Received: 11 January 2016 | Revised: 2 April 2017 | Accepted: 11 April 2017

DOI: 10.1002/zoo.21361

RESEARCH ARTICLE

WILEY ZOOBIOLOGY

The effects of intrinsic enrichment on captive felids

Juliana Damasceno[1,2] | Gelson Genaro[3] | Thomas Quirke[2] | Shannen McCarthy[2] | Sean McKeown[4] | Ruth O'Riordan[2]

[1] Postgraduate Program in Psychobiology, Faculty of Philosophy, Sciences and Languages of Ribeirão Preto, University of São Paulo, Ribeirão Preto, São Paulo, Brazil

[2] The School of Biological, Earth and Environmental Sciences and Environmental Research Institute, University College Cork, Ireland

[3] Centro Universitário Barão de Mauá, Ribeirão Preto, São Paulo, Brazil

[4] Fota Wildlife Park, Carrigtwohill, Co. Cork, Ireland

Correspondence
Dr Juliana Damasceno, Post-Graduate Program in Psychobiology, FFCLRP, USP., Programa de Pós-Graduação em Psicobiologia, Departamento de Psicologia, Faculdade de Filosofia Ciências e Letras de Ribeirão Preto, Universidade de São Paulo, Av. Bandeirantes 3900, Monte Alegre, Ribeirão Preto CEP: 14040-901, São Paulo, Brasil.
Email: juliana.damasc@gmail.com; judamasceno@usp.br

Funding information
Coordenação de Aperfeiçoamento de Pessoal de Nível Superior; Conselho Nacional de Desenvolvimento Científico e Tecnológico

Environmental enrichment is a well-known technique, which has been used to enhance the welfare of captive animals. The aim of this study is to investigate how three different forms of intrinsic enrichment, namely, a hay ball without scent, a hay ball with catnip, and a hay ball with cinnamon, influenced the behavior of six cheetah and two Sumatran tigers at Fota Wildlife Park, Ireland. Enrichment-directed behaviors, as well as pacing, locomotion, inactive, and exploratory behaviors were investigated. The results indicated that the three forms of enrichment had similar effects, in terms of enrichment-directed behavior, with cinnamon resulting in the highest levels of enrichment-directed behaviors. The cinnamon treatment resulted in a significant decrease in pacing behavior when compared with baseline observations. No evidence of habituation (i.e., a significant reduction in enrichment-directed behaviors) was observed for any of the three enrichments. This means that these low cost, easy to apply, practical forms of enrichment could be frequently applied for these species as part of an enrichment regime.

KEYWORDS
animal welfare, felids, novelty, olfactory

1 | INTRODUCTION

The World Association of Zoos and Aquariums (WAZA) has committed to improving the physiological and psychological welfare of captive animals, through the use of environmental enrichment (Mellor, Hunt, & Gusset, 2015). Environmental enrichment is a tool that includes a range of techniques, aimed at stimulating species-specific behaviors (Carlstead & Shepherdson, 1994; Ellis, 2009; Law, Graham, & Mcgowan, 2001). Time and resources (Hoy, Murray, & Tribe, 2010; Mellor et al., 2015), a lack of variety in effective techniques for certain species, the need for methodological control and evaluation, as well as habituation to the stimuli that are used (Tarou & Bashaw, 2007), are all factors that can impact upon the success of environmental enrichment. Habituation is defined as a decrease in response to a stimulus, after repeated exposure to that stimulus. This process is an evolutionarily advantageous strategy in animals, which is related to exploration and consequent adaptation to the environment (Thompson & Spencer, 1966; Wong et al., 2010). However, with respect to environmental enrichment, the habituation process can eventually reduce the effectiveness of a particular enrichment (Tarou & Bashaw, 2007).

Enriching captive felids is challenging, due to the complexity of behaviors required for predation and exploration in these species (Quirke, O'Riordan, & Davenport, 2013; Skibiel, Trevino, & Naugher, 2007). The absence of a range of stimuli in captivity can cause stress and lead to the development of abnormal behaviors, such as abnormal stereotypical pacing behavior, best described as a repetitive, maladaptive, and apparently functionless behavior (Mason, 1991). This type of stereotypy occurs frequently in captive carnivores. Some authors have suggested that this is because of the ranging behavior and activity patterns shown by these animals in the wild (Clubb & Mason, 2003, 2007). The existing literature on enrichment for captive

felids has focused upon the stimulation of natural active behaviors, such as hunting and exploration (Quirke & O'Riordan, 2011; Szokalski, Litchfield, & Foster, 2012). Quirke and O'Riordan (2011) pointed out the relative lack of research investigating novel effective strategies of enrichment for some species, such as cheetah.

