Long-Term Macroevaluation of Environmental Enrichment in Three Brown Bears (*Ursus arctos*) at Barcelona Zoo

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**ABSTRACT**

The evaluation of enrichment programs is important to determine their effect on nonhuman animal welfare. The daily activity pattern and use of space of 3 brown bears (*Ursus arctos*) were used for long-term macroevaluation of enrichment to compare the baseline and enrichment phases. Focal sampling methods were used for data collection, and instantaneous scans were made at 2-min intervals during 15 sessions of 1 hr for each animal during the 2 study periods. The enrichment devices were categorized as feeding, occupational, and sensorial. The long-term macroevaluation in 3 bears showed statistically significant differences in some types of activity but not in others. There were also statistically significant differences for the use of space in 4 of the 8 zones in which the enclosures were divided. A more homogenous pattern in the use of space was only observed during the enrichment phase in the old female. The 3 brown bears followed different patterns concerning the enrichment program.

In the past 15 to 20 years, there has been a significant growth in the number of published studies about the evaluation of enrichment programs to determine their effect on the physical and psychological welfare of nonhuman animals (Mellen & McPhee, 2001; Shepherdson, 2003; Swaisgood & Shepherdson, 2005). The authors’ review of these published studies led to the description of a classification system for the environmental enrichment evaluation studies that clarified the methodology used in this area until now. The classification has two aspects.

First, Novak, Kinsey, Jorgensen, and Hazen (1998) described two concepts in relation to the time elapsed from use of the enrichment device to recording of the data. In short-term evaluation studies, the data are collected at the time in which the enrichment device is introduced to the animal (e.g., from 0 min to 24 hr; Morimura & Ueno, 1999). In long-term evaluation studies, the data are collected starting 24 hr after the application of the enrichment device. The device can be removed—as is the case in this study—or it can remain (Bashaw, Bloomsmith, Marr, & Maple, 2003; Soriano, Ensenyat, Serrat, & Maté, 2006).

Second, according to the specificity of the studied variables, there are also two classifications. In macroevaluation studies, the impact of environmental enrichment on the general variables related to the daily activity patterns, abnormal behaviors, social interactions, and use of space (Schneider, Nogge, & Kolter, 2014) are evaluated. In microevaluation studies, some parameters related specifically to the enrichment devices—for example, latency, intensity, or duration of the interaction between the animal and the enrichment device—are studied (Carlstead, Seidensticker, & Baldwin, 1991).

Some studies have been conducted on the effect of an enrichment program on the behavior of brown bears (*Ursus arctos*; Law & Reid, 2010). Soriano et al. (2006) conducted structural enrichment and
long-term macroevaluation studies. They found that time engaged in vigilance, maintenance, and inactivity increased with seminaturalization of the bears’ exhibit. Moreover, the percentages of time when the bears were active and inactive were very similar to those of wild bears. Spandrup and Larsson (1997) conducted a study related to structural enrichment and short-term macroevaluation in which they evaluated the importance of the size of the installations that brown bears inhabit and the importance of enriching in small installations to reduce stereotyped behaviors.

Carlstead et al. (1991) studied feeding enrichment and short-term microevaluation and found a habituation of brown bears to honey-filled logs. Several researchers have studied short-term macroevaluation. Forthman et al. (1992) found that brown bears were more active, less passive, and less often engaged in abnormal behavior during sessions with enrichment. Grandia, van Dijk, and Koene (2001) found significant differences in active and foraging behavioral categories in brown bears when feeding was increased from three to six times daily, suggesting a more natural behavioral pattern.

Hare (1995) found that the automatic feeder coupled with operant conditioning techniques appeared to affect the captive brown bears’ behavior: There was a decrease in stereotyped behavior and the bears used the space in a desirable manner. Larsson and Tove (1995) studied the brown bears’ positive responses to many of the feeding enrichment methods; being fed more often increased the activity of these animals. McGowan, Robbins, Alldredge, and Newberry (2010) found contrafreeloading opportunities such as a foraging enrichment strategy for captive wildlife. In addition, Morimura and Ueno (1999) found that brown bears’ feeding times increased when foods were spatially and temporally distributed. The species-typical behavioral rhythm of alternate feeding and sleeping was also apparent.

The evaluation of environmental enrichment programs determines if the goals of the environmental enrichment are being achieved: (a) reduction in stereotypic behavior and other non-desirable behaviors such as visitor interaction or animals out of sight; (b) increased desirable behaviors such as play, feeding, activity, or exploration; (c) increased species-typical behaviors such as scent marking, winter sleeping, or salmon fishing; and (d) increased diversity of space use (Shepherdson, 2013).

The aim of this study was to determine the effects of a feeding, occupational, and sensorial enrichment program on the daily activities and use of space of three brown bears at the Barcelona Zoo. This study was classified as long-term macroevaluation—conducted 48 hr after the enrichment session and without the enrichment device—and was used to compare the baseline and enrichment phases.

**Materials and methods**

**Animals and housing**

The subjects included in this study were three brown bears (*U. arctos*) housed at the Barcelona Zoo (see Table 1).

