Zoo Biology 26:371–381 (2007)

RESEARCH ARTICLE

Comparison of Several Types of Enrichment for Captive Felids

Amy L. Skibiel,[1]* Heather S. Trevino,[1] and Ken Naugher[2]

[1]*Department of Biological Sciences, Auburn University, Auburn, Alabama*
[2]*Montgomery Zoo, Montgomery, Alabama*

Enrichment can increase the complexity of the captive environment and possibly enhance captive animals' well-being by stimulating active behaviors and reducing stereotypical behaviors commonly seen in zoo felids. In this study, three different enrichment items were added to outdoor enclosures of felids at the Montgomery Zoo to test their effects on activity levels and stereotypic pacing. Bones, frozen fish, and spices (cinnamon, chili powder, and cumin) were presented over a 3-month period to six species of felids: cheetah, cougar, jaguar, lion, ocelot, and tiger. Proportion of time spent engaging in active behaviors and stereotypic pacing were compared before, during, and after treatments. All treatments resulted in a significant increase in activity level from baseline (bones: +15.59%; frozen fish: +35.7%; spices: +12.38%). Effects of enrichment items on activity levels were not sustained 7 days after removal. Proportion of time spent pacing significantly decreased during presentation of spices (−21.25%) and frozen fish (−26.58%), but not with the addition of bones. However, only the effect of frozen fish on stereotypic behavior was sustained 7 days after removal of the enrichment item. In conclusion, bones, spices, and frozen fish are inexpensive and easy-to-administer enrichment items that may be used to increase active behaviors of captive felids. Zoo Biol 26:371–381, 2007. © 2007 Wiley-Liss, Inc.

Keywords: scents; bones; frozen treats; activity; stereotypies

INTRODUCTION

The literature is replete with information pertaining to the effects of captive life on animal welfare [Hediger, 1955, 1964; Carlstead, 1996; Mench and Kreger, 1996;

*Correspondence to: Amy L. Skibiel, Department of Biological Sciences, 331 Funchess Hall, Auburn University, AL 36849. E-mail: skibiam@auburn.edu

Received 5 April 2006; Revised 29 March 2007; Accepted 4 May 2007

DOI 10.1002/zoo.20147
Published online 24 July 2007 in Wiley InterScience (www.interscience.wiley.com).

Poole, 1998]. Historically, captive animals have been housed in restrictive enclosures without stimuli prevalent in nature [Mench and Kreger, 1996], such as those associated with predators, prey, social groups, mates, and environmental stochasticity [White et al., 2003; Wielebnowski, 2003], although much is currently being done to make improvements in care programs [Hutchins, 2006]. In natural populations, complexities in the environment place physical and cognitive demands on animals [Swaisgood et al., 2003] and motivate them to perform behaviors necessary for survival [Shepherdson et al., 1993]. Static conditions in captivity and lack of appropriate stimuli may result in boredom, an inability to cope with ordinary stressors, lack of motivation, lack of opportunity to perform natural species-specific behaviors [McPhee, 2002], and development of inactive, abnormal, or repetitive behaviors [Swaisgood et al., 2003].

Environmental enrichment is one of many tools used by zoo staff to create a more stimulating and complex environment that promotes psychological and physiological improvements of animals in captivity. Enrichment generates opportunities for animals to exhibit a diverse array of behaviors [Carlstead and Shepherdson, 1994; Shepherdson, 1998], encourages social interactions by reducing aggression and initiating play, reduces abnormal behaviors, and improves health, all of which may influence reproductive success [Carlstead and Shepherdson, 1994]. By encouraging species-specific behaviors, enrichment facilitates normal development [Carlstead and Shepherdson, 1994] and may increase the probability of survival when captive animals are reintroduced into the wild [Shepherdson, 1998]. Enrichment also enhances the experience of visitors to the zoo, not only because more interest is generated by watching active felids [Margulis et al., 2003], but also because visitors learn more about the animals by seeing them in a more naturalistic setting, displaying behaviors that would be seen in the wild [Shepherdson, 1998; Jones et al., 2005].

