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Research article

Environmental enrichment for collared peccaries *Dicotyles tajacu*, Tayassuidae in managed care: Different items provoke different behavioural responses

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Abstract

Being in human care often modifies the behaviour of animals, mainly because of the lack of environmental stimuli, and the ease of finding food and reproductive partners. Animals in human care may have a poorer behavioural repertoire and lower welfare than their wild conspecifics. Environmental enrichment is a technique that introduces stimuli into enclosures, thereby enhancing the welfare of the animals. In the present study, the effect of different environmental-enrichment items on the behaviour of collared peccary *Dicotyles tajacu* was investigated. Basins with food, cardboard boxes filled with paper and food items, scent trails and piles of straw mixed with food items were provided to the peccaries. Behavioural recordings were made during the three phases of the experiment: baseline, enrichment and post-enrichment. The environmental enrichment items—especially the straw pile and cardboard boxes—increased exploratory behaviours, decreased inactivity and increased behavioural diversity in the collared peccaries. Enrichment items associated with food rewards resulted in the most significant positive changes in behaviour and should be used for collared peccaries in human care. An increased behavioural repertoire, with less inactivity and greater exploration of the environment, are important for animals that are under human-managed care and indicate an increase in animal welfare.

Introduction

Animal welfare can be defined as the state of an animal in relation to its environment, nutrition, health, behaviour, intra- and interspecific interactions and mental state (Mellor et al. 2015); more positive experiences in the animal's life will lead to better welfare (Mellor et al. 2020). Animals can live in the wild or under human care, and animals in human care can experience boredom because of a lack of stimulation that would facilitate the expression of natural behaviours in their environment (Burn 2017; Meagher and Mason 2012). Boredom can be indicated by the appearance of physiological and behavioural problems (Liu et al. 2017; McPhee and Carlstead 2010; Wemelsfelder 1997). Distress (i.e. long-term stress) (National Research Council 2008), immunosuppression and lower neuronal plasticity are examples of physiological problems that can appear in barren environments (Rojas-Carvajal et al. 2020). Stereotypic behaviours (i.e. those expressed in a repetitive manner and with no apparent function) (Garner 2005; Shepherdson 1989), as well as quantitative abnormal behaviours (normal behaviours that are under or over-expressed) (Boere 2001; Carlstead 1996; Paquette and Prescott 1988; Price 2002), are examples of outcomes originating from a life in human care. These are all symptoms showing animals have a welfare problem (Bracke and Hopster 2006; Broom 1986, 2010).

The insertion of stimuli into the environment can increase the quality of animal life by augmenting mental and physical welfare (Carlstead 1996; Meagher and Mason 2012; Silva et al. 2017; Young 2003). This technique, known as environmental

enrichment, can generate considerable behavioural and physiological changes in the animals (Andrade and Azevedo 2011; Charmoy et al. 2015; van Praag et al. 2000; Wagman et al. 2018; Young 2003), such as reducing the amount of inactivity, and the expression of stereotypic and abnormal behaviours. At the same time, environmental enrichment can increase the amount of exploratory, play, foraging, reproductive, and social affiliative behaviours, and the diversity of these positive behaviours expressed, indirectly enhancing the welfare of the animals (Borges et al. 2011; Lopes et al. 2018; Marcon et al. 2018). A reduction in stress hormones is also observed in many environmental enrichment studies (Godyn et al. 2019; Lima et al. 2019; Marcon et al. 2018), although an increase in stress hormones is not always directly linked to welfare issues, its production being context-dependent (Ralph and Tilbrook 2016). Most of the benefits from environmental enrichment result from increases in unpredictability, choice and control of the captive environment by the animals (Watters 2009). Unpredictability enhances novelty in captivity, decreasing boredom (Burn 2017; Mason et al. 2007). Choice and control over the environment make animals more certain of the outcomes of their actions, since animals can decide whether or not to use the offered enrichment items (Coleman and Novak 2017).

Changes in feeding routine (e.g. time and place at which food is provided, new food items, how food is provided [chopped, whole, sliced]), changes in the physical structure of the enclosures, cognitive challenges (e.g. puzzles, levers) and different sensory stimulation (e.g. odours, visual, auditory) are examples of how environmental enrichment can be used to improve animal welfare (Carlstead 1996; Shepherdson et al. 1998; Vaicekauskaite et al. 2019; Vinhas and Oliva 2016; Young 2003). A decrease in the expression of abnormal behaviours, as well as an increase in the behavioural repertoire (i.e. an increase in the number and quantity of normal and positive behaviours such as reproductive, exploratory and social affiliative behaviours), is a measure of the efficiency of environmental enrichment (Tarou and Bashaw 2007).

