Zoodiversity, **57**(3): 239–250, 2023
DOI 10.15407/zoo2023.03.239

UDC 599.824:591.5(541.35)

MOTOR STEREOTYPIC BEHAVIORS IN ZOO RHESUS MONKEYS: A CASE STUDY OF THE CENTRAL ZOO, KATHMANDU, NEPAL

S. Sharma, S. Shrestha, & L. Khanal*

Central Department of Zoology, Institute of Science and Technology, Tribhuvan University, Kirtipur, Kathmandu 44618, Nepal
**Corresponding author*
E-mail: lkhanal@cdztu.edu.np

S. Sharma (https://orcid.org/0000-0003-4988-2342)
S. Shrestha (https://orcid.org/0000-0002-4032-7409)
L. Khanal (https://orcid.org/0000-0003-2411-3627)

urn:lsid:zoobank.org:pub:36ACE994-DB46-437D-8AEC-CD2D5E7CA896

Motor Stereotypic Behaviors in Zoo Rhesus Monkeys: a Case Study of the Central Zoo, Kathmandu, Nepal. Sharma, S., Shrestha, S. & Khanal, L. — Motor stereotypic behaviors (MSBs) are a kind of repetitive behaviors performed by stressed animals and are more common in captivity. This study aimed to assess whether the MSB in captive rhesus monkeys varies between males and females, and with the extent of visitor-monkey interactions. A group of six rhesus monkeys (two adult males and four adult females; among females, two were rescued from the wild and two were captive-born) housed in the Central Zoo, Kathmandu Nepal were sampled in the study. Behavioral observations were done by focal animal sampling for 30 minutes in each session from 8:00 AM till 10:00 AM in the absence of visitors and 10:00 AM–12:00 PM in the presence of visitors. At every 10 minutes interval, the number of visitors around the cage and the level of visitor-monkey interactions were scanned. Pacing and bounce were the MSBs performed by the zoo rhesus monkeys. Females, especially the rescued ones, performed significantly more MSBs than the males. An increase in visitor-monkey interaction involved the monkeys into more begging and feeding, which in turn lowered the MSBs. The findings of this study indicate that interactive enrichment such as feeding and visitor-monkey interactions help to reduce MSBs in zoo monkeys.
Key words: ethogram; focal animal sampling; stereotypies; visitor-monkey interaction; zoo enrichment.

Introduction

Zoos and aquariums are sites for entertainment, education, conservation and research (Carr & Cohen, 2015). Zoos possess and manage a large number of wild (non-domesticated) animals inside captivity so that they are easier to see and study than in nature (Barongi et al., 2015). Zoos and aquariums are home to one in seven threatened terrestrial vertebrate species which is about 15 % of all threatened species. Not only the number of species, the number of individuals should also be considered for a proper ex-situ conservation plan (Conde et al., 2011). A large number of zoos or wildlife parks have been performing a very crucial role in the conservation of endangered species through ex-situ conservation activities (Barongi et al., 2015). Zoos also play an important role in the dissemination of conservation knowledge on endangered species, monitoring live animal trade, conservation of biodiversity (Patrick & Caplow, 2018; Cuarón, 2005; Conde et al., 2011), supporting research activities and even making a considerable economic contribution to the nation through zoo tourism (Carr & Cohen, 2015). However, the captive animals in the zoo encounter multiple stressors and exhibit abnormal behaviors.

Stereotypic behaviors are the kind of continuously repetitive behavioral patterns which serve no specific function to the performer. Such repetitive behaviors include a broad array of behaviors which are characterized by some specific identifiable patterns such as repetition, rigidity or inflexibility, and lack of clear function. Continuous performance of the stereotypies in captive animals may represent their current sufferings (Lewis & Kim, 2009; Mason, 1991; Mason & Latham, 2004). Motor stereotypic behaviors (MSBs) are the full body repetitive behaviors performed by the captive animals recklessly in such a way for longer duration and frequency (e. g., pace, bounce, swing, rock, etc.) (Polanco et al., 2021).

Stereotypic behavior in animals are developed due to some very promising reasons such as low enrichment, physical restraints, and unavoidable fear or frustration situations inside the captive conditions (Mason, 1991; Shih et al., 2016). There are several hypotheses regarding development of the stereotypic behavior in captive animals. The motivation hypothesis states that animals perform stereotypic behavior to fulfil their natural requirement to outer stimuli. For example, oral stereotypic behavior is developed due to feeding motivation (Bashaw et al., 2001), and pacing stereotypic behavior is developed to ranging motivation. The neuropathologic hypothesis proposes that stereotypic behaviors are the results of physiologic malfunction, functional and structural alteration of the central nervous system or imbalance in neurotransmitters (Shih et al., 2016; Lewis & Kim, 2009)

Major stressors for the zoo animals are reduction in feeding/foraging opportunities, limited retreat space, visitors crowd, animal-visitor interactions, regular husbandry procedures, artificial lighting and scents, placement in an abnormal social group sometimes having unknown companions, unfavorable cage placement, lack of proper enrichment (Hosey, 2008; Morgan & Tromborg, 2007; Vanlangendonck et al., 2015), etc. Zoos in highly urbanized areas have additional stressors including noise and interaction from visitors, intense noise from construction and traffic, etc. (Jakob-Hoff et al., 2019). Zoo visitors could be one of the major causes of behavioral alterations in zoo animals. For example, visitors around the cage had a significant influence on the performance of the abnormal behavior and enclosure space used by the lion-tailed macaques (*Macaca silenus* Linnaeus, 1758) in captivity. Similarly, abnormal behavior performed by the monkeys was higher during the 'on exhibit' days than the 'off exhibit' days as the monkeys spent a significantly high amount of time by the edge of the cage during the former condition (Mallapur et al., 2005). Stereotypic behavior, feeding behavior and clinging behavior increase with the number of visitors around the captivity (Wells, 2005; Hashmi & Sullivan, 2020). Research on the captive lemur (*Lemur catta* Linnaeus, 1758) concluded that increase in number of visitors near the cage negatively affected feeding/foraging and sunbathing behavior whereas it was positively associated with repetitive locomotion and alertness (Goodenough et al., 2019). In some cases, visitor-animal interaction acts as an enrichment for the captive animals. Such as in captive crown lemurs (*Eulemur coronatus* (Gray, 1842)), visitors-lemurs interactions decrease the performance of the aggression and animals spend more time interacting with the zoo keepers (Jones et al., 2016). Honess & Marin (2006) concluded that abnormal behavior and aggression in captive animals are the results of poor enrichment. Appropriate enrichment in and around the captivity results in a reduction of aggressive and abnormal behaviors in the captive primates and enhances their welfare.