During the observations, the brown bears were housed singly in two moat-style, seminaturalized enclosures with a structure originally made from cement (see Figure 1). A wall divided each enclosure with an opening to connect the two parts. Enclosure 1 had an area of 150 m² and Enclosure 2 was 230 m² (see Figure 1). Each enclosure had an aquatic zone for the animals to drink and bathe. The features in each of the enclosures were trees, bushes, several large stones, large overturned logs for climbing, and several terraces at different levels with a natural substratum of gravel, sand, and bark. The honey dispenser was located in Enclosure 2, but it was not tested during this study. The indoor enclosures were cement cages out of sight from the public, with a drinking trough and bath (total surface area of approximately 10 m² each).

| Name            | Birth date | Born       | Rearing condition | Arrival date at zoo   |
|-----------------|------------|------------|-------------------|-----------------------|
| Old female      | January 1987 | in captivity | Mother            | Since birth           |
| Male            | June 1995  | in the wild | Hand              | December 18, 1999     |
| Young female    | May 2000   | in the wild | Mother            | December 28, 2000     |
Daily management

The studied animals were individually housed, taking into account their solitary lifestyle (Stirling, 1993). The enclosures were designed to allow future interactions among the bears during the mating season if necessary, but these interactions did not occur during this study. The management protocol allowed the bears to go into their indoor enclosures depending on the hours of daylight (9:00 a.m. to 5:00 p.m. in December, January, and February; 9:00 a.m. to 6:00 p.m. in March; and 9:00 a.m. to 7:30 p.m. in April, May, and June). The old female, who occupied Enclosure 2, and the young female, who occupied Enclosure 1, went out on 4 alternate days a week (Mondays, Wednesdays, Fridays, and Sundays). Meanwhile, the male, who occupied Enclosure 1, and a male black bear (*U. americanus*; not included in the study), who occupied Enclosure 2, went out on the remaining days (Tuesdays, Thursdays, and Saturdays).

The brown bears’ diet was seasonally unvaried and consisted of 8 kg of fruit and vegetables, 4 kg of meat (a mix of horse, chicken, and veal), 2 kg of dog chow, and 1 kg of bread once a day per each bear. The food was placed in their indoor enclosures, and the bears ate it when they went back into their indoor enclosures in the evening. All aspects of animal husbandry that have been described were the same for both phases of the study.

During the enrichment program phase (EP), two enrichment applications were held on the same day once per week for each subject during 10 weeks from December 2001 to June 2002. Each bear received the same enrichment device per application. During the first application, the keeper put the enrichment device in the enclosure before the animals went out, around 9:00 a.m. The keeper prepared the second enrichment application around 1:00 p.m.; in this case, the enrichment device was thrown from the visitor viewing area. The enrichment sessions for the young female took place on Mondays; for the male, they took place on Tuesdays; and for the old female, they took place on Wednesdays. These devices or their residues were removed the following morning, when the keeper cleaned the bear enclosures (8:00 a.m.).

The schedule of the brown bears’ enrichment program and their different devices and categories are described in Table 2: (a) feeding, with devices that contained a quantity of food that was subtracted from the established diet (e.g., live fish, vegetables inside a sack, or fruit inside traffic cones); (b) sensorial, which consisted of maximizing the sensorial capabilities of the bears (e.g., different kinds of spices or feces of different herbivores); and (c) occupational, to maximize physical and manipulative skills (e.g., balls, tires, or traffic cones; Soriano, 2013).

Procedure

The baseline phase (BP) was conducted in June and July 2001 to document the bears’ activity and use of space prior to the EP, which took place from December 2001 through May 2002.
The time of the study during these two phases was not the same due to the long-term evaluation during the EP. During the BP, the animals were studied in summer; and during the EP, they were studied in spring, autumn, and winter. The number of observation sessions was balanced to compare the results during the two phases. During the BP, the animals were recorded when they were in the outdoor enclosures 2 or 3 days a week. During the EP, the data were only collected 1 or 2 days because the day of the enrichment application was not included in this study.

Focal sampling methods were used for data collection, and instantaneous scans were made at 2-min intervals during 1-hr sessions (Altmann, 1974). Both phases consisted of 45 observation sessions per animal with 930 sampling points that were balanced for the daily periods to obtain the daily activity pattern.

The information recorded for three brown bears at each observational session was (a) the phase of the study (BP or EP); (b) the period of day (in December, from 9:00 a.m. to 1:00 p.m., 1:00 p.m. to 4:00 p.m., and 4:00 p.m. to 5:00 p.m.; and from March to May, from 4:00 p.m. to 7:00 p.m.); (c) the activity patterns (behavioral categories were defined as comprehensive and mutually exclusive; Table 3; Lehner, 1998); and (d) the use of space, where the two enclosures were divided into eight similarly sized zones from Zone 1 to Zone 16 (see Figure 2).

