Zaragoza, Félix; Ibáñez, Miguel; Mas, Blanca; Laiglesia, Santiago; Anzola, Bernadette
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Universidad del Zulia
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INFLUENCE OF ENVIRONMENTAL ENRICHMENT IN CAPTIVE CHIMPANZEEES (Pan troglodytes spp.) AND GORILLAS (Gorilla gorilla gorilla): BEHAVIOR AND FAECAL CORTISOL LEVELS

Influencia del enriquecimiento ambiental de chimpancés (Pan troglodytes spp.) y gorilas (Gorilla gorilla gorilla) en cautividad: comportamiento y niveles de cortisol en heces

Félix Zaragoza 1, Miguel Ibáñez 2, Blanca Mas 2, Santiago Laiglesia 2 y Bernadette Anzola 3

1Facultad de Veterinaria, Universidad Alfonso X el Sabio. Villanueva de la Cañada, 28691 Madrid. 2Departamento de Producción Animal, Facultad de Veterinaria. Universidad Complutense de Madrid. Avda Puerta de Hierro s/n 28040 Madrid. 3Departamento de Producción Animal. Decanato de Ciencias Veterinarias. Universidad Central de Venezuela. * Corresponding author. Tel.: +34913943760. E-mail: mibanez@vet.ucm.es

ABSTRACT

It is considered of significant importance to provide wild animals in captivity with environmental enrichment elements to improve their psychological and physiological well being, stimulating a higher activity and behavioral variety. This study evaluated the effect of different enrichment elements (explorative/manipulative, physical and feeding enrichment devices) on the behavior and physiology of two groups of great apes, gorillas (Gorilla gorilla) and chimpanzees (Pan troglodytes) at the Zoo-Aquarium of Madrid. The proposed prediction was that there would be a reduction of inactivity, anomalous and non-desired behavior, also on cortisol levels, as a result of the stimulator improvements. The behaviors and cortisol faecal levels were compared between two different conditions: 1. previous phase without enrichment, 2. enrichment phase. The data analysis allowed measuring the efficiency of the enrichment, revealing that the frequency of inactivity and anomalous behaviors was significantly reduced in the enrichment phase. On the other hand, the frequency of exploratory-manipulative behavior increased in both species, whereas locomotors and feeding behaviors were reduced in gorillas but increased in chimpanzees. Also, the preferences of chimpanzees and gorillas for the diverse enrichments elements were different. In relation to the levels of cortisol, the results do not support the proposal for the initial hypothesis, both in the case of chimpanzees as in the case of gorillas, it had increased to such levels in the enrichment phase, the increase being significant just in the gorillas. The results on the behavioral parameters are consistent with the hypothesis because there is improvement induced by environmental enrichment.

Key words: Chimpazee, gorilla, behavior, cortisol, environmental enrichment.

RESUMEN

Se considera de gran importancia proveer a los animales salvajes en cautividad de elementos para el enriquecimiento ambiental buscando mejorar su bienestar psicológico y fisiológico, estimulando así una mayor actividad y variedad del comportamiento. Este estudio evaluó el efecto de los diferentes elementos de enriquecimiento (dispositivos de tipo exploratorio/manipulativo, físico, y alimenticio) sobre el comportamiento y la fisiología de dos grupos de los grandes simios, los gorilas (Gorilla gorilla) y los chimpancés (Pan troglodytes), alojados en el Zoo-Aquarium de Madrid. La hipótesis planteada fue que habría una reducción de la inactividad, de las conductas anómalas y no deseadas, y de los niveles de cortisol, como consecuencia de las mejoras estimulantes introducidas. Tanto el comportamiento como los niveles de cortisol en heces fueron comparados bajo dos diferentes condiciones: 1. fase previa sin enriquecimiento, 2. fase de enriquecimiento. El análisis de los datos permitió medir el efecto del enriquecimiento revelando que las frecuencias de la inactividad y de las conductas anómalas se redujeron significativamente en la fase de enriquecimiento. Por otro lado, la frecuencia de la conducta exploratoria-manipulatoria aumentó en ambas especies, mientras que las frecuencias de las conductas locomotrices y alimenticias se redujeron en los gorilas, pero aumentaron en los chimpancés. Además, las preferencias de los chimpancés y de los gorilas por los distintos elementos de enriquecimiento fueron diferentes. En relación con los niveles de cortisol, los resultados no apoyan la propuesta de la hipótesis inicial; tanto en el caso de los
chimpancés como en el caso de los gorilas, hubo un incremen-
to de tales niveles en la fase de enriquecimiento, siendo signi-
ficativo dicho aumento sólo en los gorilas. Los resultados so-
bre los parámetros de comportamiento son consistentes con la
hipótesis planteada, debido a que se observaron mejorías in-
ducidas por el enriquecimiento ambiental.