The expression of abnormal behavior by the captive animals increases as the number of visitors increases. In some cases, animals take visitors' presence and interactions as a source of enrichment and perform less abnormal behaviors (Sharma et al., 2023). The present study was conducted to examine the effects of the sex, rearing history, begging behavior and its intensities, feeding behavior, and visitor-monkeys interaction probabilities on the performance of the motor stereotypic behavior by the captive rhesus monkeys (*Macaca mulatta* (Zimmermann, 1780)) at Central Zoo, Kathmandu, Nepal. This study was performed with three basic hypotheses: i) since females are involved in nursing the infants, females are stressed more and show more MSB; ii) MSB is influenced by the number of visitors around the cage; and, iii) begging or foraging interactions reduce

the MSB in captive monkeys. The findings of this study on stereotypic behavior could provide some alternative ways to deal with the problem arising in captive animals that in turn could significantly improve their welfare.

Material and Methods

Study subjects and study area

The Central Zoo, Jawalakhel, Kathmandu is the only zoo in the capital city of Nepal. It houses wild animals of different taxa for ex-situ conservation, research and education. In this study, a group of six adult rhesus monkeys (two males and four females) housed in a fenced enclosure of 10 × 20 m^2 dimension in the zoo were studied. The ages of adult monkeys ranged between 4 and 12 years. Each individual animal was identified on the basis of the physical marks on their body (table 1). Two adult males (M1 and M3) and two females (F4 and F6) were born in the zoo itself (hereafter referred as- captive born) and remaining two females (F2 and F8) were rescued from outside the zoo when they were young (hereafter referred as- rescued). Two of the females (F2 and F4) were lactating their infants of 3–4 months age. Animals were fed by the zoo workers three times in a day; in morning, afternoon and evening while water was provided *ad libitum*. The fenced enclosure was cleaned as per the requirement (~3–4 times in a week). Demographic data on the study animals and zoo management practices were collected by direct observation and personal conversation with the zoo officials.

Fallen logs and hanging ropes were present inside the enclosure as source of enrichment for the study subjects. Iron wires were used for fencing the enclosure. Three sides of the enclosure were fenced with iron wires while the back contained a concrete house as a shelter for monkeys for providing hiding and resting place. The enclosure was on the side of boundary wall of the zoo, outside of it was a noisy motorable road within 6–7 m distance from the enclosure. On the right side of the enclosure there was another enclosure for langur monkeys (*Semnopithecus hector* (Pocock, 1928)). Visitors could watch and interact with rhesus monkeys from the front side of the enclosure while left side of the enclosure was accessible to the zoo keepers only.

The data on MSBs were collected between 01 December 2020 to 23 February 2021. Each day, observation was done in two sessions each of two hours. Behavioral samplings were done for two hours during complete absence of the visitors i. e., before 10:00 AM (8:00 AM–10:00 AM) and for another two hours when the zoo opened for visitors after 10:00 AM (10:00 AM–12:00 PM). Behavioral sampling was done by focal animal sampling method (Altmann, 1974). A focal animal was observed for 30 minutes during each sampling bout and switched to the next animal for another similar bout. A total of 147 hours of samplings was done. Altogether nine behavioral states under two categories, namely general behaviors and motor stereotypic behaviors (MSBs) (table 2) were recorded. At every 10 minutes of interval, numbers of visitors around the enclosure of the study animals were scanned. Everyday each focal animal was sampled at least twice, one focal sample before 10:00 AM in the absence of visitors and the next after 10:00 AM. During the behavioral sample collection, focal individual was selected by lucky draw method for avoiding the sampling bias. The behavior sampling was aborted if the focal animal went out of sight for more than 10 minutes.

During each sampling period, begging behavior performed by the focal animals was recorded with ID of the animal. Different begging intensities were categorized into two categories on the basis of the mean and standard deviation. The first category was setup as low intensity of begging (values lesser than the lower limit of mean and standard deviation which included less than or equals to five minute of continuous begging behavior). If the begging continuously prolonged for more than five minutes, that was categorized as high intensity of begging. The probability of visitors-monkeys interaction with the zoo monkeys in the form of begging

Table 1. Identification characteristics, age and relations of captive rhesus monkeys in Central Zoo. Results of Motor stereotypic behavior (MSB) for each study individual is presented as percentage

ID	Identification characteristics	Age, years	Relations with group members	MSB, %
M1	Huge male without tail. Leader of the group	7	Child of F2	6.34
M3	Younger male. Healthy, with normal tail	6	Child of F4	14.98
F2	Older female having male infant, shorter tail	12	Rescued	50.24
F4	Female having female infant with saggy belly skin	9	Her mother died long ago	23.33
F6	Healthy-looking female in the group	5	Child of F2	0.00
F8	Female with scars on forehead. Weaker one in the whole group	4	Rescued	5.11

Table 2. An ethogram of general and motor stereotypic behavior of rhesus monkeys used in the study