### Table 2. Number of week, time of day, and description of the brown bears’ enrichment devices.

| Week Number | 9:00 a.m. | 1:00 p.m. |
|-------------|-----------|-----------|
| 1 | One burlap sack fixed with an iron chained to tree protection inside, in which 1 kg of raw lean meat was placed | One frozen fruit juice thrown into the lake |
| 2 | One cardboard box with 15 live grasshoppers | 500 g of fruit spread throughout the enclosure |
| 3 | 500 g of honey spread on the tree trunks of the enclosure | 20 live worms spread throughout the enclosure |
| 4 | 500 g of nuts inside PVC tubes | One block of ice containing fish thrown into the lake |
| 5 | One tire fixed with an iron chained to tree protection inside, in which 500 g of fruit were placed | One frozen chicken broth carton thrown into the lake |
| 6 | One tire inside, which was placed a burlap sack containing 500 g of fruit | One frozen chicken broth carton thrown into the lake |
| 7 | Three cans of spices (parsley, cinnamon, and oregano) spread throughout the enclosure | One cardboard box with 200 g of jam in Zone 2 or 10 |
| 8 | Three handfuls of deer feces spread throughout the enclosure | One Boomer Ball thrown into the lake |
| 9 | 500 g of fruit buried in the sand substrates | One Boomer Ball thrown into the lake |
| 10 | 500 g of nuts buried in the sand substrates | One melon thrown into the lake |

### Table 3. Definitions of the daily activities and their classifications into three macrocategories.

Activity is any behavior not classified as inactive, which includes:
- Exploration: The animal sniffs the air, substrate, food, or objects.
- Vigilance: The bear is alert with head up and eyes open.
- Locomotion: The animal moves around the enclosure.
- Scent marking: The animal rubs against logs.
- Feeding: The bear consumes food items; this includes drinking.
- Maintenance: The animal self-grooms with mouth and/or paws, scratches, urinates, defecates, or shakes.
- Manipulation: The bear claws at, swipes at, nibbles at, and picks up food and nonfood items with mouth and/or paws.
- Human interaction: The bear sits or stands up while looking at humans; this includes different forms of begging—for example, while the bear is sitting or standing up, he/she opens his/her mouth and waves his/her head from side to side; the animal tries to communicate with humans.
- Stereotyped behavior: This behavior has no goal and it is repetitive, lasting for a constant time and occurring in the same places.

The young female roamed in a fixed way in space and time (pacing). The male had an oral stereotypy that consisted of a lateral and repeated bite.

Inactivity
- Stationary: The bear rests, sitting or lying with musculature relaxed.
- Not visible: The bear or his/her behavior was not observable because the enclosure design allowed the brown bears to hide (i.e., behind the stones or the logs).
Data analyses

All data analyses were performed using the Statistical Package for the Social Sciences Version 21.0 (SPSS Inc., Chicago, IL). Using contingency tables, we analyzed the observed frequencies of the categorical data for the daily activity and use of space obtained in this study. These tables enabled us to determine whether there were statistically significant differences in the two study phases for the two dependent variables by means of a chi-square test and the Fisher’s exact test. These statistical tests were used to determine which categories of the activities and use of space showed statistically significant differences. The adjusted residual statistic used had an absolute value of 1.96 for a normal distribution, assuming that the significance level is .05 (Forthman & Bakeman, 1992; Haberman, 1978; Soriano et al., 2006).

To analyze the effect of the enrichment program on a more homogeneous use of the space, a spread-of-participation index (SPI) for observed frequencies was used. A value of 1 indicated minimum use of the facility, and a value of 0 indicated that use of the space was totally homogeneous (Dickens, 1955; Shepherdson, Carlstead, Mellen, & Seidensticker, 1993).

Results

In Table 4, the values of the chi-square test and the Fisher’s exact test are shown to determine the statistically significant differences between the daily activity patterns in each of the three brown bears.
for the two studied phases. The long-term evaluation in these three bears showed a decrease in the time spent engaged in vigilance, and no changes were observed in maintenance. During the EP, the old female showed, with statistically significant differences, an increase in exploration (BP, 9.7%; EP, 10.1%), manipulation (BP, 0.7%; EP, 1.3%), and stationary behaviors (BP, 9.2%; EP, 45.6%), as well as a decrease in vigilance (BP, 22.8%; EP, 14.0%), locomotion (BP, 37.6%; EP, 18.9%), and feeding behaviors (BP, 4.5%; EP, 1.7%).

During the EP, the male showed, with statistically significant differences, an appearance of not visible (BP, 0.0%; EP, 2.1%) and solitary play (BP, 0%; EP, 2.0%), an increase in locomotion (BP, 19.1%; EP, 40.2%), and a decrease in vigilance (BP, 16.1%; EP, 11.0%), stereotyped behavior (BP, 4.1%; EP, 1.9%), and stationary behavior (BP, 37.8%; EP, 21.7%). Finally, during the EP, the young female showed, with statistically significant differences, an appearance of stereotyped behavior (BP, 0.0%; EP, 14.2%) and a decrease in vigilance (BP, 25.2%; EP, 16.5%) and solitary play (BP, 2.6%; EP, 2.0%).