The collared peccary *Dicotyles tajacu* (Tayassuidae, Cetartiodactyla) is a group-living species, with herds varying from two to more than fifty individuals (Sowls 1997). This species inhabits various habitats, from forests to grasslands, ranging from the United States to northern Argentina (Sowls 1997). Collared peccaries are not threatened with extinction in most of their range (listed as Least Concern; Gongora et al. 2011); however, they are vulnerable to extinction in the Atlantic Forest domain of Minas Gerais state, south-eastern Brazil, mainly as a result of habitat loss and hunting (COPAM 2010). Collared peccaries are exploratory animals, spending more than 15% of their day exploring their environment (Byers and Bekoff 1981; Silva et al. 2020). Thus, in enclosures with little environmental stimulation, exploratory behaviours can be replaced by abnormal behaviours, such as pacing, self-mutilation and over expression of inactivity, aggression, or other natural behaviours (Andrade and Azevedo 2011; Garner 2005; Jacobson et al. 2016; Mason 1991; Nogueira-Filho et al. 2017; Vaz et al. 2017; Young 2003). From a search on the Zoological Information Management Software (ZIMS) Species 360 database (ZIMS 2021), it was found that 95 zoos around the world have this species in their collections; thus, information to help in the maintenance of high welfare is important.

Although the maintenance of collared peccaries is common, few studies have focused on the efficiency of different environmental enrichment items on the welfare of individuals (Dubost 2001; Dutertre et al. 2001). The aim of the present study was to evaluate how different environmental enrichment items influenced the behavioural repertoire of captive-born collared peccaries. We hypothesised that the environmental enrichment would increase exploratory behaviours, decrease inactivity and increase the diversity of behaviours expressed by the collared peccaries.

Material and methods

Study site, animals and maintenance

The study was conducted at Engenho D'Água farm, located in the district of São Bartolomeu (20º15'41" S, 43º36'34" W), Ouro Preto municipality, Minas Gerais state, south-eastern Brazil. This study was approved by the Animal Ethics Committee of the Federal University of Ouro Preto, under protocol number 2015/26.

Twenty captive-born collared peccaries were studied. Peccaries were divided into two groups of ten adult individuals (more than 2 years old) in April 2016, each comprised of eight females and two males. The two groups were formed by individuals from a

Table 1. Ethogram used during the environmental enrichment study with captive-born collared peccaries *Dicotyles tajacu*. The ethogram was based on Byers and Bekoff (1981) and on 30 hours of preliminary observations

Acronym	Behaviour	Description
MOV	Moving	The individual walked, ran or trotted in enclosure in a calm manner, not escaping from any stimuli
INA	Inactive	The individual remained standing, laying down or sitting still, inactive in enclosure
INS	Inspecting	The individual lifted its nose and smelled the air, trying to reach some stimulus (flehmen)
AGO	Agonistic interactions	The individual attacked another (fights, biting or displaying teeth chattering)
ALE	Alert	The individual remained standing, with raised head, ears upright, facing forward, watching its surroundings closely
ESC	Escaping	The individual escaped from some frightening stimulus by running away from it
AFI	Affiliative interactions	The individual sniffed and rubbed its nose/body on another individual's body or gives gentle bites on another individual's body
SNI	Sniffing	The individual lowered its nose to the ground and sniffed
FEE	Feeding	The individual ate, chewing food inside its mouth, or foraged, walking and sniffing the ground at the same time, searching for food
OTH	Other behaviours	Other behaviours not already described in the ethogram
NV	Not visible	Collared peccary out of sight

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larger group of animals (more than 70 individuals). The 20 study individuals were randomly selected from this larger group and put together in new smaller study groups. Data collection occurred one month after the formation of the groups. The groups were maintained in two similar enclosures, with an area of 625 m^2 each, and the enclosures had some clumps of tall grass *Urochloa* spp., five concrete pipes used as hiding places by the animals, and a few small trees. The areas were enclosed by wire mesh. Peccaries received water ad libitum, and food was offered in a feeder of 4m^2 area twice a day at 0600 and 1700. Food comprised a mixture of vegetables (10 kg per day per group: corn, pumpkins, soybean meal) and dry food for pigs *Sus scrofa* (CCPR®: a mixture of cotton bran, soybean meal, corn, molasses, vitamins and minerals).

Environmental enrichment and study protocol

Food and sensorial (olfactory) enrichment items were used in this study. Food items were pumpkins, sweet potatoes and yams (5 kg each), and corn (3 kg) (enrichment food quantities given on a group basis). Olfactory items were macerated leaves of coriander and bay (0.4 kg each). These items were chosen to stimulate foraging and exploratory behaviours. These enrichment items are commonly used for pigs and peccaries in farms and in zoos (Godyn et al. 2019; Nogueira et al. 2011). The items were never offered together, and they were offered on consecutive days. Enrichment was always offered to the peccaries at 1000, with an item being chosen randomly and with no repetitions on consecutive days. The food items were offered inside four cardboard boxes, or mixed with 2 m^2 of straw, or within six basins scattered through the enclosure. Olfactory items were used to build scent trails through the enclosure.

