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The Effects of Housing on Zoo Elephant Behavior: A Quantitative Case Study of Diurnal and Seasonal Variation

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One of the greatest challenges for zoo managers is ensuring the best possible welfare for zoo elephants. Few studies have focused on behavioral health of elephants over a 24-hour period and across seasons, making evaluations of behavioral variation challenging. This study examined the behavior of two zoo-housed African elephants (*Loxodonta africana*) over a two-year period to determine the roles of 1) indoor/outdoor housing, 2) time of day, and 3) seasonal variation on activity. Daytime behavioral differences were contrasted with nighttime activity, and across seasons. Significant differences were noted when the elephants were indoors vs. outdoors, between day and night, and between summer and winter, suggesting that evaluations of zoo elephant activity should occur throughout circadian cycles and account for seasonal variability.

Throughout the past several decades, concern for the physical and psychological health of zoo animals has become more prevalent in the zoological profession. At the forefront of this issue is good welfare for elephants (Veasey, 2006) and other long-lived social mammals, in part because of their intelligence and status as charismatic flagship species (Plotnik, de Waal, Moore, & Reiss, 2010). Members of both the scientific community and animal welfare organizations have raised concerns that the welfare of zoo elephants may not be adequate (e.g., Clubb & Mason, 2002; Clubb et al., 2008; Mason & Veasey, 2010). Zoo elephants, in particular, have been the subject of numerous welfare debates, especially related to foot health, walking, and stereotypic behavior. However, only a few scientific studies have focused comprehensively on the activity and behavioral health of elephants in human care (Clubb & Mason, 2002; Rees, 2009; Stoinski, Daniel, & Maple, 2000). Harris, Sherwin, and Harris (2008) attempted to determine the effects of various factors on elephant health and welfare by studying the behavior and welfare of elephants in all 13 UK zoos over an 18-month period; their 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.

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; Harris et al., 2008; Rees, 2009; Stoinski et al., 2000; Tresz & Wright, 2006; Wilson, Bloomsmith, & Maple, 2004) or have focused solely on nighttime behavior (e.g., Brockett, Stoinski, Black, Markowitz, & Maple, 1999; Wilson, Bashaw, Fountain, Kieschnick, & Maple, 2006). Few have examined elephant

We thank the Toledo Zoo and especially Don RedFox, Randi Meyerson, and the elephant keepers, who work so diligently to provide the best care possible for the Zoo's elephants. We thank the Toledo Zoo's animal behavior interns, Allison Gutwillig, Sheri Sanders, Theresa Domanski, Lindsay Cosens, Jessica Weeks, and especially Joanne Joys for their help collecting and entering hours of data. Two anonymous reviewers provided valuable feedback on this manuscript. Correspondence concerning this article should be sent to Beth Posta, Curator of Behavioral Husbandry and Research, Toledo Zoo, PO Box 140130, Toledo, OH , 43614, U.S.A.(beth.posta@toledozoo.org)

behavior over a 24-hour period and across the year, making evaluation of diurnal and seasonal variations in behavior challenging (Rees, 2009).

Elephants in the wild spend the majority of their day foraging, feeding up to 16 hours per day on a variety of grasses, twigs, bark, roots, and leaves (Carrington, 1958; Hatt & Clauss, 2006; Laws, 1970; Shepherdson, 1999). It is suggested that the availability of food and water drives elephant movement in the wild. Elephants will typically travel farther during the dry season, when resources are depleted, to obtain sufficient food and water (Viljoen, 1989; Whitehouse & Schoeman, 2003; Wittemyer, Getz, Vollrath, & Douglas-Hamilton, 2007; Wittemyer, Polansky, Douglas-Hamilton, & Getz, 2008).

In a zoo environment, elephants are not under pressure to seek food or water, and instead are more prone to obesity due to the high quality of feed and the addition of enrichment foods (Harris et al., 2008; Hatt & Clauss, 2006). Thus, the management of zoo elephants must consider the animals' occupational need to forage, while simultaneously providing diets that meet elephants' physical health and welfare requirements (Hediger, 1968; Hediger & Sircom, 1964). It is difficult, in a zoo, for managers to create environments that mimic the feeding behavior of wild elephants, which spend between 60 and 80 percent of their time foraging for food (Laws, 1970; Wyatt & Eltringham, 1974). 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 (Grandin & Johnson, 2009; Hediger, 1969; Murphy, 2004; Veasey, 2006). According to Veasey (2006), the majority of a zoo elephant's day should be spent on 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 may indicate decreased welfare (Swaisgood & Shepherdson, 2006). Husbandry practices should encourage a variety of behaviors, including exploration of different areas of the animals' 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 develop exhibits to encourage species-appropriate behaviors that incorporate choice and control by the animals.