Enrichment techniques can be classified in a number of ways- as animate and inanimate (Ellis, 2009), as cognitive (occupational), food (nutritional), structural, social, and sensory (Bloomsmith, Brent, & Schapiro, 1991; De Azevedo, Cipreste, & Young, 2007; Young, 2003), or as physical, social, and temporal (Carlstead & Sheperdson, 2000). Tarou and Bashaw (2007) proposed a new kind of classification, based upon experiments analyzing the behavioral response of animals to the enrichment and how the stimuli could influence their behavior, in terms of reinforcement. According to Tarou and Bashaw (2007), behavior, expressed as a result of enrichment, can be intrinsically or extrinsically reinforced. The behavior can increase or decrease, as a function of the reinforcement, with the consequence that the behavior can be either intrinsically or extrinsically motivating. The addition of a novel object into an enclosure, which an animal then investigates (the behavior), may be regarded as an intrinsic form of enrichment. The consequence of investigating this new object may be, for example, the discovery of a new scent. The motivation to investigate another object, placed in the enclosure at a later date, is internal; the animal investigates this new object through its own desire to interact with it. In contrast, a puzzle feeder may be regarded as an extrinsic form of enrichment. The food reward, which is received through interaction with the feeder, acts as an external motivator for the animal to engage with the puzzle feeder again at a later date, in order to receive the food reward.

The introduction of intrinsic enrichment, such as new objects and scents into the captive environment, can increase exploration and stimulate territorial behaviors, such as scent marking, while also improving psychological well-being (Quirke & O'Riordan, 2015; Tarou & Bashaw, 2007; Wells, 2009; Wells & Egli, 2004). Wells and Egli (2004) introduced three different types of odors to black-footed cats (*Felis nigripes*) and observed an increase in activity and exploration. However, over their 5 days of testing, a decrease in the animal's response to the odors was observed, which indicated evidence of habituation. This is in accordance with Tarou and Bashaw's (2007) predictions, which had suggested that intrinsic enrichment can promote a short-lived effect and result in a fast habituation process, both within and between sessions.

The present study applied three types of intrinsic enrichment to captive cheetahs (*Acinonyx jubatus*) and Sumatran tigers (*Panthera tigris sumatrae*), aiming to: (1) assess the effectiveness of these forms of enrichment, in terms of the level of interaction by the cats with the enrichment, and changes in their levels of pacing, locomotion, exploratory, and inactive behaviors and (2) evaluate if habituation occurred, for any of these types of enrichment, over the 7 days of application. The three types of enrichment were designed to be of low cost, practical, and easy to apply in the zoo setting.

2 | MATERIALS AND METHODS

2.1 | Study site and animals

The study was carried out at Fota Wildlife Park (51.8992°N, 8.2982° W), Carrigtwohill Co. Cork, Ireland, between January and May 2015. The subjects of the study were a male and a female Sumatran tiger (*Panthera tigris sumatrae*), two female and four male cheetahs (*Acinonyx jubatus jubatus*). All cats were adults and captive born, aged between 2 and 7 years old (Table 1). The eight animals were housed singly or in pairs, in six enclosures measuring between 420 and 3,500 m^2. The enclosures contained vertical areas, trees, refuges, and raised areas. Individuals were fed with rabbit, chicken, horsemeat, or beef. To simulate the variability of food availability in the wild, the cheetahs are fed 6 days a week only (between 14:00 and 16:00 hr) with approximately 1.8 kg of food, while the tigers are fed 5 days a week only (at about 16:00 hr) with 5 kg in each serving.

2.2 | Intrinsic enrichment items

Each form of enrichment utilized in this study had not been previously introduced to the animals. The three forms of enrichment applied were as follows;

1. Hay ball (HB): a ball made with hay (approximately 30 cm in diameter) tied using natural jute string (used in gardening, which is safe in case of ingestion).
2. Catnip (CA): using the hay ball as the vector, 5 ml of liquid catnip herb (*Nepeta cataria*), (the Kong® brand Kong Company, Salisburg, UK), was sprayed on the Hay ball.
3. Cinnamon (CI): using the hay ball as the vector, 5 ml of cinnamon (*Cinnamomum zeylanicum*), (Colony ™ brand, Wax Lyrical Ltd., Cumbria, UK), was sprayed on the hay ball.

The first application of the hayball (HB) enrichment was characterized as an intrinsic enrichment as it was a new object in the environment.

The enrichment items utilized in this study were simple to build (it took less than 5 min to construct each hay ball), easy to apply (i.e., thrown over the fence into the environment from outside the enclosure), and also of low cost (due the availability of hay and string material within the zoo setting).

TABLE 1 Description of the subjects observed in this study

Animal	Enclosure	Specie	Gender	Age (years)
Gimpy	A	Cheetah	Female	5
Claude	B	Cheetah	Male	5
Pompom	B	Cheetah	Male	5
Marvin	C	Cheetah	Male	2
Bandy	D	Cheetah	Male	5
Topaze	D	Cheetah	Female	6
Dourga	E	Sumatran tiger	Female	3
Denar	F	Sumatran tiger	Male	2

The cats with the same enclosure letter were housed together. All animals were captive born.