Category	Behavior	Description
General behavior	Feeding/ foraging	State of searching food in surrounding or anything palatable, put in their mouth, hands engaged and chewing for at least 15 seconds.
	Begging	State of animal sitting near fence in presence of visitor and one or both hands out of fence for beg food or sitting in such a way that animals look towards visitors for at least 30 seconds.
Motor stereotypic behavior (MSB)	Pace	Walking back and forth or in a circular pattern, in such a way that the pattern can be predictable, for at least five seconds.
	Bounce	Moving jerkily, usually up and down anywhere inside the enclosure, for at least five seconds.
	Flip	Turning a somersault, usually in a backwards fashion, for at least five seconds.
	Twirl	Swinging in a circle or spinning, for at least five seconds.
	Swing	Moving back and forth suspended from above, for at least five seconds
	Head Twist	Moving or lifting the head with a sudden motion, for at least five seconds.
	Rock	Moving back and forth or from side to side, especially gently or rhythmically, for at least five seconds.

was categorized into four levels: zero interaction probability, low interaction probability, medium interaction probability and high interaction probability following the methods of Sharma et al. (2023). All the interaction probability categories were defined on the basis of number of visitors and their food supplementary behavior to the monkeys around the fenced enclosure. Focal animals were visually tracked and every episode of MSB was counted and duration was recorded precisely throughout the sampling period. If the animal stopped MSB for more than 10 seconds and repeated it, it was considered as two distinct episodes of MSB.

Data analysis

The normality of the data was tested using Shapiro-Wilk test (Shapiro & Wilk, 1965) and homogeneity of the variance was checked through the Bartlett test (Bartlett & Fowler, 1937). Due to the violation of the assumptions of normality and homogeneity of variance, Kruskal–Wallis' one-way ANOVA was performed to find whether MSB in the captive monkeys differed across the different categories of visitor-monkey interactions. The relationship between variables was measured as an effect size using the package "effectsize" (Ben-Shachar et al., 2020). Mann-Whitney U tests were performed to identify possible difference of MSB by the sex (males and females), rearing history (rescued and captive born), time of the day (morning and afternoon) and begging intensities (low begging and higher begging). The effect size for the Mann-Whitney U tests was calculated by using "rcompanion" package (Mangiafico, 2022). For determining difference between pace and bounce behavior and to identify sex-based difference on the performance of begging, Mann-Whitney U test was performed. Spearman's rank correlation coefficients were calculated to explain the association between begging and feeding behaviors with MSB. Multiple test correction was performed (for the two correlation tests) by using "Bonferroni correction method" to avoid false positive correlations. The duration of each behavior in minutes was presented as mean ± SE (bar graphs) and median ± SE (box plots). All the statistical tests were conducted using R version 4.2.1 (R Core Team, 2022).

Results

Motor stereotypic behavior (MSB) in captive rhesus monkeys

Out of seven motor stereotypic behaviors included in the ethogram, only two, i. e., pace (10.58 % of total observation time), and bounce (0.18 % of total observation time) were performed by the captive rhesus monkeys. Pacing (mean time in minutes per focal animal sampling bout = 3.17 ± 0.32) was performed for longer duration than bouncing behavior (mean time in minutes per focal animal sampling bout = 0.05 ± 0.01). Those two behaviors significantly differed with each other ($U = 55075$, $p < 0.01$, $r = 0.05$) for the group

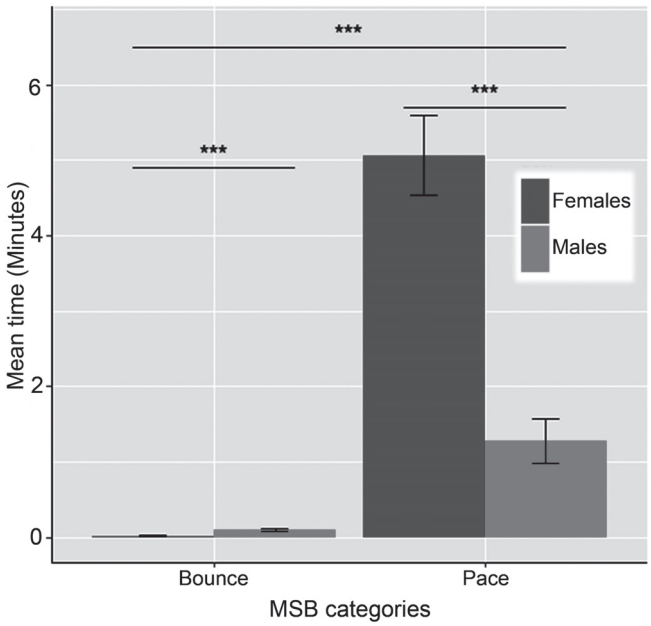

Fig. 1. Mean time invested on motor stereotypic behavior per focal sampling bout of 30 minutes by adult males and females (*** statistically significant difference).

of rhesus monkeys. The performance of the pacing and bouncing behaviors between males and females also differed significantly (fig. 1).

The rhesus monkeys performed MSBs for 10.76 % of the total observation time. The females (median ± SE = 2.58 ± 0.52) performed MSBs for longer duration than the males (median ± SE = 0.05 ± 0.29) (fig. 2, A) and the difference was statistically significant (U = 14714, $p < 0.01$, r = 0.32, CI (95 %) = 0.21, 0.42). The rescued monkeys (median ± SE = 4.82 ± 0.82) performed significantly more MSB than the captive-born (median ± SE = 0.01 ± 0.28) (U = 3405, $p < 0.01$, r = 0.45, CI (95 %) = −0.45, −0.35) (fig. 2, B).