The percentages and statistically significant differences in activity for the period of time in the two studied phases are shown through adjusted residuals in Table 5. The statistically significant differences during the EP for the old female in the morning were observed as increases in exploration, vigilance, and stationary behaviors. In the midday, an increase in stationary behaviors and decreases in exploration, vigilance, locomotion, and manipulation occurred. In the afternoon, locomotion increased and stationary behavior decreased.

The statistically significant differences during the EP for the male in the morning were observed as increases in not being visible, vigilance, solitary play, stereotyped behavior, and stationary behavior and as a decrease in locomotion. In the midday, an increase in not being visible and solitary play behavior were observed, and in the afternoon, there were increases in not being visible, locomotion, and solitary play behavior and a decrease in vigilance, stereotyped behavior, and stationary behavior. The statistically significant difference during the EP for the young female was observed in stereotyped behavior in the three periods of day. These statistically significant differences were also observed in the morning as an increase in vigilance and as a decrease in solitary play, and in the afternoon, they were observed as an increase in solitary play.

Table 6 shows the values of chi-square and Fisher’s tests to determine the statistically significant differences between the uses of space in the three brown bears for the two studied phases. The long-term evaluation in the three bears showed statistically significant differences in the use of Zones 2 and 10, Zones 3 and 11, Zones 4 and 12, and Zones 6 and 14. During the EP, the old female showed, with statistically significant differences, an increase in use of Zone 9 (BP, 9.5%; EP, 17.6%), Zone 10 (BP, 4.3%; EP, 9.7%), and Zone 13 (BP, 5.4%; EP, 28.4%), as well as a decrease in Zone 11 (BP, 23.0%; EP, 17.6%), Zone 12 (BP, 27.7%; EP, 10.3%), Zone 14 (BP, 4.3%; EP, 2.4%), Zone 15 (BP, 14.2%; EP, 5.8%), and Zone 16 (BP, 11.6%; EP, 8.2%).

During the EP, the male showed, with statistically significant differences, an increase in use of Zone 2 (BP, 11.8%; EP, 15.3%) and Zone 3 (BP, 5.2%; EP, 12.2%), as well as a decrease in Zone 4 (BP, 9%; EP, 6.7%), Zone 5 (BP, 19.8%; EP, 7.2%), and Zone 6 (BP, 21.1%; EP, 6.4%). During the EP, the young female showed, with statistically significant differences, an increase in use of Zone 2 (BP, 8.2%; EP, 15.9%), Zone 3 (BP, 15.9%; EP, 18.9%), and Zone 6 (BP, 21.3%; EP, 31.8%), as well as a decrease in Zone 4 (BP, 11.0%; EP, 8.8%).

The percentages and statistically significant differences—through adjusted residuals—of the use of space for the period of time in the two studied phases are shown in Table 7. During the EP, the old female showed, with statistically significant differences, in the morning a decrease in use of Zone 10, Zone 11, Zone 15, and Zone 16; in the midday an increase in use of Zone 9 and Zone 13 and a decrease in use of Zone 12, Zone 14, Zone 15, and Zone 16; and finally, in the afternoon, an increase in use of Zone 14 and a decrease in use of Zone 13. During the EP, the male showed, with statistically significant differences, in the morning an increase in use of Zone 2 and a decrease in use of Zone 3 and Zone 5; and in the midday, the male showed an increase in use of Zone 3 and Zone 6 and a decrease in use of Zone 2. During the EP, the young female showed, with statistically significant differences, in the morning an increase in use of Zone 6 and a decrease in use of Zone 3 and Zone 4; in the midday, she showed an.
Table 5. Percentage of each activity for periods of time and two studied phases.

| Activity          | Old female | Male     | Young female |
|-------------------|------------|----------|--------------|
|                   | BP         | EP       | BP           | EP           | BP           | EP           |
|                   | Morning    | Midday   | Afternoon    | Morning      | Midday       | Afternoon    |
| Exploration       | 20.0       | 33.3     | 46.7         | 48.9*        | 8.5*         | 42.6         |
| Vigilance         | 35.8       | 32.1     | 32.1         | 53.8*        | 13.8*        | 32.3         |
| Locomotion        | 44.0       | 36.6     | 19.4         | 38.6         | 13.6*        | 47.7*        |
| Scent marking     | 0.0        | 0.0      | 0.0          | 0.0          | 0.0          | 0.0          |
| Feeding           | 14.3       | 52.4     | 33.3         | 37.5         | 0.0*         | 62.5         |
| Solitary play     | 0.0        | 0.0      | 0.0          | 0.0          | 0.0          | 0.0          |
| Maintenance       | 50.0       | 25.0     | 25.0         | 40.0         | 40.0         | 20.0         |
| Manipulation      | 0.0        | 100.0    | 0.0          | 50.0         | 0.0*         | 50.0         |
| Human interaction | 33.9       | 39.0     | 27.1         | 41.7         | 41.7         | 16.7         |
| Stereotyped behavior | 0.0      | 0.0      | 0.0          | 0.0          | 0.0          | 0.0          |
| Stationary        | 7.0        | 4.7      | 88.4         | 22.2*        | 53.3*        | 24.5*        |
| Not visible       | 33.3       | 22.2     | 44.4         | 31.8         | 9.1          | 59.1         |

*Significantly different from baseline: p < .05.
increase in use of Zone 4 and a decrease in use of Zone 2; and finally, in the afternoon, she showed a decrease in use of Zone 4 and Zone 6.