The design of a zoo exhibit should focus on the species' native habitat, natural history, and ethological considerations (Forthman & Ogden, 1992; Forthman-Quick, 1984; Mellen & MacPhee, 2001; Moore, 1987). Until recently, however, many zoo exhibits were rather barren, sterile environments for the animals; this minimized health risks (Grandin & Johnson, 2009; Shettel-Neuber, 1988), but did little to enhance the residents' 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, Shepherdson, Owens, & Keele, 2010). With the design of these new facilities, opportunities arise to investigate and test broader concepts, such as changes in management, housing, or husbandry practices for elephants in ways that would enhance choice and optimize the elephants' welfare.

The purpose of this study was to measure the activity budgets of an adult elephant and her calf over a two-year period and determine how behavior was affected by housing and season. Furthermore, we explored whether daytime activity is representative of a 24-hour activity budget. The results of this study may provide a foundation for similar research on additional species and aid in assessing how various aspects of housing and management of zoo animals affect their overall behavior and well-being.

Materials and Methods

Subjects

The subjects for this study were two African elephants (*Loxodonta africana*), a mother and her calf. The 27-year old mother, Renee, 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 included both indoor and outdoor exhibits. The outdoor facility measured 916 m^2 and included a sand substrate, a deep water pool, and several trees and deadfall logs to which various enrichment items could be attached. The indoor facility included three animal areas: two heated stalls with a pool totaling 171 m^2, and a 74 m^2 sand floor addition that housed the elephant restraint device with a scale. The indoor and outdoor enclosures were separated by a public pathway. In order to move the elephants from one enclosure to another, gates were opened across the public pathway, temporarily blocking visitor access and allowing the elephants to walk from the indoor enclosure to the outdoor yard and vice-versa. Once in the designated enclosure, the gates were closed and the public pathway reopened. Thus, the elephants were provided access to either the indoor or outdoor facilities but not both areas at the same time.

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, they had access to all three indoor stalls and were not chained or otherwise restrained. The elephants were fed throughout the day and night, with piles of hay provided, as well as enrichment puzzle feeders that required manipulation to obtain the food.

Enrichment was offered on a variable schedule throughout the 24-hour period and included devices aimed to increase foraging time and complexity, such as hanging hay nets. 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 held in place by electronic magnets that were released by 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 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 varying 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 above the elephants' heads, creating an additional challenge.

Manipulable items, such as large barrels and tires, were hung from the indoor exhibit walls and from trees and poles in the outdoor area, 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 sand piles and mud wallows in various areas.

Equipment Setup

Video cameras were installed throughout the facility to facilitate nighttime monitoring. 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, 3.6 mm) was installed 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 where all camera feeds could be viewed concurrently or individually displayed in full-screen mode. Due to the configuration of the barn addition, a small area, approximately a few square meters in size, was difficult to see on video. Elephant activity was video recorded on three randomly chosen nights per week on eight-hour videotapes at the SLP setting.

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. Four lighting zones were created

in the outdoor exhibit, with each zone overlapping the adjacent one. Two flood lights with motion sensors were installed in each outdoor zone to produce enough light to allow observers to view video recordings of elephant behavior throughout most of the exhibit. The lights required minimal elephant activity to activate, allowing observers to discern many behaviors. When the lights turned off while an elephant was in a particular zone, observers scored the animal as out of view, but assumed the elephant was inactive, as small movements would activate the lights in the current zone or adjacent zones if the elephant moved into a different area. The lights provided ambient illumination 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). Data were collected over a two-year period, from June 2005 to June 2007, by six animal behavior department staff and interns with inter-observer reliability meeting a 90% requirement. Reliability was tested with each new observer and every few months with all observers using an index of concordance (Martin & Bateson, 1993). Behavioral data were collected using scan sampling with 90-s intervals during 30-min observation periods (resulting in 20 data points per observation period). Data were collected via direct observation during daytime hours, and the animals were videotaped three nights per week to allow observations during times that direct observation was not possible. A total of 12 hrs 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 during the nights that the animals were videotaped between the hours of 17:00 and 8:00. Observations were staggered throughout the day and night in order to account for the full spectrum of behavior throughout the circadian cycle. A total of 1,731 observations were conducted for a total of 865.5 hrs of data per animal.