The study was divided into three treatments: baseline (the normal husbandry conditions, prior to the enrichment; from 2 May to 13 May 2016), enrichment (the condition where the enrichment items were offered to the peccaries; from 30 May to 11 July 2016) and post-enrichment (the condition after the enrichment items have been withdrawn, where the conditions returned to those of the baseline treatment; from 12 July to 11 August 2016). Sixty-four hours of behavioural data were collected in each treatment, totalling 192 hours of observations (115,200 scans in total; the percentages of each behaviour presented in the results section represent the number of scans of a certain behaviour/total number of scans). The scan method with instantaneous recording of the behaviours every minute was used for data collection for the whole group (Altmann 1974; Azevedo and Dias 2018). Data were collected for 1–4 hours daily, from Monday to Friday, between 1000 and 1500; this period was chosen because it is one of the periods of the day that peccaries are most active (Silva et al. 2020). An ethogram for the collared peccaries was built based on 30 hours of preliminary observations and based on Byers and Bekoff (1981) (Table 1). No abnormal behaviours were recorded during the observations. All data were collected by the same researcher.

Table 2. Generalized linear mixed model (GLMM) results for the comparison of the behaviours expressed by the collared peccaries in this environmental enrichment study during baseline (b), enrichment (e) and post-enrichment (pe) treatments (treatment) and when the basin (b), cardboard box (cb), straw (s) and scent trail (st) were offered (enrichment items). All models with a Poisson error distribution. For post-hoc results, asterisks represent the treatment or enrichment item for which the behaviour was most expressed.

Response	Variable	Deviance	F	P	Post-hoc
Inspecting	Treatment	1703.3	204.1	<0.001	b ≠ e* ≠ pe
	Enrichment item	633.9	89.9	<0.001	b, s, st ≠ cb*
Sniffing	Treatment	3106.1	855.7	<0.001	b ≠ e ≠ pe*
	Enrichment item	1149.6	22.5	<0.001	b*, s ≠ cb, st
Affiliative interactions	Treatment	1285.5	71.9	<0.001	b ≠ e ≠ pe*
	Enrichment item	408.8	26.5	<0.001	b, s, cb ≠ st*
Agonistic interactions	Treatment	320.3	9.4	0.05	b, pe ≠ e*
	Enrichment item	144.3	0.8	0.84	-
Moving	Treatment	2444.8	154.9	<0.001	b* ≠ e ≠ pe
	Enrichment item	921.9	105.4	<0.001	b* ≠ s ≠ cb ≠ st
Inactive	Treatment	3445.9	714.3	<0.001	b* ≠ e ≠ pe
	Enrichment item	1022.7	139.2	<0.001	b, st ≠ s ≠ cb*
Alert	Treatment	1210.8	276.3	<0.001	e, pe ≠ b*
	Enrichment item	390.3	3.6	0.31	-
Escaping	Treatment	270.2	55.8	<0.001	b* ≠ e ≠ pe
	Enrichment item	52.9	0.9	0.83	-
Feeding	Treatment	2620.8	774.4	<0.001	e*, pe ≠ b
	Enrichment item	863.9	17.3	0.0006	b, st* ≠ s ≠ cb
Other behaviours	Treatment	899.2	52.5	<0.001	b* ≠ e ≠ pe
	Enrichment item	397.9	7.1	0.07	-
Not visible	Treatment	3827.7	398.9	<0.001	e*, pe ≠ b
	Enrichment item	1166.2	132.7	<0.001	b, s, cb ≠ st*

Statistical analysis

Generalised linear mixed models (GLMMs) were used to evaluate differences in the behavioural responses of the collared peccaries (response variables) in relation to the different treatments (baseline, enrichment and post-enrichment), enclosure (one and two), period of data recording (1000 to 1500), and enrichment items (cardboard boxes, straw piles, scattered basins and scent trails) (explanatory variables). The significance of variables was determined by model comparison and backward selection, until a minimum suitable model was reached. Due to the daily repeated assessments (i.e. longitudinal data), the sampling day was fitted as a random effect varying in the intercept (1|day). Contrast analyses were conducted as post-hoc tests. All analyses were performed in the software R v 3.3.1 (R Development Core Team 2012), using the lme4 package. All tests used a significance level of 95% (Zar 2010).

A behavioural diversity index (H) was calculated for each treatment (baseline, enrichment and post-enrichment) to evaluate the effect of the environmental enrichment items on the diversity of behaviours expressed by the collared peccaries (Shepherdson et al. 1998). This index is based on Shannon's diversity index, which is commonly used to describe behavioural diversity in animals (Miller et al. 2020). The behavioural diversity index is calculated as:

$$H = - \sum^{B}_{(i = 1)} pi \ ln \ pi$$

Where *B* is the number of behaviour types and *pi* is the proportion of behaviour *i*. The greater the H value, the more diverse are the behaviours.