2.3 | Procedures

The experiments were conducted over 7 consecutive days (Monday–Sunday) from 9:00 to 14:00 hr. This time period was chosen since neither feeding nor cleaning takes place at this time. Therefore this minimized any possible interference with the introduction of the enrichment. Behavior data were recorded directly, consisting of 1 hr per enclosure per day (one enclosure at a time), in a randomized order on each day of observations. Focal animal sampling or all occurrence sampling (Altmann, 1974) was utilized to collect behavior data according to the ethogram shown in Table 2.

In order to minimize the possibility of any conflict between the animals, due to the enrichment, and to reduce the probability of monopolization (Damasceno & Genaro, 2014), one item was introduced for each cat when more than one cat was housed in the same enclosure and new items were given to the subjects for each session. Baseline (BL) observations were carried out for 1 week (7 days) prior to the start of the enrichment, followed by HB for 7 days, then 7 days of interval (without any data collection or introduction of enrichment), then CA for 7 days, another 7 days of interval and, finally, CI also for 7 days. According to Clark and King (2008), it is necessary to leave a gap between the introduction of different scents to allow the dissipation of the previous scent and avoid accumulation of scent. Each enrichment treatment was applied for seven continuous days, in order to analyze whether habituation to each form of enrichment occurred and also to provide replicate treatments for behavioral data analysis. The entire schedule took 4 weeks. Three enclosures were observed between January and February and the other three enclosures were observed from February to May.

2.4 | Data analysis

Data from tigers and cheetahs were combined, due to the fact that there was no difference among the species for the observed behaviors. The duration (in minutes) that each animal spent interacting with each form of enrichment during the first hour after each introduction was utilized in the analysis. The duration (in minutes) that each animal spent performing pacing, inactive, exploratory, and locomotion behaviors was also considered during data analysis. Since the data violated normality and homogeneity of variance assumptions, a Friedman ANOVA was used for data analysis. The average duration that each animal interacted, with each form of enrichment, over the seven days of introduction, was calculated. A Friedman ANOVA ($n = 8$) was then conducted, in order to determine if there was a significant difference in the interaction time between the three different forms of enrichment (Hay ball, Catnip, and Cinnamon). This procedure was repeated using the average duration (in minutes) that each animal spent in pacing, inactive, exploratory, and locomotion behaviors, during baseline and each enrichment phase, in order to determine if there was a significant difference, between the different phases of the study. The average latency for each animal to start interacting with enrichment was calculated, across the 7 days of introduction, for each type of enrichment. A Friedman ANOVA was conducted, in order to determine if there was a significant difference in latency between enrichment types. Secondly, in order to determine if habituation to enrichment occurred, over the 7 days of introduction, three Friedman ANOVAs ($n = 8$), one for each enrichment type, were conducted using the duration that each animal spent interacting with each enrichment on each day of introduction. The same procedure was carried out using the pacing data. The alpha level for statistical significance was taken to be $p < 0.05$ for all Friedman ANOVAs. If the Friedman tests were significant, Wilcoxon signed rank tests with a Bonferroni correction, applied for multiple tests, were performed to determine significant pair-wise relationships. All analyses were conducted using R version 3.2.

TABLE 2 Categories of behavior taken into account during the observation period

Categories of behavior	Definition
Enrichment	Interacting with the enrichment item, any kind of direct contact as touching, rolling, sniffing, playing, catching, rubbing, carrying, and other.
Exploration	Urine spray, sniffing, scratching, or rubbing objects or enclosure substrate.
Self-grooming	Licking own body.
Inactive	Lying, sitting, or standing still.
Locomotion	Running, walking, climbing, or jumping.
Negative social	Aggression, strikes with a paw, bites, shows teeth with vocalization, chasing other cat.
Pacing	Repetitive locomotory movement along a given route (up/down fence line, around enclosure, or object in enclosure) uninterrupted by other behaviors.
Positive social	Playing together, allogrooming, or allorubbing.

This ethogram was adapted from, Quirke and O'Riordan (2011).

3 | RESULTS

3.1 | Interaction time

The mean interaction time (minutes ± SE), across all treatments was $\bar{x} = 5.15 \pm 0.42$ min. There was no significant difference in interaction time between the three different forms of enrichment ($\chi^2 = 3.25$, d.f. = 2, $p = 0.197$) (Figure 1). The longest mean interaction time (mean in minutes ± SE) across the 7 days of introduction was observed for cinnamon ($\bar{x} = 5.43 \pm 0.85$) followed by the hay ball ($\bar{x} = 4.16 \pm 0.76$) and catnip ($\bar{x} = 3.11 \pm 0.64$) (Figure 1). There was no significant difference ($\chi^2 = 6.00$, d.f. = 6, $p = 0.423$), in interaction time, between the 7 days of introduction, for the hay ball enrichment (Figure 2). The longest interaction time was observed on day 1 of introduction ($\bar{x} = 7.89 \pm 3.285$) with the shortest interaction time occurring on day 4 of introduction ($\bar{x} = 2.75 \pm 1.064$) (Figure 2). There was no significant difference ($\chi^2 = 5.52$, d.f. = 6, $p = 0.479$), in interaction time, between the 7 days of introduction, for the catnip enrichment. The longest interaction time was observed on day 6 of introduction ($\bar{x} = 4.36 \pm 2.11$), with the shortest interaction time occurring on day 3 of introduction ($\bar{x} = 1.49 \pm 0.77$) (Figure 2). There was no significant difference ($\chi^2 = 12.90$, d.f. = 6, $p = 0.051$) in interaction time, between the 7 days of introduction, for the cinnamon

