Research Article

Environmental enrichment utilizing stimulus objects for African lions (*Panthera leo leo*) and Sumatran tigers (*Panthera tigris sumatrae*)

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Abstract. In this study, stimulus objects (frozen blood balls, fresh zebra dung, scented squash, and cardboard boxes) were utilized in an enrichment program aimed to increase the diversity of behaviors exhibited by one female and three male tigers (*Panthera tigris sumatrae*) and two male lions (*Panthera leo leo*). Three enrichment sessions consisting of pre-enrichment control, enrichment, and post-enrichment trials of 30-min each were conducted over a two-day period. Stimulus objects were present only in the enrichment trials. The enrichment sessions were replicated three times for each stimulus object. Behavioral states, discrete behaviors, and object-directed behaviors were recorded. Behavioral diversity indices (BDIs) for each trial were calculated using the Shannon Diversity Index. The stimulus objects increased behavioral diversity during the enrichment trials compared to the control trials, but this effect did not persist to the post-enrichment trials the following day. The lions benefited the most from the enrichment, exhibiting increased activity, decreased sleeping, and the greatest increase in discrete behaviors BDIs during the enrichment trials. The type of stimulus object did not affect behavioral states or discrete behaviors BDIs, but the frozen blood balls elicited lower object-directed BDIs than other stimulus objects. Responses to enrichment did not change over time, suggesting that the subjects did not habituate to the stimulus objects during the 10 weeks of the study. Enrichment utilizing stimulus objects was successful in increasing behavioral diversity of lion and tiger subjects. Differences in the study among subjects in their response to enrichment suggest that the effects of enrichment on animals of different age, sex, and species should be further explored and taken into consideration in the design of enrichment programs.

Introduction

Enrichment can be defined as a dynamic process that structures and changes animal environments in a way that provides for behavioral choices and draws out species-appropriate behaviors and abilities (Martin, 1999; Ben-Ari, 2001). The benefits of enrichment in a zoo setting are manifested to the animal(s), to the visiting public, and toward zoo conservation goals. Any given enrichment study may target one or more of these goals, but it may ultimately fulfill all three. Such enrichment is consistent with concepts such as the "Fourth Generation Zoo" which aims not only to educate, but to excite the public about different types of ecosystems via the animals that inhabit them (Johnson, 1996).

However, enrichment programs vary within and between zoos. In fact, the methods and rea-

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sons for implementing enrichment, as well as assessments of its effectiveness, may be as varied as the animal subjects of enrichment studies themselves. Different types of enrichment include large or small scale change in exhibit design (e.g. addition or change of substrate or change in overall structure of exhibit), positive reinforcement training sessions, presentation of sensory stimulus objects, and a change in routine husbandry procedures (e.g. feeding times, presentation of food) (Martin, 1999).

In some cases, enrichment is implemented with the sole intent of improving animal welfare. Hughes and Duncan (1988) suggest that physiological and psychological welfare may be inextricably linked. The expression of certain species-specific behaviors in response to both internal (hormonal or neural) and external (environmental) stimuli are significant to the maintenance of an animals' physiological and psychological health and well-being. Research has also shown that enrichment can be used to reduce negative behaviors, such as stereotypies (repetitive behaviors without obvious function: Carlstead, 1996; Martin, 1999; Swaisgood et al., 2001), increase positive behaviors, such as exploratory or species-specific behaviors (Shepherdson et al., 1993; Carlstead, 1996; Mench, 1998; Swaisgood et al., 2001) or encourage trained behaviors necessary to zoo functioning (Bloomsmith et al., 2003). Enrichment may also provide cognitive stimulation and promote healthy early neural development in captive animals (Carlstead, 1996; Shepherdson 1998; Ben-Ari, 2001).

Ultimately, enrichment can benefit both the animal directly (i.e. physically/mentally) and the visiting public indirectly (via a positive change in animal behavior). Benefits to the public focus on creating a positive zoo experience, preferably by enabling viewing of physically and behaviorally accurate representations of species. Enrichment has been shown to improve visitor experience by increasing animal visibility and decreasing stereotypic behaviors (Bashaw et al., 2003). Given in an ecological context, such experiences at a zoo can foster appropriate attitudes towards conservation and ideally inspire action (Martin, 1999). Such goals are particularly relevant for species that are threatened or endangered, such as the critically endangered Sumatran tiger (*Panthera tigris sumatrae*) (IUCN, 2004).

