


Figure 8. Overall activity budget in each location for Louie based on 1730 observations. Inside represents all three indoor locations. Outside represents the outdoor exhibit area. Feeding and lying were the most common behaviors inside, with Louie spending more than 20% of his activity budget on each of these activities. When outside, Louie spent most of his time feeding, walking and using enrichment.

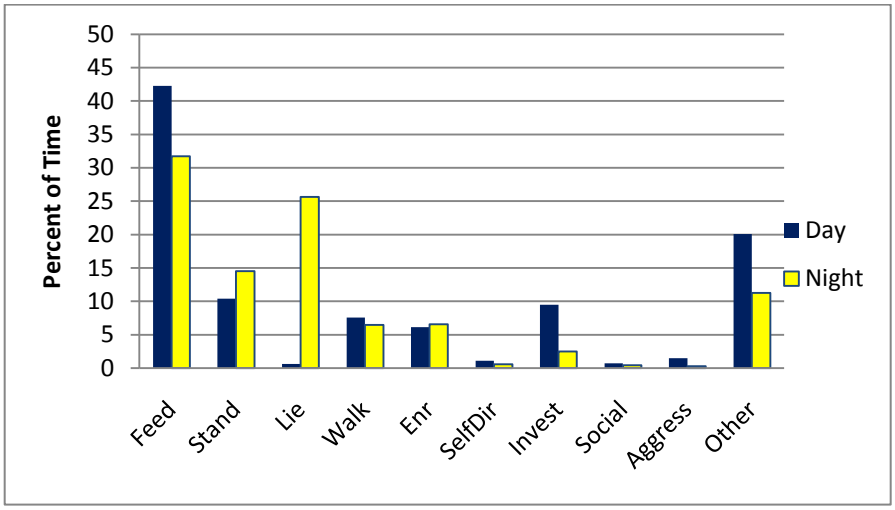
Table 4 shows the frequency of Louie's behavior in each exhibit area for day and night time, as well as effects of season on behavior. As with Renee, there is a significant effect of location on Louie's behavior ($G= 21868$; $P<<0.0001$). While he would walk in both areas, Louie walked much more frequently outside and much less frequently inside than would be expected. He was involved in self directed and social behaviors more frequently outside than in, although these behaviors occurred less frequently than walking, feeding, and enrichment use. Inside, predominant behaviors included lying down and feeding. While Louie would lie down much more frequently inside than out, he did show a trend of standing more often than expected when outside and less often than expected inside.

Table 4. Frequency data for replicated goodness of fit tests for Louie. Levels of analysis are indicated by indentations.