Results

The collared peccaries changed their behavioural expression during the enrichment treatment and according to the enrichment item used (no influences of the enclosure nor period of data recording were observed) (Table 2). All results are presented as mean±SE. The behaviours 'inspecting' (baseline: 11.8±1.6; enrichment: 15.4±1.8; post-enrichment: 9.9±1.2), 'agonistic interactions'

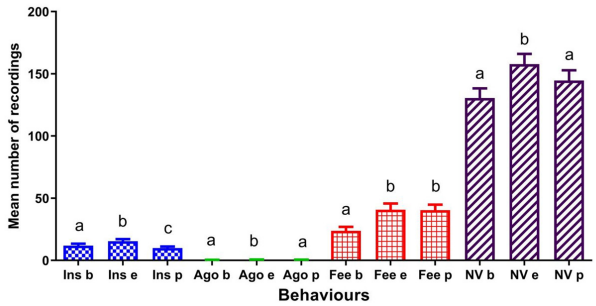

Figure 1. Mean±SE of the behaviours exhibited by collared peccaries *Dicotyles tajacu* during three study treatments (baseline, enrichment and post-enrichment). Each column represents the mean value of the daily records of a certain behaviour per treatment. Ins=inspecting, Ago=agonistic interactions, Fee=feeding, NV=not visible, b=baseline, e=enrichment treatment, p=post-enrichment treatment. Letters above the columns indicate significant statistical differences between the treatments of each behaviour separately according to the contrast post-hoc analysis.

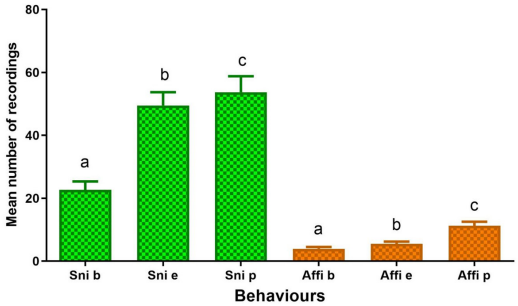

Figure 2. Mean±SE of the behaviours exhibited by collared peccaries *Dicotyles tajacu* during three study treatments (baseline, enrichment and post-enrichment). Each column represents the mean value of the daily records of a certain behaviour per treatment. Sni=sniffing, Affi=affiliative interactions, b=baseline, e=enrichment treatment, p=post-enrichment treatment. Letters above the columns indicate significant statistical differences between the treatments of each behaviour separately according to the contrast post-hoc analysis.

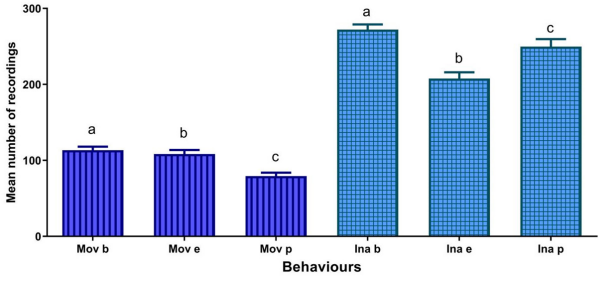

Figure 3. Mean±SE of the behaviours exhibited by collared peccaries *Dicotyles tajacu* during three study treatments (baseline, enrichment and post-enrichment). Each column represents the mean value of the daily records of a certain behaviour per treatment. Mov=moving, Ina=inactive, b=baseline, e=enrichment treatment, p=post-enrichment treatment. Letters above the columns indicate significant statistical differences between the treatments of each behaviour separately according to the contrast post-hoc analysis.

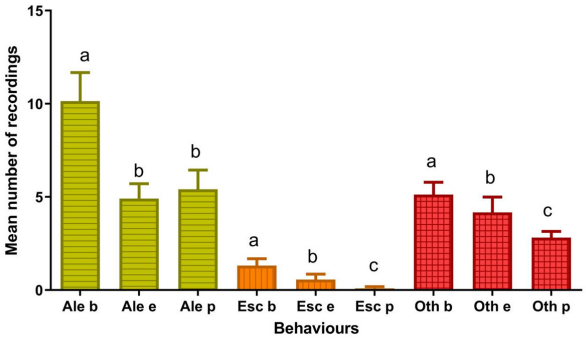

Figure 4. Mean±SE of the behaviours exhibited by collared peccaries *Dicotyles tajacu* during three study treatments (baseline, enrichment and post-enrichment). Each column represents the mean value of the daily records of a certain behaviour per treatment. Ale=alert, Esc=escaping, Oth=other behaviours, b=baseline, e=enrichment treatment, p=post-enrichment treatment. Letters above the columns indicate significant statistical differences between the treatments of each behaviour separately according to the contrast post-hoc analysis.

(baseline: 0.5±0.1; enrichment: 0.6±0.2; post-enrichment: 0.5±0.1), 'feeding' (baseline: 23.8±3.2; enrichment: 40.8±4.9; post-enrichment: 40.4±4.5) and 'not visible' (baseline: 130.5±7.8; enrichment: 157.8±8.2; post-enrichment: 144.6±8.2) increased from baseline to the enrichment treatment and decreased in the post-enrichment treatment (Figure 1). 'Affiliative interactions' (baseline: 3.9±0.6; enrichment: 5.5±0.7; post-enrichment: 11.3±1.3) and 'sniffing' (baseline: 22.7±2.7; enrichment:49.5±4.2; post-enrichment: 53.7±5.1) also increased significantly from the baseline to the enrichment to the post-enrichment treatment (Figure 2). Results of post-hoc tests can be seen in Table 2.