**Palabras clave:** Chimpancé, gorila, comportamiento, cortisol, 
enriquecimiento ambiental.

**INTRODUCTION**

Natural environment of living animal consists of a rich
mixture of stimulant elements producing adequate responses
in order to survive and breed. However, captivity drastically af-
ffects animal behavior [23, 34, 46]. Animal confining in a cage
or pen reduces complexity and increases “predictability”, so
that several animal behavioral responses such as boredom or
pathological behavior may arise [19, 34, 76]. Abnormal behav-
ior is considered the consequence of stressing situations, stress
implying physiological and psychological responses [12,
75]. Wild animal also suffer some stress as a result of stimular
influence of natural environment. But in this case stress is ren-
dered as a benefit, for stress allows wild animal to respond to
danger situations in which organism activation is required [30,
63]. Nevertheless, captive animal under given conditions can-
not face external stressing factors and when this situation per-
sists over time, helplessness and frustration may arise [33].

Referring to animal welfare, separating physical aspects
from physiological aspects becomes very difficult. When physio-
logical needs are not covered it is highly probable that also psy-
chological needs are not covered and vice versa [25, 26, 38]. A
combination of physiological and behavioral measurements may
provide an effective way of furthering the understanding of animal
welfare [11, 67]. As physiological stress indicator, among others,
in animals as well as in humans, cortisol levels have been used
[8, 67, 77]. In highly stressing situations animal body reacts se-
creting great quantities of this substance, being its function to
cope with the stress situation and repairing the damages that
such a situation may have caused in the animal organismo [60].
Nevertheless, stress and cortisol level relationship is not always
direct, clear and simple; high stress level may increase, may de-
crease or may have no effect on cortisol levels [70].

Environmental enrichment is a concept which de-
scribes how the environments of captive animals can be
changed for the benefit of the inhabitants. Behavioral oppor-
tunities that may arise or increase as a result of environ-
mental enrichment can be appropriately described as behav-
ioral enrichment [36, 65].

Enrichment systems are devised in order to reduce the ef-
cfects of boredom and stress in captive animals and to reduce
their abnormal behaviors [26, 36, 64, 66]. Well designed en-
vironmental enrichment programs must provide well being and life
quality benefits through enhanced opportunities for the animal
eliciting natural species-typical activities and promoting in-
creased physical activity [2, 3]. Manipulating animal environ-
ment may increase daily activity and may also increase the
time spent in species typical behavior that animal would show
in the wild [80].

In the case of primate species, facilities enrichment re-
quirements are even more important because of their notorious
capacity of environment exploration, their intelligence charac-
teristics and their rich behavioral repertoire [13, 72]. Thus, pri-
mates under impoverished husbandry conditions in captivity,
lacking environment stimulation and showing inactivity routines
frequently elicit abnormal and pathological behaviors reflecting
boredom and stress in this situation [51, 61].

Therefore, zoological parks facilities for these animals re-
quire enrichment systems for the enhancement of their com-
plex behavioral repertoire resulting in the improvement of their
psychological well being and of their life quality [3, 6, 56]. Great
apes (gorillas, chimpanzees, bonobos and orangutans) exhibit
psychological and behavioral characteristics so that their hous-
ing in captivity results in mental health, social, maternal and
sexual behavior alterations [37, 39]. Abnormal behavior, stress
and boredom occurrence are generally regarded as factors indi-
cating a restrictive or impoverished captivity environment and
consequently related with enrichment systems requirement to
suppress abnormal behavior and elicit great apes typical natu-
ral behavior [28]. Due to high cognitive and manipulative skills
of these great apes, explorative behavior represents a signifi-
cative proportion in great apes' behavioral repertoire [14]. Ac-
cordingly, enrichment systems considering these characteristics
should achieve big success in generating a high response in
manipulative and explorative behaviors.