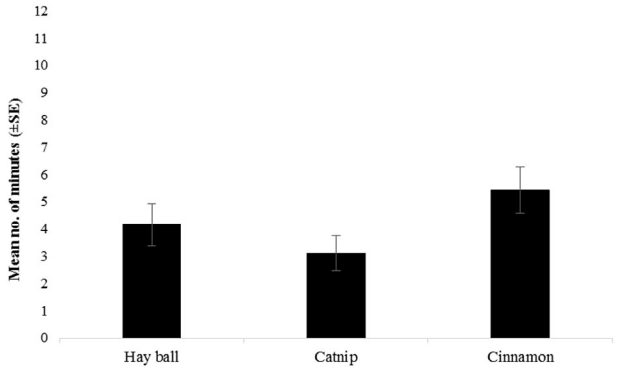

FIGURE 1 Mean ± SE of the total cats' interaction time (minutes) with the enrichment forms (Hay Ball [no scent], Catnip, and Cinnamon)

enrichment. The longest interaction time was observed on day 6 of introduction ($\bar{x}$ = 7.51 ± 2.27), with the shortest interaction time occuring on day 3 of introduction ($\bar{x}$ = 2.70 ± 1.382).

In terms of latency, the overall mean was $\bar{x}$ = 18.95 ± 2.92 for all enrichment types combined. There was no significant difference in the latency between the three types of enrichment (χ^2 = 3.161, d.f. = 2, p = 0.206). The longest latency was for catnip ($\bar{x}$ = 24.8 ± 4.85), followed by the hay ball ($\bar{x}$ = 16.15 ± 5.61), and the shortest latency was for cinnamon ($\bar{x}$ = 15.9 ± 4.01).

The individual variability in terms of time spent interacting with each enrichment type over the 7 days of introduction, can be seen in Figure 3.

3.2 | Pacing behavior

There was a significant difference (χ^2 = 10.35, d.f. = 3, p = 0.016) in time spent pacing between baseline ($\bar{x}$ = 17.06 ± 2.75), hay ball ($\bar{x}$ = 11.36 ± 3.77), catnip ($\bar{x}$ = 7.35 ± 4.11), and cinnamon treatments ($\bar{x}$ = 7.19 ± 1.97) (Figure 4). Pairwise comparisons between baseline and each enrichment phase, using a Bonferroni adjusted alpha level of 0.016, highlighted a significant difference between the baseline phase and cinnamon enrichment phase (W = 56, p = 0.0104). No significant differences were highlighted when comparing the baseline and hay ball phases (W = 47, p = 0.1304) or between baseline and catnip phases (W = 51, p = 0.0498). There was no significant difference in time spent pacing between each day of introduction for the hay ball (χ^2 = 3.17, d.f. = 6, p = 0.787), catnip (χ^2 = 8.94, d.f = 6, p = 0.177), and cinnamon (χ^2 = 8.98, d.f. = 6, p = 0.174) (Figure 5).

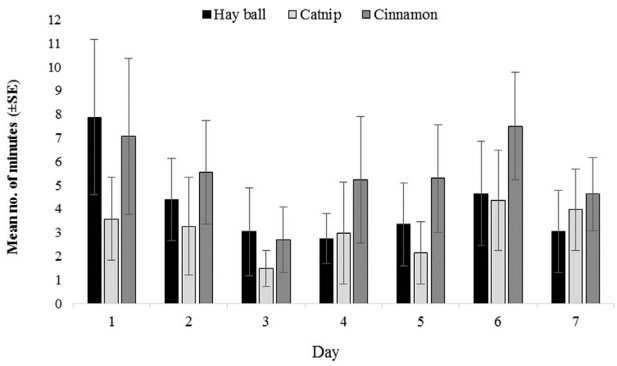

FIGURE 2 Mean ± SE of the cats' interaction time (minutes) with the enrichment forms (Hay Ball [no scent], Catnip, and Cinnamon) according to the day during the treatment application

3.3 | Locomotion, inactive, and exploratory behaviors

There was no significant difference in mean time spent in locomotion (χ^2 = 1.05, d.f. = 3, p = 0.789) and exploratory (χ^2 = 2.85, d.f. = 3, p = 0.415), but a significant difference was observed for inactive behaviors (χ^2 = 8.55, d.f. = 3, p = 0.036), between baseline, hay ball, catnip, and cinnamon treatments (Figure 6). Pairwise comparisons between baseline and each enrichment phase, using a Bonferroni adjusted alpha level of 0.016, revealed no significant differences between baseline and hay ball (W = 7, p = 0.1484), catnip (W = 4, p = 0.054), or cinnamon (W = 7, p = 0.1484).