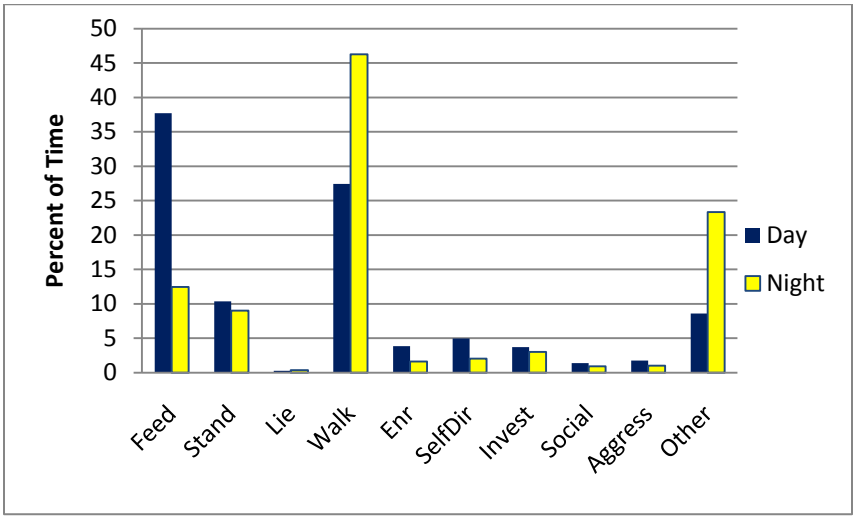
	Feed	Nurse	Stand	Lie	Walk	Enr	Self Dir	Invest	Social	Aggress	Other	Total	Treatment		df	G	P
Inside vs.	4639	820	823	4568	1217	2163	262	1000	538	109	3721	19880	Inside		10	15782.20	<0.0001
Outside	2285	616	870	1527	2407	1986	911	829	616	81	2612	14740	Outside		10	6086.75	<0.0001
														Total	20	21868.95	<0.0001
Σ	6944	1436	1693	6095	3624	4149	1173	1829	1154	190	6333	34620		Pooled	10	19182.45	<0.0001
														Heterogeneity	10	2686.50	<0.0001
Day vs. Night	3387	426	435	569	824	1466	216	741	391	89	2236	10780	Day		10	8736.499	<0.0001
Inside	1272	394	388	3999	393	697	46	259	147	20	1485	9100	Night		10	11914.00	<0.0001
														Total	20	20650.49	<0.0001
Σ	4639	820	823	4568	1217	2163	262	1000	538	109	3721	19880		Pooled	10	15782.20	<0.0001
														Heterogeneity	10	4868.30	<0.0001
Day vs. Night	2070	454	530	1369	1710	1615	795	628	515	71	1143	10900	Day		10	4361.54	<0.0001
Outside	215	162	340	158	697	371	116	201	101	10	1469	3840	Night		10	3706.26	<0.0001
														Total	20	8067.80	<0.0001
Σ	2285	616	870	1527	2407	1986	911	829	616	81	2612	14740		Pooled	10		
														Heterogeneity	10		
Inside Day	680	85	42	66	186	357	38	162	60	18	446	2140	Fall		10	2036.22	<0.0001
	934	121	188	176	237	380	65	229	120	32	718	3200	Spring		10	2370.69	<0.0001
	319	49	82	192	110	179	31	96	63	11	208	1360	Summer		10	661.79	<0.0001
	1454	171	123	135	291	550	62	254	148	28	864	4080	Winter		10	4086.02	<0.0001
														Total	40	9154.72	<0.0001
Σ	3387	426	435	569	824	1466	216	741	391	89	2236	10780		Pooled	10	8736.50	<0.0001
														Heterogeneity	30	418.22	<0.0001
Inside Night	308	156	98	1581	145	320	11	114	63	1	323	3320	Fall		10	4703.83	<0.0001
	294	105	146	860	92	123	9	33	31	16	271	1980	Spring		10	2456.41	<0.0001
	69	28	69	425	31	49	12	32	7	1	277	1000	Summer		10	1498.47	<0.0001
	401	105	75	1133	125	205	14	80	46	2	614	2800	Winter		10	3750.25	<0.0001
														Total	40	12408.95	<0.0001
Σ	1272	394	388	3999	393	697	46	259	147	20	1485	9100		Pooled	10	11914.00	<0.0001
														Heterogeneity	30	494.96	<0.0001
Outside Day	737	142	191	224	579	515	146	217	207	20	282	3260	Fall		10	1558.89	<0.0001
	414	88	121	220	324	354	159	134	84	16	246	2160	Spring		10	869.38	<0.0001
	828	187	179	924	492	530	435	183	156	24	582	4520	Summer		10	2233.03	<0.0001
	91	37	39	1	315	216	55	94	68	11	33	960	Winter		10	891.95	<0.0001
														Total	40	5553.25	<0.0001
Σ	2070	454	530	1369	1710	1615	795	628	515	71	1143	10900		Pooled	10	4361.54	<0.0001
														Heterogeneity	30	1191.72	<0.0001
Outside Night	84	68	135	59	266	141	20	70	30	3	444	1320	Fall		10	1189.17	<0.0001
	17	12	36	22	63	28	12	17	7	1	185	400	Spring		10	498.51	<0.0001
	114	82	169	77	368	202	84	114	64	6	840	2120	Summer		10	2080.67	<0.0001
														Total	30	3768.35	<0.0001
Σ	215	162	340	158	697	371	116	201	101	10	1469	3840		Pooled	20	3706.26	<0.0001
														Heterogeneity	10	62.09	<0.0001

Behavior Based on Location and Time of Day (Analysis Nodes II and III)

Figure 9 illustrates Louie's activity budgets in each location. Clear differences can be seen, with Louie lying down much of the night when inside, and spending much of the day inside eating. Little walking occurred inside, whether day (7%) or night (4%), and enrichment use occupied Louie for 14% of his daytime activity and 7% of nighttime behavior. Outdoor behavior was more varied, with feeding occupying 18% of the day and only 5% of the night. Walking, lying, and enrichment use rounded out much of Louie's day. At night when outside, he was often out of view (scored under "Other"); however, when visible, he was observed walking more than 15% of the time and using enrichment 9% of the time.



