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RESEARCH ARTICLE

Evaluation and Interpretation of the Effects of Environmental Enrichment Utilizing Varying Degrees of Sampling Effort

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Documenting the effects of novel forms of enrichment is becoming increasingly important within the field of environmental enrichment. Appropriate documentation and evaluation must accompany any enrichment research project in order for accurate results to be obtained. The objective of the present study was to provide an example of how the level of effort in documenting the effect of enrichment is linked to how it is evaluated. This study was carried out on eight cheetahs (*Acinonyx jubatus*) at Fota Wildlife Park, Ireland. Temporal feeding variation was the enrichment type used during this study. Behavior data were collected in five different ways in order to simulate varying degrees of effort. Randomization tests were utilized to analyze behavior data. Significant behavioral differences were observed in the first four sampling methods with patterns of behavior remaining similar in all five methods. However, only the most time intensive method concurred with findings previously published utilizing this form of enrichment. No significant differences in behavior were detected when the least time intensive method was used. Between 1 and 2 hr of data collection daily is necessary to evaluate temporal feeding variation accurately. However, 30–45 min of data collection also gave an insight into the effectiveness of the enrichment. Methods of evaluation can influence the interpretations of the strength of the enriching effect of the treatment. Appropriate evaluation and accurate reporting of enrichment is crucial for the future development of the environmental enrichment field. Zoo Biol. 00:1–11, 2012. © 2012 Wiley Periodicals, Inc.

Keywords: behavior; enrichment evaluation; sampling effort

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INTRODUCTION

Enrichment is now widely recognized as a method for improving the quality of life of captive animals in terms of providing the opportunity for optimal behavioral, psychological, and physiological well-being [Swaisgood and Shepherdson, 2005]. A meta-analysis by Swaisgood and Shepherdson [2006], utilizing published research on enrichment revealed that zoo enrichment works well, with a reduction in stereotypical behaviors of between 50% and 60% being observed for a range of carnivores, primates, and other species. Increasing the prevalence of natural behaviors and reducing stereotypical behaviors is one of the primary goals of enrichment. There are multiple examples of successful use of environmental enrichment [Carlstead et al., 1993; Jenny and Schmid, 2002; Kistler et al., 2009; McPhee, 2002; Shepherdson et al., 1993].

The use of enrichment in zoological institutions worldwide is now common, with specific programs/schedules being employed for a wide range of species in captivity. In a recent survey, 50% of respondents from zoological institutions said that enrichment schedules were determined by individual staff members, and that 45% implemented enrichment without any approval process [Hoy et al., 2010]. It was also reported that 70% used literature on previously studied enrichment, some of the time prior to carrying out enrichment [Hoy et al., 2010]. Recently, Disney's animal program created the S.P.I.D.E.R. framework for enrichment projects [Mellen and McPhee, 2001]. Setting goals, Planning, Implementing, Documenting, Evaluating, and Re-adjusting are the steps highlighted by this framework. Arguably, the most important part of this framework involves the documenting and evaluating of the particular enrichment. There are many methods of documenting enrichment ranging from rigorous scientific behavior data collection, including the use of instantaneous scan sampling and focal sampling [Altmann, 1974]. The S.P.I.D.E.R. framework identifies other methods including the recording of certain events and the animals' interactions with the enrichment, using 1–5 scales describing the levels of interaction with enrichment, indirect evidence of interaction with enrichment and goal scales, assessing whether the animal uses a particular enrichment in the intended way. Appropriate, goal-directed, documentation leads directly to accurate evaluation and subsequent positive contributions to the field of environmental enrichment.

Behavioral responses toward devices and environmental changes have been documented to decrease quickly [Celli et al., 2003]. For example, Wells and Egli [2004] showed that olfactory enrichment can increase activity levels in black-footed cats (*Felis nigripes*). However, no behavioral responses were observed on the third day of exposure to the scents. Therefore, the documenting and testing of novel forms of enrichment in captivity is important to the ever-evolving environmental enrichment field. Significant time constraints and large workloads for zookeepers worldwide can limit their ability to fully document and evaluate environmental enrichment practices employed at their institution [Hoy et al., 2010]. What effect does this have on the perceived usefulness and effectiveness of an enrichment? Are the goals set out at the beginning of an enrichment schedule being met? According to AAZK [1995] "Proper documentation of animal enrichment is as equally important as the enrichment itself." Swaisgood and Shepherdson [2006] cited the importance of reporting negative and nonsignificant

findings on the effects of enrichment, as well as the need to conduct further meta-analyses with non-published data, in order to advance the field of environmental enrichment. In order to achieve these goals, more enrichment experiments in captivity, utilizing accurate and appropriate documenting of the effects of enrichment, must be completed.