Meanwhile, the behaviours 'moving' (baseline: 113.4±4.7; enrichment: 108.4±5.4; post-enrichment: 79.3±4.6) and 'inactive' (baseline: 272.1±6.9; enrichment: 207.7±8.3; post-enrichment: 249.8±9.9) decreased significantly during the enrichment treatment (Figure 3). The behaviours 'alert' (baseline: 10.1±1.5; enrichment: 5.0±0.8; post-enrichment: 5.4±1.0), 'escaping' (baseline: 1.3±0.4; enrichment: 0.6±0.3; post-enrichment: 0.1±0.1) and 'other behaviours' (baseline: 2.7±0.6; enrichment: 2.7±0.8; post-enrichment: 1.6±0.2) also decreased significantly during the enrichment treatment (Figure 4). Results of post-hoc tests can be seen in Table 2.

The behaviours expressed by the collared peccaries were influenced by the enrichment items. Peccaries moved more when the basins were offered (enrichment: 136.6±10.9), followed by the cardboard boxes (enrichment: 114.2±9.1), straw piles (enrichment: 96.2±8.0) and scent trails (enrichment: 86.8±10.9) (Figure 5). Peccaries were more inactive when the cardboard boxes and the straw piles were offered (enrichment: 218.5±12.2 and 216.8±18.3, respectively), followed by the scent trails (enrichment: 214.8±20.8) and basins (enrichment: 180.6±12.6) (Figure 5). Inspecting was exhibited more when the cardboard boxes were offered to the animals (enrichment: 21.9±5.3), followed by the basins (enrichment: 14.0±2.8), scent trails (enrichment: 13.4±3.0) and straw piles (enrichment: 12.3±1.9) (Figure 5). Results of post-hoc tests can be seen in Table 2.

The collared peccaries 'sniffed' more when the basins with corn (enrichment: 53.5±9.2) and the straw piles (enrichment: 52.6±8.0) were available and sniffed less when the cardboard boxes (enrichment: 47.9±7.6) and the scent trail were used (enrichment: 44.0±9.2) (Figure 6). The 'affiliative behaviours' were exhibited more by the peccaries when the straw piles were offered (enrichment: 19.1±2.3) (scent trail enrichment: 7.4±1.7; cardboard boxes enrichment: 6.3±1.5; basins enrichment: 8.4±2.1) (Figure 6), and 'feeding' was expressed more with the scent trails (enrichment: 46.4±11.3), followed by the straw piles (enrichment: 42.9±8.2) and by the basins with corn (enrichment: 39.7±12.7) (Figure 6). Finally, the collared peccaries were out of sight (i.e. 'not visible') more when the scent trail was available (enrichment: 180.3±19.2) (basins enrichment: 155.0±17.6; cardboard boxes enrichment: 150.3±18.0; straw piles enrichment: 145.6±9.4) (Figure 6). No other behaviour differed depending on the environmental enrichment item offered. Results of post-hoc tests can be seen in Table 2.

The behavioural diversity index (H) showed an increase during the enrichment treatment (0.719) in relation to the baseline (0.655). During the post-enrichment treatment, the behavioural diversity index decreased (0.692) in relation to the enrichment treatment but remained higher than the baseline.