Inside



Outside

Figure 9. Activity budgets for indoor and outdoor activity based on time of day for 1732 observations. Daytime hours range from 08:00 to 17:00. Nighttime hours range from 17:01 to 07:59. Feeding was the most common behavior inside during the day, with enrichment use the second most frequent behavior. At night, Louie spent more than 40% of his time inside lying down. Outside, his behaviors were more variable during the day, with feeding, lying, walking, and using enrichment each occupying more than 10% of the day. At night, walking remained the most frequent behavior, with enrichment use the second most frequent behavior. Feeding occupied very little of Louie's time at night, at 6%, versus 19% during the day.

Inside

Like Renee, Louie exhibited behavioral trends, with feeding frequency being much higher during the day than during the night. Enrichment and investigation were more common during the day as well, and below expected frequencies at night. Lying was well below expected frequencies during the day but was the predominant behavior and above expected frequencies at night. Louie walked less than would be expected at all times when inside, with less walking occurring at night than during the day. While he would use enrichment more frequently during the day, Louie's nighttime enrichment use was lower than expected frequencies.

Outside

Behavioral differences were apparent between day and night in the outdoor exhibit. Louie fed much less at night than during the day and feeding behavior was less frequent than expected overall outdoors. Lying was far below expected frequencies during both day and night when Louie was outside. The frequency of walking was similar for both day and night and was above expected frequencies during both time periods. Self directed behaviors were more common during the daytime, when the animals were more prone to dusting, digging, and rubbing on objects in the exhibit. Louie used enrichment in both areas, with slightly higher frequency during the day than at night. "Other" behaviors were scored during much of the night time activity, with many observations being out of the observer's view.

Seasonal Effect on Behavior (Analysis Nodes IV-VII)

Time of year had a large effect on Louie's behavior in both locations for both day and night. Behavior often varied more between the summer and winter months when the animals

were housed primarily inside or primarily outside.

Inside during the day

During the daytime when Louie was inside (G= 9154.72, P<<0.0001) feeding was at its highest during the winter and lowest during the summer. The opposite was true with lying down. While this behavior occurred less often than expected during all seasons, Louie would lie down least often in the winter and most often during the summer during the heat of the day. Walking was below expected frequencies during all seasons, but especially during the winter. Louie continued to use enrichment throughout all seasons, with more enrichment use occurring during the fall and winter and least often during the spring. Self directed behavior varied among the seasons as well, but fell below expected frequencies during the fall, spring, and winter.

Inside during the night

Feeding was below expected frequencies in all seasons, and especially summer. While lowest during the summer, Louie spent similar amounts of time eating throughout the other three seasons. He spent much of the nights inside lying down. While above expected frequencies year round, this behavior was less frequent in the summer than other seasons. Trends were observed among several behaviors, with walking, enrichment use, self directed behaviors, investigation, and social behaviors occurring infrequently and falling below expected frequencies; however the variation within each behavior was evident among the different seasons (G= 12408.95, P<<0.0001). Standing was more prevalent and above expected frequencies during the spring and summer and below expected frequencies during the fall and winter.

Outside during the day

Seasonal variations were observed when Louie was outside during the day (G= 5553.25, P<<0.0001). Feeding was more frequent during the fall months and least common during the winter. Lying was less frequent than expected during three seasons, with Louie lying more often in the summer months and least often during the cold winter months. Louie walked most often during the winter and fall when the elephants typically had less access to the outdoor yard than during the warmer months. Several other behaviors, including enrichment use and investigation, were more common during the winter than other seasons. Self directed and social behaviors were most common during the warm summer months.

Outside during the night

When Louie was outside at night trends were observed, with walking, enrichment use, and investigation lowest in the spring. During all seasons, walking was the dominant behavior and, while more frequent than would be expected, was more common during the fall and summer months than during the spring. “Other” behaviors were scored at high frequencies during the dark hours of the night. “Other” included scans when the animals were out of the observer’s view, which was common during the nighttime videotaping. Other behaviors occurred with less frequency but showed significant variation among the seasons as seen by the high G values (G= 3768.35, P<<0.0001). Variations were evident with feeding and lying occurring less frequently during the summer than other months and self directed behaviors occurring more frequently during the summer.

Walking

Louie's walking patterns varied seasonally during the daytime, walking more on average during the fall (0.9 km/hour) and winter (0.76 km/hour) months than during the summer (0.18 km/h). During the summer nights he walked more than twice that of summer days at an average of 0.47 km/hour. Overall, during the night, his behavior was fairly consistent, walking between 0.47 and 0.6 km per hour. Being so young, he spent more time sleeping than Renee but often followed in her walking pattern.