This research involved the introduction of temporal feeding variation enrichment to cheetahs (*Acinonyx jubatus*). This form of enrichment has been previously shown to reduce levels of pacing behavior and increase active behaviors in cheetahs [Quirke and O'Riordan, 2011]. Through the utilization of previous research which has shown the efficacy of the enrichment, the objective was to determine how the level of effort in documenting the effect of enrichment is linked to enrichment evaluation. The aim was to provide zoological institutions with information on the minimal, least time consuming, appropriate level of sampling effort required to accurately evaluate the effectiveness of enrichment. This will facilitate more efficient monitoring of old and novel forms of enrichment in zoological institutions worldwide, which will be beneficial for the future development of the field of environmental enrichment.

METHODS

Study Site and Animals

This research was carried out at Fota Wildlife Park (51.8992°N, 8.2982°W), Carrigtwohill, Co. Cork, Ireland, over 16 days during March 2010. This study was carried out on eight cheetahs held in five enclosures at the Park (Table 1). The cheetahs were usually fed at a regular time (around 16:00 hr) once daily, 6 days a week on whole dead rabbits or chickens.

Procedure

Temporal feeding variation, previously shown to have an enriching effect on cheetahs, was chosen as the enrichment type to be used during this study. Baseline days consisted of days in which the normal feeding schedule at Fota Wildlife Park was employed while on temporal feeding variation days, the cheetahs were fed at a random time during the day, which was not the regular feeding time. Random number tables were utilized to select the hour in which the cheetahs were fed. Over the 16 days of this study, 8 days were randomly chosen as baseline days using random number tables. Similarly, 8 days were chosen as temporal feeding variation days. Each baseline and enrichment day was arbitrarily divided into two time periods namely, 09:00–13:00 hr and 13:00–17:00 hr. Each time period was assigned to four baseline and enrichment days.

TABLE 1. Cheetahs observed in the study

Enclosure	Cheetahs	Age	Relationship
1	Solitary hand-reared male	4 years	-
2	Solitary female	9 years	-
3	Solitary female	5 years	-
4	Coalition of two males	12 years	Unrelated
5	Female with two cubs	10 years, >10 months × 2	Mother and cubs

TABLE 2. Ethogram of behaviors recorded during this study

Category	Behavior	Description
Exploratory	Olfaction	Sniffing any object
	Scent-marking	Spraying urine on prominent feature/tree scratching
Inactive	Auto-grooming	Grooming self
	Lying down	Cheetah on ground with legs stretched out away from body or held under body
	Sitting	Two front legs held straight and upright in front of body while leaning on rear legs
	Shelter	Cheetah inside hut/house/indoor enclosure
Locomotion	Walking	Locomotion at a normal speed
	Running	Locomotion at a fast speed
Other	Aggression	Hissing/spitting, stamping legs on ground directed at cheetah/keeper/public
	Allo-grooming	Grooming other cheetah
	Feeding	Eating food item
	Playing	Chasing other cheetah, pawing or rolling around with object or other cheetah
	Standing	Stationary on all four legs
	Vocalization	Purring, stutter-barking, growling, chirping, or yowling
Stereotypical	Pacing	Repetitive locomotory movement along a given route (up/down fence line, around enclosure, around object in enclosure) without being interrupted by any other behavior
Vigilance	Vigilance	Head held rigid, eyes focused on one point, ears pinned back

Two hours of data collection was carried out daily. Instantaneous scan sampling with a 5 min inter-scan interval was employed. In order to select when data collection started daily, the 4-hr time period was divided into sixteen 15-min time periods. The use of random number tables then indicated when data collection would begin daily. By splitting each baseline and enrichment day into two time periods, and randomly sampling from within one time period for each day, this ensured that data collection was evenly distributed across all hours of the day over the course of the study. Sixteen behaviors, grouped into six categories, namely, exploratory, inactive, locomotion, other, pacing, and vigilance were recorded during this study (Table 2).