Felid enrichment

Because felids in captive environments are often inactive, spending large amounts of time not visible to zoo visitors or asleep, they are popular targets of enrichment. Many studies have administered feeding enrichment in order to elicit a higher frequency or wider variety of species-specific appetitive and consummatory behaviors and/or to reduce abnormal behaviors, such as stereotypies (Shepherdson et al., 1993; Charlton, 1998; Mellen et al., 1998; Shepherdson 1998; McPhee, 2002; Bashaw et al., 2003; Walters, 2003). Enrichment with non-food-related stimulus objects has also produced positive behavioral changes. Lions exposed to hanging logs, various scents, and ice balls increased their activity and their use of space compared to baseline measurements (Powell, 1995).

In this study, stimulus objects were utilized in an enrichment program aimed to increase the diversity of normal behaviors exhibited in two African lions (*Panthera leo leo*) and four Sumatran tigers (*Panthera tigris sumatrae*). We wanted to determine if stimulus objects could successfully increase behavioral diversity relative to baseline measurements. In order for enrichment to improve animals' psychological well-being, its positive effects should be maintained after exposure to the enrichment, so behavioral diversity was also measured the day after exposure to the stimulus objects. Individual differences in response to enrichment, change over time in response to enrichment (i.e., the potential for habituation), and the relative effectiveness of the stimulus objects in producing behavioral change were also explored.

Materials and Methods

Study subjects and their captive environment

The study was conducted at the Smithsonian National Zoological Park in Washington, D.C. Two lions and four Sumatran tigers were utilized

(Table 1). Subjects were rotated between indoor concrete cages and vegetated outdoor enclosures. Subjects spent 3–8 hours per day in outdoor enclosures, where they were visible to the public. Outdoor enclosures have multiple tiers, are vegetated with grasses, trees, and bamboo and have alcoves for resting purposes. Indoors, subjects were fed 7–10 pounds of prepared zoo carnivore diet (primarily horse meat) once per day, 6 days a week, and occasionally received treats (e.g. frozen rabbit, rawhide bones, horsetails). Because they inhabit indoor enclosures at night, the zoo felids are typically diurnal; peak activity is observed midday and at feeding times (Babitz, pers. comm.).

Based on normal housing arrangements, the two lions (brothers Tana and Tsavo) were tested together, as were the tigers Soyono and Berani (mother and cub, respectively). The other two tigers, Rokan and Eric, were tested individually.

Ethogram

After initial observations of the lions and tigers in their captive environment for several weeks, an ethogram was developed describing five behavioral states, fourteen discrete behaviors and eight object-directed behaviors (Table 2). No stereotypies were observed during the course of the study.

Stimulus objects

Stimulus objects were chosen for use during enrichment sessions based on anticipated appeal via various sensory modalities (e.g. vision, scent, ability to manipulate) and availability. Permission was obtained from the zoo veterinarian, the zoo nutritionist, the head curator, and the Great Cats keepers for use of objects not previously approved. The selected objects were empty metal kegs, frozen blood balls, zebra dung in paper bags, and scented squash. For lions, cardboard boxes replaced kegs because of potential contact of the metal keg with an electrified wire in their enclosure.

The preparation of stimulus objects was designed to be simple and time-efficient. Objects were prepared directly before use in trials. The keg and cardboard boxes required no preparation. Reserved blood from bags of zoo carnivore diet was used to make frozen blood balls. Zebra dung was obtained fresh from the zoo's Hoofstock Department on the days it was used, and placed in the bottom of small brown paper bags. Two types of squash were used: butternut squash injected with cinnamon scent and acorn injected with vanilla scent.

Table 1. Subjects of Stimulus Object Enrichment Study—NZP, 2002.

Species	Birthyear	Name	Sex
Panthera tigris sumatrae	1992	Rokan	male
Panthera tigris sumatrae	1995	Soyono	female
Panthera tigris sumatrae	1999	Eric	male
Panthera tigris sumatrae	2002	Berani	male
Panthera leo	1990	Tana*	male
Panthera leo	1990	Tsavo*	male

*Tana and Tsavo are brothers.