Most wild animals spend a considerable amount of time acquiring and consuming food [Bond and Lindburg, 1990; Gilchrist et al., 2005], but many animals in captivity are fed preprocessed diets that do not require natural foraging tactics, energy expenditure, or much use of appendages such as limbs, jaws, and teeth to capture, kill, and process food [Lindburg, 1988; Bond and Lindburg, 1990]. Therefore, unnatural food items may inhibit expression of appetitive behaviors involved in the acquisition of food [Lindburg, 1988], resulting in aberrant behaviors [Shepherdson et al., 1993], deterioration of oral health [Fitch and Fagan, 1982; Vosburgh et al., 1982; Haberstroh et al., 1984; Bond and Lindburg, 1990], and alteration of skeletal morphology [see the review O'Regan and Kitchener, 2005]. Supplementing the diet with more natural foods is a form of enrichment that can promote natural foraging strategies [Lindburg, 1988], may prevent physiological and morphological changes in captive animals [O'Regan and Kitchener, 2005], and can reduce abnormal behaviors [Shepherdson et al., 1993].

Although scent enrichment has been less studied and documented than feeding enrichment, it may also encourage display of natural behaviors. While scent is not the primary sense used by felids to locate prey [Kitchener, 1991], odors can have psychological effects on animals and are important cues used to identify conspecifics and assess their reproductive status and quality, and to maintain territories [Ewer, 1973; Rich and Hurst, 1998]. Boredom, in captive situations, may be alleviated by adding novel stimuli, such as odors, to the enclosure [Powell, 1995].

Here we present the results of a 3-month study to document the response of captive felids to presentation of horse bones, frozen fish, and three types of spices. We predict that these feeding and scent enrichments will diminish stereotypic behaviors and increase the amount of time the felids are engaged in active behaviors. While the objects used in this study have been implemented in enrichment studies on felids at other zoos, few studies have examined sustained effects on behavior following enrichment provisioning [but see Shepherdson et al., 1993; Bashaw et al., 2003].

METHODS

Subjects and Husbandry

The subjects in this experiment were 14 individuals representing six species of felids (*Panthera tigris*, *Leopardus pardalis*, *Panthera onca*, *Puma concolor*, *Acinonyx jubatus*, *Panthera leo*) at the Montgomery Zoo in Montgomery, Alabama. We observed three tigers, two ocelots, one jaguar, three cougars, two cheetahs, and three lions. All the animals were fed Nebraska Premium Feline diet (Central Nebraska Packing Inc., North Platte, NE), except the cheetahs, that were fed Qual Pet (National By-Products, LLC, Des Moines, IA) once a day, 7 days a week. A female cheetah and male ocelot were also given less than 0.45 kg of chicken daily in addition to their normal diet. From 0800 to 1700 hr, animals are on exhibit in their outdoor enclosures. Individuals of each species were displayed together in their respective outdoor enclosures, except for tigers. For the first 2 months of the study, the male and one of the female tigers were placed on display together, and rotated with the other female tiger every second day. For the last month of the study, all the tigers were placed on display singly.

Experimental Conditions

This experiment consisted of baseline, three enrichment treatments (bones, spices, and frozen fish), and post-enrichment observations. Before enrichment treatments, all enrichment items (i.e., Boomer balls, bowling pins, barrels, etc.) currently in the felids' outdoor enclosures were removed. Baseline data were then recorded on all felids for 4 weeks.

For the three enrichment treatments, items were given to the felids daily for ≥ 4 days. All items were placed on land and in areas of the enclosure visible to the public before the animals were placed on exhibit. The remainders of the enrichment items were removed from enclosures before provisioning for the next day. Two weeks of no enrichment occurred between each treatment to allow behavior to return to baseline and to avoid cumulative effects of multiple treatments.

With the bone enrichment treatment, each animal received one horse knuckle or shank bone (Central Nebraska Packaging Inc., North Platte, NE) daily, for 7 consecutive days, except tigers, that received bones for 4 consecutive days because of their daily rotation. The jaguar was not given this form of enrichment because he cracks the bones, creating splinters that become lodged in his palate. The two ocelots were given one bone in total due to veterinary concerns that the male, which had a urinary tract infection, would not eat his antibiotic infused meat if he ate the bones given during enrichment.

For the scent treatment, 30 ml of cinnamon, chili powder, and cumin were sprinkled on the ground, rocks, and logs of the enclosures daily. Spices were placed ≥ 10 m apart and the location of each spice was changed every day. All species received spices for 9 consecutive days, except for the tigers, that received spices for 5 consecutive days.

