Improving the welfare of a zoo-housed male drill (*Mandrillus leucophaeus poensis*) aggressive towards visitors

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Running headline: IMPROVING THE WELFARE OF AN AGGRESSIVE MALE DRILL

Improving captive animal welfare and maintaining its behavioral competence for future conservation purposes is of highest priority for zoos. The behavior of an aggressive male drill (*Mandrillus leucophaeus poensis*) was assessed in Barcelona zoo. The two-year study presented in this article examines the effects of introducing changes in the exhibit of the drill in order to improve its welfare by analyzing scan behaviors. First, a partial visual barrier was applied which proved to be insufficient to decrease the long-term stress indicators assessed. After this a feeding enrichment program was implemented. The results obtained supported our hypothesis that feeding and explorative activities would increase whereas apathetic and stereotypic behavior would decrease. However, the visitor-directed aggression did not vary, indicating that more profound structural modifications were needed to reduce the negative impact of the agonistic interactions between the drill and the public. The study emphasizes the usefulness of environmental enrichment evaluations in assessing captive animal welfare.

Keywords: Activity patterns, aggression, feeding enrichment, animal welfare, space use.

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Introduction

Most modern z*o*os have five primary, interconnected goals: animal welfare, conservation, education of the public, research, and entertainment (Fernandez et al., 2009). Maintaining natural behaviors in captive animals is vital to the success of conservation efforts such as education and reintroduction into their native habitat (McPhee & Carlstead, 2010). When an animal lacks control over its interactions with the environment because there is frustration or unpredictability, its welfare is compromised (Broom & Johnson, 1993) and, consequently, so are its conservation and educational roles. Moreover, when welfare is not guaranteed, the consequences can be highly deleterious for the individual. As reviewed by McPhee and Carlstead (2010), prolonged periods of high levels of hypothalamic pituitary-adrenal activity in response to repeated or chronically present stressors may have costly biological consequences, such as immunosuppression and disease, atrophy of tissues, decreased reproductive function, or maladaptive behavior including various combinations of protective or defensive behavior. The consequences of these stress related situations can lead to responses that include increased aggression, stereotypies and apathetic or unresponsive behavior which can be considered indicatives of poor animal welfare (Broom & Johnson, 1993).

Many zoos are harboring threatened species, with stocks mainly originating from wild-caught animals, kept under sub-optimal environmental conditions. Zoos should consider the possibility of providing stimulation for such animals in order to simulate the conditions of natural environments Non-human primates are especially sensitive to behavioral management practices (Coleman, 2012). The public attending the zoo does not like to watch sick animals or animals that show aggressive behaviors. However, animals (especially primates) in poor welfare conditions exacerbate these behaviors under the influence of visitors. Several studies have indicated that the presence of visitors may have adverse effects on primate behavior (see, for example, Chamove et al., 1988). Maintaining the psychological, as well as the physical, well-being of primates is of paramount importance to zoos (Hosey, 2005). This is of great importance when managing a threatened species because one wild individual represents a contribution to its genetic heritage of incalculable value and its conservation may depend on the reproduction of a limited number of captive specimens. Because of this commitment, few zoos house endangered species. Zimmerman & Wilkinson (2007) found that for 72% of institutions, fewer than 30% of their species were listed in an IUCN threat category. These data were obtained from surveys conducted at 725 zoos and aquariums from 68 countries, among which only 190 institutions from 40 countries responded. This constitutes a response rate of 27%, or approximately 16% of the WAZA network. Other information obtained from the ZAW (Zoos and Aquariums of the World, which is available from the International Zoo Yearbook) shows the number of animals belonging to threatened species kept in captivity (according to census data IZY of rare animals). According to this information source, zoological institutions in Europe (including zoos and aquariums) show a ratio of only 5.69 individuals per center belonging to threatened species. This average is 8.79 in Africa 7.75 in America, 5.84 in Asia and 6 in Australasia. According to this census, the proportion of individuals of rare species calculated for all zoological institutions worldwide is 6.53 (Fisken et al., 2010; Fa et al., 2011). Apart from the obvious benefit to the animals, environmental enrichment makes the exhibition of captive animals more acceptable to the public. In order to improve the welfare of captive animals, environmental enrichment has become a common practice in many zoos. Behavioral opportunities that may arise or increase as a result of environmental enrichment can be appropriately described as behavioral enrichment (Shepherdson, 1994). The goals of environmental enrichment are to (1) increase behavioral diversity; (2) reduce the rate of abnormal behaviors; (3) increase the range or number of normal (i.e. wild) behavior patterns; (4) increase positive utilization of the environment and (5) increase the ability to cope with challenges in a more natural way (Young, 2003). Several studies have proved the positive effects of feeding enrichment in primates by detecting a significant reduction in agonism and abnormal behaviors (Bloomsmith et al., 1988; Pyle et al., 1996) or stimulating activity (Anderson & Chamove, 1984; Reinhardt, 1994).

