Journal of the American Association for Laboratory Animal Science
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Vol 45, No 5
September 2006
Pages 31-34

Use of Enclosures with Functional Vertical Space by Captive Rhesus Monkeys (*Macaca mulatta*) Involved in Biomedical Research

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We assessed space use by 2 pairs of captive female rhesus monkeys recently transferred into 2 enclosures moderately larger than their former traditional research cages and providing elevated perches at or above human eye level for all monkeys. This new space did not affect the ongoing biomedical research in which these captive monkeys were involved, and we sought to determine whether they used the elevated positions preferentially, as do wild animals. The frequency and duration of visits at each of the 9 distinct regions within these enclosures was calculated during 30-min morning and evening sessions over 20 d. We found that the monkeys frequented all regions of their enclosures in a similar manner during both morning and evening sessions. However, the duration spent at each region varied significantly between morning and evening sessions, with high perches being chosen preferentially in the evenings. Overall, the monkeys spent the majority of their time at elevated positions. These results support the view that access to functional vertical space provides a preferred environment for species-specific behavior and is an option that should be considered by other research facilities.

Studies of the relationship between living environment and animal behavior have shown that complex environments provide opportunities for monkeys to engage in species-typical behavior.[2,5,8,12,13] Several authors contend that elevated positions promote the well-being of both wild and captive monkeys, including the semiterrestrial rhesus monkey.[7,10] In the wild, such positions offer the animals refuge from predators as well as safe sleeping sites.[4,9,20,26] In captivity, elevated perches allow upward flight responses by providing safe locations to retreat in alarming situations.[14,16,19]

Previous studies identified the importance of functional vertical space to captive monkeys by assessing large sanctuary-like enclosures that are unsuitable for biomedical research because of space, cost, and practicability constraints.[12,14] Nevertheless, as recognized by the National Research Council,[10] "although considerable information is available on the natural history of primates, we do not yet know how to incorporate aspects of natural history into a practical, sensitive, and valid program of colony management that serves the dual interests of primate well-being and the research enterprise."

Our study aims to bridge this gap by providing a compromise between space, cost, and effects on ongoing research. We opted for a modest increase in the housing space of our captive monkeys by adjoining enclosures to a caging unit, which we continued to use daily for transferring the animals in and out of the holding room for biomedical experiments conducted in a remote laboratory. These enclosures were contained within the holding room and were connected to the cages through sliding doors: they expanded the living space of the cages, especially in the vertical dimension (Figure 1), without markedly affecting the transfer process. Finally, the enclosures were built with simple materials, which made them relatively inexpensive. This study assessed how our monkeys use their new space. In particular, we wished to determine whether they chose to spend significant time at the elevated regions made available by the enclosures.

Received: 4 Aug 2005. Revision requested: 24 Mar 2006. Accepted: 7 Apr 2006.
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Materials and Methods

Subjects. Data were collected from 4 healthy female rhesus monkeys (*Macaca mulatta*; ClinTrials BioResearch, Montreal, Quebec, Canada; Covance Research Products, Alice, TX) that were 6 to 7 y of age and weighed 5 to 7 kg. The monkeys were grouped into 2 separate compatible pairs. The monkeys had been acclimated to the current enclosures for several months prior to this study, were fed a commercial diet (Lab Diet high protein monkey chow, Purina Mills, Oakville, ON, Canada) provided twice a day at approximately 0800 and 1500, and were supplemented with daily fruit rations as well as extras (for example, peanuts, dried fruit). Separate from the current study, the monkeys participated in daily biomedical experiments outside the holding rooms in which water was used as a motivational tool.[11] Water is provided to satiation during these experimental sessions. Body weight, urine production, fecal consistency, hydration assessments, coat appearance, skin turgor, general appearance and demeanor were all monitored on a daily basis to assess the health of the animals. Any animals not participating in the experimental studies were provided with water ad libitum within their enclosure. The holding room environment was set on a diurnal light cycle providing light from 0700 to 1900. Constant temperature (19 °C) and humidity (45% to 60%) levels were maintained. All monkeys were cared for under experimental protocols approved by the Queen's University Animal Care Committee and in accordance with the Canadian Council on Animal Care guidelines[1.]