Enrichment sessions

Each enrichment session consisted of three 30-min trials over two consecutive days. On the first day of an enrichment session, a pre-enrichment (control) trial was conducted 30 to 60 minutes prior to an enrichment trial. Next, a stimulus object was placed in the subject's enclosure during the enrichment trial. The following day, a post-enrichment trial was conducted without the stimulus object. Behavioral data were recorded using time sampling with 30-sec intervals. Behavioral states were recorded using instantaneous sampling, and discrete behaviors and object-directed behaviors (recorded only during enrichment trials) were recorded using one-zero sampling (Altmann, 1974).

Enrichment sessions were conducted between 0900 and 1500 h from June 2002 to August 2002. Sessions with each subject were replicated three times for each of four stimulus objects (Table 3). For each replicate, the stimulus objects were presented in a random and novel order.

The method of presentation of the stimulus objects was the same for all objects, except for the cardboard boxes. Objects were thrown from the top of the enclosure across the moat. Kegs were thrown into the water. All other objects

Table 2. Ethogram used in the study.

Category	Behavior	Description
Behavioral states	Locomotion	Walking or otherwise moving about enclosure
	Rest	In a reclined position, head may be up and/or eyes open
	Sit	Haunches in contact with ground, chest and forearms upright
	Sleep	In a reclined position with head down and eyes closed
	Swim	Any activity with more than one paw in the water
Discrete behaviors	Climb	Changing tiers in the enclosure by leaping (thrusting with hind end) or walking (pulling with front end)
	Defecate	Urinating or passing feces
	Drink	Lowering head to moat and lapping water into mouth with tongue
	Groom (allo/self)	Licking and/or biting (with intent of cleaning) any body part on conspecific or self
	Lick	Running tongue over lips (action may be repeated multiple times)
	Mark	Spraying an object via anal secretions (e.g. on tree) or rubbing paws on ground
	Paw	Reaching with a paw (usually front) towards an object (e.g. moat)
	Roll	Lowering body to ground and pushing from side to side
	Rub	Pushing head and/or rest of body against an object (e.g. bamboo, tree)
	Scratch	Pulling claws along an object (e.g. bark of tree, log on ground)
	Sniff	Inhaling scent from an object or air
	Stretch	Extending part of the body to its full length
	Vocalize	Creating any noise (e.g. roar, hiss)
	Yawn	Opening mouth widely while inhaling then exhaling deeply
Object-directed	Bite	Bite, mouth or chew object
	Carry	Hold object in mouth or paws while traveling 1 meter or more
	Investigate	Sniff or lick object
	Manipulate	Pick up or hold object in paws
	Object Paw	Push, swat or roll object with paws
	Object Roll	Roll entire body with object
	Pounce	Lunge at object from a crouched (hunting) position
	Other	Any other behavior directed towards object

Table 3. Subjects, order of object presentation, and dates for data collection for each of three replicate enrichment sessions.

Replicate	Subject group[1]	Date	Object order[2]
1	A	6/3/02 – 6/14/02	1, 2, 3, 4
	B	6/17/02 – 6/28/02	
2	A	7/1/02 – 7/11/02	2, 3, 4, 1
	B	7/12/02 – 7/23/02	
3	A	7/24/02 – 8/2/02	1, 3, 4, 2
	B	8/5/02 – 8/15/02	

[1] Group A = Soyono, Berani, Eric; Group B = Tana, Tsavo, Rokan

[2] 1 = keg/box, 2 = squash, 3 = blood, 4 = dung.

Table 4. ANOVA results testing the main effects of stimulus object type (dung, squash, blood, keg, and box) and replicate (1, 2, 3) on difference scores for behavioral states and discrete behaviors.

Main effect	Data set	Score	F	df	p
object	Behavioral states	*E-C*	0.997	4,37	0.422
		PE-C	0.128	4,31	0.971
	Discrete behaviors	*E-C*	1.749	4,37	0.160
		PE-C	2.516	4,32	0.061
replicate	Behavioral states	*E-C*	0.738	2,39	0.485
		PE-C	0.197	2,33	0.822
	Discrete behaviors	*E-C*	1.314	2,39	0.280
		PE-C	0.341	2,34	0.713

were thrown onto land. Cardboard boxes were placed in enclosures prior to subject occupation. In enrichment trials, data collection began one-half to one minute prior to presentation of the stimulus object. Zoo-keepers were present when objects were thrown. A vocal cue was given to subjects from the zoo-keeper prior to throwing the object (e.g. calling subject name and jingling keys). After trials were completed, objects were removed from the enclosures between shifts to prevent the out-coming felid being exposed to the stimulus object.