In order to simulate varying degrees of sampling effort, a decreasing number of scan samples were subsampled from the daily 2 hr (24 scan samples, method A) of data collection.

- Method A consisted of carrying out 24 instantaneous scan samples (2 hr) simultaneously for each enclosure with a 5 min inter-scan interval in order to simulate intensive data collection by a scientist examining the behavioral effect of the enrichment.
- Method B involved subsampling 16 instantaneous scan samples (1 hr 40 min) in order to simulate data collection by a zookeeper who has set aside a significant proportion of their time in order to examine the behavioral effect of enrichment.
- Method C involved subsampling nine instantaneous scan samples (45 min) in order to simulate data collection by a zookeeper who has set aside a proportion of their time in order to examine the behavioral effect of enrichment.

- Method D involved subsampling six instantaneous scan samples (30 min) in order to simulate data collection by a zookeeper who has not set aside a significant proportion of time for examining the behavioral effect of enrichment but who wishes to carry out a preliminary examination.
- Method E involved subsampling three instantaneous scan samples (15 min) in order to simulate data collection by a zookeeper who has not set aside a significant proportion of time for examining the behavioral effect of enrichment.

Data Analysis

For each individual data collection method, levels of each of the six behaviors during baseline and enrichment days were compared using randomization tests [Plowman, 2008; Todman and Dugard, 2001]. The difference in the mean proportion of scan samples in which each behavior was observed during baseline and enrichment days was calculated with data from each enclosure representing one data point. One thousand re-randomized pseudo samples were then generated in R version 2.12.0, by randomizing data for the behavior in question across both conditions (baseline and enrichment days). The difference in the mean proportion of scan samples was calculated for each re-randomization. The number of times in which the difference in means was equal to or greater than the observed calculated value, for the difference in means between conditions, was recorded and divided by the number of permutations (1,000) in order to calculate the P value. A P value of 0.05 or lower indicated that there was a real difference between baseline and enrichment days for the given behavior.

This procedure was carried out for each behavior for each method of data collection. This was in order to highlight the individual statistical outcomes of comparing each of the six behavioral categories between baseline and enrichment days for each data collection method without taking into account that other data collection methods were carried out. This will highlight any differences that may occur if zoological institutions carried out only one data collection method and interpreted their results based on that data collection method alone. Individual variation in behavioral reactions to the enrichment between cheetahs in different enclosures was not analyzed as previous research has already documented this [Quirke and O'Riordan, 2011].

RESULTS

Data Collection Method A

The difference in observed levels of other behavior (aggression, allo-grooming, feeding, playing, standing, and vocalization) was statistically significant ($P \leq 0.001$; two-tailed) with levels increasing during enrichment days (Fig. 1). Levels of stereotypical behavior ($P = 0.04$) were also significantly different between baseline and enrichment days ($P < 0.05$; two-tailed) with levels decreasing during enrichment days. Levels of exploratory ($P = 0.45$) and inactive ($P = 0.42$) were greater during enrichment days, but not significantly so (Fig. 1). Levels of locomotion ($P = 0.09$) and vigilance ($P = 0.62$) behavior were greater during baseline days, but not significantly so (Fig. 1).