Table 8 shows the values of the SPI with their statistically significant differences for the two studied phases and for the three subjects studied. During the EP, only the old female used the space more homogeneously than she did in the BP. Meanwhile, the male and the young female used the space less homogeneously during the EP than they did during the BP. The three brown bears used the space differently during the two studied phases.

**Discussion**

The evaluation of a feeding, sensorial, and occupational environmental enrichment program allowed us to determine the long-term effect on the enrichment in the brown bears’ daily activity and use of space. During the EP, there were desirable behaviors to enhance in relation to daily activity (e.g., species-typical behaviors), undesirable behaviors to decrease (e.g., behaviors derived from poor captive environments), or determined behaviors to avoid as far as extreme values (e.g., locomotion, maintenance, or stationary; Shepherdson, 2013).

The first group included daily activity patterns with values that should have decreased during the EP. One pattern was human interaction. In general, the effect of the visitors on animal behavior has been described as positive, neutral, or negative (Soriano, Vinyoles, & Maté, 2013). In this case, the human interaction had a negative impact because the brown bears ate inappropriate food (i.e., chips, cookies, sausage, and so on) in large quantities (Markowitz, 1982). During the EP, only the young female showed a disappearance of this activity, which was also observed in a study of the effects of enrichment on captive long-tailed otters (*Lontra longicaudis*; Sevghenian, Bosso, & Tabach, 2007). Stereotyped behavior was another pattern. The old female did not show stereotyped behavior in any of the two study phases, perhaps because she was born in captivity and her forefathers were too. During the EP, the male’s stereotyped behavior decreased, but the young female’s stereotyped behavior appeared. In general, the young animals seem to develop fewer stereotypies because they have more behavioral plasticity during their ontogeny (Mason & Rushen, 2006). A study in Asiatic black bears (*U. thibetanus*) and Malayan sun bears (*Helarctos malayanus*) showed that the frequencies of stereotypies increase with the age of the animals (Vickery & Mason, 2003). More studies will be necessary to determine if animals who are wild-caught are more sensitive in captivity to the development stereotypies than captive-born animals, and to determine the relation between the development of stereotypies and the time spent in captivity or the number of generations lived in captivity.
Table 7. Percentages for each spatial category, periods of time, and two studied phases.

| Zones   | Old female | | | Male | | | Young female | | |
|---------|------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| E1 E2  | Morning | Midday | Afternoon | Morning | Midday | Afternoon | Morning | Midday | Afternoon | Morning | Midday | Afternoon |
| Zones 1 | 25.0 | 11.4 | 63.6 | 12.2 | 40.2* | 47.6 | 30.1 | 46.9 | 23.0 | 34.1 | 38.8 | 27.1 | 49.0 | 18.0 | 33.0 | 34.3 |
| Zones 2 | 55.0 | 15.0 | 30.0 | 24.4* | 35.6 | 40.0 | 9.1 | 56.4 | 34.5 | 52.1* | 15.5* | 32.4 | 26.3 | 42.1 | 31.6 | 37.8 | 18.9* | 43.2 |
| Zones 3 | 43.0 | 27.1 | 29.9 | 61.0* | 18.3 | 20.7 | 58.3 | 12.5 | 29.2 | 31.6* | 38.6* | 29.8 | 55.7 | 19.3 | 25.0 | 16.7* | 41.7 | 41.7 |
| Zones 4 | 28.7 | 31.0 | 40.3 | 43.8 | 10.4* | 45.8 | 38.1 | 28.6 | 33.3 | 19.4 | 16.1 | 64.5 | 33.3 | 37.3 | 29.4 | 12.2* | 85.4* | 2.4* |
| Zones 5 | 20.0 | 20.0 | 60.0 | 13.6 | 56.8* | 29.5* | 65.2 | 7.6 | 27.2 | 14.3* | 45.7* | 40.0 | 65.2 | 17.4 | 17.4 | 51.9 | 22.2 | 25.9 |
| Zones 6 | 30.0 | 65.0 | 5.0 | 9.1 | 9.1* | 81.8* | 12.6 | 23.3 | 64.1 | 20.0 | 53.3* | 26.7 | 12.1 | 54.5 | 33.3 | 33.8* | 45.3 | 20.9* |
| Zones 7 | 25.8 | 56.1 | 18.2 | 70.4* | 7.4* | 22.2 | 46.2 | 30.8 | 23.1 | 20.0 | 40.0 | 40.0 | 19.4 | 35.5 | 45.2 | 33.3 | 16.7 | 50.0 |
| Zones 8 | 40.7 | 42.6 | 16.7 | 76.3* | 0.0* | 23.7 | 30.4 | 30.4 | 39.1 | 23.5 | 11.8 | 64.7 | 22.9 | 14.3 | 62.9 | 36.4 | 9.1 | 54.5 |

E1 Male and young female.
E2 Old female.
Statistically significant differences: p < .05.
The decrease in the stereotyped behavior in the male during the EP is consistent with the results of Morimura and Ueno (1999), who studied how the brown bears’ stereotypies disappeared due to the effect of a feeding enrichment program. Hare (1995) also showed a decrease in brown bears’ stereotypies during a feeding enrichment program. On the other hand, Broom (1983) suggested that more than 10% of activity in stereotyped behavior was not acceptable in terms of animal welfare. During the EP, the old female and the male showed acceptable values, unlike the young female, who showed an unacceptable value.