The drill (*Mandrillus leucophaeus*) is a primate belonging to the family Cercopithecidae. It is listed as Endangered in the IUCN Red List since 1986. Wild populations occur along the Sanaga and Cross rivers in Cameroon and Nigeria. There is a population of the subspecies *M. l. poensis* on Bioko Island (Groves, 2001; Grubb, 1973). As they have a very limited distribution, drills are especially vulnerable to habitat loss and fragmentation, as well as to pressures from the bush meat trade. This poses a serious threat on the sustainability of their populations (Gadsby et al., 1994; Ting et al., 2012). In fact, there is a concern for their survival and, on the basis of taxonomic distinctiveness and degree of threat, the species is of the highest priority for the African primate conservation action (Astaras et al., 2008; Maté & Colell, 1995; Oates, 1996; Wild et al., 2005). Due to the limited number of drills in the wild (see Morgan et al., 2013), it is extremely important to ensure the survival of this species through captive populations. In order to accomplish this goal, more behavioral studies performed under different conditions of captivity and in different types of zoos (such as the one conducted by Marty et al., 2009) are needed. Zoological parks worldwide have achieved a high reproductive rate so that the number of individuals kept in captivity is growing. According to the last published International Studbook from 2007, the number of captive drills was 245 (110.133.2) held in 19 institutions worldwide (Knieriem, 2007).

The main purpose of this study was to investigate the effect of a partial visual barrier and the efficiency of a feeding enrichment program over two indicators of poor animal welfare (aggression and stereotypies) in a male drill (*M. l. poensis*) housed at Barcelona Zoo. This male was a wild-born specimen which performed important and frequent assaults to the visitors resulting in large crowds of people in front of his cage. These assaults were observed during more than 10% of the time when performing behavioral records. This feedback loop aggressive behavior ended up with outbursts. This male drill was the breeding partner of a female (also caught from the wild) whose behaviors observed at any given point in time were not described as abnormal or aberrant. For this reason, we focused on the analysis of the highly aggressive male, who posed a serious problem given its adverse interaction with visitors. Our concern to improve the welfare of the male and promote its breeding in captivity led us to the implementation of the aforementioned enrichment programs and the evaluation their effectiveness. During one year, preliminary observations were done in order to assess the male's behavior and activity pattern. We tested the hypotheses that, on the one hand, levels of long-term poor animal welfare indicators would decrease and that, on the other hand, normal solitary and social behavioral patterns would increase. The use of space was also analyzed in this study as an indicator of enclosure appropriateness.

Materials and Methods

Subjects

The study subject was a male drill (*M. l. poensis*) that lived together with the female drill. Both individuals were confiscated from a circus and are thought to have been wild caught from Bioko Island. They have been housed together at Barcelona Zoo since March 1987. At the time of the study the age of both animals was estimated to be around 9-10 years old.

Housing and husbandry

The outdoor enclosure was an irregular $40m^2$ rectangle (8 x 5 x 4 m) with tiled walls fronted by a thick $21m^2$ (7 x 3) glass window starting at one meter from the floor. Apart from one small corner, the public had visual access to the entire enclosure. The structural elements of the exhibit consisted of four wooden platforms of various sizes and different heights (from 1 up to 2m high), one iron structure with a wooden platform 0.5m high in the center of the enclosure and a mesh roof with several ropes. The animals had year-round access to the exhibit, from approximately 10.00 to 17.00 hrs in autumn-winter (mid-September until mid-March) and from 10.00 to 20.00 hrs in spring-summer (mid-March until mid-September). Under adverse weather conditions (i.e., temperatures below 10ºC), the animals were kept in their indoor enclosures.