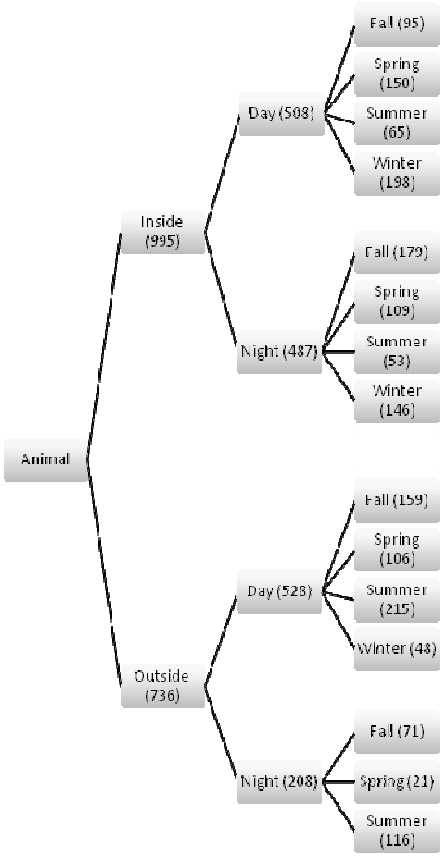

Figure 1. Flow chart for data analysis showing the layers of comparison. The number of observations is noted in each cell. Because the elephants were not given access outside during the winter nights, there is no analysis of behavior for outside at night during winter.

Table 1
African elephant (Loxodonta africana) ethogram

Feed	Seeking or ingesting of food or water. Often involves gathering food with its trunk and lifting it into its mouth. Animals is not engaged in any other behavior.
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.
Affiliation	Positive interactive behaviors such as social 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, trunk or legs, sparring, head butting, pushing and tusking. Does not include aggression toward keepers.
Threat/ Display	Aggression between conspecifics that 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 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. 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
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.
Stereotypy	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 discernible
Out of View/ Active	Elephant is visibly engaged in a behavior but the behavior itself is not discernible.

Note: Rare behaviors are listed as sub categories

Data Analysis

Behavioral data for each elephant were analyzed separately by calculating the mean percentage of time engaged in each behavior throughout each condition. The frequency of each behavior during every observation period

was tallied and then averaged within each treatment. The analysis was layered to permit behavioral analyses under different conditions (Figure 1). Seven sub-analyses were performed under one test to evaluate: differences in behavior indoors versus outdoors; within each location variation in behavior between day and night; and further behavioral variation between seasons. Behavior 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. During data analysis, several rarely observed, similar behaviors were combined. Those behaviors are shown within the ethogram as sub-headings under the more general categories. Stereotypic behavior was never observed and was omitted from the categories being analyzed.

Results

Clear differences in behavior were observed in each condition. Both elephants exhibited behavioral preferences within the various exhibit locales and during the day or night, which varied throughout the year. Each elephant is discussed separately since they showed different, yet significant behavioral trends. Little behavioral difference was noted between spring and fall, when average temperatures varied no more than 5°F within each location. The elephants were often housed inside during the cooler days and nights, when temperatures averaged 46-47 °F, and were outside when temperatures averaged above 60 °F.

Renee

Effects of location on behavior. Overall, Renee spent most of her time feeding and walking (Figure 2a). Her behavior indoors was comprised of feeding 37% of the time and walking 7% of the time. When outside, she spent 31% of the time feeding and 33% of her time walking. She would lie down inside, a behavior rarely observed when she was outside in the yard. She stood in the exhibit 10% of the time, often under the shade of trees during the hot summer days. Self-directed behaviors such as dusting and rubbing occupied 4% of Renee's time while outside compared to only 1% of the time inside. Other behaviors were observed infrequently and in similar frequencies indoors and out.

Circadian variation in behavior. Further analysis revealed behavioral differences between day and night within the different exhibit locations. While inside (Figure 2c), Renee spent 42% of the daytime engaged in feeding activities. The remainder of the day was occupied by standing (10%), investigating her surroundings (9%) and walking (7%) primarily. In comparison, during the nighttime while she was inside, Renee was occupied 31% of the time feeding. She was rarely observed lying down during the day inside, but at night spent time inactive, including lying down (26%) and standing (15%).

Renee's behavior when outside also differed between day and nighttime (Figure 2e). She was occupied with feeding activities during 37% of the day and walking 27% of the day. However, when outside during the night, she spent only 13% of the time feeding and 46% of the time walking. Other behaviors were either rarely observed or differed little between day and night. Renee was out of the observer's view more often at night (23%) but was observed to still be active during 9% of those observations where the observers were able to see activity but could not discern the particular behavior Renee was involved in at the time.

Seasonal variation in behavior. Feeding remained the predominant behavior in most scenarios (Figure 3). However, when Renee was outside during the night (Figure 3d), she preferred to walk, an average of 41% of the time during the summer months and more than 50% of the time during the fall and spring. She also showed a preference for walking outside during the winter days (Figure 3c), spending on average 61% of the time walking versus 19% during the summer and 22% and 32% during the spring and fall respectively. She spent only 14% of the time

feeding during the winter days when she was outside, compared to 36% or more during the other seasons.