During the EP, the male showed an increase in not being visible; meanwhile, the young female showed a disappearance. The increase in visibility during the enrichment programs has also been observed in other studies with Asian elephants (Elephas maximus; Stoinski, Daniel, & Maple, 2000), Sumatran tigers (Panthera tigris sumatrae), and African lions (P. leo; Bashaw et al., 2003).

The second group included daily activity patterns with values that should have increased during EP. Exploration was one pattern. During EP, this behavior only increased in the old female during the morning, and it decreased at midday, unlike the behavior of two brown bears from the San Diego Zoo whose exploration increased in the three periods of day during a feeding enrichment program (Hare, 1995).

Scent marking was another pattern observed. During the EP, the three brown bears did not show differences in relation to scent marking, unlike a study with maned wolves (Chrysocyon brachyurus) in which scent marking increased during the enrichment program (Cummings, Brown, Rodden, & Songsasen, 2007).

The unique change observed in relation to feeding was observed in the old female, with a decrease during the EP, unlike the increase observed in four adult Malayan sun bears during an unpredictable feeding enrichment (Schneider et al., 2014) and in brown bears during a feeding enrichment program (Grandia et al., 2001; Morimura & Ueno, 1999).

During the EP, the young female showed a decrease in solitary play; meanwhile, the same behavior appeared in the brown bear male. This behavior was also observed in the Nile soft-shelled turtle (Trionyx triunguis), whose play behavior increased in the presence of enrichment devices (Burghardt, Ward, & Roscoe, 1996).

During the EP, the manipulation only increased in the old female. This increase was also observed in chimpanzees (Pan troglodytes) with the implementation of different tool tasks (Brent & Eichberg, 1991; Celli, Tomonaga, Udono, Teramoto, & Nagano, 2003).

The third group included daily activity patterns with extreme values that indicate poor welfare of animals surely due to understimulated zoo environments. The optimal values should be known based on the studies conducted with wild brown bears, so that enrichment programs can be adapted to ensure empowerment through species-specific behaviors (Veasey, Waran, & Young, 1996). Roth (1983) determined that wild European brown bears spent 50% of the time engaged in active behaviors, which was the case for both of the female brown bears during the EP. The experimental design of future studies in ursid species should take into account the possible seasonal variations. This group included vigilance, maintenance, locomotion, and stationary.

During the EP, vigilance significantly decreased in the three brown bears. In another study on a structural enrichment program with the same old female and with the same male, this behavior

| Table 8. Chi-square values and SPI for the three subjects and the two studied phases. |
|---------------------------------|-------|-------|-------|-------|-------|-------|
|                                 | Old female |     | Male |     | Young female |     |
|                                 | BP    | EP    | BP    | EP    | BP    | EP    |
| SPI value                       | 0.31  | 0.29  | 0.33  | 0.41  | 0.27  | 0.46  |
| Chi-square value                | 156.12 | 115.27 | 108.43 |  |
| df                              | 7     | 7     | 7     |  |
| *P                              | 0*    | 0*    | 0*    |  |

Note. SPI = spread-of-participation index; BP = baseline phase; EP = enrichment program phase. *Statistically significant differences: p < .05.
increased (Soriano et al., 2006). The three brown bears did not change maintenance behavior during the EP, although the same old female and the same male increased maintenance during a structural enrichment program (Soriano et al., 2006).

During the EP, locomotion decreased in the old female but increased in the male, although the opposite results were observed during structural enrichment for the same animals (Soriano et al., 2006). The high values of locomotion and maintenance may be interpreted as stereotypies such as pacing or self-biting, respectively (Fox, 1968). During the EP, stationary behavior increased in the old female and decreased in the male; meanwhile, for the same animals, this behavior increased during a structural enrichment program (Soriano et al., 2006). The 13 brown bears of Ouwehands Zoo also decreased inactivity during the enrichment programs (Grandia et al., 2001).

The principal aim of the enrichment programs is to increase the homogeneity of the use of space (Shepherdson, 2013; Young, 2003). At the Barcelona Zoo during the EP, only three zones were used more homogenously; as a consequence, other zones lost their homogeneity. Hare (1995) observed that some brown bears used the zones differently than in the nonenrichment phase like the brown bears of this study. The old female was the unique brown bear who showed a use of space more homogeneously during the EP than during the BP, although the three brown bears showed statistically significant differences.