Frozen treats were made by freezing six small trouts (SR Trout, LLC, Sandy, UT) in a 2-l soda bottle filled with water. The treats were supplied to the animals daily, immediately preceding observation. All species received frozen treats for 8 consecutive days and tigers received frozen treats for 5 consecutive days.

Data Collection

Data were recorded in 10 observation periods over 4 weeks during baseline and on day 1, day 2, and the last day of enrichment provisioning for each of the three enrichment treatments, and on the 7th day following the last day of enrichment. Each cat was observed for two 30-min sessions between 0800 and 1230 hr using instantaneous scan sampling at 1-min intervals [Altmann, 1974]. A total of 300 observations for each species during baseline, 180 observations during each treatment, and 28 post-enrichment observations were made. During each scan, behaviors of all animals in the exhibit were recorded, according to a list of behaviors (Table 1) developed from observing felid activities prior to the start of the project. These 14 behaviors were then categorized as active or inactive. Active behaviors included feeding, social interactions, locomoting, playing, rolling, swimming, alertness, scent-marking, and vocalizing. Inactive behaviors included sleeping, lying down with eyes open, sitting, grooming, and urinating/defecating. Stereotypic behaviors were also noted. Stereotypic pacing was defined as locomoting along a definite path for more than 3 min, such as along the wall of the exhibit or around a fixture in the exhibit. The only stereotypy observed was pacing.

If animals were exhibiting two behaviors simultaneously, only the active behavior was recorded. An animal was considered to be interacting with the treatment if it was within 0.30 m of the item. Observations were made from public-viewing areas while animals were on exhibit. The specific time of observation for each species within the 4.5-hr observation period was changed during observation days so that each species was observed at different times throughout the morning. The order in which species were observed was chosen randomly. However, on some days we were not able to observe species at the time intended due to the zookeepers' schedules. Two observers collected a total of 238 hr of data. Thirty minutes of simultaneous data collection yielded an inter-observer index of reliability $>88.5\%$ [Martin and Bateson, 1986].

Data Analysis

Counts were totaled for each animal across all observation days. A mean value for the proportion of scans categorized as active behaviors (excluding scans when animals were pacing) and the proportion of active behaviors classified as stereotypic for each treatment was calculated for all subjects, which were then used in the analyses. Counts where animals were out of sight were removed from the data set and not analyzed. Analyses were performed using SPSS 11.0.0 for Windows statistical software (2001). The level of significance for all tests was $\alpha = 0.05$, unless noted otherwise.

TABLE 1. List of felid behaviors

Active behaviors	
Feeding	Eating, drinking, chewing, or licking edible substances.
Social interactions	Engaging in any affiliative or aggressive behavior with another, including allo-grooming.
Locomotion	Walking, running, climbing or pacing.
Playing alone	Engaging in playful activities alone.
Rolling	Animal on one side and completely rotates to the other side while laying down.
Swimming	Any activity when the animal is in the water.
Alert	Animal disengages from all other activities with eyes open and aware of surroundings.
Scent marking	Animal releases spray from posterior toward an object.
Vocalize	Animal makes noise with the mouth.
Other	Any active behavior that does not fit the above behaviors.
Inactive behaviors	
Sleeping	Laying down with eyes closed.
Laying down	Laying down with eyes open and not vigilant.
Sitting	Sitting down and not vigilant.
Grooming	Animal licking or scratching itself.
Urinating/defecating	Any projection of bodily fluids (except scent-marking), includes vomiting.
Others	Any inactive behavior that does not fit the above behaviors.

The Bartlett test of sphericity was significant ($\chi^2 = 41.09$. $df = 9$, $P < 0.001$), violating the assumption of independence between measures of the dependent variable. As we had a small sample size, and because our data were neither normally distributed nor independent, nonparametric tests were employed. Owing to the small sample sizes within species, data were pooled among species for examining treatment effects. The nonparametric repeated measures analysis (Friedman's test) was used to compare treatment effects on activity and stereotypic levels as well as residual effects the week after enrichment. If the Friedman's test was significant, a Wilcoxon signed-rank test was performed to determine significant pair-wise relationships, corrected for multiple comparisons with a Bonferroni correction (dividing the *P*-value by the number of comparisons). Significance level after the Bonferroni correction was $\alpha = 0.02$.