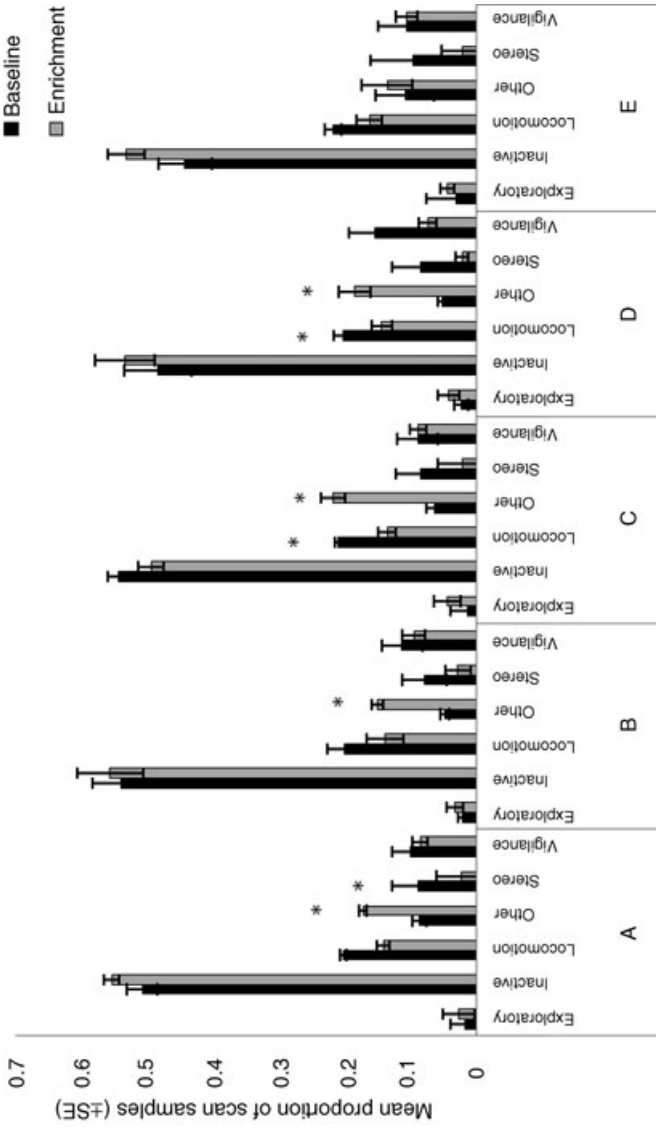

Fig. 1. Mean proportion of scan samples in which each behavior was observed for baseline and enrichment days for each data collection method.
*Significant difference in the level of behavior between baseline and enrichment days.

Data Collection Method B

Similar to data collection method A, levels of other behavior were significantly greater ($P = 0.002$; two-tailed) during enrichment days compared to baseline days (Fig. 1). Levels of stereotypical behavior ($P = 0.27$), vigilance behavior ($P = 0.71$), and locomotion behavior ($P = 0.14$) were lower during enrichment days compared to baseline days, but not significantly so (Fig. 1). Similar to method A, levels of exploratory ($P = 0.43$) and inactive ($P = 0.82$) behavior were greater during enrichment days, but not significantly so (Fig. 1).

Data Collection Method C

Levels of other behavior were significantly greater ($P = 0.001$; two-tailed) during enrichment days while locomotion behavior was significantly greater ($P = 0.04$; two-tailed) during baseline days (Fig. 1). Inactive ($P = 0.37$) and stereotypical behaviors ($P = 0.09$) were greater during baseline days compared to enrichment days, whereas levels of exploratory ($P = 0.06$) and vigilance behaviors ($P = 0.995$) were greater during enrichment days (Fig. 1), but these levels were not significantly different.

Data Collection Method D

Similar to method C, levels of other behavior were significantly greater ($P = 0.01$; two-tailed) during enrichment days. Locomotion behavior was significantly greater ($P = 0.02$; two-tailed) during baseline days (Fig. 1). Levels of stereotypical behavior ($P = 0.13$) and vigilance ($P = 0.06$) behavior were lower during enrichment days while levels of exploratory ($P = 0.45$) and inactive ($P = 0.48$) behaviors were greater during enrichment days but not significantly so (Fig. 1).

Data Collection Method E

Using data collection method E, no behaviors were significantly different between baseline and enrichment days. Locomotion ($P = 0.24$) and stereotypical ($P = 0.13$) behavior were greater during baseline days compared to enrichment days. Exploratory ($P = 0.64$), other ($P = 0.68$), and inactive ($P = 0.23$) behaviors were greater during enrichment days compared to baseline days (Fig. 1). Vigilance behavior ($P = 0.98$) remained at similar levels between baseline and enrichment days.

DISCUSSION

Hoy et al. [2010] reported that the time it takes to carry out other husbandry work and to provide time-consuming enrichments is a limiting factor in the provisioning of enrichment, regardless of its importance. In a recent survey of zoological institutions, 97% of respondents replied stating that when enrichment is provided, it is also evaluated [Roberts, 2005]. Over half of these respondents used rating scales to evaluate the enrichment, while 26% and 10% used daily log books and simple observations of the animals with the enrichment, respectively [Roberts, 2005]. Of concern is the finding that only half of these felt that their methods of evaluation were accurate, while quite a large proportion would prefer more formal methods of evaluation, including a more scientific approach to evaluation [Roberts, 2005].