Data analysis

The data for the subjects tested at the same time in the same enclosure were pooled, resulting in four subject groups (Berani/Soyono, Eric, Rokan, and Tana/Tsavo). For each trial, behavioral diversity indices (hereafter BDIs) were calculated from each data set (behavioral states, discrete behaviors, and object-directed behaviors) using the Shannon Diversity Index (Zar, 1974): $H = -\sum_{i=1}^{k} p_i \log p_i$, where p_i is the proportion of observations in which the i^{th} behavioral state (or discrete behavior) of k behavioral states (or discrete behaviors) was recorded. To examine the effect of the enrichment on behavior, the following analysis was performed with both the behavioral states BDIs and the discrete behavior BDIs. For each enrichment session, the control trial BDI was subtracted from the enrichment trial BDI, resulting in an *E-C* score. If the enrichment trial affected behavioral diversity, then *E-C* scores should be significantly different from zero. In addition, the control trial BDI was subtracted from the post-enrichment trial BDI, resulting in a *PE-C* score. If the effect of enrichment persisted after the enrichment trial, then the *PE-C* scores should be significantly different from zero.

Table 5. One-sample t-test results for *E-C* and *PE-C* scores for behavioral states and discrete behaviors data.

Data set	Score	Mean (SEM)	*t* statistic	df	*p*
Behavioral states	*E-C*	0.093 (0.035)	2.693	41	0.010
Behavioral states	*PE-C*	-0.010 (0.033)	-0.316	35	0.754
Discrete behaviors	*E-C*	0.221 (0.063)	3.505	41	0.001
Discrete behaviors	*PE-C*	0.049 (0.053)	0.928	36	0.36

Table 6. Results of the contingency-table chi-square analysis examining the effect of trial type (C = control, E = enrichment, and PE = post-enrichment) on the proportion of observation intervals spent sleeping for each subject group. Berani, Soyono, Eric, and Rokan are tigers; Tana and Tsavo are lions.

Subject group	Trial type	Number of observation intervals	Proportion of intervals spent sleeping	χ^2	df	p
Berani/Soyono	C	1402	0.034	53.9	2	<0.0001
	E	1074	0.002			
	PE	1221	0.005			
Eric	C	618	0.084	50.4	2	<0.0001
	E	622	0.010			
	PE	599	0.105			
Rokan	C	655	0.489	256.6	2	<0.0001
	E	523	0.174			
	PE	462	0.671			
Tana/Tsavo	C	1329	0.825	786.0	2	<0.0001
	E	1275	0.354			
	PE	1202	0.794			

For all dependent variables, one-sample Kolmogorov-Smirnov tests were used to test for deviations from normality and the homogeneity assumption was tested with Bartlett's test (Zar, 1974). Nonparametric counterparts were employed if the data did not meet the assumptions of parametric tests.

Initial analyses determined that the type of stimulus object did not significantly affect *E-C* or *PE-C* scores (Table 4), therefore the object variable was removed from subsequent analyses of these difference scores. In addition, the *E-C* and *PE-C* scores did not vary significantly over time (Table 4), so the replicates for each subject group were treated as equal and independent measures of responses to enrichment.

One-sample t-tests were used to test the hypothesis that the *E-C* scores and the *PE-C* scores were significantly different from zero. In addition, a one-way ANOVA was performed in order to examine the effect of subject group on BDI difference scores for both behavioral states data and discrete behaviors. A Tukey post-hoc test was employed to determine the source of significant differences.

For each trial, the proportion of intervals spent active was calculated by adding the proportion of intervals spent swimming and in locomotion. The proportion of intervals spent sleeping was also calculated for each trial. For each subject, the effect of trial type on proportion of intervals spent active and sleeping was determined using contingency table chi-square analysis, with a Bonferroni-adjusted α level of 0.0125 for the four tests for each dependent variable.