Motor stereotypic behavior in response to interaction with zoo visitors

The MSB was higher in the absence of visitors (i. e., before 10:00 AM, median ± SE = 0.13 ± 0.30) than their presence (i. e., after 10:00 AM, median ± SE = 0.06 ± 0.45, fig. 3, A)

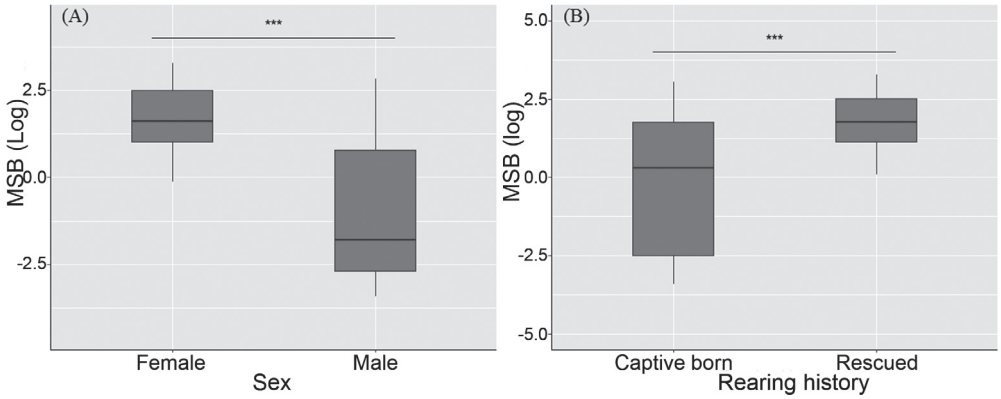

Fig. 2. Motor stereotypic behavior shown by the captive rhesus monkeys: A — difference between males and females; and B — on the basis of the different rearing histories (*** statistically significant difference).

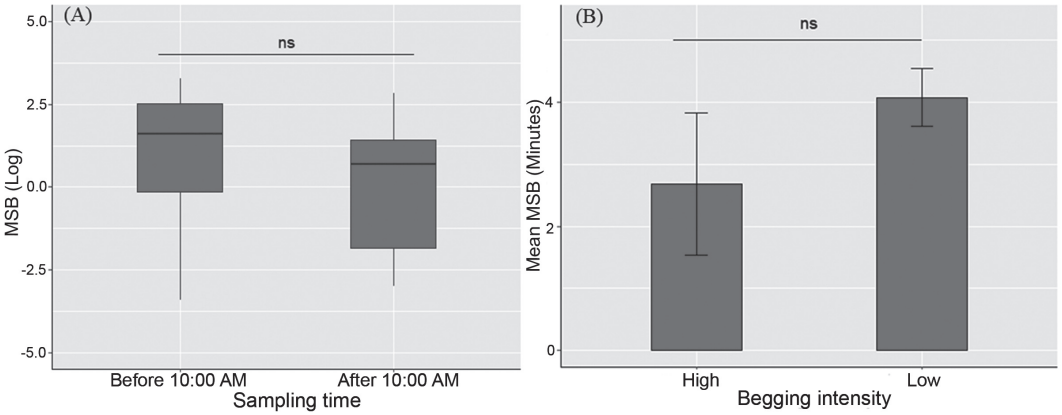

Fig. 3. Motor stereotypic behavior performed by the captive rhesus monkeys; A — under different time of the day; B — under different begging intensities (ns = statistically not significant difference).

but it did not differ significantly (U = 9977, $p > 0.05$, r = 0.03, CI (95 %) = [−0.08, 0.13]). Similarly, MSB was recorded higher during the low begging intensity (mean ± SE = 4.08 ± 0.467) than the high begging intensity (mean ± SE = 2.68 ±1.14) category (fig. 3, B). This difference also was not statistically significant (U = 1126, $p > 0.05$, r = 0.32, CI (95 %) = [0.17, 0.44]).

Association of motor stereotypic behavior with begging and feeding

The relationship between MSB and begging was found to be negative for the zoo monkeys, however the relationship was not statistically significant ($r_s = -0.07$, *p.adjust* > 0.05, fig. 4, A). Males performed significantly more begging (mean ± SE = 1.04 ± 0.24) than the females (mean ± SE = 0.45 ± 0.17) (U = 8686, $p < 0.01$, r = 0.25, CI (95 %) = [−0.35, −0.14]). Begging increased when there was higher probability of visitor-monkey interaction that led to sharp decline in the MSB (fig. 4, B). Monkeys performed more MSB under the low inter-

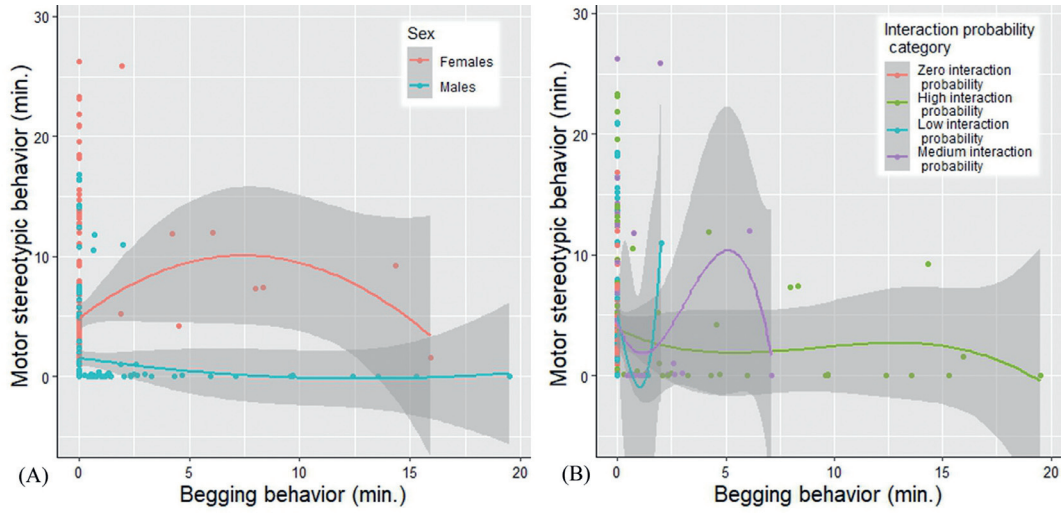

Fig. 4. Probable relationship between the MSB and begging. A — by controlling for sex of the captive monkeys; and, B — by controlling for the different probability of the visitor-monkey interaction (Min. — minutes).