Different studies about the SPI were used to study the effect of environmental enrichment on different species of mammals. Some results demonstrated a use of space more homogeneous in kinkajous (Potos flavus; Blount & Taylor, 2000), fishing cats (Felis viverrina; Shepherdson et al., 1993), and tigers (P. tigris; Walters, 2003). Other studies did not show statistically significant differences such as studied of South American tapirs (Tapirus terrestris; Sharpe, 1997) and brown bears (Soriano et al., 2006).

**Conclusion**

This study provides several new suggestions for future research. Grandia et al. (2001) and Morimura and Ueno (1999) proposed that the bears’ management should include a pattern related to scatter food six times daily to stimulate a more natural behavior. It would be interesting to propose an increase in the bears’ feeding frequency at Barcelona Zoo and other zoos and then examine the effects.

The long-term studies have some disadvantages because they are conducted over time and the immediate effects of enrichment in animals are unknown. However, these studies have one advantage because they can show what happens after the enrichment application. In many cases, the short-term evaluation showed encouraging results in terms of animal welfare, but they seemed to disappear over time. In many cases, this disappearance—also called habituation—means that the short-term evaluation may overestimate the enrichment program effects (Anderson, Arun, & Jensen, 2010).

Finally, the results showed how the three subjects responded differently to the environmental enrichment period. This was also observed during structural enrichment in the same old female and the same male of this study (Soriano et al., 2006) and in another study in giant pandas (Ailuropoda melanoleuca; Hare, Ripsky, Battershill, Hawk, & Swaisgood, 2003). Future studies on environmental enrichment should take into account not only species differences, but also differences between individual animals of the same species. Currently, zoos are developing an interest in the needs of individual animals to improve their welfare and enhance conservation of the species (Carere & Eens, 2005).

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References

Altmann, J. (1974). Observational study of behavior: Sampling methods. *Behaviour, 49*, 227–267.

Anderson, C., Arun, A. S., & Jensen, P. (2010). Habituation to environmental enrichment in captive sloth bears: Effect on stereotypies. *Zoo Biology, 29*, 705–714.

Bashaw, M. J., Bloomsmit, M. A., Marr, M. J., & Maple, T. L. (2003). To hunt or not to hunt? A feeding enrichment experiment with captive large felids. *Zoo Biology, 22*, 189–198.

Blount, J. D., & Taylor, N. J. (2000). The relative effectiveness of manipulable feeders and olfactory enrichment for kinkajous. *International Zoo Yearbook, 37*, 381–394.

Brent, L., & Eichberg, J. W. (1991). Primate puzzleboard: A simple environmental enrichment device for captive chimpanzees. *Zoo Biology, 10*, 353–360.

Broom, D. M. (1983). Stereotypies as animal welfare indicators. *Current Topics in Veterinary Medicine and Animal Science, 23*, 81–87.

Burghardt, G. M., Ward, B., & Roscoe, R. (1996). Problem of reptile play: Environmental enrichment and play behavior in a captive Nile soft-shelled turtle (*Tryonix triunguis*). *Zoo Biology, 15*, 223–238.

Carere, C., & Eens, M. (2005). Unraveling animal personalities: How and why individuals consistently differ. *Behaviour, 142*, 1149–1157.

Carlstead, K., Seidensticker, J., & Baldwin, R. (1991). Environmental enrichment for zoo bears. *Zoo Biology, 10*, 3–6.

Cariati, M. L., Tomonaga, M., Udoni, T., Teramoto, M., & Nagano, K. (2003). Tool use task as environmental enrichment for captive chimpanzees. *Applied Animal Behaviour Science, 81*, 171–182.

Cummings, D., Brown, J. L., Rodden, M. D., & Songsasen, N. (2007). Behavioral and physiologic responses to environmental enrichment in the maned wolf (*Chrysocyon brachyurus*). *Zoo Biology, 26*, 331–343.

Dickens, M. (1955). A statistical formula to quantify the ‘spread-of-participation-index’ in group discussion. *Speech Monographs*, 22, 28–31.

Forthman, D. L., & Bakeman, R. (1992). Environmental and social influences on enclosure use and activity patterns of captive sloth bears (*Ursus ursinus*). *Zoo Biology, 11*, 405–415.

Forthman, D. L., Elder, D. E., Bakeman, R., Kurkowski, T. W., Noble, C. C., & Winslow, S. W. (1992). Effects of feeding enrichment on behavior of the three species of captive bears. *Zoo Biology, 11*, 187–195.

Fox, M. W. (1968). *Abnormal behavior in animals*. Philadelphia, PA: W. B. Saunders.

Grandia, P. A., van Dijk, J. J., & Koene, P. (2001). Stimulating natural behavior in captive bears. *Ursus, 12*, 199–202.

Haberman, S. J. (1978). *Analysis of qualitative data* (Vol. 1). New York, NY: Academic Press.

Hare, V. J. (1983). Diel activity of a remnant population of European brown bears (*Ursus arctos gyas*) using automated food dispensers. In B. Holst (Ed.), *Proceedings of the Second International Conference on Environmental Enrichment* (pp. 39–61). Copenhagen, Denmark: The Shape of Enrichment, Inc.