Previous research has highlighted the enriching effect of temporal feeding variation on cheetahs, with decreases in pacing as well as significant increases in active behavior diversity and exploratory behaviors being recorded [Quirke and O'Riordan, 2011]. However, if the outcomes of the five methods used in the present study are evaluated individually, varying views and recommendations about the efficacy of the use of temporal feeding variation as an enrichment treatment for cheetahs may be obtained. First, method A, similar to that used by Quirke and O'Riordan [2011] revealed positive behavioral changes as a result of the enrichment. Levels of the other behavior category which consisted of a range of active behaviors such as vocalization, allo-grooming, and feeding were significantly increased through the use of this enrichment treatment. The significant reduction in levels of pacing behavior also contributes to a positive view of the enrichment treatment. Based on these results, curators, zookeepers, and scientists alike would feel positive about implementing temporal feeding variation, in order to enhance the quality of life of captive cheetahs and encourage behavioral diversity, while limiting the prevalence of stereotypical pacing behavior. Method B produced similar results in relation to other behavior, once again showing an increase during enrichment days. Patterns of behavior similar to method A were observed and the large albeit nonsignificant decrease in stereotypical behavior therefore would have resulted in a positive view of the enrichment utilizing method B to evaluate. Methods C and D also showed behavioral patterns very similar to method A, except for inactive behavior which deviated from the pattern observed for other methods. Upon evaluation of the results from methods B, C, and D, given time constraints in relation to time dedicated to enrichment evaluation, one would be confident about employing temporal feeding variation as a method of enrichment which could supplement other forms of enrichment in order to increase active behaviors and possibly stimulate a significant reduction in pacing behavior. Finally, method E revealed no significant behavioral effects of the enrichment. Although trends in the levels of different behaviors seem to suggest the potential for the enrichment treatment to have a beneficial effect, the evidence for this argument would not be particularly powerful, based on the statistical outcomes and the sampling effort employed.

Clearly, the choice of method for evaluating the behavioral effects of the enrichment can influence the interpretations of the strength of the enriching effect of the treatment. Up to 2 hr of data collection (method A) daily is necessary to evaluate temporal feeding variation accurately. However, methods B, C, and D involving 1 hr 40 min, 45 min, and 30 min, respectively, of data collection daily also gave a useful insight into the effectiveness of the enrichment, and some would argue more than enough evidence to prove its efficacy and stimulate its future use as an enrichment strategy. In contrast, method E, involving 15 min of data collection suggested, incorrectly that the enrichment had no significant effect on cheetah behavior.

Hoy et al. [2010] reported that up to 28% of respondents to a survey spent less than an hour on tasks related to enrichment while nearly 40% spent 1 hr, 22% spent 2 hr, and 5.6% spent 3 hr. The present study highlights that between 30 and 120 min would be sufficient in order to confidently assess an enrichment treatment such as temporal feeding variation. It is encouraging that time is being spent on enrichment but a large proportion of this time is spent preparing and provisioning the enrichment rather than evaluating enrichment. Margulis and Westhus [2008] utilized three different forms of data collection to analyze the behavior of polar bears (*Ursus maritimus*), brown bears (*Ursus arctos*), and bottlenose dolphins (*Tursiops truncatus*), and found that, for

common behaviors, differences in sampling regime in relation to scan interval did not result in significant differences in these behaviors. However, for rare behaviors, there were significant differences. A key finding was that data reliability also increased with increasing observation number [Margulis and Westhus, 2008]. Although the patterns of behavior were extremely similar for each data collection method in the current study, utilizing patterns of behavior with fewer observations for evaluation of enrichment can be problematic and limit how reliable the data can be. An example is the levels of inactive behavior during method C of the current study, which showed a different pattern to the other methods. It is worth noting that a 95% confidence level of significance for the detection of an effect may not be required in order for the practical application of an enrichment treatment within a zoological institution. Therefore, as the patterns of behavior were largely similar for each data collection method for this particular type of enrichment in the current study, incorporation of this enrichment could have occurred upon evaluation with the lower levels of sampling intensity. However, to ensure that the behavioral patterns accurately reflect the actual behavioral effects of the enrichment, sampling according to the higher sampling intensity regimes are still highly recommended.