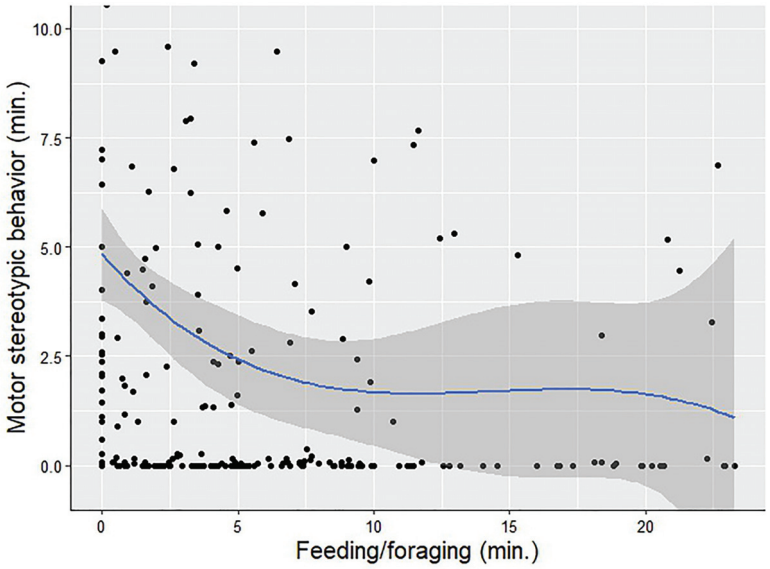

Fig. 5. Association between motor stereotypic and feeding behavior (Min. — minutes).

action category (mean ± SE = 4.71 ± 0.87) than medium (mean ± SE = 3.96 ± 0.828), high interaction (mean ± SE = 3.36 ± 0.63), and complete absence of the visitors (mean ± SE = 1.74 ± 0.31). Results from the Kruskal-Wallis one-way ANOVA revealed that MSB differ significantly across the different categories of the visitor-monkey interactions (Chi-square = 4.99, $p < 0.05$, $\eta^2 = 0.01$, CI (95 %) = [0.01, 0.06]).

The MSB and feeding had a significant negative relationship ($r_s = -0.15$, *p.adjust* < 0.05) implying that higher feeding/foraging engagement of the captive rhesus monkeys in Central Zoo lowered their MSBs (fig. 5).

Discussion

Animals in captivity are stressed due to multiple reasons including lowered food and space availability, disturbance from the crowd, animal-visitor interactions, an abnormal social grouping, lack of proper enrichment, etc. and they end up performing motor stereotypic behaviors (MSBs). By behavioral observations in a group of rhesus monkeys housed in the Central Zoo, Kathmandu, Nepal, this study assessed whether the MSBs in zoo monkeys differ between adult males and females, and with a different number of visitors and levels of interactions with them. The results revealed pacing and bounce as frequently performed MSBs by the captive rhesus monkeys. Out of two frequently performed stereotypic behaviors, the pacing was more common. Whole body stereotypic/motor stereotypic behaviors (e. g., pacing, rocking, swinging and back flipping) are more common in captive animals than self-directed stereotypies (Lutz et al., 2003, 2014; Poirier & Bateson, 2017). In captivity, stress behavior might be related to multiple factors: cage size, age-sex of the animals, housing condition, the clinical condition of the animals, husbandry procedures, rearing condition, and the animal species and genetics (Lutz et al., 2014, 2022). At the Central Zoo, lack of proper enrichment, rearing condition, age-sex of the monkeys, and animal genetics itself might be playing significant roles in the MSBs, however, a systematic identification is yet to be done. Species under study also have to be taken into consideration while interpret-

ing the results because some species have a higher tendency to express abnormal behavior than others. A cross-species comparison of abnormal behavior emphasized macaques being more likely to exhibit motor stereotypic and self-directed behavior than baboons (Lutz, 2018). The MSBs in animals are also associated with inflammation or immune response (Pan et al., 2021). It is acknowledged that we did not analyze cross-species variation and the health status of the study animals.

Female rhesus monkeys performed more pacing behavior than males whereas males performed more bounce. An extensive review concluded that pacing behavior is the frequently performed stereotypic behavior in captive animals (Poirier & Bateson, 2017). Captive monkeys perform more pacing behavior than other kinds of motor stereotypic behavior (Polanco et al., 2021; Pomerantz et al., 2012; Schapiro et al., 1995). Higher pacing stereotypic behavior in captive monkeys at the Central Zoo might be related to the cage size, because the zoo has limited space for performing ranging behavior. Animals' rearing experiences might also be related to the MSB as some animals are moved from a bigger natural group to a smaller captive group (rescued) with unknown companions. More pacing by the females of the Central Zoo might be related to their rearing history. The rescued female (F2) monkey performed pacing more than the other members inside the enclosure which alone constituted the highest proportion of pacing behavior among all the members. Hand-reared (more relatable to the rescued-rearing) animals perform more stereotypic behavior than mother-reared ones (Marriner & Drickamer, 1994). Pacing behavior in the animals is developed soon after animals are deliberately taken from a natural group to the smaller managed group (Capitanio, 1986). Regarding the bouncing behavior, Polanco et al. (2021) also observed males more likely to perform bounce than females.

The female rhesus monkeys in the Central Zoo performed more MSBs than the males. Similarly, rescued monkeys overperformed the captive-born. Higher MSBs in the captive monkeys might be related to their past survival experiences. Early life history or rearing history and environmental deprivation are the most crucial factors for the development of abnormal behavior in captive animals (Mallapur & Choudhury, 2003; Rommeck et al., 2009; Marriner & Drickamer, 1994) as the rearing history of the animals is very crucial on the development of the MSB. Nursery-reared monkeys have been observed performing more stereotypic behavior than mother-reared ones (Crast et al., 2014). Two rescued female monkeys of the Central Zoo overperformed the MSBs than other two captive-born females and the males. Females have been observed performing more motor stereotypic behavior than males (Crast et al., 2014; de la Barrera Cardozo et al., 2021). However, a lack of sex-based differences in MSBs has also been reported from captive primates (Hook et al. 2002; Marriner & Drickamer, 1994). Some studies even provided contradictory evidence that males performed more MSBs than females (Gottlieb et al., 2013 a, 2015; Jacobson et al., 2016; Lutz et al., 2003; Lutz, 2018; Vandeleest et al., 2011). Animal sex alone might not be the determinant of MSBs, other traits including rearing history, health, lactation, etc. in combination with sex might affect it.