4 | DISCUSSION

The response of the captive cats (tigers and cheetah), to the three forms of enrichment, highlight their effectiveness, as short-term environmental enrichment options, for these species. The subjects interacted with the three items for a short period of time, an average of just over 5 min, across the three enrichment types for all of the introductions. The enrichment utilized in this study was easily destroyed through the cats' interaction with it, which contributed to the short length of interaction time. However, with respect to the hay balls that had been sprayed with catnip and cinnamon, the scents remained on the hay even after the hay ball had been destroyed, therefore still providing a scent stimulus. There was, however, no significant difference in the level of interaction with each of the three forms of enrichment, meaning that the cats interacted with the hay ball as a new object at the same level, whether it was infused with a scent (catnip or cinnamon) or not. Ellis and Wells (2010) offered cloth with and without scent to domestic cats, and found high levels of interaction with cloths even without scent. Despite there being no statistically significant difference in the current study, there was a trend towards increased levels of interaction with cinnamon, which is also shown by the shortest latency time.

The habituation process can occur within the same session (intra-session) or between sessions (inter-session) (Leussis & Bolivar, 2006). In the study conducted by Ellis and Wells (2010), cloths without odor, with catnip, lavender, and prey scent, respectively, were introduced to domestic cats housed in a shelter, for 3 hr over 5 consecutive days. It was observed in all experimental conditions that there was a reduction in the animal's response after the first hour, suggesting that the cats had habituated to the stimuli within each session. Hall, Bradshaw, and Robinson (2002) presented a new object to domestic cats for four sessions during the same day, with a duration of two minutes for each session. The highest frequency of interaction with the objects was observed during the first session, suggesting that habituation had

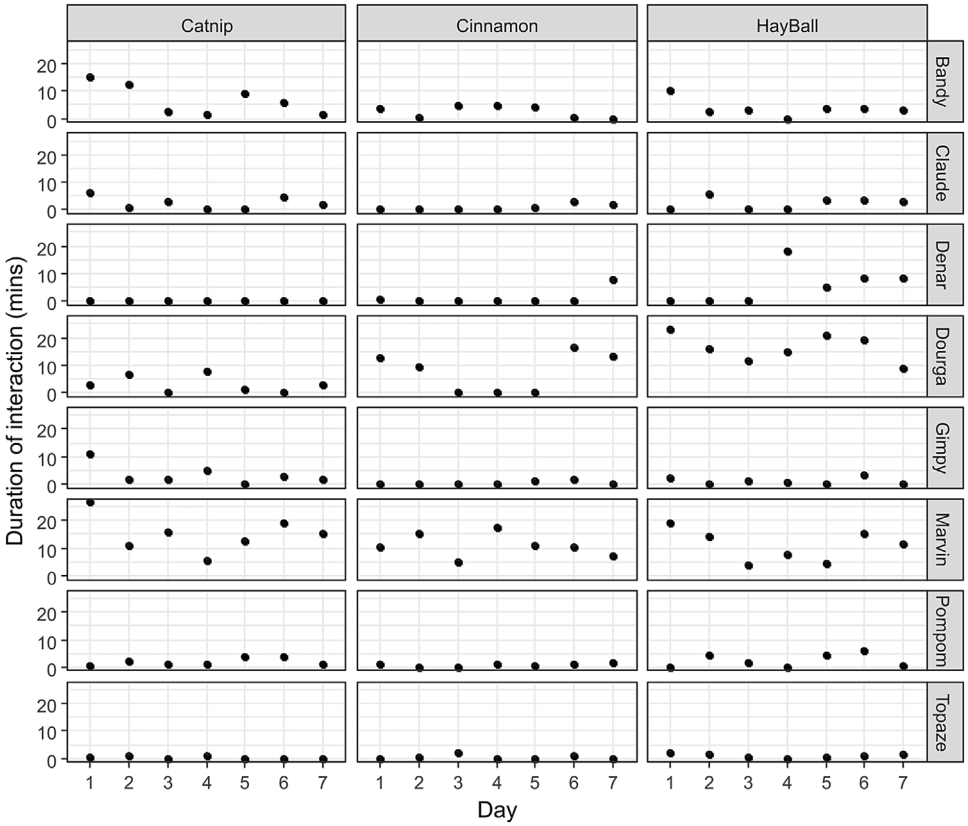

FIGURE 3 Individual variability in enrichment interaction expressed by each captive wild cat over the 7 days of the three enrichment treatments (Hay Ball [no scent], Catnip, and Cinnamon)

occurred. In the present study, as predicted by Tarou and Bashaw (2007), there was habituation within sessions to the different forms of enrichment, as, demonstrated by the aforementioned short interaction time with each enrichment. However, no evidence of habituation was observed between different days (sessions) for each form of enrichment. This suggests that these three types of enrichment can be used repeatedly for captive cheetahs and tigers.