One of the sampling regimes in the study of Margulis and Westhus [2008] consisted of keepers carrying out samples as they passed the enclosure during their working day, resulting in a number of random samples each day which, according to the authors, produced invaluable information over time. Similarly, Canino and Powell [2010] also used this "multi-point" sampling technique and were able to collect reliable and useful data in order to assess a polar bear's behavior in response to enrichment without significantly adding to the keeper's daily workload. During the present study, more behaviors were observed given more time to collect data. This is important when it comes to certain types of enrichment, particularly enrichment that is focused on stimulating rare behaviors, for example, scent marking in cheetahs. Collecting "multi-point" samples throughout the day may miss these rare behaviors and therefore consider the enrichment a failure even though it could have been promoting this behavior. Given a more rigorous data collection effort, the opposite might be the case and less time can be put into developing a new enrichment treatment.

Ideally, upon the provisioning of enrichment, the present study would recommend the use of method A, or similar methods, in order to fully understand and evaluate the behavioral effects of the enrichment accurately. However, methods B, C, and D also have their advantages in terms of a balance between keeper time and sampling intensity in that less time is required to obtain some useful information regarding the efficacy of the enrichment, however, without fully discrediting or confirming its positive/negative effects. Method E may be of use for interactive enrichment devices whereby keepers can introduce the device and observe and record data for 15 min after provision. This would provide evidence of how the enrichment was initially received and if it has potential to have beneficial behavioral effects going forward. It is clear that time is the major limiting factor in any study of enrichment within the zoological setting. A possible solution to evaluating enrichment such as temporal feeding variation may be to combine the "multi-point" sampling technique with method E as used in the present study. Taking 15 min, maybe two-three times daily will not only provide a greater number of samples, but will also provide random sampling throughout the day, which will allow the full effects of the enrichment in terms of entire activity budgets to be evaluated. The combination of this regime with the use of personal digital as-

sistants, behavior coding, and tabulation systems such as EVENT, JWatcher, and The Observer can limit the time spent on data entry and maintenance of enrichment logbooks and files, thus allowing the multiple 15-min sampling points to be taken without compromising the work schedule of keepers or other staff. Creative scheduling, as well as cooperation between staff members, could also facilitate increased effort in the evaluation of enrichment. The publishing of all enrichment experiments is important, even studies which show that the enrichment had a negative or even no effect on the animals in question [De Azevedo et al. 2007; Swaisgood and Shepherdson, 2006]. In order to do this, however, appropriate and accurate evaluation of enrichment must take place. The rationale behind carrying out the present research was to highlight that, while carrying out enrichment is extremely important, effective evaluation must accompany it, and the aim was to determine the minimum effort that was realistically required of zoo-keeping staff in order to provide valuable data in relation to evaluation of an enrichment treatment. Although it is a simple example, the present study highlights that zookeepers and researchers alike should bear in mind that effort put into evaluation can reap rewards, especially in relation to time spent developing a new enrichment treatment. If evaluation of the current enrichment treatment, which is effective, is conducted appropriately, less time will be spent developing and implementing a new enrichment treatment because it will be clear through proper evaluation that the current enrichment treatment is having the desired effect. The inappropriate evaluation and inaccurate reporting of the effects of enrichment is similar to not testing the enrichment at all. Individual institutions may benefit from the development of a uniform schedule structure in relation to allowing time for appropriate evaluation when incorporating enrichment. Revealing effective and non-effective enrichments will benefit animal welfare in captivity and contribute to further development of the field of environmental enrichment.

CONCLUSIONS

1. The present study highlights that methods of evaluation can have consequences in relation to how the enrichment is interpreted, and therefore effect future enrichment studies.
2. Between 60 and 120 min of behavior data collection daily is sufficient to accurately record behavioral changes associated with temporal feeding variation.
3. Between 30 and 60 min of behavior data collection daily can provide a useful insight into the effectiveness of such an enrichment type.
4. Collection of behavior data for 15 min daily is not appropriate in order to accurately assess temporal feeding variation. However, this may be of use when interactive enrichment devices are employed.
5. Although significant statistical differences were primarily observed in the more time intensive sampling methods, the intuitive and cautious study of patterns of behavior utilizing less time intensive methods can be advantageous in relation to evaluating enrichment given the ever-problematic time constraints on zookeepers in today's zoological institutions.
6. Development of specific and innovative schedules within zoological institutions for evaluation of enrichment, incorporating multiple shorter data collection periods

daily in order to add up to between 60 and 120 min of data collection daily can be utilized to effectively evaluate enrichment.