When the group was off-exhibit they were housed in an indoor unit which served as a dormitory and was connected to the outside enclosure via two guillotine doors. The exhibit had both natural and fluorescent light. A group of Western gorillas (*Gorilla gorilla*) were exhibited in front of the drills' enclosure enabling visual contact between them. The drills were fed twice a day. In the morning the food was placed in a pile in the center of the outside enclosure and in the afternoon the food was scattered on the floor of their night cages. The diet consisted of measured amounts of monkey chow and sliced fruits and vegetables. Water was available ad libitum through one automatic drinking nipple.

Study phases

A one-year behavioral assessment (*BePh*) of the male drill was completed to describe its behavior and seasonal activity pattern over 11 months. A baseline phase (*BaLi*) was done in order to compare it with two successive phases: *ViBa* (introduction of a partial visual barrier phase) and *FeEn* (feeding enrichment program phase). The last phase of this study (*Non-FeEn*) was used to evaluate the effectiveness of the feeding enrichment program (**Table 1**).

Behavioral assessment phase (BePh): Behavioral activity patterns were assessed from June 1994 to May 1995. The results of the observations made during this period (excluding the month of April due to the small sample size; **Table 1**) were compared with those obtained by Chang et al. (1999) who studied a group of mandrills housed in an ecologically representative exhibit at Zoo Atlanta. As there are no studies on activity budgets for free-ranging captive drills, available information about closely-related species (such as the mandrill) were used to compare our data with those obtained in animals kept in better conditions. It is assumed that this can serve as a suitable model for the drill (Terdal, 1996). The number of hours of observation and number of scans collected over 11 months are shown in **Table 1**.

Visual barrier phase (ViBa): The visual barrier phase (August-September 1996) was compared with the baseline phase (April–May 1996, BaLi). A modification was done at the exhibit with the aim of reducing the interactions between the drills and the visitors by diminishing direct visual contact (*ViBa*). A black adhesive strip 40 cm wide was placed at the bottom of the front glass together with a sticker that informed the public that hitting the glass was not permitted. The observers were allowed to warn the visitors if they disturbed the primates. Once the partial visual barrier was introduced, we started recording the drill’s position in the enclosure to establish whether upper structures and ground space were equally used. The Spread Participation Index (SPI) could not be used because the enclosure could not be divided into zones of equal size. The distance of the male to the glass (and to the public) was also recorded. Data from this phase were compared with those recorded before placing this visual barrier (*BaLi*). The number of hours of observation and number of scans collected for each phase are shown in **Table 1**.

Feeding enrichment phase (FeEn): The feeding enrichment phase (December 1996 – May 1997) was compared to the baseline phase (April – May 1996, BaLi). A feeding enrichment program was implemented in order to reinforce a primary behavioral pattern such as hiding food, as well as to offering a variety of food items that enriched the diet of the individual and increased his curiosity. The food items used during the enrichment program consisted of fruits, vegetables, nuts, cereals, pasta, rice, honey, fish puree, aromatic herbs and life prey items, such as snails and termites. At the beginning, food was offered in PVC tubes but this method proved to be easily achievable for the animal. In order to increase complexity and unpredictability, hiding places in the outdoor enclosure were used to place and scatter the enrichment items before the animal had outdoor access. Other structures used for hiding the food were boxes, sacks, mesh, shells and barrels. The number of hours of observation and number of scans collected for each phase are shown in **Table 1**.

Feeding enrichment efficiency (Non-FeEn): A non-feeding enrichment phase (April – May 1997) was interspersed during the feeding enrichment program in order to assess the long-term effectiveness of this program. These data were compared with *FeEn* and *Viba* phases. The number of hours of observation and number of scans collected for each phase are shown in **Table 1**.