Intrinsic forms of enrichment appear to have short-lived effects but can still function effectively (Tarou & Bashaw, 2007). In the present study, the animals engaged in enrichment-directed behaviors, which are related to novelty seeking, play and exploration. The introduction of new scents into the captive environment can also stimulate scent marking and other exploratory behaviors, while also encouraging greater overall activity levels (Mellen & Shepherdson, 1997). After the introduction of various perfumes and colognes to captive and free-ranging cheetahs, leopards, and lions, Thomas, Balme, Hunter, and McCabe-Parodi (2005) found that each species engaged more frequently in exploratory behaviors, such as cheek-rubbing and

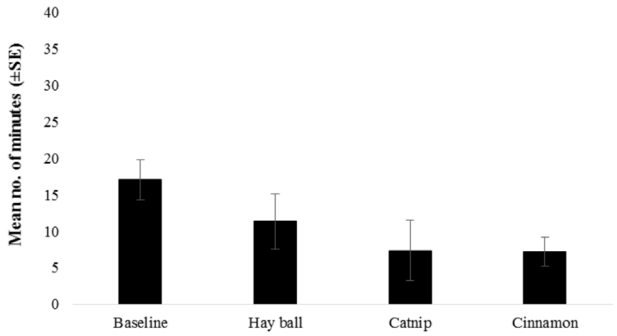

FIGURE 4 Mean ± SE of time spent (minutes) by the cats (n = 8) in pacing behavior during the application of each type of enrichment (Hay Ball [no scent], Catnip, and Cinnamon), during the 7 days of each treatment compared with Baseline observations (without enrichment)

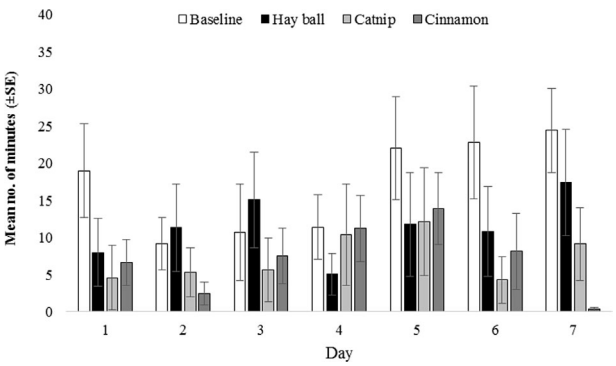

FIGURE 5 Mean ± SE of time spent (minutes) by the cats (n = 8) in pacing behavior during the application of the enrichment forms (Hay Ball [no scent], Catnip, and Cinnamon) for baseline period and days during the treatment application

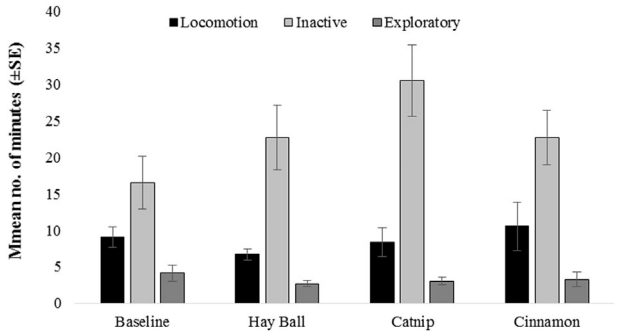

FIGURE 6 Mean ± SE amount of time (minutes) cats (n = 8) spent in locomotion, inactive, and exploratory behavior during the application of type of enrichment (Hay Ball [no scent], Catnip, and Cinnamon), for the 7 days of each treatment compared with baseline observations (without enrichment)

scent-marking. Wells and Egli (2004), observed a reduction in the levels of inactivity upon the introduction of nutmeg (*Myristica fragrans*), catnip, and prey odor (quail, *Coturnix coturnix*) into the enclosures of captive black-footed cats (*Felis nigripes).* Upon introducing rat scent to 21 domestic cats in a shelter, Machado and Genaro (2014), observed an increase in exploration behaviors, such as sniffing, rubbing, and urine spraying. In contrast to these previous studies, levels of locomotion and exploratory behaviors did not show any significant change upon the introduction of the three forms of enrichment in the present study. Similarly, Resende et al. (2011) did not find any significant change in the levels of active or resting behaviors after applying catnip and cinnamon to oncilla (*Leopardus tigrinus*) enclosures. However, there was a trend for levels of inactivity to increase for each enrichment treatment, when compared to baseline levels in the present study.