Hare, V. J., Ripsky, D., Battershill, R., Hawk, K., & Swaisgood, R. (2003). Giant panda enrichment: Meeting everyone’s needs. *Zoo Biology, 22*, 401–416.

Larsson, H. O., & Tove, S. (1995). Daily activity and effects of feeding enriched environment in brown bear (*Ursus arctos*). In B. Holst (Ed.), *Proceedings of the Second International Conference on Environmental Enrichment* (p. 289). Copenhagen, Denmark: The Shape of Enrichment, Inc.

Law, G., & Reid, A. (2010). Enriching the lives of bears in zoos. *International Zoo Yearbook, 44*, 65–74.

Lehner, P. N. (1998). *Handbook of ethological methods* (2nd ed.). Cambridge, England: Cambridge University Press.

Markowitz, B. (1982). An alternative to begging bears. In H. Markowitz (Ed.), *Lehner, P. N. (1998). Morimura, N., & Ueno, Y. (1999). Influences on the feeding behavior of three mammals in the Maruyama Zoo: Bears, elephants, and chimpanzees. *Journal of Applied Animal Welfare Science, 2*, 169–186.

Novak, M. A., Kinsey, J. H., Jorgensen, M. J., & Hazen, T. J. (1998). Effects of puzzle feeders on pathological behavior in individually housed rhesus monkeys. *American Journal of Primatology, 46*, 213–227.

Roth, H. U. (1983). Diel activity of a remnant population of European brown bears. *International Conference on Bear Research and Management, 5*, 223–229.

Schneider, M., Nogge, G., & Kolter, L. (2014). Implementing unpredictability in feeding enrichment for Malayan sun bears (*Helarctos malayanus*). *Zoo Biology, 33*, 54–62.

Sevghenian, E., Bosso, P. L., & Tabach, R. (2007). Enrichment techniques to minimize the public influence on captive otters (*Lontra longicaudis*) at Fundação Parque Zoológico de São Paulo, São Paulo, Brazil. In V. J. Hare & J. E. Kroshko (Eds.), *Proceedings of the Eighth International Conference on Environmental Enrichment* (pp. 261–262). San Diego, CA: Shape of Enrichment.
Sharpe, S. (1997). Environmental enrichment for singly-housed South American tapirs. *International Zoo News*, **44**, 85–95.

Shepherdson, D. J. (2003). Environmental enrichment: Past, present and future. *International Zoo Yearbook*, **38**, 118–124.

Shepherdson, D. J. (2013). Enrichment. In M. D. Irwin, J. B. Stoner, & A. M. Cobaugh (Eds.), *Zookeeping: An introduction to the science and technology* (pp. 407–415). Chicago, IL: University of Chicago Press.

Shepherdson, D. J., Carlstead, K., Mellen, J. D., & Seidensticker, J. (1993). The influence of food presentation on the behavior of small cats in confined environments. *Zoo Biology*, **12**, 203–216.

Soriano, A. I. (2013). *Wild ideas: Atlas fotográfico sobre el enriquecimiento ambiental* [Wild ideas: Environmental enrichment photographic atlas]. Almería, Spain: Editorial Círculo Rojo.

Soriano, A. I., Ensenyat, C., Serrat, S., & Maté, C. (2006). Introducing a semi-naturalistic exhibit as structural enrichment for two brown bears (*Ursus arctos*): Does this ensure their captive well-being? *Journal of Applied Animal Welfare Science*, **9**, 299–314.

Soriano, A. I., Vinyoles, D., & Maté, C. (2013). The influence of visitors on behavior and on the use of space in two species of Ursids: A management question? *International Zoo News*, **60**, 341–356.

Spendrup, S., & Larsson, H. O. (1997). A comparative study of brown bear *Ursus arctos* in five different enclosure sizes and types. In V. J. Hare & K. E. Worley (Eds.), *Proceedings of the Third International Conference on Environmental Enrichment* (pp. 391–398). Orlando, FL: The Shape of Enrichment, Inc.

Stirling, I. (1993). *Bears: Majestic creatures of the world*. London, England: Harper Collins.

Stoinski, T. S., Daniel, E., & Maple, T. L. (2000). A preliminary study of the behavioral effects of feeding enrichment on African elephants. *Zoo Biology*, **19**, 485–493.

Swaisgood, R. R., & Shepherdson, D. J. (2005). Scientific approaches to enrichment and stereotypies in zoo animals: What’s been done and where should we go next? *Zoo Biology*, **24**, 499–518.

Veasey, J. S., Waran, N. K., & Young, R. J. (1996). On comparing the behaviour of zoo housed animals with wild conspecifics as a welfare indicator. *Animal Welfare*, **5**, 13–24.

Vickery, S. S., & Mason, G. J. (2003). Behavioral persistence in captive bears: Implications for reintroduction. *Ursus*, **14**, 35–43.

Walters, T. (2003). Observations of the short-term behavioural response of a captive male tiger (*Panthera tigris*) to changes in feeding enrichment. *Ratel*, **30**, 29–47.

Young, R. J. (2003). *Environmental enrichment for captive animals* (Universities Federation for Animal Welfare). Oxford, England: Blackwell.