RESULTS

Activity Level

Although a small sample size within species precludes statistical analysis of species differences, observations seem to suggest that changes in activity level and stereotypic behaviors following enrichment may differ among species. All the species exhibited an increase in active behavior when provisioned with bones and frozen fish compared to baseline (Fig. 1). Ocelots and tigers had the greatest increase in activity of all the species during the bone treatment (% change $\pm$ SE; ocelot: $25.78 \pm 6.78\%$;

tiger: 25.67 ± 11.69%), and frozen fish treatment (ocelot: 55.49 ± 18.49%; tiger: 57.89 ± 10.82%). Five of the six species of felids had an increase in active behaviors when provisioned with spices (Fig. 1). Tigers exhibited the highest increases in active behaviors with the addition of spices to their enclosures (tiger: 22.33 ± 8.03%).

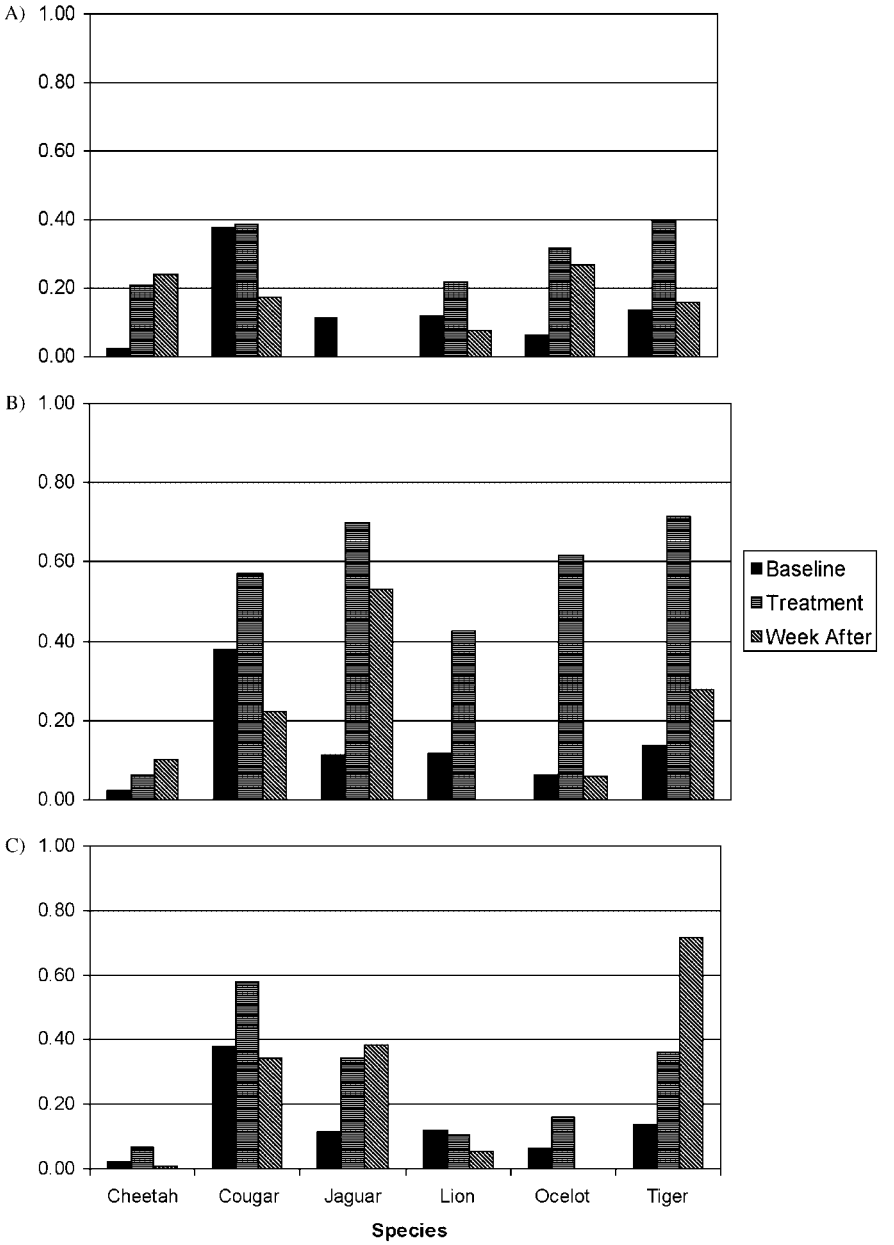

Fig. 1. The proportion of behaviors classified as active averaged among individuals for each species of felid for each treatment: (A) bones, (B) frozen fish, and (C) spices. The jaguar did not participate in the bones treatment.