Most of the seasonal differences in behavior occurred when the elephants were inside during the night (Figure 3b). Renee's behavior was indiscernible and scored as out of view but active 17% of the time during the summer nights. During the summer, her nighttime feeding frequency decreased to 20% as compared to the other seasons when she spent 32-36% of the night feeding. It is possible that she was feeding during the times she was scored at out of view but active. Therefore, it is difficult to draw a definite conclusion regarding her feeding habits during these summer nights indoors. Smaller, but notable differences occurred in standing and lying down, where, in the springtime, Renee stood more frequently (21%) and lied down less frequently (20%) than during other seasons.

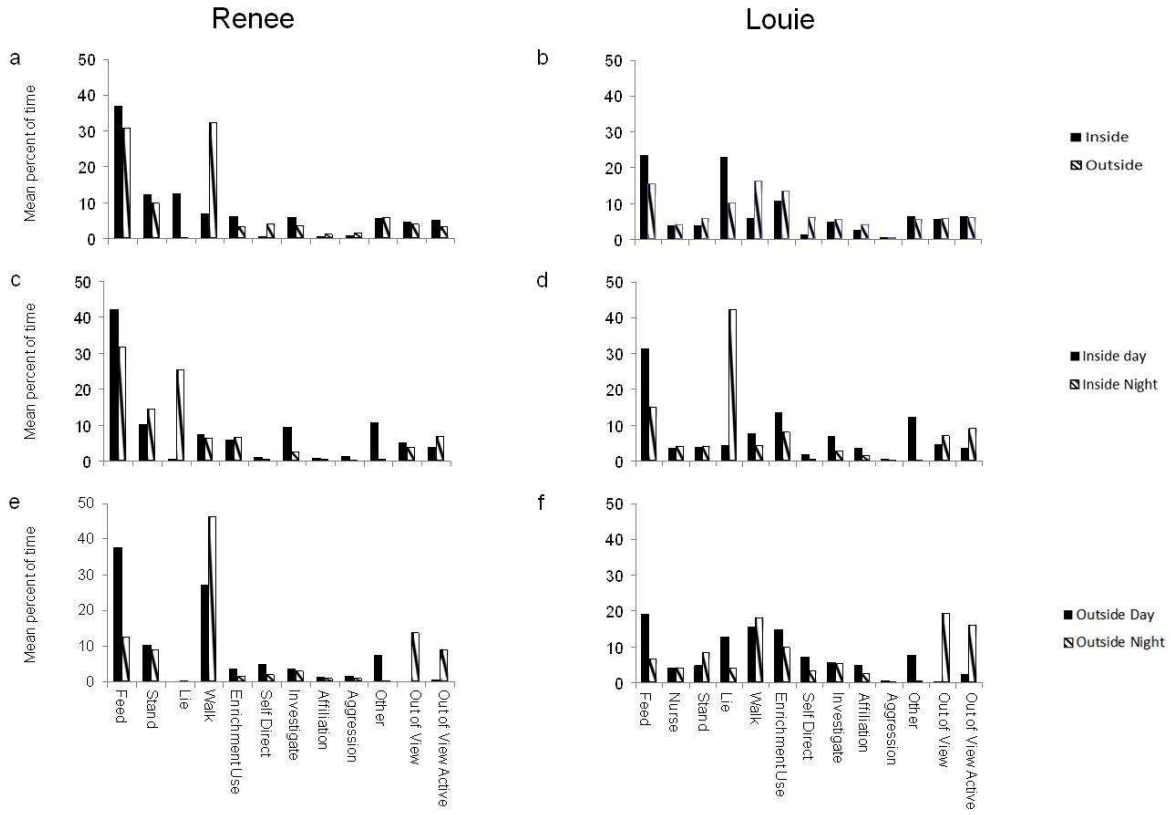

Figure 2. Percent of time spent in each behavior when (**a**, **b**) inside and outside, (**c**, **d**) inside during the day and night and (**e**, **f**) outside during the day and night for each elephant.