Enclosures. The enclosures were designed to fit into our holding room (width, 3.6 m; length, 5.0 m; height, 3.15 m) and to incorporate the existing commercially purchased 2-tiered caging unit (width, 0.8 m; depth, 1.2 m; height, 2.0 m), which were used as entry and exit points for the daily transfer of the animals

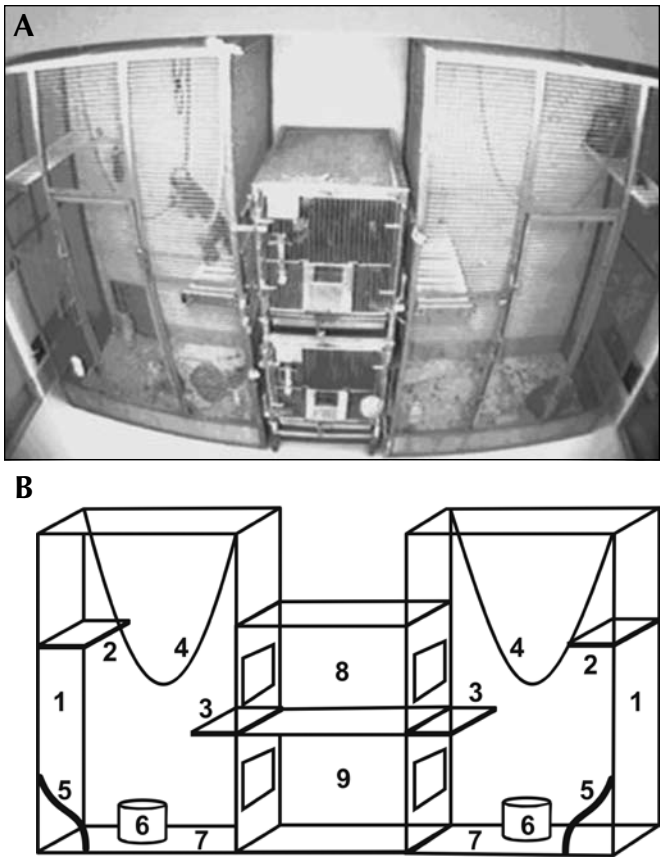

Figure 1. (A) View from the observation camera of the enclosures housing the monkeys. (B) Schematic of the enclosures, showing the 9 regions considered in the analyses (see Methods for details).

between their housing space and the research laboratory; acrylic sliding doors provided access between the enclosures and the caging unit (Figure 1). The enclosures were made of easily obtainable stainless-steel grid panels, which a local welder attached together. Once fabricated, the enclosures were installed in 1 d by anchoring them directly to 1 wall and the floor of the holding room. The overall cost of this structure, including installation, was approximately Can $8500 (US $7600).

Each enclosure housed 1 pair of monkeys and measured 2.76 m high with a floor area of 2.0 m^2. This dimension, excluding the home cages, exceeds the current Canadian Council on Animal Care guidelines.[1] The space available for each monkey consisted of the following 9 regions (Figure 1, bottom): 1) stainless-steel grid panels forming the walls of the enclosure; 2) a high perch placed 2.0 m above the ground; 3) a mid-level perch located 1.4 m above ground; 4) polyvinyl chloride tubing attached to the top of the pen to allow swinging motion and transfer to the high and mid-level perches, with the lowest point of the loop located 1.63 m above the ground; 5) a low corner branch perch; 6) a tree stump on the floor; 7) a floor space covered with deep woodchip bedding; and the 8) top and 9) bottom cages of a traditional caging unit separating the two enclosures.

Furnishings in each enclosure were structurally similar and included a variety of other objects used for manipulation (for example, mirrors, toys). The 2 enclosures were close enough to each other to allow visual, auditory, and olfactory communication between the 2 pairs. It is important to note that continued access to the top and bottom cages of the traditional caging unit were provided to only 1 pair of monkeys at a time. During the first 10 d of observation, 1 pair had access to the top homecage, while the other pair had access to the bottom homecage. For the last 10 d, access to these home cages was reversed.

Observation procedure. Observations of space use were collected twice daily on weekdays by videorecording (infrared camera, Supercircuits, Liberty Hill, TX, mounted 3 m above ground and 2 m from the pen enclosure). Videorecorded observations were chosen over instantaneous scan samples taken by a human observer, because familiar observers have the potential to influence animal behavior.[14] The morning session (0715 to 0745) began 15 min after the room lights were turned on, whereas the evening session (1815 to 1845) ended 15 min before the room lights were turned off. These recording periods occurred before and after regular working hours to avoid room interruptions by Research or Animal Care Services personnel, therefore minimizing disturbance due to outside noise. In total, there were 20 morning sessions and 20 evening sessions recorded over the weekdays of 2 wk.