Table 7. Results of the contingency-table chi-square analysis examining the effect of trial type (C = control, E = enrichment, and PE = post-enrichment) on the proportion of observation intervals spent active (swimming + locomotion) for each subject group. Berani, Soyono, Eric, and Rokan are tigers; Tana and Tsavo are lions.

Subject group	Trial type	Number of observation intervals	Proportion of intervals spent active	χ^2	df	p
Berani/Soyono	C	1402	0.337	8.6	2	0.014
	E	1074	0.289			
	PE	1221	0.340			
Eric	C	618	0.338	32.7	2	<0.0001
	E	622	0.339			
	PE	599	0.209			
Rokan	C	655	0.260	125.3	2	<0.0001
	E	523	0.298			
	PE	462	0.030			
Tana/Tsavo	C	1329	0.005	92.3	2	<0.0001
	E	1275	0.064			
	PE	1202	0.015			

A Kruskal-Wallis ANOVA was used to determine the effect of subject group on object-directed BDIs measured during the enrichment trials. A Kruskal-Wallis ANOVA was also used to determine if the stimulus object type affected object-directed BDIs for the objects tested on all subjects (blood, dung, and squash).

Unless otherwise noted, the α level for all statistical tests is 0.05.

Results

Behavioral states

For all enrichment sessions, the behavioral states *E-C* scores were significantly different from zero but the *PE-C* scores were not significantly different from zero (Table 5). There were no significant differences among the four subject groups in *E-C* scores ($F_{3,38} = 1.327$; $p = 0.280$) or *PE-C* scores ($F_{3,33} = 0.382$; $p = 0.767$). Overall, subjects spent fewer observation intervals sleeping during the enrichment sessions than during the control or post-enrichment trials (Table 6). Trial type significantly affected the proportion of observation intervals spent active (locomotion and swimming) for three of the four subject groups, but only Tana/Tsavo exhibited increased activity during the enrichment sessions compared to the control and post-enrichment sessions (Table 7).

Discrete behaviors

For all enrichment sessions, the *E-C* scores from the discrete behaviors data set were significantly different from zero, but the *PE-C* scores were not significantly different from zero (Table 5). *E-C* scores for discrete behaviors differed significantly among subject groups ($F_{3,38} = 5.272$; $p = 0.004$; Figure 1). A Tukey post-hoc test revealed that the *E-C* scores for the lions Tana/Tsavo were significantly higher than the *E-C* scores for the tigers ($p < 0.05$). No other post-hoc contrasts were significant. The subject groups did not differ in *PE-C* scores ($F_{3,33} = 2.292$; $p = 0.096$).

Object-directed behaviors

The Kruskal-Wallis ANOVA determined that BDIs for object-directed behaviors recorded during enrichment trials differed significantly

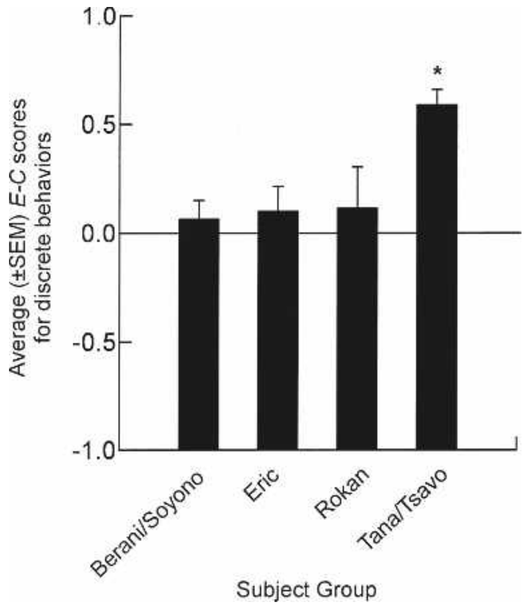

Figure 1. Average (±SEM) *E-C* scores for the discrete behaviors data. *E-C* scores were calculated for each enrichment session, and are equal to the difference between the BDI for the enrichment trial and the control trial. The solid line indicates an *E-C* score of zero (no difference in BDI between the enrichment and control trials). *The *E-C* scores for the lions Tana/Tsavo are significantly higher than the *E-C* scores for the other three tiger subject groups ($p < 0.05$).