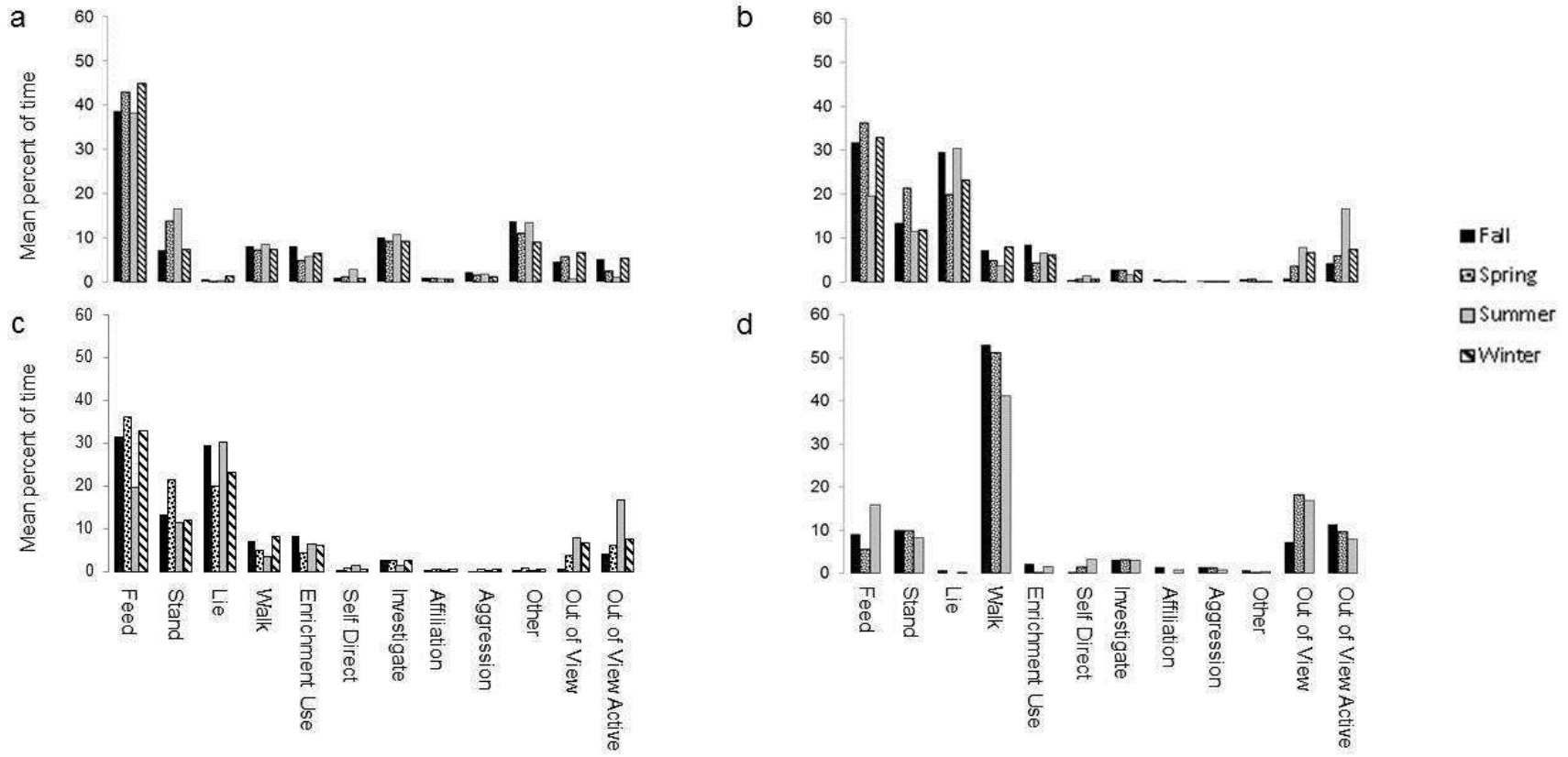

Figure 3. Behavioral patterns for Renee throughout each season (**a**) inside during the day, (**b**) inside during the night, (**c**) outside during the day, and (**d**) outside during the night. Each graph summarizes the percent time spent in each behavior. No data were collected outside at night during the winter because the elephants were not housed outside during the winter nights.

Louie

Effects of location on behavior. Overall, Louie's behavior varied between the two locations, with considerably more time spent feeding (23%) and lying down (23%) inside than outside, where those behaviors were observed 16% and 10% of the time respectively (Figure 2b). Louie used enrichment in both areas, but slightly more often when outside. Self-directed behaviors also occurred outside more often (6%), where he had access to the sun and sand, versus inside, where this behavior was observed 1% of the time. Louie spent more time walking when outside (16%) than when he was inside (6%).

Circadian variation in behavior. Louie spent much of the nights while inside lying down on the sand. This behavior occupied 42% of his nighttime activity versus 4% during the day (Figure 2d). He spent 15% of the nighttime feeding and 8% of the night using enrichment; these behaviors were more frequent during the day when he would feed 31% of the time and use enrichment 14% of the time. He walked twice as much when inside during the day (8%) than at night (4%). Louie was out of view 7% of the night and out of view but still active an additional 9%. Thus, while inside, he was active during 87% of the day and 53% of the night.

Outdoor behavior varied as well, with more time spent feeding, lying down, using enrichment and engaging in self-directed behaviors during the day than at night (Figure 2f). Louie walked slightly more at night (18%) than during the day (16%). He spent 20% of the night out of view and an additional 16% out of view but still active, leaving a total of 36% of his nighttime activity budget under question. We can assume that Louie was lying down or standing asleep during the out of view observations, since activity would activate the motion sensor lights.