Data collection

Hearn et al. (1987, 1988) developed a protocol for behavioral studies of confined drills which we adapted for this research (**Table 2**). Two observers (Maté, C. and Martin, M.) conducted the behavioral observations. To ensure between-observer reliability, 30 hrs of preliminary training observations were undertaken after which a reliability test was done (K= 98.2% according to Kappa coefficient). Each one-hr sample was divided into one-min focal periods. We calculated the proportion of all sample intervals during which the behavior pattern occurred. We performed 260 hrs of observations between June 1994 and June 1997 (**Table 1**). One-hr observation sessions were balanced across the 10.00-20.00 hrs exhibition period in spring-summer (mid-March until mid-September) and 10.00-17.00 hrs exhibition period in autumn-winter (mid-September until mid-March) from Monday to Sunday. Usually two sessions per day at different hourly intervals were done. Observations were made using instantaneous scan sampling of the individuals at one-min intervals (Altmann, 1974). Scan data were used to determine the proportion of all sample intervals during which the behavior pattern occurred. In this study, visitor-directed aggression and stereotypes were used as behavioral symptoms indicative of a compromised welfare. Temperature (ºC) and relative humidity (%) were also taken to assess the possible effect of environmental variables on the male drill behavior, during the sampling days. These data were provided by the "Servei Metereològic de Catalunya". Following the criterion of NRC (1996), the recommended temperature and relative humidity ranges for captive primates are between 18-24ºC and 30-70%, respectively. Both variables were within the recommended ranges over the study periods. The mean temperature and relative humidity in Barcelona metropolitan area did not vary much between the study years (17.4ºC and 77% for 1994-95, and 16.2ºC and 80.3% for 1996-97); the Mediterranean climate does not show extreme seasonal variations which minimizes the effect of season and other confounding factors (Dawkins, 2007).

Data analysis

χ^2 tests of independence were conducted to compare the proportions of the behavioral categories across phases. When expected frequencies lower than 5 were present, p-values were computed from a Monte Carlo test. The influence of each category on the significance of a given test was determined by the absolute value of the Pearson residuals of such categories, being those with values greater than 2 significant contributors. The program *R* (*R* Development Core Team, 2012) was used for the analyses.

Results

One-year behavioral assessment (BePh)

The average occurrence of behaviors of the male drill were: 3% social interactions, 16% feeding, <1% exploring, 9% moving, 11% engaged in maintenance behaviors, 38% stationary, 11% visitor-directed aggression, 4% stereotypic (repetitive) behaviors and 7% not visible (**Table 3**). The seasonal behavioral analysis showed that there are statistical differences between the four seasons (χ^2 = 379.23, d. f. = 9, P < 0.001, n = 4,806). The indicators of poor welfare decreased statistically in spring and increased in autumn. On the other hand, the drill was significantly more visible to the public in autumn and winter than in spring. During spring there was a significant increase in the social behaviors and a decrease in the solitary behavioral patterns.

Enclosure modification: Partial visual barrier

The difference between the *BaLi* and the *ViBa* was significant (χ^2 = 176.25, d. f. = 8, P < 0.001, n = 5,969; **Fig. 1**). After introducing the partial visual barrier, we observed that there were no statistical differences between the new situation and the baseline concerning the two long-term stress indicators. Stationary behavior significantly increased after applying the adhesive strip (38% vs. 27%), and this was the drill's most observed behavior. The behavior proportion of the animal being not visible in the enclosure was significantly lower than in the previous condition (i.e., *BaLi*: 33% vs 22%). However, after applying the adhesive strip, being not visible still occupied a considerable portion of the male drill's activity. Social interactions did statistically decrease (2% vs. 3%) as well as locomotion behavioral patterns (3% vs. 6%). Explorative solitary behavior increased statistically (1% vs. <1%) but it still showed a low proportion. During the *ViBa* phase, the male showed preference for the upper level of the enclosure (65%) against the ground (χ^2 =75.448, d. f. = 1, P < 0.001 with Yates' continuity correction). When the enclosure was divided into four homogeneous zones with similar structures and sizes, statistically significant differences were obtained and there was a preference for the C "up" zone (40%) (χ^2 = 1779.92, d. f. = 7, P <0.001), which is the area corresponding to the bottom part of the enclosure where the animal could remain out of sight. In this area, the percentage of occurrence of the male drill during the phase ViBa was 22%.

Feeding enrichment program

The *FeEn* and the *BaLi* phases showed statistical differences (χ^2 = 1,141.7, d. f. = 8, P < 0.001, n= 4,133; **Fig. 2**). In fact, the *FeEn* program had a significant effect in all assessed behavioral patterns but the aggressive interactions towards visitors persisted with a high frequency of occurrence of almost 7%. After applying the *FeEn*, the feeding behavior showed the highest percentage (63% vs. 15%) with a significant difference when compared to the baseline. Exploring behavior also increased statistically (1% vs. <1%)..