TABLE 2. Activity and stereotypic levels with results of Wilcoxon signed-rank tests (comparisons between enrichment and baseline)

	Active behaviors			Stereotypic pacing		
Treatment	Mean % active (±SE)	Wilcoxon Signed-rank test (z)	P	Mean % stereotypic (±SE)	Wilcoxon signed-rank test (z)	P
Baseline	15.64±3.88			26.8±7.60		
Bones	31.23±4.80	−2.41	0.02*	32.11±3.48	−1.96	0.05
Fish Frozen in Ice	51.34±6.74	−3.30	<0.01*	4.12±1.98	−2.50	0.01*
Spices	28.02±6.69	−2.73	<0.01*	10.85±4.58	−2.67	<0.01*

*Statistically significant at the $P = 0.02$ level (due to Bonferroni correction for multiple comparisons).

A significant difference in the proportion of behaviors classified as active was observed across the four treatments ($\chi^2 = 19.80$, $df = 3$, $P < 0.01$). For all treatments, significant differences in activity levels were found between baseline and treatment (Table 2). Overall, activity levels increased by 22.92±7.83%. Increased activity levels due to treatments were not maintained 7 days after the removal of treatment objects (bones: $z = -0.25$, $P = 0.81$; frozen fish: $z = -0.91$, $P = 0.36$; spices: $z = -0.16$, $P = 0.88$).

Stereotypic Behavior

When provided with enrichment, a decline in stereotypic behaviors was seen for all species that exhibited stereotypies during baseline observations (Fig. 2). During the study, cheetahs were the only species that did not exhibit any stereotypic behaviors. Both ocelots and tigers had the greatest decreases in the proportion of active behaviors that were stereotypic with the addition of bones and spices (bones: ocelot 26.77±21.05%, tiger 23.98±1.29%; spices: ocelot 47.82±3.61%, tiger 32.85±23.49%). However, with the fish frozen in ice treatment, jaguar and ocelots exhibited the greatest decrease in amount of stereotypic pacing (jaguar: 56.52%; ocelot: 47.82±16.67%).

A significant difference in stereotypic pacing was observed across treatments ($\chi^2 = 11.13$, $df = 3$, $P = 0.01$). Both the addition of frozen treats and spices to the enclosures of felids resulted in significant decreases in percentage of stereotypic pacing exhibited when compared to baseline observations (frozen treats: $z = -2.50$, $n = 13$, $P = 0.01$; spices: $z = -2.67$, $n = 13$, $P = 0.01$; Table 2). Bones did not result in a significant decrease in stereotypic pacing compared to baseline ($z = -1.96$, $n = 12$, $P = 0.05$). Overall, stereotypic behaviors decreased by 21.25±7.33%.

The amount of stereotypic pacing a week after enrichment was similar to that exhibited during baseline observations, except after the addition of frozen fish (bones: $z = -1.96$, $n = 12$, $P = 0.05$; fish frozen in ice: $z = -2.29$, $n = 13$, $P = 0.02$; spices: $z = -1.89$, $n = 13$, $P = 0.06$). With the frozen fish treatment, four of the six species did not exhibit any stereotypical pacing 7 days after removal of the enrichment item. Only one species (jaguar) displayed an increase in the percentage of active behaviors that were stereotypic (+31.95%) one week after the enrichment treatment.