Quirke, O'Riordan, and Zuur (2012) noted that stereotypical behaviors in cheetah are influenced by many factors, such as enclosure size, feeding time, group membership, and ability to view conspecifics in adjoining enclosures. Although, Hönig and Gusset (2010), found that variables such as species, age, sex, and social housing did not affect stereotypy expression in captive felids, these must be considered as contributory factors. In the current study, the level of interaction with the enrichment items, combined with the observed lower levels of pacing behavior during enrichment treatments, suggests that these forms of enrichment could potentially be applied during periods when pacing levels are high, in order to combat the expression of this behavior and to provide sensory stimulation. Similar to our study, Resende et al. (2011) introduced cinnamon and catnip to eight captive Oncilla and also found a decrease in pacing behavior during their cinnamon treatment. Skibiel et al. (2007) identified consistent reductions in levels of pacing behavior in five species of felid after the introduction of spices such as cinnamon, chili powder, and cumin. The combination of the interaction with the enrichment and a decrease in pacing behavior, could explain the trend in the observed increased levels of inactivity. This can be considered a positive result, as abnormal stereotypical behavior is widely regarded as an indicator of reduced animal welfare.

There is a continuous need to develop effective, naturalistic, practical, and time efficient methods of enrichment for captive animals (Markowitz, 1982; Markowitz & Spinelli, 1986; Markowitz & Stevens, 1978; Mellor et al., 2015). The three forms of enrichment utilized in the current study are cheap, easy to build, and to apply. Additionally, the combination of the lack of a decreased response to each form of enrichment over the course of 7 days and the observed decrease in pacing behavior, suggests that these three forms of enrichment are effective and can be incorporated regularly within the enrichment schedules of cheetahs and tigers in order to improve their welfare.

5 | CONCLUSIONS

1. Hay balls without scent or with either catnip or cinnamon scent, were observed to be effective short-term forms of enrichment for cheetahs and Sumatran tigers in captivity.
2. No habituation in response, in terms of interaction with enrichment, was observed across the 7 days of introduction for each type of enrichment.
3. The animals interacted more with the hay ball with cinnamon scent, in comparison to the hay ball alone or the hay ball infused with catnip.
4. Pacing behavior was significantly lower during the cinnamon enrichment treatment when compared to baseline levels.
5. These three forms of enrichment are easy to administer, inexpensive, practical, and interactive options for enrichment of cheetahs and tigers in captivity.

ACKNOWLEDGMENTS

The authors would like to thank the following Fota Wildlife Park keepers: Kelly Lambe, Julien Fonteneau, Liam McConville. and Jean Taylor for providing support during this study. Thanks also to the Coordination for the Improvement of Higher Education Personnel (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—CAPES) and the National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico—Cnpq) for financial support, and finally, thanks to Dr Mateus José Rodrigues Paranhos da Costa for the final review and relevant suggestions.

REFERENCES

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

Bloomsmith, M. A., Brent, L. Y., & Schapiro, S. J. (1991). Guidelines for developing and managing an environmental enrichment program for nonhuman primates. *Laboratory Animal Science*, *41*, 372–377.

Carlstead, K., & Shepherdson, D. J. (1994). Effects of environmental enrichment on reproduction. *Zoo Biology*, *13*, 447–458.

Carlstead, K., & Sheperdson, 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). Wallinford, Oxon, UK: CABI Publishing.

Clark, F., & King, A. J., (2008). A critical review of zoo-based olfactory enrichment. In J. L. Hurst, R. J. Beynon, S. C. Roberts, & T. D. Wyatt (Eds.), *Chemical signals in vertebrates 11* (pp. 391–398). New York: Springer.

Clubb, R., & Mason, G. (2003). Animal welfare: Ccaptivity effects on wide-ranging carnivores. *Nature*, *425*, 473–474.

Clubb, R., & Mason, G. J. (2007). Natural behavioral biology as a risk factor in carnivore welfare: How analysing species differences could help zoos improve enclosures. *Applied Animal Behaviour Science*, *102*, 303–328.

Damasceno, J., & Genaro, G. (2014). Dynamics of the access of captive domestic cats to a feed environmental enrichment item. *Applied Animal Behaviour Science*, *151*, 67–74.

De Azevedo, C. S., Cipreste, C. F., & Young, R. J. (2007). Environmental enrichment: A GAP analysis. *Applied Animal Behaviour Science*, *102*, 329–343.

Ellis, S. (2009). Environmental enrichment practical strategies for improving feline welfare. *Journal of Feline Medicine and Surgery*, *11*, 901–912.

Ellis, S. L. H., & Wells, D. L. (2010). The influence of olfactory stimulation on the behavior of cats housed in a rescue shelter. *Applied Animal Behaviour Science*, *123*, 56–62.

Hall, S. L., Bradshaw, J. W. S., & Robinson, I. H. (2002). Object play in adult domestic cats: The roles of habituation and disinhibition. *Applied Animal Behaviour Science*, *79*, 263–271.

Hönig, D., & Gusset, M. (2010). Test multipler Hypothesen zum Auftreten von stereotypen Verhaltensweisen bei Großkatzen im Zoo Leipzig. *Der Zoologische Garten*, *79*(1), 38–52.

Hoy, J. M., Murray, P. J., & Tribe, A. (2010). Thirty years later: Enrichment practices for captive mammals. *Zoo Biology*, *29*, 303–316.

Law, G., Graham, D., & Mcgowan, P. (2001). Environmental enrichment for zoo and domestic cats. *Animal Feed Science and Technology*, *52*, 155–163.