The monkeys performed noticeably more MSBs during the absence of zoo visitors and low begging intensities. The number of visitors around the captivity also controls behavioral repertoire of the animals inside it. Higher MSBs during the morning and low begging intensity in captive rhesus monkeys might be related to the lesser behavioral diversity in the absence of visitors. As the number of visitors around the cage increased, animals started interacting with the visitors and performed array of diverse behaviors. A greater number of visitors near the cage led to diverse behaviors by the Diana monkeys,

Cercopithecus diana diana (Linnaeus, 1758), as grooming and resting behavior decreased significantly and playing, feeding/chewing significantly increased (Todd et al., 2007). Captive rhesus monkeys at the Central Zoo might take visitors as a source of interactive enrichment (Hosey, 2013; Sharma et al. 2023; Shyne, 2006) so that monkeys engaged themselves in interaction with the visitors ultimately reducing their time spent on MSBs. Responsive enrichments inside the captivity have a strong potential of reducing abnormal behavior in the captive rhesus monkeys (Line et al., 1991). Other kinds of toy enrichment are not working as strongly as responsive enrichment. Interactions between visitors and animals are known to have a positive effect on suppressing aggressive behavior, which is a sign of stress response (Jones et al., 2016). For example, captive lion-tailed macaques were found to have a direct relation between begging behavior and the number of visitors near the cage (Mallapur et al., 2005). High visitor numbers around the Central Zoo were found to increase begging behavior in the rhesus monkeys, which led to a perceptible decrease in the performance of abnormal behavior.

The higher proportion of MSBs in the females compared to the males could be attributed to the lower level of begging behavior exhibited by the females. It revealed that animals which interacted more with visitors in the zoo displayed lesser MSBs than those interacting less. Visitors-monkeys interaction probability also affected the behavior of the monkeys to a great extent. A high probability of monkey-visitor interaction predicted low performance of the MSBs. Hosey & Druck (1987) concluded that large or small groups of active visitors around the cage increase the time spent on the locomotory behaviors in captive animals. Visitors can have a positive, neutral or negative impact on the captive animals depending upon the variation in the perception of the zoo animals to the visitors (Sherwen & Hemsworth, 2019). The negative association between feeding/foraging and MSBs in the rhesus monkeys might be because feeding/foraging acts as the source of enrichment engaging themselves and ultimately reducing the MSBs. Feeding/foraging enrichment in captivity has been found to reduce abnormal behaviors in rhesus monkeys (Gottlieb et al., 2013 b). Therefore, feeding/foraging enrichment can be used as the suppressor of the MSBs in zoo monkeys.

Conclusions

Captive rhesus monkeys in the Central Zoo performed only two types of motor stereotypic behaviors (MSBs): pacing and bouncing. The pacing was higher performed stereotypic behavior than bouncing. There was a gender bias in the MSB, females performed higher pacing while males performed higher bouncing. Monkeys rescued from the wild performed more MSBs than the captive-born. When the probability of visitor-monkey interactions, begging and feeding/foraging behaviors of rhesus monkeys were higher, their engagement in the MSBs was lower. Therefore, it is concluded that involving captive monkeys in other interactions can reduce their stereotypic behaviors.

Acknowledgements

We thank Rachana Shah, Lina Chalise and Ganesh Koirala of the Central Zoo, Kathmandu for their support. We would like to acknowledge the support from other officials of the Central Zoo, Lalitpur, Kathmandu, Nepal for providing relevant information regarding the study animals.

Author contributions

L. Khanal improved the manuscript, conceptualized, and supervised the study. S. Shrestha performed the behavioral sampling. S. Sharma performed data analysis. S. Sharma and S. Shrestha prepared the manuscript. All authors read and approved the manuscript for submission.

Data availability statement

All the data used in the manuscript are available on the Science Data Bank with following identifiers: DOI: https://doi.org/10.57760/sciencedb.07611 and CSTR: https://cstr.cn/31253.11.sciencedb.07611

Conflict of Interest

The authors declare no conflict of interest.

References

Altmann, J. 1974. Observational sampling study of behavior: Sampling methods. *Behavior,* **49**, 227–265.

Barongi, R., Fisken, F. A., Parker, M. & Gusset, M., eds.. 2015. *Committing to conservation: The world zoo and aquarium conservation strategy*: World Association of Zoos and Aquariums (WAZA) Executive Office, Gland, Switzerland, 1–70.

Bartlett, M. S. & Fowler, R. H. 1937. Properties of sufficiency and statistical tests. *Proceedings of the Royal Society of London. Series A — Mathematical and Physical Sciences*, **160**, 268–282. https://doi.org/doi:10.1098/rspa.1937.0109.

Bashaw, M. J., Tarou, L. R., Maki, T. S. & Maple, T. L. 2001. A survey assessment of variable related to stereotypy in captive giraffe and okapi. *Applied Animal Behaviour Science*, **73**, 235–247.

Ben-Shachar, M., Lüdecke, D. & Makowski, D. 2020. effectsize: Estimation of effect size indices and standardized parameters. *Journal of Open Source Software,* **5**, 2815. https://doi.org/10.21105/joss.02815.

Capitanio, J. P. 1986. Behavioral pathology. *In:* Mitchell, G., Erwin, J. & Swindler, D., eds. *Comparative primate biology. Behavior, Conservation and Ecology.* A.R. Liss, New York, 411–454.

Carr, N. & Cohen, S. 2015. The public face of zoos: Images of entertainment, education and conservation. *Anthrozoös,* **24**, 175–189. https://doi.org/10.2752/175303711x12998632257620.

Conde, D. A., Flesness, N., Colchero, F., Jones, O. R. & Scheuerlein, A. 2011. Conservation: An emerging role of zoos to conserve biodiversity. *Science,* **331**, 1390–1391. https://doi.org/10.1126/science.1200674.