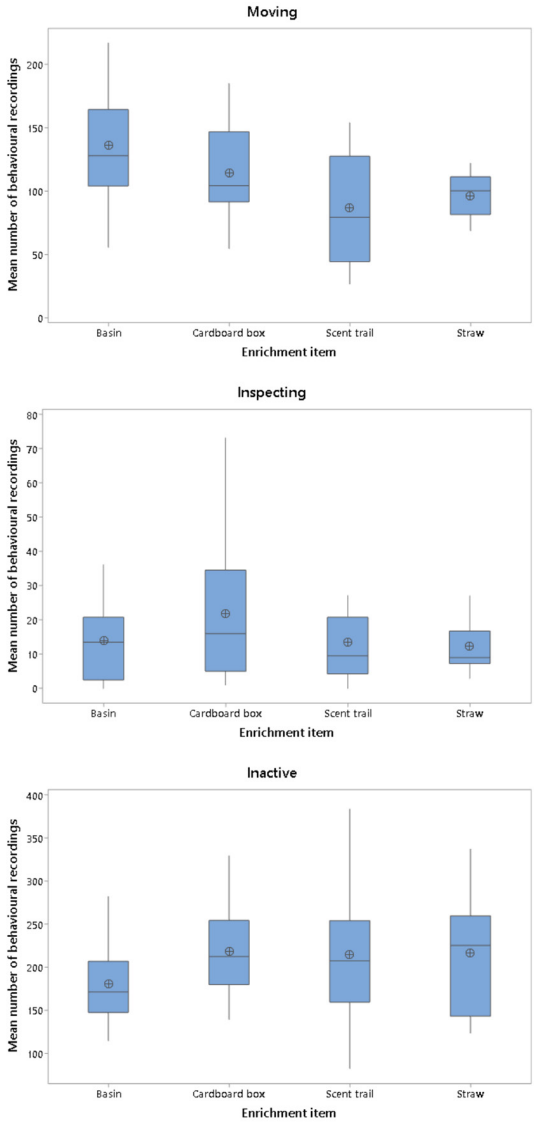

Figure 5. Comparison between the four enrichment items offered to captive-born collared peccaries *Dicotyles tajacu*. Letters above the boxplots indicate significant statistical differences between the enrichment items of each behaviour separately according to the contrast post-hoc analysis. Boxplots represent the median (horizontal line inside the box), first (lower horizontal line of the box) and third (upper horizontal line of the box) quartiles, and maximum and minimum values (upper and lower vertical lines of the box, respectively) of the daily records of the behaviour per environmental enrichment item during the enrichment treatment.

Discussion

The provision of environmental enrichment in this study proved to be adequate to increase exploratory behaviours, decrease inactivity and increase behavioural diversity, corroborating the initial hypothesis. The behaviours 'inspecting', 'sniffing' and 'feeding' increased significantly during the enrichment treatment, while 'inactivity' decreased significantly at the same time. Also, the behavioural diversity index increased during the enrichment treatment. These responses suggest that the enrichment items effectively stimulated peccaries to explore them, decreasing boredom and probably enhancing their welfare (Andrade and Azevedo 2011; Young 2003). Inactivity was the most expressed behaviour during the baseline treatment (45% of the daily activity budget), while moving was the second most expressed behaviour during baseline (19% of the daily activity budget) and foraging corresponded to only 4% of the daily activity budget

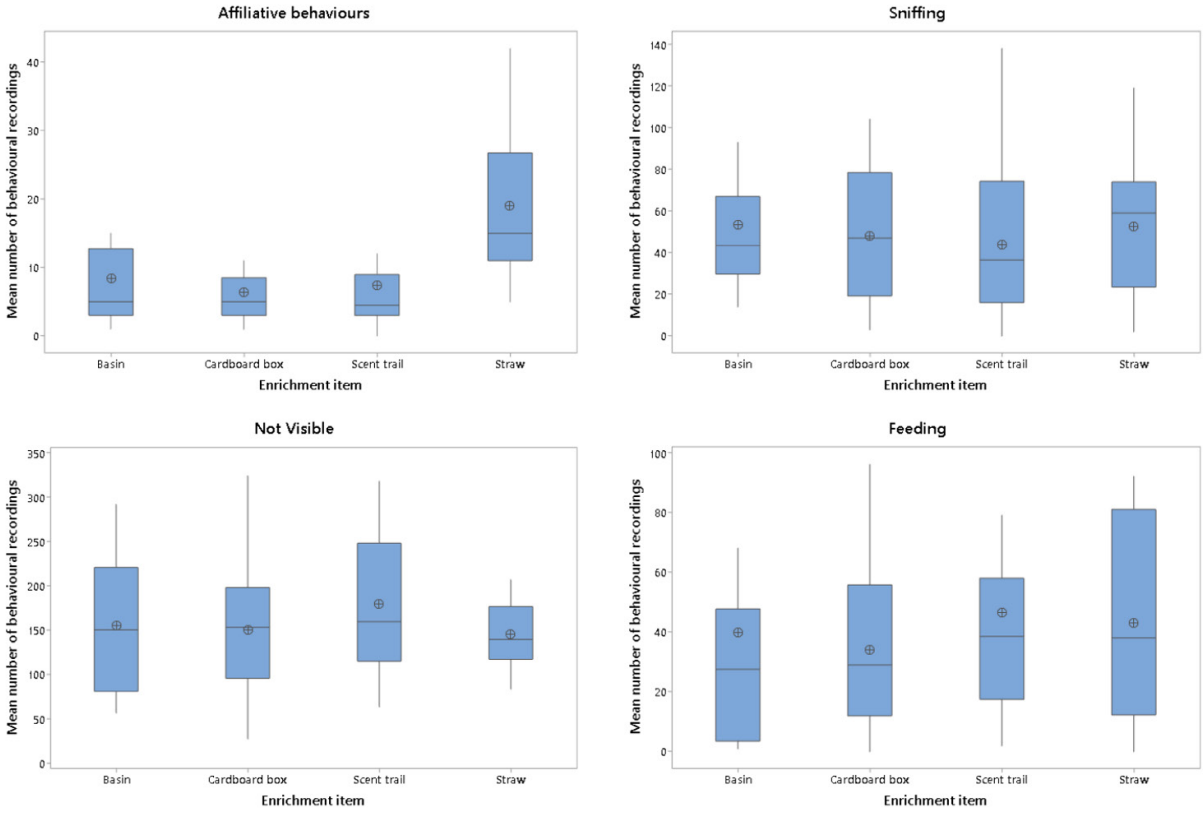

Figure 6. Comparison between the four enrichment items offered to captive-born collared peccaries *Dicotyles tajacu*. Different letters over the boxplots indicate significant statistical differences between the treatments of each behaviour separately according to the contrast post-hoc analysis. Boxplots represent the median (horizontal line inside the box), first (lower horizontal line of the box) and third (upper horizontal line of the box) quartiles, and maximum and minimum values (upper and lower vertical lines of the box, respectively) of the daily records of the behaviour per environmental enrichment item during the enrichment treatment.