Keeper Documentation of Enrichment Offered

With five occurrences of sand being moved or piled in the outdoor exhibit, variations were observed in Renee's behavior. The goals of this enrichment activity were to increase time spent walking and dusting. The elephants were also encouraged to investigate the sand piles and were able to lie or lean on them when resting.

An increase in walking and self directed behaviors, including dusting, was observed during three of the five occasions the enrichment was offered (Figure 10). Investigatory behavior increased on two occasions but also decreased on two other occasions. A large increase in resting was observed only during the last offering of sand. This enrichment was offered three times during the first summer of this study, and then again the following fall, with the last offering during the next year's summer. No behavioral trends emerged through the analysis that would indicate the effectiveness of this particular enrichment in enticing particular behaviors, although the zoo keepers anecdotally commented that they observed the elephants investigating the sand piles and moving the sand around the exhibit.

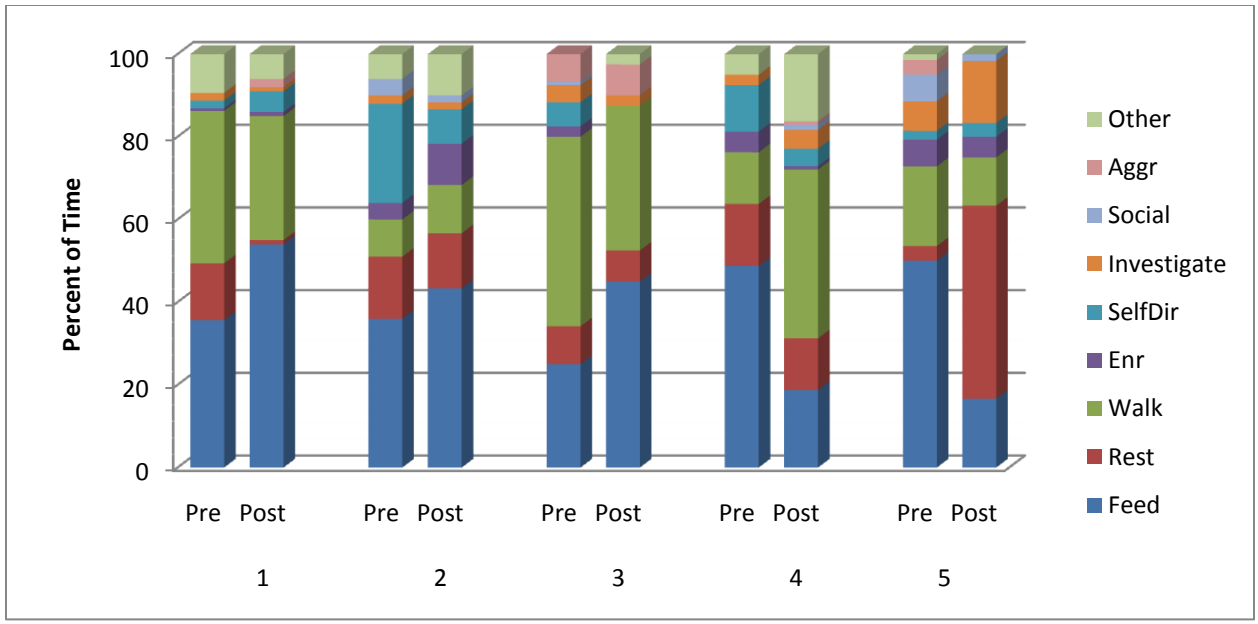


Figure 10. Data collected 2 days prior (Pre) to and 2 days following (Post) the day sand piles were created in the exhibit. No clear behavioral trends were observed. Sand piles were one of many enrichment opportunities offered to the elephants.

The automatic feeder was installed and removed numerous times during the study due to mechanical issues or damage caused by the elephants. This enrichment item was intended to lead to an increase primarily in time spent feeding as well as time spent walking, as the elephants were encouraged to walk to the feeder area throughout the day to check for food items. Of the four times it was offered during the study period an increase in feeding time was observed once (Figure 11). Walking frequency increased slightly during the last two occasions the feeder was used. As with the sand pile enrichment, no clear behavioral trends emerged when this item was offered. Both the sand pile enrichment and the automatic feeders were only a part of the enrichment offered on those days. Of the more than 100 enrichment items approved for the elephants, more than 25 might have been offered throughout any given day in different combinations, each with a behavioral goal associated with it. It is possible that the additional

enrichment items encouraged behaviors that did not coincide with the behavioral goals associated with the sand piles.