Seasonal variation in behavior. The time of year had a large effect on Louie's behavior. Several behaviors varied the most between summer and winter months when the animals were housed primarily outside or primarily inside; however differences were observed throughout all seasons (Figure 4). Like Renee, Louie's behavioral patterns were similar during the spring and fall months when the average temperatures were similar and time spent inside and outside were comparable. While Louie ate consistent amounts throughout the 24-hour period, his feeding patterns varied seasonally. When inside during the day in the summer, Louie spent less time feeding than during the other seasons, but more time lying down. He spent 36% of the winter days feeding, whereas during the summer this dropped to 24%. Louie lied down 13% in the summer versus 3% in the winter. A smaller difference was noted with enrichment use being higher in the fall (17%) than the other seasons (12-13%). When inside at night (Figure 4b), there was little difference throughout the seasons with the exception that he spent 7% of the time feeding during the summer, while during the other seasons, this behavior was observed at least 15% of the time. However, Louie was also scored as out of view but active 13% of the time. Thus, is it possible that he was eating during at least some of those observations.

During the days when Louie was outside (Figure 4c), walking and enrichment use were significantly higher during the winter, when the animals typically had less frequent access to the outdoor yard. Feeding frequency was lower during the winter than other seasons, and was replaced with walking and manipulating enrichment. During the summer, Louie would lie down in the sand more often than the other seasons. Self-directed behaviors were more common during the spring and summer months than fall and winter.

Louie's behavior at night was more difficult to determine, as he was scored out of view 10-28% of the time and out of view but active between 13 and 22% of the time. However, walking and enrichment use were observed less often during the spring than the other seasons.