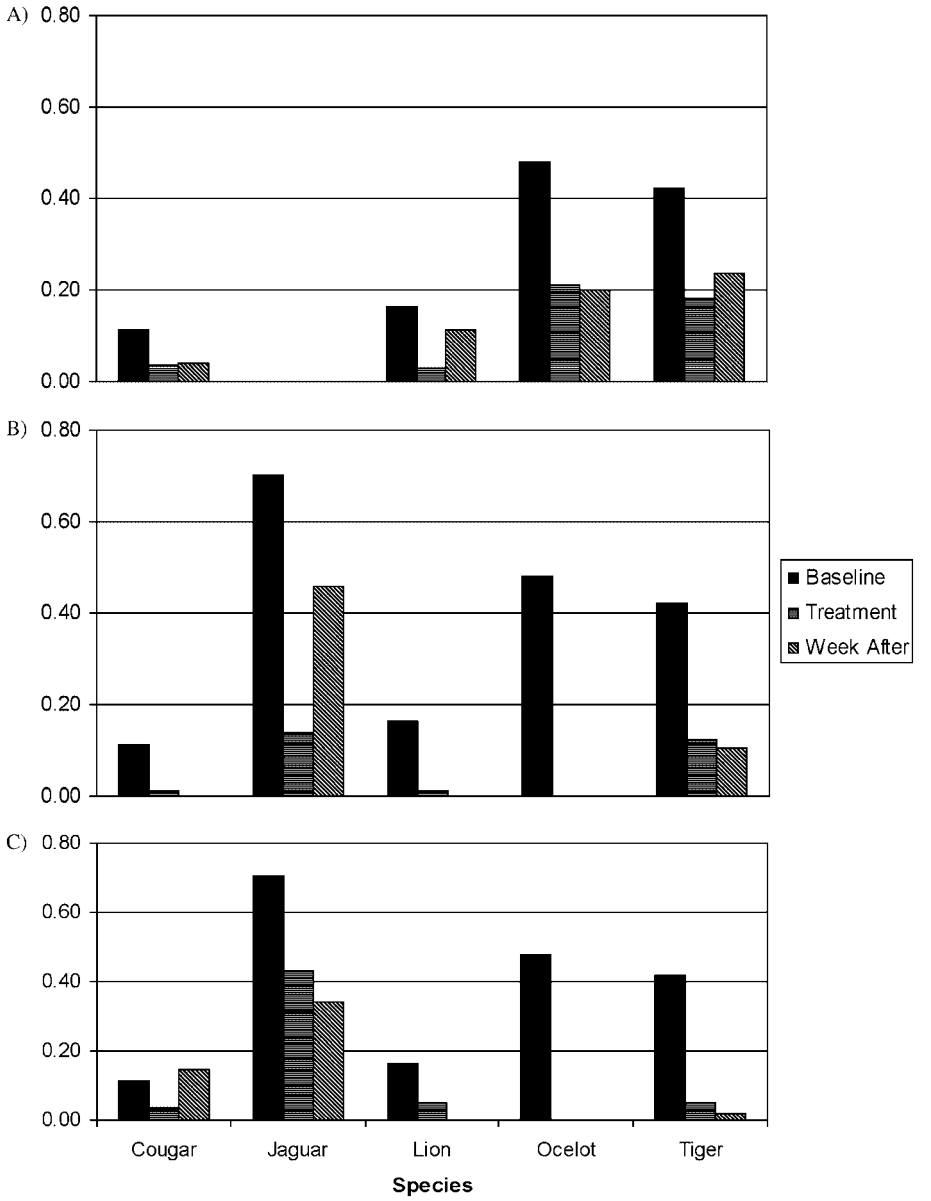

Fig. 2. The proportion of active behaviors that were considered stereotypic averaged among animals for each species of felid for each treatment: (A) bones, (B) frozen fish, and (C) spices. The jaguar did not participate in the bones treatment. Cheetahs did not exhibit any stereotypic pacing during the course of the study. With the addition of spices and frozen treats, no stereotypical pacing was recorded for ocelots.

DISCUSSION

Environmental enrichment has been often used to reduce stereotypic behaviors, enhance activity, and even reduce aggression in several species of captive

animals [Bloomsmith et al., 1988; Carlstead et al., 1991; Forthman et al., 1992; Shepherdson et al., 1993; Powell, 1995; McPhee, 2002; Bashaw et al., 2003]. Although we could not statistically test species-specific changes in activity levels and stereotypic behaviors due to the small sample size, observations appeared to reflect differences in behavioral patterns among species after enrichment. Ocelots and tigers had the highest increase in activity when bones were added to the enclosure. This may have occurred in the ocelots because only one bone was given to be shared between the two animals, which resulted in more interactions between the two as they fought over custody of the single bone.

All three enrichment items resulted in a lesser amount of time spent pacing compared to baseline for all species in the study, except cheetahs, which showed no stereotypies during baseline (Fig. 2). Cheetahs also had the highest percentage of inactive behaviors during baseline, which in part explains the lack of stereotypic behaviors. When cheetahs were active, they were either alert or walking to find a new resting area. Ocelots showed a complete cessation of stereotypic pacing following provisioning of spices and frozen treats.