Leussis, M. P., & Bolivar, V. J. (2006). Habituation in rodents: A review of behavior, neurobiology, and genetics. *Neuroscience and Biobehavioral Reviews*, *30*, 1045–1064.

Machado, J. C., & Genaro, G. (2014). Influence of olfactory enrichment on the exploratory behavior of captive- housed domestic cats. *Australian Veterinary Journal*, *92*, 492–498.

Markowitz, H. (1982). *Behavioral enrichment in the zoo*. New York: Van Nostrand Reinhold.

Markowitz, H., & Spinelli, J., (1986). In Benirschke, K. Priopopulations (Ed.), *Environmental engineering for primates*. New York: Springer-Verlag.

Markowitz, H., & Stevens, V. (1978). (Eds.). *The behavior of captive wild animals*. Chicago: Nelson-Hall.

Mason, G. J. (1991). Stereotypies: A critical review. *Animal Behavior*, *41*, 1015–1037.

Mellen, J. D., & Shepherdson, D. J. (1997). Environmental enrichment for felids: An integrated approach. *International Zoo Yearbook*, *35*, 191–197.

Mellor, D. J., Hunt, S., & Gusset, M. (2015). *Caring for wildlife: The world zoo and aquarium welfare strategy*. Gland: WAZA Executive Office, (p. 87).

Quirke, T., & O'Riordan, R. M. (2011). The effect of a randomized enrichment treatment schedule on the behavior of cheetahs (*Acinonyx jubatus*). *Applied Animal Behaviour Science*, *135*, 103–109.

Quirke, T., & O'Riordan, R. (2015). An investigation into the prevalence of exploratory behavior in captive cheetahs (*Acinonyx jubatus*). *Zoo Biology*, *34*, 130–138.

Quirke, T., O'Riordan, R., & Davenport, J. (2013). A comparative study of the speeds attained by captive cheetahs during the enrichment practice of the 'cheetah run'. *Zoo Biology*, *32*, 490–496.

Quirke, T., O'Riordan, R. M., & Zuur, A. (2012). Factors influencing the prevalence of stereotypical behavior in captive cheetahs (*Acinonyx jubatus*). *Applied Animal Behaviour Science*, *142*, 189–197.

Resende, L. S., Gomes, K. C. P., Andriolo, A., Genaro, G., Remy, G. L., & Ramos Júnior, V. A. (2011). Influence of cinnamon and catnip on the stereotypical pacing of oncilla cats (*Leopardus tigrinus*) in captivity. *Journal of Applied Animal Welfare Science*, *14*, 247–254.

Skibiel, A. L., Trevino, H. S., & Naugher, K. (2007). Comparison of several types of enrichment for captive felids. *Zoo Biology*, *26*, 371–381.

Szokalski, M. S., Litchfield, C. A., & Foster, W. K. (2012). Enrichment for captive tigers (*Panthera tigris*): Current knowledge and future directions. *Applied Animal Behaviour Science*, *139*, 1–9.

Tarou, L. R., & Bashaw, M. J. (2007). Maximizing the effectiveness of environmental enrichment: Suggestions from the experimental analysis of behavior. *Applied Animal Behaviour Science*, *102*, 189–204.

Thomas, P., Balme, G., Hunter, L., & McCabe-Parodi, J. (2005). Using scent attractants to non invasively collect hair samples from cheetahs, leopards and lions. *Animal Keeper's Forum*, *8*, 342–384.

Thompson, R. F., & Spencer, W. A. (1966). Habituation: A model phenomenon for the study of neuronal substrates of behavior. *Psychological Review*, *73*, 16–43.

Wells, D. L. (2009). Sensory stimulation as environmental enrichment for captive animals: A review. *Applied Animal Behaviour Science*, *118*, 1–11.

Wells, D. L., & Egli, J. M. (2004). The influence of olfactory enrichment on the behavior of black-footed cats, *Felis nigripes*. *Applied Animal Behaviour Science*, *85*, 107–119.

Wong, K., Elegante, M., Bartels, B., Elkhayat, S., Tien, D., Roy, S., Goodspeed, J., Suciu, C., Tan, J., Grimes, C., Chung, A., Rosenberg, M., Gaikwad, S., Denmark, A., Jackson, A., Kadri, F., Chung, K. M., Stewart, A., Gilder, T., Beeson, E., Zapolsky, I., Wu, N., Cachat, J., & Kalueff, A. V. (2010). Analyzing habituation responses to novelty in zebrafish (*Danio rerio*). *Behavioural Brain Research*, *208*, 450–457.

Young, R. J. (2003). *Environmental Enrichment for Captive Animals*. Oxford: Blackwell.

How to cite this article: Damasceno J, Genaro G, Quirke T, McCarthy S, McKeown S, O'Riordan R. The effects of intrinsic enrichment on captive felids. *Zoo Biology*. 2017;36:186–192. https://doi.org/10.1002/zoo.21361