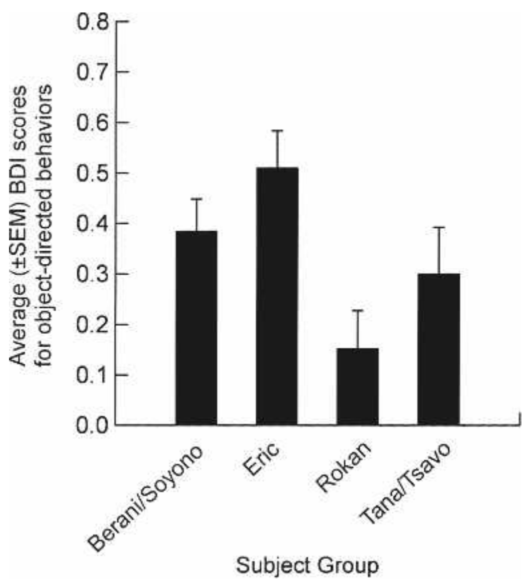

Figure 2. Average (±SEM) BDIs for object-directed behaviors recorded during enrichment trials for each subject ($p = 0.012$). Berani, Soyono, Eric, and Rokan, and are tigers; Tana and Tsavo are lions (Table 1).

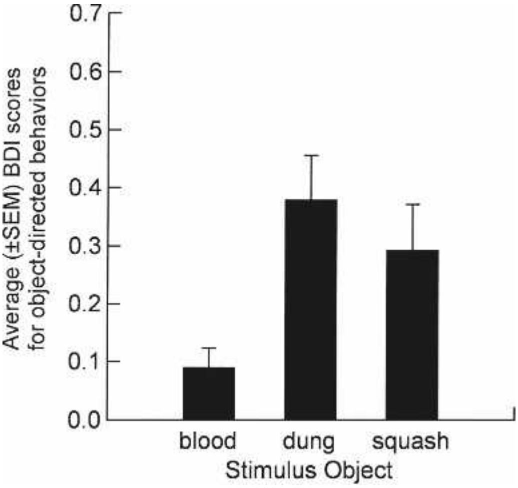

Figure 3. Average (±SEM) BDIs for object-directed behaviors recorded during enrichment trials for the enrichment objects tested in all subject groups (p = 0.046).

among subject groups (H = 12.91, df = 3, p = 0.012; Figure 2). The type of stimulus object significantly affected object-directed BDIs (H = 6.172, df = 2, p = 0.046; Figure 3), in that the BDIs were lower for the frozen blood balls than for the dung or squash stimulus objects.

Discussion

Overall, enrichment efficacy and differences among subjects are the focus of the data analysis. The results indicate that the stimulus objects encouraged a greater variety of non-object-directed species-specific behaviors (e.g., increased diversity of behavioral states; increased diversity of discrete behaviors such as climb, groom, mark, rub, vocalize). In addition, when the stimulus objects were present, subjects spent more time active and less time sleeping than during control trials in which the stimulus objects were absent. Both increased behavioral diversity and increased activity may benefit the psychological and physiological well-being of the lions and tigers (Hughes and Duncan, 1988), and may improve the zoo experience for visitors (Bashaw et al., 2003).

In this study, immediate effectiveness of stimulus objects as enrichment can be gauged by the *E-C* score. If enrichment increases the behavioral diversity of subjects, then *E-C* should be significantly greater than zero. *E-C* scores for both behavioral states and discrete behaviors were significantly different from zero, allowing us to conclude that the stimulus objects had an immediate positive influence on behavioral diversity of lion and tiger subjects. However, a complete analysis of behavior changes requires investigation of both the *E-C* and the *PE-C* scores. The *PE-C* scores were not significantly different from zero in either behavioral states or discrete behavior analysis. So, although stimulus objects did cause an immediate change in behavioral diversity, the effects did not carry over to the post-enrichment trial on the day following enrichment. If enrichment is to improve psychological well-being via the reduction of ethological needs (Hughes and Duncan 1988), then its positive effects must continue even when the animal is not exposed to the enrichment item. These results are consistent with other studies in felids failing to demonstrate persistence of positive behavioral gains after enrichment (Charlton, 1998; Shepherdson et al., 1993; Bashaw et al., 2003), and suggest that on-going enrichment may be necessary to maintain behavioral gains. However, one concern with on-going enrichment is that habituation may reduce the effectiveness of the enrichment. In this study, felids were exposed to a variety of stimulus objects over a 10-week period, and no habituation was observed, a result consistent with the findings of Swaisgood et al. (2001) in giant pandas. Rotating stimulus objects used in enrichment may be a good approach to avoid attenuation in enrichment response due to habituation.