When species data were pooled, a significant increase in activity level from baseline occurred with all enrichment treatments. This lends support to other studies that have found dramatic changes in felid activity when provisioned with similar treatment items. Bashaw et al. [2003] found an increase in activity, specifically in consumptive behaviors, when lions were provisioned with bones and Powell [1995] found that sniffing and flehman behaviors significantly increased when adult lions and cubs were given spices. In addition, inactivity decreased when lions were given cinnamon, chili powder, ginger, and zebra dung [Schuett and Frase, 2001].

Examining effects of a treatment after the item has been removed is important in studies of enrichment because only long-term changes are indicative of an improvement in underlying behavioral patterns [Bashaw et al., 2003]. In this study, activity levels were still higher than baseline 7 days after removal of enrichment items, but were not significant (bones: +1.66%; fish: +1.14%; spices: +11.14%). No significant difference in the proportion of time spent pacing was found a week after treatment with bones or spices. However, the amount of time spent pacing was significantly different from baseline levels a week after provisioning with frozen fish. In fact, four of the six species showed no stereotypic pacing a week after the frozen fish treatment.

Since different enrichment items in this study resulted in different changes in behaviors, it may be most beneficial to the animals to provide them with various enrichment items at the same time. For example, in this study, cats showed a decrease in stereotypic behaviors with spices and an increase in activity with all treatments. Perhaps addition of spices and one of the other treatment items would result in a reduction of stereotypic behaviors and enhanced activity concurrently. Also, providing animals with a variety of enrichment objects may decrease habituation to those items [Carlstead et al., 1991].

This study shows that providing captive felids with inexpensive, easy-to-administer enrichment objects can have profound effects on activity and stereotypic behaviors. Several studies show that animals express more natural behaviors when given the opportunity [Bond and Lindburg, 1990; Carlstead et al., 1991; Powell, 1995; McPhee, 2002]. Promotion of natural behaviors is another goal of enrichment that was fulfilled in this study. Enrichment items elicited appetitive behaviors that

might be seen in the wild, such as rubbing and rolling with addition of spices, and object manipulation and searching when provisioned with bones and fish. While not all enrichment objects resulted in sustained effects, all enrichment items used show the importance of introduction of novel objects to change behavioral patterns.

CONCLUSIONS

1. Easy to administer novel objects impacted behavior patterns of felids.
2. Provisioning with bones, frozen fish, and spices resulted in greater activity levels.
3. Addition of spices and frozen fish caused a decrease in stereotypic pacing.
4. Changes in activity levels were not sustained a week after removal of treatment items.
5. Changes in stereotypical behavior were sustained a week after removal of frozen fish.

ACKNOWLEDGMENTS

Special thanks are extended to the zoo keepers, and staff at the Montgomery Zoo, especially Stacy Young, Anna Dembowski, and Robert Koppen, for their presentation of the treatments to the animals. F. Stephen Dobson, and Linda Pastorello provided statistical help. Thanks also to Kathleen Holt for her assistance in data entry. Bonnie Fairbanks, and Troy L. Best provided helpful comments on the manuscript.

REFERENCES

Altmann J. 1974. Observational study of behavior: sampling methods. Behavior 48: 227–265.

Bashaw MJ, Bloomsmith MA, Marr MJ, Maple TL. 2003. To hunt or not to hunt? A feeding enrichment experiment with captive large felids. Zoo Biol 22:189–198.

Bloomsmith MA, Alford PL, Maple TL. 1988. Successful feeding enrichment for captive chimpanzees. Am J Primatol 16:155–164.

Bond JC, Lindburg DG. 1990. Carcass feeding of captive cheetahs (*Acinonyx jubatus*): the effects of a naturalistic feeding program on oral health and psychological well-being. Appl Anim Behav Sci 26:373–382.

Carlstead K, Seidensticker J, Baldwin R. 1991. Environmental enrichment for zoo bears. Zoo Biol 10:3–16.

Carlstead K, Shepherdson DJ. 1994. Effects of environmental enrichment on reproduction. Zoo Biol 13:447–458.

Carlstead K. 1996. Effects of captivity on the behavior of wild mammals. In: Kleiman DG, Allen ME, Thompson KV, Lumpkin S, editors. Wild mammals in captivity: principles and techniques. Chicago, Illinois: The University of Chicago Press. p 317–333.

Ewer RF. 1973. The carnivores. New York: Cornell University Press. 494p.