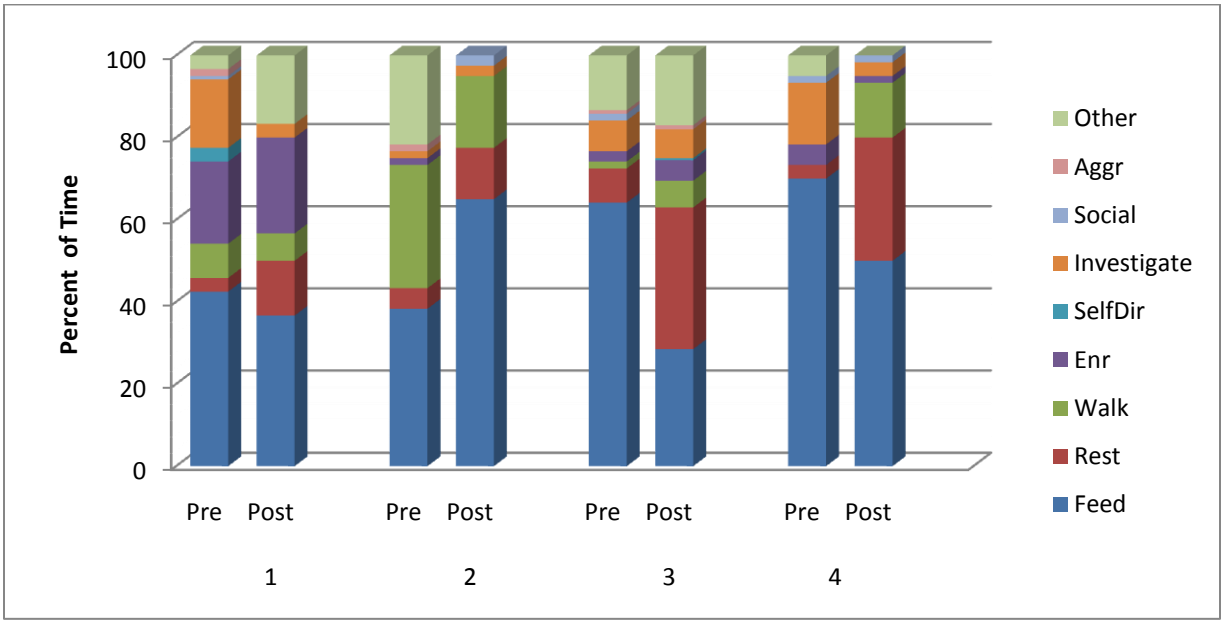


Figure 11. Data collected 2 days prior (Pre) and 2 days following (Post) the day the automatic timed feeders were installed in the exhibit. The feeders were part of the enrichment offerings on the given days. No clear behavioral trends were observed. An increase in time spent feeding was observed during one trial, while an increase in walking was observed during different trial. A decrease was observed in both of these goal behaviors during three trials.

DISCUSSION

This study illustrated the different environmental factors that affected two African elephants. Behavior varied seasonally, throughout the day, and among exhibit areas. Wild elephant behavior is often governed by proximity to water (Guy, 1976; Viljoen, 1989; Wittemyer et al., 2007; Wittemyer et al., 2008; Loarie et al., 2009; Ngene et al., 2010). Elephants spend more time near water sources during the wet season yet because water is in good supply, they will maintain a larger home range. They will walk long distances between wet and dry seasons in an effort to locate water and food sources; however, during the dry season elephants are more restricted to a smaller range where there is sufficient food and water (Viljoen, 1989; Wittemyer et al., 2007; Wittemyer et al., 2008; Loarie et al., 2009). Zoo housed elephants may experience a greater environmental range based on longitude. Whereas wild African elephants typically experience only two seasons, the study elephants live in the northern United States where they are exposed to four seasons and have a constant supply of food and water. Therefore, it is plausible that zoo elephant behavior would be influenced by other factors. There was considerable variability in behavior of The Toledo Zoo's two elephants; primarily they feed more frequently when inside and more often during the day than night, and vary walking patterns throughout the circadian and seasonal cycles.