As result of the enforcement of captive chimpanzee life
quality improvement regulation (Chimpanzee Health Improve-
ment, Maintenance and Protection Act) undersigned in Decem-
ber 2000, many chimpanzees have been transferred from envi-
ronmental impoverished facilities to others provided with more
natural and enrichment devices. Studies about the effects of
several of these devices on the chimpanzee behavioral budget
changes have shown a significative increase of desirable be-
havior (mutual grooming, play, tool use, social interaction) and
significant decreases in abnormal behavior (coprophagy, hair
pulling and ingestion, self mutilation, repetitive regurgitation
and vomit ingestion, aggression, stereotyped movements such
as swinging and self embrace) [28, 32]. Thus, the im-
provement of housing facilities conditions for great apes, such
as chimpanzees and gorillas, has become a priority within the
zoological parks enrichment programs [27, 28].

The aim of present research was to study the effects of
environmental enrichment devices in captivity conditions of
wild great apes species, common chimpanzee (Pan trogl-
dytes spp.) and western plain gorilla (Gorilla gorilla gorilla). The
main proposed objectives were as follows: a) to assess behav-
ioral changes associated with environmental enrichment devices introduction in their facilities, on the hypothesis that stimulation increase in captive animals enhances activity and reduces inactivity and abnormal behaviors, and b) evaluating if this environmental stimular change results in a decrease in faecal cortisol levels.

**MATERIALS AND METHODS**

**Subjects and housing conditions**

The study was performed on two groups of housed primates, one of chimpanzees and one of gorillas, in Zoo-Aquarium in Madrid. During experimental period, the chimpanzees group included 9 individually identifiable members: 2 adult males, 3 immature males and 4 adult females. Gorillas group included 1 adult male and 3 adult females.

Chimpanzee facility consisted of a wide outside zone (469.09 m²), and 4 bedrooms (two of 9.4 m² and 11.4 m² two other). The outside zone comprised a large area with concrete floor and a low wall of 1 m high and 5 m. long as a visual barrier, also there was a strucure of wood and metal (2 x 2 m) shaped platform with two height levels where chimpanzees climbed up and lay down, additionally, in the center of the enclosure was located on an artificial mound. Covering the entire top of the exhibit, to 2.5 m height above ground, there was a metallic structure, of 3 m high, that forms a network of bars for animal climbing. Surrounding the perimeter of the cage there were several walls of glass through which the public could see the animals.

Gorillas were housed indoors. This enclosure was 182 m², with two dorm rooms of 44 and 42 m². In this exhibit, there were several main artificial rock structures, forming columns and shelves on which the gorillas could climb on it. In the center of the facility was the artificial termite mound. It also stuck to the walls, there were two small areas of natural vegetation, with a purely ornamental, surrounded by an electrical fence to prevent the gorillas from eating plants. Natural light entered the enclosure through the windows located in the top of the main room. In this exhibition, as in chimpanzees, there were several glass walls to watch the animals.

Both gorillas and chimpanzees were fed at two times of day: early morning, immediately after removing them from their bedrooms, and in the evening, shortly after entering the bedroom. The diet consisted mainly of fruits and vegetables. Access to water was *ad libitum*.

**Materials and procedures**

The study was conducted in two phases: 1) control period without enrichment and 2) enrichment phase, lasting six weeks each. Data on primate’s behavior were collected during these phases using an instantaneous scan sampling [1, 42] every ten minutes. Data compilation period extended from October 2004 to January 2005. All observations were conducted two hours and a half everyday, between 10:00 and 14:00 h. Data on activity and behavior of every animal, including individual use of enrichment devices, were taken in every sampling.

Categories of behaviors observed were as indicated in TABLE I. Enrichment devices used in phase 2 are presented in TABLE II; every week a new set of elements was introduced in alternative days, retiring the remainder of the previous one. The sixth enrichment device was different for each species: for the chimpanzees, last week enrichment device was of locomotive type, while for gorillas a manipulative-exploring device was used (TABLE II).