during baseline. Some studies have reported a high occurrence of inactivity in the wild, especially during the summer (Byers and Bekoff 1981; Sowls 1997); however, such studies made no mention of the percentage of expression of inactivity in the daily activity budget. Collared peccaries spend much of their time foraging in nature (more than 80% of the activity budget, mainly in the coldest months; inactivity was expressed for more than 60% of the activity budget in the hottest months; Bigler 1974). Foraging was also the most expressed behaviour of a group of reintroduced peccaries in Argentina (30% of the activity budget while resting corresponded to 27% of the activity budget; Hurtado et al. 2018). This daily activity budget pattern is unlike that expressed by wild conspecifics. Although a similarity between behaviours expressed by captive and wild individuals is considered positive because this shows that the environmental enrichment is able to elicit more natural behaviours, this does not always means an increase in the welfare of the captive individuals (Veasey et al. 1996) because behaviours are stimulus-driven rather than internally generated. Therefore, the expression of more natural behaviours should be correlated with enhanced welfare instead of being interpreted as causing enhanced welfare. Yeates (2018) discusses the invalidity of considering animal welfare synonymous with natural behaviours, because some natural behaviours are clearly related to unpleasant situations in nature (e.g. predation).

The behaviour 'moving' inside the enclosure diminished during the enrichment treatment; however, the animals spent more time in other exploratory behaviours, especially 'inspecting' the enrichment items. The same was observed by Beattie et al. (2000) when studying domestic pigs; the enrichment items were mixed in straw, and this significantly increased the exploration of the straw by the pigs. Venturieri and Le Pendu (2006) found that the most performed behaviour by the captive collared peccaries in their study, which were not provided with environmental enrichment, was movement, which is in accordance with our results for the baseline treatment. These results, taken together, could indicate an increase in the peccaries' welfare since their activity budget becomes more like their wild conspecifics (Veasey et al. 1996) and the decrease in inactivity and the increase in activity (exploration and feeding) appears to indicate a decrease in the boredom generated by the captive environment.

In the post-enrichment treatment, the behaviours 'sniffing' and 'feeding' increased while 'inspecting' and 'moving' decreased. Associated with these results, inactivity increased during the post-enrichment treatment. These results reinforce the benefits provided by the environmental enrichment for the studied collared peccaries. Even after the removal of the items, peccaries continued to sniff the ground and to forage (i.e. behavioural activation; Vinhas and Oliva 2016), but only in specific parts of the enclosure, since their movement and inspection decreased overall. These results were also observed in other studies with different animal groups (fishes: Lee and Berejikian 2008; Stevens et al. 2021; Williams et al. 2009; birds: Azevedo et al. 2016; Clyvia et al. 2015; Lima et al.

2019; mammals: Costa et al. 2018; Resende et al. 2009; Sampaio et al. 2019), demonstrating that the lack of stimulation decreases overall positive activities such as exploration. Furthermore, they demonstrate that animals remain motivated to express some behaviours such as foraging; therefore, the use of environmental enrichment should occur as routine animal husbandry (Rampim and Olivia 2016; Vasconcellos and Ades 2012). The behavioural diversity index decreased during post-enrichment treatment in relation to the enrichment treatment but remained higher than that observed in the baseline. This result confirms the idea that the peccaries were motivated to express some of the behaviours expressed during the enrichment treatment, illustrating the long-term effects of the environmental enrichment (Young 2003).

There was also an increase in the 'affiliative interactions' of the collared peccaries during the enrichment treatment. This shows a positive effect of the enrichment for the entire group, because this behaviour is indicative of an increase in herd cohesion (Borges et al. 2011). However, since we did not evaluate the effects of environmental enrichment on peccaries' hierarchy or group cohesion, an increase in these aspects is speculative. 'Affiliative interactions', such as sniffing and rubbing on another individual's body, are common behaviours exhibited by collared peccaries (Biondo et al. 2014; Silva et al. 2016; Sowls 1997) and these behaviours were recorded more often during enrichment provision. The increase in the affiliative behaviours can be considered a sign of greater welfare (Broom and Johnson 1993). Affiliative interactions increased even more in the post-enrichment treatment, showing that the positive influence of the enrichment items persisted even when the items were not available anymore. This result is important since it can indicate pleasant experiences, which could result in greater group cohesion (Aguayo-Ulloa et al. 2015).