The primary behavior for both Renee and Louie was feeding, occupying 34% of Renee's activity and 20% of Louie's. These values were comparable to elephants in Ponogola Game Reserve who spent 48% of the time feeding and those in Pilanesberg National Park who were observed feeding 36% of the time (Shannon et al., 2008). Elephants in Rhodesia were observed feeding between 12 and 14 hours per day (Guy, 1976) but in most other studies feeding and

foraging activities are estimated to occupy 75% of wild African elephants' daily activity. In the zoo, there is less pressure for elephants to find food; due to the ample food supply in zoos, one of the challenges in managing elephants is encouraging natural behaviors that discourage stereotypic behavior (Rees, 2002). Most of the food provided to the study elephants was offered in enrichment devices that encouraged walking, object manipulation, and cognitive abilities. The zoo elephants spent less time engaged in feeding activities than their wild counterparts, possibly because they were provided with high quality diets within a smaller range. Thus, zoo elephants need not walk long distances to find food but instead must figure out how to obtain the food provided.

The Effect of Location on Behavior

The zoo elephants were given access to either indoor or outdoor facilities at any given time. Although there were some similarities in behavior across the different enclosures, each space appeared to lend itself to different activities. While feeding was a dominant behavior in both locales, it was more prevalent inside, whereas walking was observed more frequently outdoors. That the elephants spend most of the time feeding is not a surprise given their large size and natural history. In addition, enrichment goals for the elephants included items that encouraged time spent feeding and walking. The prevalence of walking while outside suggests that the outdoor exhibit is better suited for this activity, possibly due to the size of the yard as well as the sandy substrate. It is also likely that the broader expanse of the yard lends itself to better placement of enrichment items that encourage the elephants to walk from one area to another. Douglas-Hamilton and Krink (2005) found that wild African elephants in some areas occupied a smaller but more complex range than in other areas. It is possible that elephants

living in complex environments, such as zoo exhibits with ample enrichment, may walk less than those in less complex areas and expend energy in other, more intricate, activities.

Louie's behavior differed from Renee's most likely due to his young age and his need to rest more often (Wuestenhagen et al., 2000). Indoor activities consisted mostly of feeding and lying down, whereas his activity budget outside was more varied. Like Renee, Louie walked looped patterns around the exhibit but would lie down on sand piles made by the keepers at night. It is possible that Louie's enrichment use increased outside because the enrichment was more spread out where Renee could not dominate all of it at once. Louie walked less than Renee when outside, averaging 0.52 km/hour. This too might be due to his age and need to rest, as well as more time spent using enrichment items. However, Louie's and Renee's behavior is comparable to that of African elephants at elephants at Disney's Animal Kingdom who were observed walking 0.409 km/hour during daytime outdoor observations. Other zoo facilities have reported similar behavior (Clubb and Mason, 2002). This number decreased when the elephants were inside, however, with Louie walking on average 0.15 km/hour and Renee walking an average of 0.20 km/hour.

Daytime vs. Nighttime Behavior

Most studies of wild elephants were conducted during daylight hours only (Eltringham, 1982) leaving us to wonder what wild elephants do at night. Wyatt and Eltringham (1974) noted the need for observing elephants at night yet few studies have done so. Those that have are focused on the effects of chaining elephants overnight, limiting their behavioral opportunities (Brockett et al., 1999; Wilson et al., 2006). The elephants in this study were not restrained at night. Both Renee's and Louie's behavior differed overnight depending on where they were

housed but also differed considerably from their daytime behavior. While feeding remained a dominant behavior, a decrease in nighttime feeding was observed when the elephants were outside as was in increase in nighttime walking, similar to that of wild elephants in Uganda (Wyatt and Eltringham, 1974). Renee spent more time lying down at night inside, a behavior also observed in other zoo elephants (Brockett et al., 1999; Wilson et al., 2006). Overall activity levels differed between day and night, with Renee spending just 11% of daytime inactive but 41% of the night inactive indoors. She remained more active outside with similar levels of activity during both day (89%) and night (91%).

Louie's behavior followed a similar trend, with much time spent feeding during the day; however, feeding frequency decreased at night and resting, or more specifically, lying down, increased to more than 40%. This is comparable to the behavior of other young zoo elephants that slept for longer periods of time than adults (Wuestenhagen et al., 2000). Active behaviors consumed 70% of Louie's day inside, but only 35% of the night, when inactivity increased from 9% to 48%. Louie's outdoor activity was slightly less variable, with most behaviors following similar patterns day and night. Outside, Louie was active during 72% of the day. At night, activity decreased to 49% with Louie spending 22% of the night inactive. Due to camera angles and challenges of lighting the entire enclosure at night, Louie was scored as involved in "other" behaviors during 38% of the night when outside. This category includes times when he was out of the observers' view or the observers were unable to discern his behavior on videotapes well enough to determine which behavior he was involved in. Renee was involved in" other" behaviors or out of view 23% of the time when outside at night. The exhibit lighting was designed to provide ambient light for animal viewing without affecting elephant behavior. However, because the lighting system was in place prior to the start of this study, a lack of effect

could not be confirmed. Therefore, it is possible that elephant behavior was influenced to some degree by the lights. However, upon examination of the outdoor motion sensor lights, these appeared to be similar in effect to moonlight.