<table>
<thead>
<tr>
<th>Behaviour category</th>
<th>Behaviour elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inactivity</td>
<td>Sit, stand or lie</td>
</tr>
<tr>
<td>Feeding</td>
<td>Forage, eat and drink</td>
</tr>
<tr>
<td>Social</td>
<td>Allogrooming, play, display, chase, sexual, social conflicts</td>
</tr>
<tr>
<td>Locomotive</td>
<td>Brachiate, run, jump, walk</td>
</tr>
<tr>
<td>Explorative</td>
<td>Manipulative, tool use</td>
</tr>
<tr>
<td>Abnormal</td>
<td>Coprophagy and faecal manipulation, hair pulling and ingestion, repetitive regurgitation and vomit reingestion, stereotyped movements such as swinging and self embracement</td>
</tr>
<tr>
<td>Interaction with visitors</td>
<td>Every behaviour that primates performed to visitors</td>
</tr>
</tbody>
</table>

**TABLE I**

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boxes</td>
<td>Cardboard closed boxes filled with wood chips, newspapers and magazines, clothes, plastic curtains, paper strips, dried grapefruits, dates, fruit and vegetables, peanuts and several seeds.</td>
</tr>
<tr>
<td>Termite mound</td>
<td>Artificial termite mound filled with honey or yogurt. PVC tubes with honey and dried grapefruits inside.</td>
</tr>
<tr>
<td>Balls</td>
<td>Rubber balls and balloons. Nautical defences.</td>
</tr>
<tr>
<td>Mirrors</td>
<td>90 x 40 cm mirrors.</td>
</tr>
<tr>
<td>Buoys</td>
<td>Nautical hollow buoys with holes and stuffed with dried grapefruits.</td>
</tr>
<tr>
<td>Fire hoses</td>
<td>Hanging hoses, ladders and hammocks made with fire hose. Pneumatic tyres and ropes.</td>
</tr>
<tr>
<td>Fire hose ball</td>
<td>Fire hoses braided in the shape of a ball.</td>
</tr>
</tbody>
</table>
Faecal samples were collected at random in the facilities of both primates in order to analyse cortisol levels [12, 31]. Samples were collected from the daytime enclosure in the afternoon, once the primates had been transferred to their night quarters. Individual identity of each faecal sample was not determined. The number of fecal samples collected everyday was equal to the number of individuals in each enclosure (4 for gorillas and 9 for chimpanzees). Faecal samples were frozen (NuAire laboratory freezer: Mod. NU-9333E; air-cooled cascade refrigeration system; temperature range -20° to -86°C; electrical requirements 230V 50 Hz; Japan) and later assayed for cortisol at the Veterinary laboratories of the Universidad Complutense of Madrid. Subsequently, faecal cortisol levels recorded for both phases, control and enrichment, were compared.

Statistical analysis

A total of 280 instantaneous scan-samplings for chimpanzee group and 250 for gorilla group, for each phase were analysed and data comparison between phases was accomplished. Statistical procedures used in this study were non parametrical tests (Wilcoxon, Friedman and Mann-Whitney tests), as the collected data did not satisfy equivalent parametrical test conditions [69, 81]. Depending on the problem to solve in each of the phases, repeated measures analysis were used: Wilcoxon, for comparing behavior and physiological data from control and enrichment phases and Friedman for enrichment devices comparison or Mann-Whitney independent samples tests in the case of sex and age effect assessing. Spearman correlation coefficient [69, 81] was used. And except other indications, alpha significance level used to reject the cero hypothesis was 5 per cent and contrasts were bilateral. Due to the small size of the gorilla group, pooled data were used for behavior data analysis in this case.

Of every study phase, 48 faecal samples were collected and analyzed of gorilla group and 108 faecal samples of chimpanzee group.