The stereotypic long-term stress indicator decreased significantly (<1% vs 1%). Other behaviors which had a statistically lower proportion after applying the *FeEn* were maintenance (4% vs. 7%), locomotion (3% vs. 6%) and social interactions between drills (2% vs. 3%). The stationary behavior was drastically reduced from 27% to 4%. The behavioral proportion of the male drill being out of sight decreased significantly from 33%

to 17%. During this phase, the male drill used a similar amount of ground and upper level of the enclosure, showing no preference (χ^2 = 8.32 d. f. = 1, $P < 0.005$ with Yates' continuity correction). It should be noted that when preparing the enclosure the items were spread throughout the structures and surfaces as homogeneously as possible.

Feeding enrichment efficiency

When assessing the efficiency of the enrichment program by comparing the phase in which the *FeEn* was implemented with the *Non-FeEn* (non-feeding enrichment), statistical differences were found (χ^2= 281.35, d. f. = 8, $P < 0.001$, n = 1,780). During the *FeEn* condition feeding was statistically higher and maintenance and stationary behavior were statistically lower.

Long-term benefits of the feeding enrichment program were analyzed through a final comparison between the observations undertaken during the *ViBa* and the *Non-FeEn* phase. Statistically significant differences obtained in this comparison (χ^2= 149.58, d. f. = 8, $P <$ 0.001, n= 1,596) suggest a long-term effectiveness of the feeding enrichment program. The results showed a decrease in the stationary behavior and in the visitor-aggressive interactions during the *Non-FeEn* (**Fig. 3**). On the other hand, there was an increase in the feeding behavior. All these results were statistically significant. When comparing the use of space between this phase and the previous one (*FeEn*) significant differences were observed (χ^2 = 8.3, d. f. = 1, $P < 0.05$), but none of the cells showed a significant effect that could explain the observed differences.

Discussion

When comparing the occurrence of drill behaviors with the results from Chang et al. (1999), we observed a much higher percentage of long-term stress indicators such as repetitive stereotypic behavior (4% vs. 0%), and visitor-directed aggression (11%), the latter not being observed at all at Chang et al. (1999). As stated by Broom and Johnson (1993) individuals that do not respond to events in their surroundings are clearly behaving in an abnormal and unadaptive way. This indicates that the high frequency of stationary behavior is a sign of poor welfare (38% vs. 12%). The male drill we studied had been confiscated from a circus and, even though we do not know the details of his past experience with humans, our observations suggest that he perceived humans as agonistic competitors. Hosey (2008) already pointed out that the history of interactions that animals have had with people is likely to affect how they subsequently respond to their presence. On the other hand, maintenance behavior and hiding from the public eye were higher than in Chang's et al. (1999) study (11% vs. 3% and 7% vs. 3%). In fact, the proportion of observations of the drill being not visible were lower in winter and autumn and higher in spring when the zoological collection was exhibited for three additional hours during the afternoon. This longer exhibition time, together with the high affluence of public during this season, might be extra challenging for the drill to cope with. Numerous studies show that the presence of large active groups of visitors is an important cause of stress and/or aggression for zoo primates (Chamove et al., 1988; Hosey, 2000). The international drill Studbook warns about the effect of visitors, leading to visitor-directed aggression and stereotyped behavior and encourages to taking it into consideration (Knieriem, 2007). The drill's feeding behavior occurrence was much lower than the one observed in the mandrills housed at Zoo Atlanta (16% vs. 66%). This is likely to be due to the fact that the small, poorly furnished enclosure offered limited possibilities for exploration and foraging behavior. Playing episodes were never observed and social interactions with conspecifics were very low (3 vs. 4%) but similar to the results found by Chang et al. (1999).

Drill species live in a forest habitat with plenty of natural visual barriers which are thought to limit the frequency as well as the intensity of aggressive interactions between conspecifics (Cox, 1997). Contrary to what we expected, the stationary behavior increased after introducing the visual barrier (38% vs. 27%). On the other hand, the drill was more visible than before. On the basis of the underlying analysis, the reason why these two variables increased instead of decreasing remains unclear to us. Visitor-directed aggression did not significantly decrease and remained the same (8%). Based on these results, we concluded that the partial visual barrier proved to be insufficient to prevent agonistic interactions with the visiting public. However the drill spent less time engaged in social interactions with its partner as well as in locomotive behaviors, and more time in explorative behavior. This finding agrees with the reduction of social interaction observed by MacMillan (1991) who studied the effects of visual barriers on the behavior of drill groups. Nevertheless, taking into account that the visual barrier seemed to be insufficient for reducing the long-term stress indicators as well as the increase in stationary behavior, the precise reason for the decline in social interaction remains to be fully explained. The preference of the male drill for the use of elevated platforms when the visual barrier was implemented is also surprising. This suggests that the drill used them to maintain a negative interaction with the visitors, even if such interactions entailed a decrease in social interactions with the partner. This shows that empirical measures of animal behavior and space use in a captive environment can provide critical information about the animals' requirements, preferences and possible internal states (Ross et al. 2009).