It is evident that the elephants' behavior during the day does not represent their activity at night and therefore is not indicative of a 24-hour activity budget. During the daytime, the animals may be influenced by the presence of keepers, observing keeper activity, interacting with the keepers, or partaking in keeper-initiated activities, such as enrichment, which may be more controlled while the keepers are at the zoo. In addition, the elephants are likely influenced by the daylight, spending more time foraging for food, interacting with their environment, and using enrichment when it is more visible. Self maintenance behaviors, such as dusting, serve a purpose during the heat of the day, protecting the elephants from the sun's rays, a behavior that is unnecessary at night. With elephants demonstrating different behavioral needs throughout the 24-hour period it becomes clear that we cannot observe elephants during the day and make broad assumptions about their behavior at night.

Seasonal Effects on Behavior

Wild elephants typically experience wet and dry seasons (Wyatt and Eltringham, 1974; Viljoen, 1989; Vinod and Cheeran, 1997; Wittemyer et al., 2007; Loarie et al., 2009; Ngene et al., 2010), although elephants in Namibia and Rhodesia live in habitats in which they experience hot, cold, and wet seasons (Guy, 1976; Viljoen, 1989). Wild elephant behavior is greatly influenced by the season, with elephants staying near water sources and moving less during the dry season, but venturing farther during the wet seasons (Loarie et al., 2009). Feeding patterns vary between the seasons, with elephants feeding more during the wet season when browse is

more readily available (Wyatt and Eltringham, 1974; Guy, 1976; Vinod and Cheeran, 1997; Wittemyer et al., 2007). Although the North American climate differs considerably from that of the African plains, The Toledo Zoo elephants followed seasonal patterns in their behavior. The greatest differences occurred between summer and winter, similar to the wet and dry seasons in Africa, with both Renee and Louie feeding more often during the night in the colder months and walking more at night during the hotter months. The elephants tended to walk little during the hot summer days. Like their wild counterparts, Renee and Louie would follow the shade during the day (Wyatt and Eltringham, 1974; Guy, 1976; Wittemyer et al., 2008; Loarie et al., 2009) but walked up to 31 km (Renee) and 7 km (Louie) overnight when temperatures cooled. While they did not need to walk far in search of food, the enrichment feeders encouraged the elephants to use all areas of the exhibit. During the winter, when the animals spent more time inside, feeding comprised most of their activity inside but they would take advantage of access outdoors, walking for much of the day in the outdoor yard. This difference in activity might indicate a preference to be outside or that the elephants took advantage of the space available to walk, explore, and exercise. The outdoor exhibit might become more novel during the winter when the animals have less exposure to it.

When outside during the summer nights Renee and Louie would walk in looped patterns around the exhibit, similar to looping patterns in wild elephants where they reach the end of the feeding patch and turn to return to the patch (Wyatt and Eltringham, 1974; Dai et al., 2007; Loarie et al., 2009). When outside, Renee would walk on average 1.4 km/hour, a rate similar to that of wild elephants (Douglas-Hamilton and Krink, 2005) and faster than elephants that were walking while feeding (Ngene et al., 2010). Whitehouse et al. (2003) noted in their pilot study that elephants walked an average of 9.9 km per day with a maximum of 16.2 km in one day

when living in an enclosed area of a national park. Renee often walked between 20 and 32 km outside overnight during the summer months. This was significantly higher than the distance walked inside, where she averaged only 0.20 km/hour and generally walked less than 2 km per night, suggesting that the indoor areas were not as well suited for walking or that there were other activities that took the place of walking.

While Renee and Louie were inside during the winter their behavior was focused on eating during the day, possibly due to the large number of enrichment feeding activities presented to them. With zoo elephants consuming up to 300 pounds of hay per day zoo keepers are challenged to provide feeding opportunities that encourage both mental and physical stimulation to ensure the elephants have species-appropriate activities and to prevent obesity. Much of the elephants' winter activity involved walking from one feeder to the next and working to obtain their food, with both elephants resting at night. Perhaps the biggest change in behavior occurred during the winter days when the elephants were able to go outside. During these days they took advantage of the large yard and walked much of the day, possibly due to the less frequent access to the yard, but also due to the varied weather conditions when the elephants could take advantage of the cool winter days to walk and exercise, and have occasional access to snow.