REFERENCES

Altmann J. 1974. Observational study of behavior: sampling methods. Behaviour 49:337–367.

American Association of Zookeepers (AAZK). 1995. Environmental Enrichment Workshop. In: Proceedings of 22nd American Association of Zookeepers National Conference. Topeka, KS: American Association of Zookeepers, Inc. p 189–191.

Canino W, Powell D. 2010. Formal behavioral evaluation of enrichment programs on a zookeeper's schedule: a case study with a polar bear (*Ursus maritimus*) at the Bronx Zoo. Zoo Biol 29:503–508.

Carlstead K, Brown JL, Seidensticker J. 1993. Behavioral and adrenocortical responses to environmental changes in leopard cats (*Felis bengalensis*). Zoo Biol 12:321–331.

Celli ML, Tomonaga M, Udono T, Teramoto M, Nagano K. 2003. Tool use task as environmental enrichment for captive chimpanzees. Appl Anim Behav Sci 81:171–182.

De Azevedo CS, Cipreste CF, Young RJ. 2007. Environmental Enrichment: A GAP Analysis, Appl Anim Behav Sci 102:329–343.

Hoy JM, Murray PJ, Tribe A. 2010. Thirty years later: enrichment practices for captive mammals. Zoo Biol 29:303–316.

Jenny S, Schmid H. 2002. Effect of feeding boxes on the behavior of stereotyping Amur Tigers (*Panthera tigris altaica*) in the Zurich Zoo, Zurich, Switzerland. Zoo Biol 21:573–584.

Kistler C, Hegglin D, Wurbel H, Konig B. 2009. Feeding enrichment in an opportunistic carnivore: the red fox. Appl Anim Behav Sci 116:260–265.

Margulis SW, Westhus EJ. 2008. Evaluation of different observational sampling regimes for use in zoological parks. Appl Anim Behav Sci 110:363–376.

McPhee ME. 2002. Intact carcasses as enrichment for large felids: effects on on- and off-exhibit behaviors. Zoo Biol 21:37–47.

Mellen J, McPhee MS. 2001. Philosophy of environmental enrichment: past, present and future. Zoo Biol 20:211–226.

Plowman AB. 2008. BIAZA statistics guidelines: toward a common application of statistical tests for zoo research. Zoo Biol 27:226–233.

Quirke T, O'Riordan R. 2011. The effect of different types of enrichment on the behavior of cheetahs (*Acinonyx jubatus*) at Fota Wildlife Park. Appl Anim Behav Sci 133:87–94.

Roberts KM, 2005. A review of the evaluation of environmental enrichment in zoos. In: Proceedings of the Seventh International Conference on Environmental Enrichment. New York: Wildlife Conservation Society. p 41–49.

Shepherdson D, Carlstead K, Mellen JM, Seidensticker J. 1993. The influence of food presentation on the behavior of small cats in confined environments. Zoo Biol 12:203–216.

Swaisgood RR, Shepherdson DJ. 2005. Scientific approaches to enrichment and stereotypies in zoo animals: what's been done and where should we go next? Zoo Biol 24:499–518.

Swaisgood RR, Shepherdson DJ. 2006. Environmental enrichment as a strategy for mitigating stereotypies in zoo animals: a literature review and meta-analysis. In: Mason G, Rushen J, editors. Stereotypic animal behavior: fundamentals and applications to welfare. Cambridge, MA: CAB International. p 256–285.

Todman JB, Dugard P. 2001. Single-case and small-n experimental designs. A practical guide to randomization tests. Mahwah, NJ: Lawrence Erlbaum Associates.

Wells DL, Egli JM. 2004. The influence of olfactory enrichment on the behavior of captive black-footed cats, *Felis nigripes*. Appl Anim Behav Sci. 85:107–119.