The feeding enrichment program demonstrated an impact in all the behavioral categories assessed in this study excluding visitor-directed aggression. Feeding behavior significantly increased showing a frequency similar to what can be considered a normal foraging rate as concluded by Chang et al. (1999). The explorative behavior also increased but observations concerning maintenance behavior and being not visible both significantly decreased, although these showed a higher percentage than that observed in a well-maintained stable mandrill group. This fact implies that the male drill still perceives the public in a direct way and as a challenge and seeks privacy. The results obtained after the feeding enrichment support the hypothesis that long-term stress indicators would decrease, with the observation of a significant reduction of the stereotypic behavior. This finding coincides with a reduction of the stationary behavior of the male drill. This result suggests that for this species, high levels of inactivity can be considered as a long-term stress indicator (this is, apathetic behavior) as already suggested by Broom and Johnson (1993). The indicator that did not statistically decrease was the visitor-directed aggression, which was continued with a similar proportion of 7%. This result indicates that other modifications are needed to reduce the negative impact of the agonistic interactions between the drill and the public. Finally, both locomotion and social interactions significantly reduced their rates during the feeding enrichment program. Similarly, other studies have reported reductions in social behavior after introducing foraging-based enrichment devices (Brent et al., 1989; Vick et al., 2000). The lack of preference between the ground and the upper level was possibly due to the fact that food enrichment items were distributed evenly in the enclosure. This can be seen when, during the next phase, there was a preference for “up” areas, which coincided again with the increase in "not visible". During the feeding enrichment sessions the drill doubled the feeding time and drastically reduced the stationary/apathetic behavior. As noted in a similar study with elephants, these changes are probably related straightaway: as the subjects feed more, they have less time to be inactive (Stoinski et al., 2000).

As already indicated by Shepherdson (1988), the objective evaluation of the behavioral effect of enrichment projects is of great importance. This ensures that the evidence of possible benefits is reliable and can prove that there is a significant change in the behavioral repertoire of the animals. The results of this study can be interpreted as an improvement in the drill's welfare suggesting that the positive effect of the feeding enrichment program persists over time and it is not restricted to the session when is it applied. On the other hand, visitor-directed aggression is significantly lower during the non-feeding enrichment sessions, meaning that the male drill was less interested in the public. Another valuable indicator of the success of the enrichment program is the fact that feeding behavior was significantly higher during the non-feeding enrichment. Moreover, the beneficial effects of the feeding enrichment program lasted over time. These findings are consistent with Carlstead and Shepherdson (2000) review in which they assert that inanimate enrichment increases the diversity of behaviors that an animal displays in order to interact with its environment and that it can effectively reduce captivity-induced stress.

Environmental enrichment is a common strategy for improving the welfare of captive animals. Studies of environmental enrichment such as the one presented here can help refining and improving our ability to successfully implement a variety of enrichment strategies. The contribution of our study has been to combine different enrichment strategies aimed at improving the welfare of a particular individual who was very aggressive towards visitors. The importance of such studies, despite being based on a single case, is to quantify the effect of various enrichment programs and to assess which of them happens to be the most efficient way to improve different aspects of animal welfare.

Conclusions

1. The partial visual barrier introduced was insufficient to avoid male's agonistic interactions with the visiting public. It did not result in a reduction of stereotypic behaviors.
2. The drill's distinct behavioral occurrences changed considerably towards less stereotypic behaviors after introducing a feeding enrichment program, indicating

that they can be reduced (or eliminated) when providing an environment which offers additional behavioral opportunities.

3. As predicted, introducing a feeding enrichment program led to a significant increase of feeding and explorative behaviors, and a decrease in inactivity and stereotypic behaviors. The behavioral repertoire during this phase most closely paralleled those of mandrills maintained in an ecologically representative enclosure.
4. When the feeding enrichment program was applied an unpredicted decrease in social interactions was observed.
5. The frequency of visitor-directed aggression was significantly reduced in the Non-Feed-Enrichment program, indicating that the environmental changes implemented had an effect.