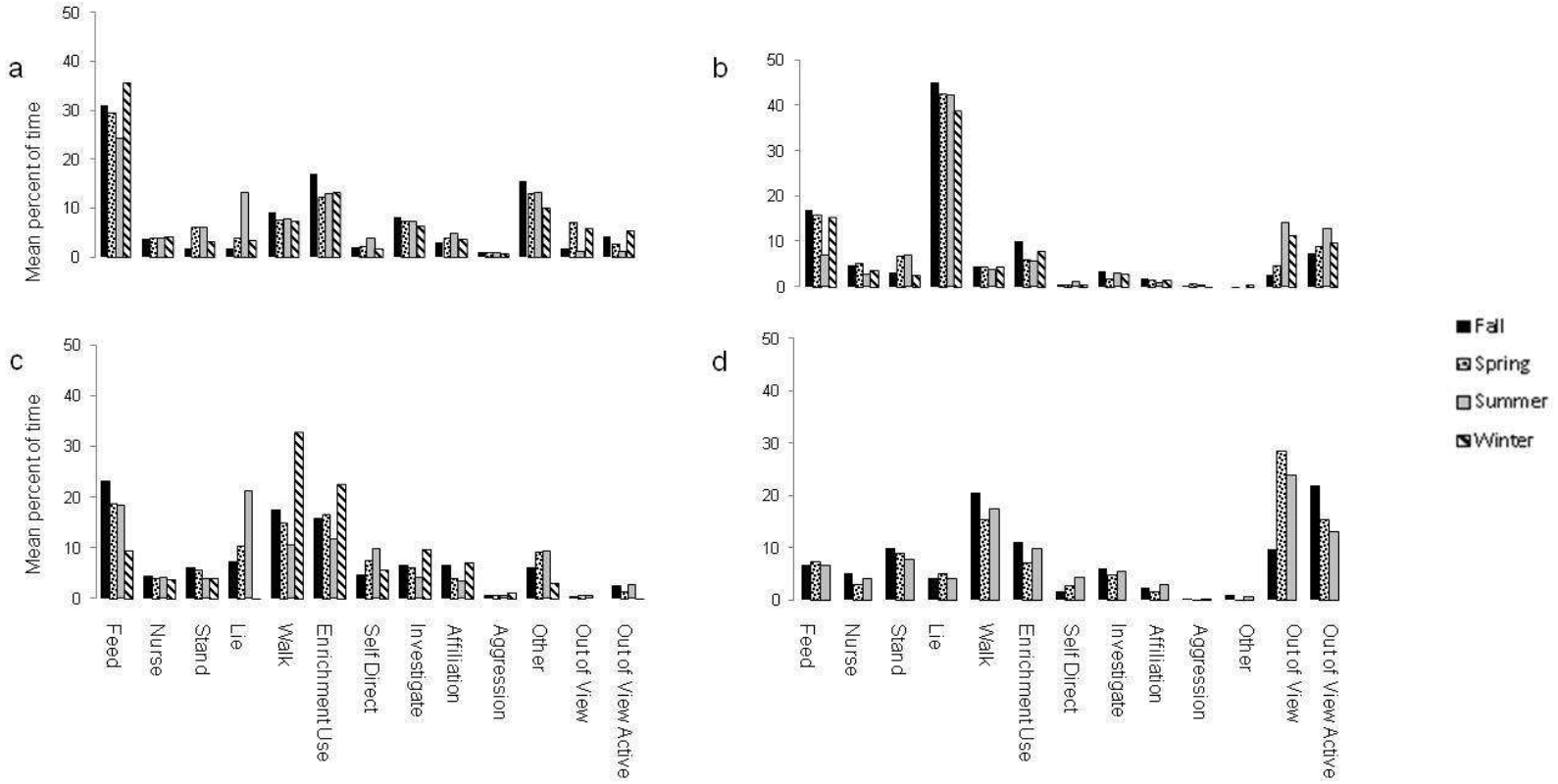

Figure 4. Behavioral patterns for Louie throughout each season (**a**) inside during the day, (**b**) inside during the night, (**c**) outside during the day, and (**d**) outside during the night. Each graph summarizes the percent of time spent in each behavior. No data were collected outside at nighit in the winter because the elephants were not housed outside during the winter nights.

Discussion

This study illustrated variability in the behavior of two African elephants throughout the day, seasonally, and among exhibit areas. Whereas wild African elephants typically experience only two to three seasons in nature (Guy, 1976; Loarie, Aarde, & Pimm, 2009; Shannon, Page, Mackey, Duffy, & Slotow, 2008; Shrader, Bell, Bertolli, & Ward, 2011; Stokke & Toit, 2000), the study elephants live in the northern United States where they are exposed to four seasons but have a constant supply of food and water. Therefore, it is plausible that their behavior would be influenced by other factors than those affecting the behavior of their wild relatives. Primarily the two study subjects feed more frequently when inside and more often during the day than night, and vary walking patterns throughout the circadian and seasonal cycles.

The prevailing behavior for both elephants was feeding, occupying an average of 34% of Renee's activity and 20% of Louie's. Renee's values were comparable to elephants in Pongola Game Reserve and Pilanesberg National Park who were observed feeding 48% and 36% of the time respectively (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. The elephants in this study spent less time engaged in feeding activities than most of their wild counterparts, possibly because they were provided with high quality diets within a smaller range. Most of the food provided was offered in enrichment devices that encouraged walking or other seeking behaviors, including object manipulation and cognitive activities. Thus, the zoo elephants need not walk long distances to find food but instead must determine how to obtain the food provided.

Effects of Location on Behavior

The elephants were given access either indoors or outdoors at any given time. Although there were behavioral similarities across the different enclosures, each area appeared to lend itself to different activities. Enrichment goals included encouraging feeding and walking in all enclosures, so there were often multiple items and activities at any given time aimed at increasing time spent exploring the exhibit and looking for food. However, the indoor and outdoor environments showed marked differences, with the indoor facility divided into several rooms, whereas the outdoor exhibit was larger and more expansive. While feeding was dominant in both locales, it was more prevalent inside, whereas walking was observed more frequently outdoors. This suggests that the outdoor exhibit is better suited for walking, possibly due to the size of the yard as well as the sandy substrate. It is also likely that the 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, Krink, and Vollrath (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 food and enrichment, may walk less than those in less complex areas and expend energy in other, more cognitively-challenging activities.

Louie's behavior, while dependent on Renee's activity, differed from his mother's most likely due to his young age; his caloric needs, and therefore his need to forage, would be lower than his mother's while his need to rest would be greater (Wuestenhagen, Weisz, & Schwammer, 2000). Indoor activities consisted mostly of feeding and lying down, whereas his activity budget

outside was more varied. Like Renee, Louie walked around the exhibit, but would lie down on sand piles (made by the keepers) at night. It is possible that his enrichment use increased outside because the enrichment was more widely dispersed where Renee could not dominate all of it at once. Louie walked less than Renee when outside, possibly due to his age and need to rest, as well as more time spent using enrichment items.

Circadian Variation in 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, and other studies of elephants in human care have focused on the effects of chaining elephants overnight and concurrent limits on behavioral opportunities (Brockett et al., 1999; Wilson et al., 2006). Both Renee's and Louie's behavior differed overnight depending on where they were housed but also differed considerably from their daytime behavior. Renee was active during 84% of the day and 56% of the night while inside; Louie showed a similar trend with 70% activity during the day and 35% at night. A decrease in nighttime feeding was observed when the elephants were housed outside, while an increase in nighttime walking occurred, similar to that of wild elephants in Uganda (Wyatt & Eltringham, 1974). Wild elephants were likely walking in search of food and water, but the zoo elephants, having an ample supply of food, were likely walking to explore their environment, or simply for exercise. Both elephants spent more time lying down at night inside, a behavior also observed in other zoo elephants (Brockett et al., 1999; Wilson et al., 2006). Louie spent 40% of the night lying down, comparable to the behavior of other young zoo elephants that slept for longer periods of time than adults (Wuestenhagen et al., 2000).