This study also compared enrichment effectiveness among subject groups. It appears that the enrichment was most effective for the lions. Of all of the subject groups, the lions showed the greatest reduction in time spent sleeping and the greatest increase in time spent active in the enrichment trials compared to the control trials. In addition, discrete behaviors *E-C* scores were higher for the lions than the three tiger groups (Figure 1). Determining the cause of these individual differences in this study is difficult, however, due to the limited sample size, and the fact that differences in age and species among subjects are confounded (Table 1). The two lions, Tana and Tsavo, are also the oldest of the subjects tested. A larger sample size would help clarify whether these trends reflect true differences between species and/or an effect of age, or another undetermined factor.

Differences in enrichment response between similar species have been noted (Wooster, 1997; Mellen et al., 1998; McPhee, 2002). For example, Wooster (1997) observed that clouded leopards did not respond to enrichment as well as did servals, ocelots, and pumas. However, because no quantitative data are reported, the degree of differences and the significance of this difference are not known. Age has also been observed to affect responsiveness to enrichment. Swaisgood et al. (2001) found that subadult pandas responded more favorably to stimulus object and feeding enrichment than adults, and that adults, but not subadults, exhibited a significant preference for feeding vs. nonfeeding enrichment.

Many felid enrichment studies focus on appetitive behaviors via food provision (Shepherdson et al., 1993; Wooster, 1997; Charlton, 1998; Mellen et al., 1998; Shepherdson, 1998; McPhee, 2002; Bashaw et al., 2003; Walters 2003). This study encouraged appetitive and related behaviors using stimulus objects in place of actual food (excepting frozen blood). This was done mainly due to limitations regarding changing existing zoo protocol for felid food provisioning. But the results of this study (significantly positive *E-C* scores) support the previous observation that such objects can successfully be used to induce feeding-related behaviors (e.g. sniff, bite, lick, stalk, pounce) (Mellen et al 1998). Felids in this study are fed a zoo carnivore diet, which does not allow them to fully use their canine teeth, jaw muscles or to engage in many natural feeding behaviors such as tearing food apart or completing a stalk-rush-kill sequence (Leyhausen 1979). Each stimulus object in this study allowed for the expression of some or many appetitive behaviors. Kegs provided an opportunity to investigate an unknown object and in some cases invoked a full stalk-rush-kill sequence. Boxes provided an opportunity to engage in similar behaviors, although a full stalk-rush-kill sequence was not observed in lion subjects. Boxes, squash, and zebra dung bags were torn apart. Squash, zebra dung and frozen blood also provided opportunities for olfactory stimulation with both familiar and novel scents.

Three of the stimulus objects were tested on all of the subject groups (frozen blood balls, fresh zebra dung, and scented squash). Subject groups exhibited lower diversity of object-directed behaviors in response to the frozen blood balls than the other two stimulus objects. This lower diversity is most likely due to the fact that the primary behaviors elicited by the frozen blood balls were sniffing and licking. However, all stimulus objects were equally effective in increasing the diversity of non-object-directed behaviors in the enrichment trials compared to the control trials.

This study has demonstrated an effective enrichment program for lions and tigers utilizing stimulus objects. The program should be tested on a wider variety of subjects to further evaluate its effectiveness in improving behavioral diversity. Because the subjects in this study did not exhibit stereotypic behavior, the effectiveness of this enrichment program in reducing stereotypies remains to be determined. The potential roles of age, species, and other factors such as sex and/or prior enrichment experience in individual responses to enrichment could be investigated using the experimental design employed in this study with the appropriate sample population, perhaps utilizing subjects from multiple zoos. The results of this study suggest, however, that enrichment programs should take into consideration individual differences in response to enrichment when designing and implementing enrichment programs to maximize physical and psychological health of the animals, improve zoo visitor experience and public education, and meet conservation goals.

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