References

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

Anderson, J. R., & Chamove, A. S. **(**1984). Allowing captive primates to forage. In Laboratory Animal Science Association, *Standards in laboratory animal management* (Volume 2, pp. 253-256). Potters Bar, England: Universities Federation for Animal Welfare.

Astaras, C., Mühlenberg, M., & Waltert, M. **(**2008). Note on drill (*Mandrillus leucophaeus*) ecology and conservation status in Korup National Park, Southwest Cameroon. *American Journal of Primatology*, 70, 306-310.

Bloomsmith, M. A., Alford, P. L., & Maple, T. L. **(**1988). Successful feeding enrichment for captive chimpanzees. *American Journal of Primatology*, 16, 155-164.

Brent, L., Lee, D. R., & Eichenberg, J. W. **(**1989). Evaluation of two environmental enrichment devices for singly housed chimpanzees. *American Journal of Primatology,* 1, 65-70.

Broom, D. M., & Johnson, K. G. (1993). *Stress and animal welfare*. London, UK: Chapman & Hall.

Carlstead, K., & Shepherdson, D. (2000). Alleviating stress in zoo animals with environmental enrichment. In G. P. Moberg, & J. A. Mench (Eds.), *The Biology of Animal Stress: Basic Principles and Implications for Animal Welfare* (pp. 337-354). Washington, DC: National Zoological Park, Smithsonian Institution.

Chamove, A. S., Hosey, G. R., & Schaetzel, P. (1988). Visitors excite primates in zoos. *Zoo Biology,* 7, 359-369.

Chang, T. R., Forthman, D. L., & Maple, T. L. (1999). Comparison of confined mandrill (*Mandrillus sphinx*) behaviour in traditional and "ecologically representative" exhibits. *Zoo Biology*, 18, 163-176.

Coleman, K. (2012). Individual differences in temperament and behavioral management practices for nonhuman primates. *Applied Animal Behaviour Science*, 137, 106– 113.

Cox, C. R. (1997). Drill conservation and research initiatives. In J. Wallis (Ed.), *Primate Conservation: The Role of Zoological Parks* (pp. 150-175). American Society of Primatologists.

Dawkins, M. S. (2007). *Observing animal behaviour: design and analysis of quantitative data*. Oxford: Oxford University Press.

Fa, J. E., Funk, S. M. & O'Connell, D. (2011). *Zoo Conservation Zoology*. Camdridge Univerity Press.

Fernandez, E. J., Tamborski, M. A., Pickens, S. R., & Timberlake, W. (2009). Animal–visitor interactions in the modern zoo: Conflicts and Interventions. *Applied Animal Behaviour Science*, 120, 1–8.

Fisken, F. A., Field, D. & Leus, K. (2010). *International Zoo Yearbook 44:Bears and Canids*. London: Collins.

Gadsby, E. L., Jenkins, J. R., & Feistner, A. T. C. (1994). Coordinating conservation for the drill (*Mandrillus leucophaeus*): endangered in forest and zoo. In P. J. S. Olney, G. M. Mace, & A. T. C. Feistner (Eds), *Creative conservation: interactive management of wild and captive animals* (pp. 439-454). London, UK: Chapman & Hall.

Groves, C. P. (2001). *Primate Taxonomy*. Smithsonian Series in Comparative Evolutionary Biology, Smithsonian Books.

Grubb, P. (1973). Distribution, divergence and speciation of the drill and mandrill. *Folia primatologica*, 20, 161-177.

Hearn, G. W., Weikel, E. C., & Schaaf, C. D. (1987). Brief ethogram for the drill in captivity. In M. Böer, Zoologischer Garten Hannover (Ed.), *International Studbook* (pp. 9-16.).

Hearn, G. W., Weikel, E. C., & Schaaf, C. D. (1988). A preliminary ethogram and study of social behaviour in captive drills, *Mandrillus leucophaeus. Primate report,* 19, 11-14.

Hosey, G. R. (2000). Zoo animals and their human audiences: what is the visitor effect? *Animal Welfare,* 9, 343-357.

Hosey, G. R. (2005). How does the zoo environment affect the behaviour of captive primates? *Applied Animal Behaviour Science*, 90, 107–129.

Hosey, G. R. (2008). A preliminary model of human-animal relationship in the zoo. *Applied Animal Behavior Science,* 109, 105-127.