Data analysis. During offline viewing of the videotapes, 2 of the authors (WMC and JPS) coded (with a resolution of 1 s) the position of each monkey as a function of time with respect to each of the 9 regions described earlier. Both the frequency and duration of the visits to these 9 regions were computed. Frequency was defined as the number of visits to each region divided by the total number of visits to all regions during each 30-min session. Duration was defined as the cumulative percentage of time spent in each region visited (for at least 5 s) during the 30-min sessions. No differences in these analyses were found between monkeys; therefore data from all 4 monkeys were pooled. Differences between the percentages of visit and time spent in the different regions of the enclosures during either morning or evening sessions were assessed by nonparametric analysis of variance (Kruskal–Wallis method on ranks). We also performed pairwise multiple comparison tests (Mann–Whitney rank sum tests) to determine whether the percentages of visit and time spent in each region of the enclosures differed significantly between morning and evening sessions. Statistical significance was set at $P < 0.05$ (that is, $P < 0.0056$ after Bonferroni correction). All statistical tests were performed using the Sigma-Stat package (Jandel Scientific, San Raphael, CA).

Results

Figure 2 shows both the individual and median percentages of visits for the morning and evening sessions across the 20-d observation period. The monkeys visited some regions more often than others ($P < 0.001$), but they generally visited all regions of their enclosures. The frequency of visits to each region was, however, not statistically different between morning and evening sessions.

Figure 3 shows both the individual and median percentages of time that the 4 animals spent at each region. The monkeys spent significantly ($P < 0.0001$) more time in some regions than others during both morning and evening sessions as well as between these sessions. First, the percentages of time spent on the mid-level perch (median, 23.9%) and in the top homecage (median, 43.9%) in the morning was significantly ($P < 0.001$) greater than in the evening (3.5% and 24.0%, respectively). Second, the percentage of time spent on the high perch was significantly ($P < 0.001$) greater in the evening (69.6%) than in the morning (34.7%). Time spent at the other regions did not vary significantly between morning and evening sessions.

Across all sessions, the monkeys visited regions at or above human eye level (perches and top home cage) significantly ($P < 0.001$) more often and occupied them for longer times than they did lower regions (bottom cage, floor, low branch perch, tree

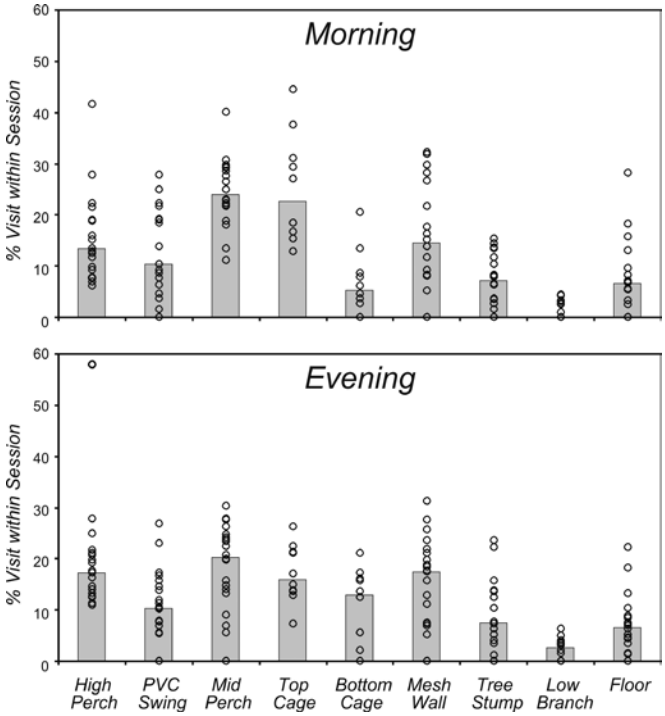

Figure 2. Percentages of visits to each region of the enclosure observed during all morning and evening sessions. Each data point indicates the percentage of visits for an individual session, and the bar indicates the median percentage for each region.