RESULTS AND DISCUSSION

Behavioral data

Chimpanzees. As shown in FIG. 1, enrichment was significant for chimpanzees’ behavior when comparing previous control phase and enrichment phase. Group inactivity was reduced during enrichment phase (Wilcoxon matched pairs test, N=9, T=-2.666, P<0.05) and consequently, feeding behaviors (Wilcoxon matched pairs test, N=9, T=-2.666, P<0.05), locomotion (Wilcoxon matched pairs test, N=9, T=-2.192, P<0.05) and exploring activities (Wilcoxon matched pairs test, N=9, T=-2.666, P<0.05) showed increased frequencies in this phase. On the other hand, abnormal behaviors were significantly reduced during the enrichment phase (Wilcoxon matched pairs test, N=9, T=-2.547, P<0.05), the same as social behavior (Wilcoxon matched pairs test, N=9, T=-2.666, P<0.05), although there was no significant effect of enrichment on chimpanzees’ interaction with visitors throughout the experimental study (Wilcoxon matched pairs test, N=9, T=-1.960, n.s.).

There was no effect of sex or age on enrichment devices use: males (24.5%) versus females (19.8%) - Mann Whitney U, n =9; Z = -0.409; n.s. - or adults (17.6%) versus immature (32%) - Mann Whitney U, n=9, Z = -1.807; n.s. - as it was found.

Gorillas. Gorillas group in this study showed inactivity reduction during enrichment phase when compared with previous period (Wilcoxon matched pairs test, N=4, T=-14.546, P<0.05). Exploring behavior frequency was the only one higher in enrichment conditions (Wilcoxon matched pairs test, N=4, T=8.354, P<0.05), whereas other animal behaviors, such as...
feeding (Wilcoxon matched pairs test, N=4, T=-15.133, P<0.05), social (Wilcoxon matched pairs test, N=4, T=-3.074, P<0.05), and locomotive (Wilcoxon matched pairs test, N=4, T=-4.143, P<0.05) were decreased. Likewise, abnormal behaviors were also reduced in the second phase (Wilcoxon matched pairs test, N=4, T=-3.879, P<0.05). Environmental enrichment did not have any significative effect on gorilla’s interaction with visitors (Wilcoxon matched pairs test, N=4, T=-1.378, P<0.05) (FIG. 3).

As shown in FIG. 4, gorillas used mostly empty and food stuffed buoys amongst enrichment devices provided in experimental enrichment phase (Friedman, n=4; df=5; $x^2 = 15.749$; P < 0.05).

Faecal cortisol levels of gorillas significantly increased in enrichment phase from 17 ng/mg in control or initial phase to 31 ng/mg (Wilcoxon tests, n=48, z = -2.093, P < 0.05) (FIG. 5).

This research results showed that environmental enrichment proved effective in chimpanzees and gorillas. In both species inactivity and abnormal behavior were significantly reduced, as was the hypothesis initially proposed. This study confirms the idea that environmental enrichment has positive effects for species kept in captivity. The environmental enrichment brings the behavioral repertoire and activity budget of captive animals similar to that of wild co specifics. Inactivity, the same as boredom and apathy related behaviors are highly reduced when compared with captive animals without enrichment husbandry conditions. Moreover, enrichment devices provided result in abnormal and pathological behavior frequency reduction. Such abnormal behavior appearance is considered as a consequence of continuous apathy and boredom situation in daily life of confined animals. The individuals in this situation showed anxiety, helplessness and frustration, and need to alleviate these symptoms may be through pathological and stereotyped behaviors which could reduce the anxiety and, although pathologically, result in a escape of the stressing conditions. Considering that through enrichment the animals are neither inactive nor bored, but highly stimulated, abnormal behavior are changed into more natural and adapted behaviors.

Other very interesting result of this study is that both chimpanzee and gorilla exhibited higher explorative and manipulative behavior frequencies in the enrichment phase compared with control period. This enhances the relevance of enrichment on manipulative and exploring behavior for primates and particularly for great apes [52, 55].

Various and diverse studies and researches have been dedicated to intelligence and cognitive capacities of primates and specifically to that of great apes [4, 14, 59, 72]. Most of them have proved clearly enough the cognitive complexity of these animals demonstrated through their high cognitive abili-
ties and skills in manipulative and exploring tasks that require mental abstraction aptitudes, establishment of cause-effect relationship, mental images association and a high eye-hand coordination.