Crast, J., Bloomsmith, M. A., Perlman, J. E., Meeker, T. L. & Remillard, C. M. 2014. Abnormal behaviour in captive sooty mangabeys. *Animal Welfare*, **23**, 167–177. https://doi.org/10.7120/09627286.23.2.167.

Cuarón, A. D. 2005. Further role of zoos in conservation: Monitoring wildlife use and the dilemma of receiving donated and confiscated animals. *Zoo Biology*, **24**, 115–124. https://doi.org/10.1002/zoo.20040.

de la Barrera Cardozo, M., Chiba de Castro, W. A. & Aguiar, L. M. 2021. Stress behaviors in captive robust capuchins: Effects of humidity, visitors, management and sex. *American Journal of Primatology,* **83**, e23265. https://doi.org/10.1002/ajp.23265.

Goodenough, A. E., McDonald, K., Moody, K. & Wheeler, C. 2019. Are "visitor effects" overestimated? Behaviour in captive lemurs is mainly driven by co-variation with time and weather. *Journal of Zoo and Aquarium Research*, **7**, 59–66. https://doi.org/10.19227/jzar.v7i2.343.

Gottlieb, D. H., Capitanio, J. P. & McCowan, B. 2013 a. Risk factors for stereotypic behavior and self-biting in rhesus macaques (*Macaca mulatta*): animal's history, current environment, and personality. *American Journal of Primatology*, **75**, 995–1008. https://doi.org/10.1002/ajp.22161.

Gottlieb, D. H., Coleman, K. & McCowan, B. 2013 b. The effects of predictability in daily husbandry routines on captive rhesus macaques (*Macaca mulatta*). *Applied Animal Behaviour Science,* **143**, 117–127. https://doi.org/10.1016/j.applanim.2012.10.010.

Gottlieb, D. H., Maier, A. & Coleman, K. 2015. Evaluation of environmental and intrinsic factors that contribute to stereotypic behavior in captive rhesus macaques (*Macaca mulatta*). *Applied Animal Behaviour Science*, **171**, 184–191. https://doi.org/10.1016/j.applanim.2015.08.005.

Hashmi, A. & Sullivan, M. 2020. The visitor effect in zoo-housed apes: The variable effect on behaviour of visitor number and noise. *Journal of Zoo and Aquarium Research*, **8**, 268–282. https://doi.org/10.19227/jzar.v8i4.523.

Honess, P. E. & Marin, C. M. 2006. Enrichment and aggression in primates. *Neuroscience and Biobehavioral Reviews*, **30**, 413–436. https://doi.org/10.1016/j.neubiorev.2005.05.002.

Hook, M. A., Lambeth, S. P., Perlman, J. E., Stavisky, R., Bloomsmith, M. A. & Schapiro, S. J. 2002. Inter-group variation in abnormal behavior in chimpanzees (*Pan troglodytes*) and rhesus macaques (*Macaca mulatta*). *Applied Animal Behaviour Science*, **76**, 165–176. https://doi.org/10.1016/s0168-1591(02)00005-9.

Hosey, G. 2008. A preliminary model of human–animal relationships in the zoo. *Applied Animal Behaviour Science*, **109**, 105–127. https://doi.org/10.1016/j.applanim.2007.04.013.

Hosey, G. 2013. Hediger revisited: How do zoo animals see us? *Journal of Applied Animal Welfare Science,* **16**, 338–359. https://doi.org/10.1080/10888705.2013.827916.

Hosey, G. R. & Druck, P. L. 1987. The influence of zoo visitors on the behaviour of captive primates. *Applied Animal Behaviour Science*, **18**, 19–29.

Jacobson, S. L., Ross, S. R. & Bloomsmith, M. A. 2016. Characterizing abnormal behavior in a large population of zoo-housed chimpanzees: prevalence and potential influencing factors. *PeerJ,* **4**, e2225. https://doi.org/10.7717/peerj.2225.

Jakob-Hoff, R., Kingan, M., Fenemore, C., Schmid, G., Cockrem, J. F., Crackle, A., Bemmel, E. V., Connor, R. & Descovich, K. 2019. Potential impact of construction noise on selected zoo animals. *Animals*, **9**, 1–25. https://doi.org/10.3390/ani9080504.

Jones, H., McGregor, P. K., Farmer, H. L. & Baker, K. R. 2016. The influence of visitor interaction on the behavior of captive crowned lemurs (*Eulemur coronatus*) and implications for welfare. *Zoo Biology*, **35**, 222–227. https://doi.org/10.1002/zoo.21291.

Lewis, M. & Kim, S. J. 2009. The pathophysiology of restricted repetitive behavior. *Journal of Neurodevelopmental Disorders*, **1**, 114–32. https://doi.org/10.1007/s11689-009-9019-6.

Line, S. W., Morgan, K. N. & Markowitz, H. 1991. Simple toys do not alter the behavior of aged rhesus monkeys. *Zoo Biology*, **10**, 473–484.

Lutz, C., Well, A. & Novak, M. 2003. Stereotypic and self-injurious behavior in rhesus macaques: a survey and retrospective analysis of environment and early experience. *American Journal of Primatology*, **60**, 1–15. https://doi.org/10.1002/ajp.10075.

Lutz, C. K. 2018. A cross-species comparison of abnormal behavior in three species of singly-housed Old world monkeys. *Applied Animal Behaviour Science*, **199**, 52–58. https://doi.org/10.1016/j.applanim.2017.10.010.

Lutz, C. K., Coleman, K., Hopper, L. M., Novak, M. A., Perlman, J. E. & Pomerantz, O. 2022. Nonhuman primate abnormal behavior: Etiology, assessment, and treatment. *American Journal of Primatology*, **84**, e23380. https://doi.org/10.1002/ajp.23380.

Lutz, C. K., Williams, P. C. & Sharp, R. M. 2014. Abnormal behavior and associated risk factors in captive baboons (*Papio hamadryas spp.*). *American Journal of Primatology*, **76**, 355–61. https://doi.org/10.1002/ajp.22239.