Fitch HM, Fagan DA. 1982. Focal palatine erosion associated with dental maloclussion in captive cheetahs. Zoo Biol 1:295–310.

Forthman DL, Elder SD, Bakeman R, Kurkowski TW, Noble CC, Winslow SW. 1992. Effects of feeding enrichment on three species of captive bears. Zoo Biol 11:187–195.

Gilchrist E, Melfi V, Clarke F. 2005. Can environmental enrichment compensate for not providing carcasses or live prey? Proceedings of the Seventh Annual Symposium on Zoo Research 2005:188–191.

Haberstroh LI, Ullrey DE, Sikarskie JG, Richter NA, Colmery BH, Myers TD. 1984. Diet and oral health in captive Amur tigers (*Panthera tigris altaica*). J Zoo Anim Med 15:142–146.

Hediger H. 1955. Studies of the psychology and behaviour of captive animals in zoos and circuses. London, England: Butterworths Scientific Publications. 166p.

Hediger H. 1964. Wild animals in captivity. New York: Dover Publications, Inc. 207 p.

Hutchins M. 2006. Variation in nature: its implications for zoo elephant management. Zoo Biol 25:161–171.

Jones MK, Marno R, Buchanan-Smith H. 2005. Novel feeding and hunting enrichment for large captive felids: the lionrover and responsive hanging prey. Proceedings of the

Seventh Annual Symposium on Zoo Research 2005:91–101.
Kitchener A. 1991. The natural history of the wild cats. Ithaca, New York: Comstock Publishing Associates. 280p.
Lindburg DG. 1988. Improving the feeding of captive felines through application of field data. Zoo Biol 7:211–218.
Margulis SW, Hoyos C, Anderson M. 2003. Effect of felid activity on zoo visitor interest. Zoo Biol 22:587–599.
Martin P, Bateson P. 1986. Measuring behavior: an introductory guide. Cambridge, United Kingdom: Cambridge University Press. 200p.
McPhee ME. 2002. Intact carcasses as enrichment for large felids: effects on on- and off-exhibit behaviors. Zoo Biol 21:37–47.
Mench JA, Kreger MD. 1996. Ethical and welfare issues associated with keeping wild mammals in captivity. In: Kleiman DG, Allen ME, Thompson KV, Lumpkin S, editors. Wild mammals in captivity: principles and techniques. Chicago, Illinois: The University of Chicago Press. p 5–15.
O'Regan HJ, Kitchener AC. 2005. The effects of captivity on the morphology of captive, domesticated and feral mammals. Mammal Rev 35: 215–230.
Poole TB. 1998. Meeting a mammal's psychological needs. In: Shepherdson DJ, Mellen JD, Hutchins M, editors. Second nature: environmental enrichment for captive animals. Washington DC: Smithsonian Institution Press. p 83–94.
Powell DM. 1995. Preliminary evaluation of environmental enrichment techniques for African lions (Panthera leo). Anim Welfare 4:361–370.
Rich TJ, Hurst JL. 1998. Scent marks as reliable signals of the competitive ability of mates. Anim Behav 56:727–735.
Schuett EB, Frase BA. 2001. Making scents: using olfactory senses for lion enrichment. The Shape of Enrichment 10:1–3.
Shepherdson DJ. 1998. Tracing the path of environmental enrichment in zoos. In: Shepherdson DJ, Mellen JD, Hutchins M, editors. Second nature: environmental enrichment for captive animals. Washington DC: Smithsonian Institution Press. p 1–12.
Shepherdson DJ, Carlstead K, Mellen JD, Seidensticker J. 1993. The influence of food presentation on the behavior of small cats in confined environments. Zoo Biol 12:203–216.
Swaisgood RR, Ellis S, Forthman DL, Shepherdson DJ. 2003. Commentary: improving well-being for captive giant pandas: theoretical and practical issues. Zoo Biol 22:347–354.
Vosburgh KM, Barbiers RB, Sikarskie JG, Ullrey DE. 1982. A soft versus hard diet and oral health in captive timber wolves. J Zoo Anim Med 13:104–107.
White BC, Houser LA, Fuller JA, Taylor S, Elliott JLL. 2003. Activity-based exhibition of five mammalian species: evaluation of behavioral changes. Zoo Biol 22:269–285.
Wielebnowski N. 2003. Stress and distress: evaluating their impact for the well-being of zoo animals. J Am Veterinary Med Assoc 223:973–977.