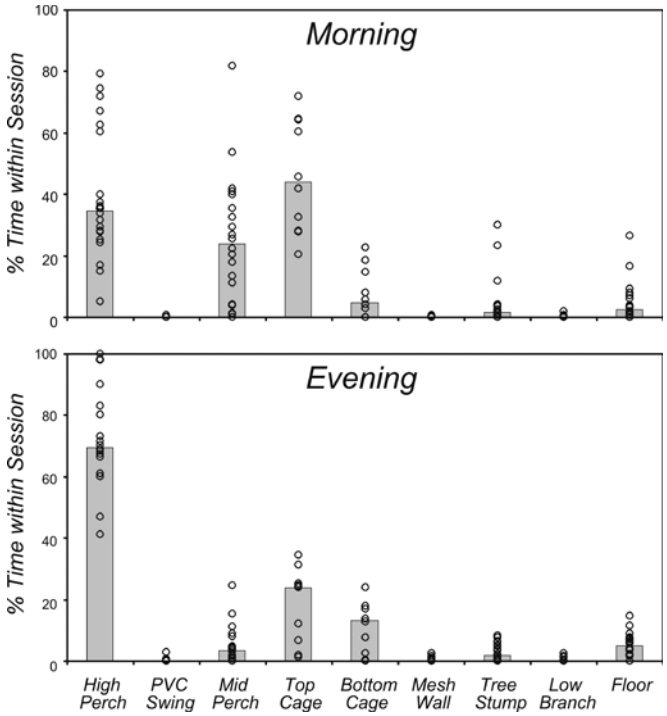

Figure 3. Percentages of time spent at each region of the enclosure observed during all morning and evening sessions. Each data point indicates the percentage for an individual session, and the bar indicates the median percentage for each region.

stump). With respect to the homecages, the total percentage of time spent in the top home cage (67.9%) was significantly ($P < 0.0001$) greater than the percentage of time spent in the bottom homecage (18.2%). The top cage also was visited significantly ($P < 0.0001$) more frequently than was the bottom cage.

Discussion

Our findings indicate that our captive rhesus monkeys used all regions of their new enclosures but that the pattern of use depended on the time of the day. Overall, the monkeys spent the majority of their time at elevated positions, especially the high perch in the evenings, and preferred the top cage to the bottom cage.

The morning and evening recording sessions allowed us to assess the effect of time of day on space use. Even though these observations were limited to specific time periods, our findings complement other observations that species-specific behaviors displayed by rhesus monkeys in captivity[14] and in the wild[23] often differ depending on the time of day. The greater time spent in the top home cage in the morning shows that these animals were not adverse to this location even though it is used daily for transfer out of the enclosure. It should be noted that the monkeys were fed in their corresponding homecages approximately 1 h after the morning session had begun. However this event alone cannot explain the extent of duration spent in the top homecage during the morning sessions, because this preference was not mimicked in the bottom homecage. It is reasonable to conclude that the monkeys spent more time in the top cage because the bottom cage was being perceived as less desirable. Regardless of whether a lower cage in itself affects the well-being of captive monkeys,[21,22,24] it does impair their natural upward flight responses[19,25] and provides diminished lighting.[15,17,18]

Together, the data show extensive use of the high perch and the preference for the top versus bottom cage. Preferences for elevated positions in the wild have been attributed to the increased sense of security[6,16] which may also underlie the preference of our captive monkeys, supporting the view that access to the vertical dimension promoted the well-being of captive monkeys.[7,10,14,16,19]

The simple and flexible design we implemented could be incorporated into other research facilities, provided that enough space is available. Since this study was conducted, 2 additional holding rooms at Queen's University have been outfitted with enclosures of similar but slightly different dimensions. These enclosures did not impede our continuing research program, which requires that our monkeys are transported daily from their holding space to the laboratory. To ensure that they move reliably from the enclosures to the homecages, in which they are handled, we implemented additional training (~1 week) with operant conditioning. During this training period, all provisions (such as food and water) were restricted to the homecages to reinforce the animals' entry. Although some extra time was spent initially to retrieve a monkey from its enclosure, retrieval was always successful. After the initial training period, retrieval time from the new enclosure was similar to that experienced with the pre-existing caging units. At no point after the introduction of the enclosures did we observe changes in either general behavior or performance during experiments. Other advantages of the new enclosures are that the deep woodchip bedding facilitates husbandry[3] (enclosures are cleaned once weekly instead of daily), and large-scale enrichment initiatives (for example, swings and climbing surfaces) can be implemented.

As recognized by the National Research Council,[10] "it should not be our goal to duplicate the natural environment but rather to identify favored activities, preferred patterns, and the general rhythms in life that organize behavior." Our study demonstrated that when provided with increased vertical space, captive mon-

keys spent significantly more time in elevated regions-behavior most likely reflecting an inherent preference. We hope this assessment encourages other researchers who also use monkeys as animal models to adopt housing environments that include functional vertical space.

Acknowledgments

This work was supported by Queen's University (Kingston, Ontario, Canada) and funding from the Canadian Institutes of Health Research (to MP and MCD). We acknowledge the critical contribution of Joan Tremblay (Manager of Animal Care Services, Faculty of Health Sciences, Queen's University), without whom the enclosures would not have been designed and made available. We also thank Jim Brown (Custom Cage Design, Kingston, Ontario, Canada) for the construction and installation of the enclosures, the Department of Mechanical Engineering at Queen's University for the alterations made to the original home cages, and Sean Hickman and Luke Robertson for the installation of the perches. All of the veterinary and technical support from the staff of Animal Care Services and the continuing efforts of Debbie Harrington, Cheryl Devries, and Julie Tourond are sincerely appreciated.

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