Due to camera angles and challenges of lighting the entire enclosure at night, nighttime observations were sometimes challenging to record from videotape. While outside at night, Renee was scored as out of view or out of view but active 21% of the time; Louie was out of view 36% of the time. The exhibit lighting was designed to provide ambient light for animal viewing without affecting elephant behavior. Because the lighting was in place prior to the start of this study, any degree of effect could not be confirmed. It is possible that the lights influenced behavior to some degree, but examination of the outdoor motion sensor lights showed that the low-level artificial lighting 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; therefore one cannot extrapolate 24-hour activity budgets from daytime-only study results. During the day, animals may be influenced by the presence of zoo keepers or other familiar staff, interacting with the animal care staff, or partaking in keeper-initiated activities such as enrichment, which may be more controlled while the keepers are at the zoo. In addition, elephants are likely influenced by the daylight, spending more time foraging for food, interacting with their environment, observing or interacting with zoo visitors, or using enrichment when it is fresh and more visible. Self-maintenance behaviors, such as dusting, serve a purpose during the heat of the day, protecting elephants from the sun's rays, a behavior that is unnecessary at night. With elephants demonstrating different behavioral needs and activity budgets throughout the 24-hour period, it becomes clear that we cannot observe them during the day and make broad assumptions about their behavior at night.

Seasonal Variation in Behavior

Seasons have a significant influence on wild elephant behavior. During the dry season, elephants stay near water sources and move less, but during wet seasons they venture farther (Loarie et al., 2009). Feeding patterns vary, with elephants feeding more during the wet season when browse is more readily available (Guy, 1976; Vinod & Cheeran, 1997; Wittemyer et al., 2007; Wyatt & Eltringham, 1974). Although the North American climate differs considerably from that of the African plains, the 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 the elephants feeding more often during the night in colder months and walking more at night during hotter months. They tended to walk little during hot summer days and, like their wild counterparts, followed the shade during the day (Guy, 1976; Loarie et al., 2009; Wittemyer et al., 2008; Wyatt & Eltringham, 1974), but during overnight hours when temperatures cooled, Renee walked up to 46% and Louie 18% of the time. While they did not need to walk far in search of food, enrichment feeders placed throughout the exhibit encouraged the elephants to use all areas of the habitat.

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. Since zoo elephants consume 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 at the same time prevent obesity. Much of the elephants' daytime winter activity involved walking from one feeder to the next and working to obtain their food, while both elephants rested at night.

Perhaps the biggest change in behavior occurred on those winter days when the elephants were able to go outside. They took advantage of the large yard and walked much of the day, possibly due to the less frequent and therefore novel access to the yard or to the varied weather conditions, such as occasional (novel) access to snow. 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. Furthermore, the outdoor exhibit might become more novel during winter when the animals have less exposure to it.

Self-directed behaviors were most common while the elephants were in the outdoor yard during the day, when they were exposed to the sun and had greater access to substrates for dusting and more natural items to rub on. As with wild elephants, these behaviors were at their highest frequency during the hot summer days (Rees, 2002).

This study was designed to evaluate the effects of various management and environmental factors on a mother and calf elephant pair. While both elephants showed behavioral trends in the different enclosures, throughout the day and seasonally, we cannot assume that this would be the case for all elephants in zoos. However, we can conclude that long-term studies, and even some short-term studies, of animal behavior throughout the 24-hour cycle can provide meaningful information regarding behavioral tendencies, preferences, and needs for each individual. This information may be helpful to zoo managers when designing animal exhibits or management plans and evaluating an individual animal's welfare. Furthermore, we should not assume that behavior remains static throughout the year and instead should consider the effects of seasonal changes in weather and temperature, and their influence on animal management when evaluating animal behavior and wellbeing. The behavior of the two elephants in this study was at times similar, and we must consider that the behavior of the calf is dependent on his mother's activity and may or may not imply behavior in the future. Thus, it would be wise

to conduct future studies to determine if his behavior changes as he matures. In general, it would be useful if zoo studies were longitudinal to evaluate changes in behavior over entire lifetimes. Finally, a study of this type can have far reaching effects on the global zoological community. By examining the daily and year-round behavior of zoo animals, and the different environments in which the animals are housed, animal care managers can design tools to ensure that programs are designed to nurture the natural behavior of the species and the needs of each animal.

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