Apes often have to manipulate and process food to eat it, because sometimes the food is hidden, or difficult to access it, or just surrounded by thorns. For example, the mountain gorilla (Gorilla gorilla berengei) must perform complex manipulations to extract the edible parts of plants that they eat, to avoid being stuck with the thorns of the plant [13]; chimpanzees (Pan troglodytes) use stones to crack open nuts, sticks to extract honey from beehives and ant or termite from nests, and even use leaves, previously chewed, like a sponge to collect water from the cavities and inaccessible sites [17, 18, 72]. This manipulating capacity of objects requires some kind of mental representation and planning [17, 59, 72]. An example of this complex skill is the use of instruments held by great apes. The use of tools for obtains food or reward is a natural behavior in this species [4, 18, 59, 68, 71]. Chimpanzees modify and even make instruments with sticks and branches, which are then used to draw, drag, crush, reach down and dig up food or objects. Such behavior may suggest that chimpanzees plan activities in advance and are able to mentally represent the requirements of this task and high eye-hand psychomotor coordination [4, 18, 59, 68, 71]. Although less studied and documented than in the case of chimpanzees, gorillas and orangutans also use tools in solving certain problems, both in captivity and in the wild. In captivity both gorillas and orangutans will use tools to obtain food, and several authors have described this behavior for gorillas [9, 10, 50, 78] and orangutans [47, 49]. In the wild, a documented case of an adult female gorilla who used a branch as a walking stick to test water deepness and to aid in her attempt to cross a pool of water [10]. Another case, observed by the same staff of researchers was the use of a trunk by another female as a stabilizing stick while dredging for the various enrichment devices employed. While chimpanzees showed a significative preference for stuffed boxes, gorillas gave preference to the stuffed buoys, being both devices within the feeding enrichment category. Previous research extensively proved that feeding type enrichment is very successful with almost all animal species studied, for getting food is a priority task in survival strategy [62, 79, 80].

A very interesting fact, worth to note, is the different ways in both primate species responded to mirrors in their facilities: gorillas showed responses to their reflected image, socially interacting with that “other” individual, while chimpanzees completely ignored this stimulus and did not show any behavior or reaction to their own image. Many studies have researched great apes behavior in front of their reflected image, demonstrating that all of them show high response levels, and even exhibit self recognition in their reflected image [21, 24, 35, 53, 54].

In chimpanzee group, faecal cortisol level differences between control and enrichment phase were not significative. Nevertheless in gorillas group, faecal cortisol levels were significantly increased during enrichment phase. These results do not corroborate reduction of faecal cortisol level as a consequence of enrichment devices introduction in facilities, as the previous hypothesis stated. Thus, it should conclude that environmental enrichment, as that in the present study, has no diminishing effect on these animal physiological stress responses. Nonetheless this conclusion could not be quite certain. Research on differences in stress hormones levels relating to the state of welfare and husbandry conditions of the animal has produced very contradictory and diverse results [22, 30, 44, 58]. Adrenal response and high glucocorticoid levels are not always associated to pathological and chronic stress, for some non related to stress situation behaviors do also require these systems activation [43]. Likewise physiological stress response is under control of different cerebral structures related to other behavioral aspects. Thus, brain stress re-
sponse depends on the organism’s previous experience, the behavioral response allowed by the context, and the predictability of the stressful events [15, 16].

The current study support, in general, the idea that environmental enrichment provide to captive primates stimulate a variety of behaviors and activities that are indicative of a well being in the captivity conditions.

Although the usefulness of the enrichment devices proposed in this study have been demonstrated to work in a daily basis with great apes, the results show differences between the reactions of both species to environmental enrichment. And, in general, these results are consistent with the hypothesis of welfare improvements due to environmental enrichment in captivity.

CONCLUSIONS AND IMPLICATIONS

The results of this study showed that in both species, inactivity and abnormal behaviors were significantly reduced during the enrichment phase. Both chimpanzee and gorilla exhibited higher explorative and manipulative behavior frequencies in the enrichment phase compared with control period.

Results related to the levels of cortisol, did not corroborate the initial hypothesis: in both species, levels of cortisol were higher during the period of enrichment that during the control period, the difference was significant only in the group of gorillas.

ACKNOWLEDGEMENTS

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