Self directed behaviors were more frequent outside and during the day, when the elephants had greater access to substrates for dusting and more natural items to rub on. These behaviors were at their highest frequency in the summer. Rees (2002) found similar results – that elephants dust more in the summer and that dusting was positively correlated with ambient temperature.

Enrichment Evaluation

Evaluating the effectiveness of individual enrichment items proved to be quite challenging, considering that the elephants were provided with numerous items throughout each day and night. As the concepts of enrichment and behavioral husbandry continue to evolve, zoo professionals are recognizing the need to evaluate enrichment programs and ensure that animal welfare is improved through the use of enrichment. The Association of Zoos and Aquariums (AZA) currently requires zoos to offer enrichment to zoo residents and document the provision of enrichment as a condition for accreditation (www.aza.org). Yet many zoos go well beyond this and have incorporated a program framework, termed SPIDER, an acronym for **S**etting behavioral goals for enrichment, **P**lanning the process to achieve these goals, **I**mplementing the enrichment, often several items and several times per day, **D**ocumenting the enrichment offered, **E**valuating the animals' response to enrichment, and **R**eadjusting the original plan based on the results of the evaluation. Much of the elephant enrichment program was designed around a similar framework, with keepers identifying behaviors to encourage through enrichment and using calendars to plan and document enrichment offered.

The evaluation of the use of sand piles and the timed automatic feeder showed no clear behavioral trends that would indicate that the goals of increasing specific behaviors were met. However, given that more than twenty other enrichment opportunities were available to the elephants during the same time as the sand piles and timed feeders, one cannot speculate on the success or failure of any individual enrichment item. Using a retrospective approach to the evaluation of enrichment use using keeper daily reports in this case may have provided inconsistent results. While the data show a decrease in goal behaviors on several occasions, the variety of enrichment opportunities provided each day may influence elephant behavior in a

positive manner but in a way that makes behavioral analysis difficult. What might be more productive would be to evaluate the animal's behavior overall to determine whether the activity budget is one that indicates good welfare and design a separate study to evaluate enrichment preferences and usage.

Further analysis was conducted using the zoo keepers' enrichment calendars of the items offered to the animals each day to determine the degree to which the keepers provided enrichment to address all of the animals' behavioral and psychological needs. All enrichment provided over a twenty-four hour period was recorded on daily calendars and specific items were often combined into broader categories, such as "treat boxes" that might include several types of enrichment provided in cardboard boxes. The time each item was added was not included. Doing so would increase the amount of time the keepers spent on paperwork, leaving them with less time with the elephants. The items documented were tallied each month and discussed with the keepers to ensure they were attempting to provide a variety of opportunities and incorporate novelty and choice in the elephants' day. Much of the enrichment evaluation consisted of observing the animals with particular items; however, we would be remiss if we did not attempt to look at the breadth of the enrichment provision i.e., just stating that enrichment was offered does not mean that all of the elephants' physical and psychological requirements have been addressed, let alone met. Evaluation of what was offered to the animals and how they used each item is necessary to determine how effective each enrichment item is in eliciting particular behaviors.

The current method of documentation allows for monitoring of enrichment provision but makes it difficult to answer the question of whether a particular enrichment item resulted in a particular behavioral outcome due to the many items offered and variables involved. Given that

there are many variations on an enrichment theme, it becomes difficult to assign only one behavioral outcome to many enrichment devices. For example, treat boxes might include small foods that take a long time to pick up, objects to manipulate, or hidden within another object that must be manipulated. While each would be documented as "treat boxes" the method in which the treat boxes are presented might target a different behavior or sense and can therefore have a varying effect on animal behavior. Still, documenting enrichment is essential to planning future enrichment to ensure that keepers do not offer the same items every day and that they use the enrichment calendar as a planning tool for variety and novelty.

CONCLUSIONS

1. The type of housing had a profound effect on elephant behavior. Indoor and outdoor enclosures offered the animals different opportunities and each had different affects on animal behavior. The elephants' behavior varied significantly among the seasons, with the greatest differences noted between summer and winter.

2. Analysis of daytime behavior is not indicative of elephant behavior at night. Therefore, we cannot assume that by collecting behavioral data during working hours, we can obtain a 24-hour activity budget of elephant behavior.

3. Documentation of enrichment activities may serve the purpose of assisting keepers in planning future enrichment, but the scientific evaluation of enrichment effectiveness requires proactive planning and experimental design. A retrospective approach to enrichment evaluation was challenging and ineffective due to the numerous variables involved.

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