During the enrichment treatment, there was also an increase in the 'agonistic interactions', a result that could be contradictory to the previously mentioned 'affiliative interactions'. However, observations of 'agonistic interactions' were very low during the study (0.08% to 0.10% of the behaviours) and the agonistic behaviours are presumed to be related to the establishment of hierarchy. Collared peccaries present a non-linear hierarchy (Biondo et al. 2014; Nogueira et al. 2010; Romero et al. 2013), and at the time of the study this hierarchy was under development because the two groups were formed by individuals from a larger group of animals (more than 70 individuals). The 20 study individuals were randomly selected from this larger group and put together in the new smaller study groups. The agonistic interactions started after an approach of certain individuals, with no apparent cause. The low incidence of agonistic behaviours during the study may be because of the size of the enclosure (i.e. the enclosure was big enough to avoid competition for space among the peccaries). A hypothesis for the increase in agonistic behaviours during the enrichment treatment is that individuals attempted to monopolize the enrichment items (McGregor and Ayling 1990). This hypothesis could be supported by the significant decrease in the expression of agonistic behaviours during the post-enrichment phase. However, no agonistic behaviours directed to individuals when using the enrichment items were recorded. Since the study occurred one month after group formation, the lack of a clear social hierarchy could be the most important factor influencing these results, and this could be a limitation of the study. It would be advisable to repeat this experiment after the establishment of the hierarchy within the groups.

The decrease in 'alert' and 'escaping' behaviours during the enrichment treatment showed that the peccaries were calm and occupied enough to direct their activities to the enrichment items. The same was observed for three bear species, sloth bear *Melursus ursinus*, American black bear *Ursus americanus* and brown bear *Ursus arctos* (Carlstead et al. 1991), brown rats *Rattus norvegicus* (Klein et al. 1994) and domestic pigs (Campos et al. 2010). The authors of these studies suggested that the diminution of alert and other anti-predator behaviours could be related to a decrease in the release of stress hormones, which eventually increases the welfare of the animals. This could also be the case in the present study, however, because no hormonal evaluation was carried out, this hypothesis needs to be tested in the future. The significant decrease in the expression of both behaviours during the post-enrichment phase supports the theory that the enrichment items used kept individuals calm and less stressed, and this generated positive experiences and increased their welfare.

Among the items, the straw piles mixed with food most stimulated exploration of the environment by the collared peccaries. When investigating the piles, peccaries found the food and this acted as a reward, naturally reinforcing this behavioural expression. Straw piles have been suggested as the best environmental enrichment for pigs (Studnitz et al. 2007) and the results of the present study corroborate this suggestion.

The collared peccaries expressed more 'inspection' behaviours when the cardboard boxes were offered. They exhibited flehmen every time they approached the boxes. The presence of food inside the boxes and the fear of the boxes (a novelty inside the enclosure) could be responsible for the increase in the expression of inspecting behaviour. In a study with lions *Panthera leo*, flehmen increased when spice trails were offered to the animals (Powell 1995). The novelty of the spice trails was suggested to cause the increase in flehmen behaviour. However, in the present study scent trails were not sufficient to elicit an increase in flehmen response by the collared peccaries.

'Moving' inside the enclosure increased when the basins filled with corn were offered. The basins were placed equidistant inside the enclosure, meaning the animals had to walk around the enclosure to reach the basins. The position of the basins also avoided monopolization of enrichment items by the more dominant individuals in the hierarchy, resulting in lower rates of 'agonistic interactions'. It is mandatory for animal welfare that an adequate number of enrichment items is provided to avoid 'agonistic interactions' (Almeida et al. 2008; Cipreste et al. 2010; Hosey et al. 2013).

The scent trail was the enrichment item that appeared to be least interesting for the peccaries. The animals showed almost no interactions with this item and did not sniff the trails when they were available. No food reward was associated with the item, and this may have been one of the reasons that the peccaries did not explore it (Domjan 2004). Collared peccaries ate more from the feeders when the scent-trail item was available. Items associated with food normally elicit a more prolonged exploration by animals (Borges et al. 2011).

Conclusion

Environmental enrichment increased the exploratory behaviours and decreased inactivity of the collared peccaries in this study, probably correlating with an increase in animal welfare. The most effective items were associated with food rewards, such as the straw piles and the cardboard boxes, and these items should be used more frequently. This study demonstrated how low-cost enrichment items can be efficient in stimulating exploration and activity in an understudied species that is well represented in captivity. Environmental enrichment should be applied for all populations of collared peccaries in human care. However, improvements could be applied in further studies, such as the offering of enrichment items to peccary groups with an already established social hierarchy, or the offering of more varied enrichment items. These improvements could result in a better

evaluation of the efficiency of the environmental enrichment for collared peccary welfare.

Product mentioned in the text

CCPR ®: dry food for pigs, manufactured by CCPR; Babita Camargos Avenue, 1355, Cidade Industrial, Contagem, Minas Gerais, 32210-180, Brazil.

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