Mallapur, A. & Choudhury, B. C. 2003. Behavioral abnormalities in captive nonhuman primates. *Journal of Applied Animal Welfare Science*, **6**, 275–84. https://doi.org/10.1207/s15327604jaws0604_2.

Mallapur, A., Sinha, A. & Waran, N. 2005. Influence of visitor presence on the behaviour of captive lion-tailed macaques (*Macaca silenus*) housed in Indian zoos. *Applied Animal Behaviour Science*, **94**, 341–352. https://doi.org/10.1016/j.applanim.2005.02.012.

Mangiafico, S. 2022. *rcompanion: Functions to Support Extension Education Program Evaluation.* [Online]. Available: https://CRAN.R-project.org/package=rcompanion.

Marriner, L. M. & Drickamer, L. C. 1994. Factors influencing stereotyped behavior of primates in a zoo. *Zoo Biology*, **13**, 267–275.

Mason, G. J. 1991. Stereotypies an suffering. *Behavioral Processes*, **25**, 103–115.

Mason, G. J. & Latham, N. 2004. Can't stop, won't stop: is stereotypy a reliable animal welfare indicator? *Animal Welfare*, **13 (Suppl.)**, S57–S69.

Morgan, K. N. & Tromborg, C. T. 2007. Sources of stress in captivity. *Applied Animal Behaviour Science,* **102**, 262–302. https://doi.org/10.1016/j.applanim.2006.05.032.

Pan, X., Liu, F., Song, Y., Wang, H., Wang, L., Qiu, H., Price, M. & Li, J. 2021. Motor stereotypic behavior was associated with immune response in macaques: Insight from transcriptome and gut microbiota analysis. *Frontiers in Microbiology*, **12**, 644540. https://doi.org/10.3389/fmicb.2021.644540.

Patrick, P. G. & Caplow, S. 2018. Identifying the foci of mission statements of the zoo and aquarium community. *Museum Management and Curatorship*, **33**, 120–135. https://doi.org/10.1080/09647775.2018.1438205.

Poirier, C. & Bateson, M. 2017. Pacing stereotypies in laboratory rhesus macaques: Implications for animal welfare and the validity of neuroscientific findings. *Neuroscience and Biobehavioral Reviews*, **83**, 508–515. https://doi.org/10.1016/j.neubiorev.2017.09.010.

Polanco, A., McCowan, B., Niel, L., Pearl, D. L. & Mason, G. 2021. Recommendations for abnormal behaviour Ethograms in monkey research. *Animals*, **11**, 1461. https://doi.org/10.3390/ani11051461.

Pomerantz, O., Paukner, A. & Terkel, J. 2012. Some stereotypic behaviors in rhesus macaques (*Macaca mulatta*) are correlated with both perseveration and the ability to cope with acute stressors. *Behavioural Brain Research*, **230**, 274–80. https://doi.org/10.1016/j.bbr.2012.02.019.

Rommeck, I., Anderson, K., Heagerty, A., Cameron, A. & McCowan, B. 2009. Risk factors and remediation of self-injurious and self-abuse behavior in rhesus macaques. *Journal of Applied Animal Welfare Science*, **12**, 61–72. https://doi.org/10.1080/10888700802536798.

Schapiro, S. J., Porter, P. M. & Suarez, S. A. 1995. The behavior of singly-caged, yearling rhesus monkeys is affected by the environment outside of the cage. *Applied Animal Behaviour Science*, **45**, 151–163.

Shapiro, S. S., Wilk, M. B. 1965. An analysis of variance test for normality (complete samples). *Biometrika*, **52**, 591–611. https://doi.org/10.2307/2333709.

Sharma, S., Khanal, L., Shrestha, S., Pandey, N., Bellanca, R. U. & Kyes, R. C. 2023. Zoo visitors as a source of enrichment to reduce abnormal behavior in captive rhesus macaques (*Macaca mulatta*) in the Central Zoo, Kathmandu, Nepal. *Journal of Animal Behaviour and Biometeorology*, **11**, e2023005. https://doi.org/10.31893/jabb.23005.

Sherwen, S. L. & Hemsworth, P. H. 2019. The visitor effect on zoo animals: Implications and opportunities for zoo animal welfare. *Animals,* **9**, https://doi.org/10.3390/ani9060366.

Shih, H.-Y., Yu, J.-F. & Wang, L.-C. 2016. Stereotypic behaviors in bears. *Taiwan Veterinary Journal*, **42**, 11–17. https://doi.org/10.1142/s168264851530004x.

Shyne, A. 2006. Meta-analytic review of the effects of enrichment on stereotypic behavior in zoo mammals. *Zoo Biology*, **25**, 317–337. https://doi.org/10.1002/zoo.20091.

Todd, P. A., Macdonald, C. & Coleman, D. 2007. Visitor-associated variation in captive Diana monkey (*Cercopithecus diana diana*) behaviour. *Applied Animal Behaviour Science,* **107**, 162–165. https://doi.org/10.1016/j.applanim.2006.09.010.

Vandeleest, J. J., McCowan, B. & Capitanio, J. P. 2011. Early rearing interacts with temperament and housing to influence the risk for motor stereotypy in rhesus monkeys (*Macaca mulatta*). *Applied Animal Behaviour Science*, **132**, 81–89. https://doi.org/10.1016/j.applanim.2011.02.010.

Vanlangendonck, N., Nuñez, G., Chaves, A. & Gutiérrez-Espeleta, G. A. 2015. New route of investigation for understanding the impact of human activities on the physiology of non-human primates. *Journal of Primatology*, **04**, 123–129. https://doi.org/10.4172/2167-6801.1000123.

Wells, D. L. 2005. A note on the influence of visitors on the behaviour and welfare of zoo-housed gorillas. *Applied Animal Behaviour Science*, **93**, 13–17. https://doi.org/10.1016/j.applanim.2005.06.019.

Received 13 February 2023
Accepted 26 April 2023