Knieriem, A. (2007). *International studbook No.5 for drill* (Mandrillus leucophaeus). Hannover: Erlebnis Zoo Hannover.

MacMillan, G. C. (1991). The effect of environmental manipulation on drill baboon social behavior. In W. V Wheeling (Ed.), *Proceeding of the American Association of*

Zoological parks and Aquariums annual conference. American Association of Zoos and Aquariums.

Marty, J. S., Higham, J. P., Gadsby, E. L., & Ross, C. (2009). Dominance, coloration, and social and sexual behavior in male drills Madrillus leucophaeus. *International Journal of Primatology* 30, 807-823.

Maté, C., & Colell, M. (1995). Relative abundance of forest cercopithecines in Arihá, Bioko Island, Republic of Guinea Equatorial. *Folia Primatologica*, 64, 49-54.

McPhee, M. E., & Carlstead, K. (2010). The importance of maintaining natural behaviors in captive animals. In D. G. Kleiman, K. V. Thompson, & K. C. Baer (Eds.), *Wild animals in captivity: Principles and techniques for zoo management* (pp. 11-21). Chicago: University of Chicago Press.

Morgan, B. J., Abwe, E. E., Dixson A. F., & Astaras, C. (2013). The Distribution, Status, and Conservation Outlook of the Drill (*Mandrillus leucophaeus*) in Cameroon. *International Journal of Primatology*, 34, 281–302.

Oates, J. F. (1996). *African Primates: Status survey and conservation action plan*. IUCN/Species Survival Commission (SSC), Primate Specialist Group. Gland, Switzerland.

Pyle, D. A., Bennett, A. L., Zarcone, T. J., Turkkan, J. S., Adams, R. J., & Hienz, R. D. (1996). Use of two food foraging devices by singly housed baboons. *Laboratory Primate Newsletter*, 35, 10-15.

R Development Core Team (2012). R: *A language and environment for statistical computing. R Foundation for Statistical Computing*. Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/

Reinhardt, V. (1994). Caged rhesus macaques voluntarily work for ordinary food. *Primates*, 35, 95-98.

Ross, S. R., Schapiro, S. J., Hau, J., & Lukas, K. E. (2009). Space use as an indicator of enclousure appropriateness: A novel measure of captive animal welfare. *Applied Animal Behaviour Science,* 121, 42-50.

Shepherdson, D. (1988). The application and evaluation of behavioral enrichment in zoos. *Primate Report*, 22, 35-42.

Shepherdson, D. (1994). The role of environmental enrichment in the captive breeding and reintroduction of endangered species. In G. Mace, P. Olney, A. T. C. Feistner (Eds), *Creative Conservation: interactive management of wild and captive animals* (pp. 167-177). London, UK: Chapman & Hall.

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

Terdal, E. S. (1996). *Captive environmental influences on behavior in zoo drills and mandrills (Mandrillus), a threatened genus of primate*. PhD. Portland: Portland State University.

Ting, N., Astaras, C., Hearn, G., Honarvar, S., Corush, J., Burrell, A. S., Phillips, N., Morgan, B. J., Gadsby, L., Raaum, R., & Roos, C. (2012). Genetic signatures of a demographic collapse in a large-bodied forest dwelling primate (*Mandrillus leucophaeus*). *Ecology and Evolution*, 2, 550-561. doi:10.1002/ece3.98.

Vick, S. J., Anderson, J. R., & Young, R. (2000). Maracas for Macaca? Evaluation of three potential enrichment objects in two species of zoo-housed macaques. *Zoo Biology*, 19, 181-191.

Wild, C., Morgan, B. J., & Dixson, A. (2005). Conservation of drill populations in Bacossiland, Cameroon: Historical trends and current status. *International Journal of Primatology*, 6, 759-773.

Young, R. J. (2003). Allowing captive primates to forage. In Laboratory Animal Science Association, *Standards in laboratory animal management* (Volume 2, pp. 253-256). Potters Bar, England: Universities Federation for Animal Welfare.

Zimmerman, A., & Wilkinson, R. (2007). The conservation mission in the wild: zoos as conservation NGOs? In A. Zimmerman, M. Hatchwell, L. A. Dickie, & C. West (Eds.), *Zoos in the 21st Century: Catalysts for Conservation?* (pp. 303-321). Cambridge: Cambridge University Press.