Parsing the Variables of Illumination and Cage Height

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Abstract

Laboratory primates are frequently housed in double-tier arrangements in which there are considerable differences between the environments of the upper and lower-row cages. Although several studies have investigated whether the sum of these differences affects monkeys' behavior, no studies have addressed the two most notable differences of light and height individually to determine the relative importance of each. In this experiment, we examined how rhesus and long-tailed macaques allocate their time between the upper and lower-row cages of a 1-over-1 apartment module under different lighting conditions. In condition A, we measured monkeys' baseline preference for the upper and lower-row cage of the apparatus. In condition B, we reversed the lighting environment by limiting illumination in the upper-row cage and increasing illumination in the lower-row cage. Across conditions, monkeys spent significantly more time in the upper-row cage indicating a strong preference for elevation regardless of illumination. The amount of time that monkeys spent in the lower-row cage increased by 7% under reversed lighting conditions, but the interaction was not significant. Our results corroborate the importance of providing captive primates with access to elevated areas. We discuss the contexts in which well-illuminated quarters are likely to be important for laboratory animals and propose further research to explore these possibilities.

Parsing the Variables of Illumination and Cage Height

Laboratory primates are often kept in double-tier cages in order to minimize the financial costs of housing and maximize the use of space in colony rooms. Although such housing arrangements are frequently employed, there is considerable debate regarding whether the double-tier system compromises the psychological wellbeing of primates housed in the lower-row cages. Some researchers have criticized double-tier arrangements because primates housed in lower-row cages are unable to perform species-typical vertical escape responses when confronted with threatening situations (Reinhardt & Reinhardt, 1999). In essence, primates confined to the lower-row are forced to adopt a terrestrial lifestyle to which they are not biologically adapted. Furthermore, lighting conditions in the lower-row cages are dramatically darker than those in the upper row. In a recent study on the lighting environment of standard double-tier cages, it was confirmed that each of nine sampled locations in the lower-row was significantly darker than the same location in the upper row (Schapiro, Stavisky & Hook, 2000).

These notable differences between the environment of the upper and lower row raise a number of concerns regarding both the psychological wellbeing of animals housed in such an arrangement, and the reliability of research conducted using these animals. Although several studies have addressed these concerns, the effects of double-tier housing remain unclear. In some studies of the behavior of laboratory primates, animals housed in the lower-row of double-tier cages exhibited more stereotypies than animals housed in the upper row (Draper & Bernstein, 1963; Watson & Shively, 1996). However, other recent investigations of this issue have found no behavioral differences (positive or stereotypical) between animals housed in the upper versus the lower row

(Schapiro & Bloomsmith, 2001; Schapiro, Stavisky, & Hook, 2000). Nevertheless, it is important to note that reports indicating that primates housed in the lower row are not affected behaviorally do not imply that these animals are not adversely affected by their environment in other, less apparent ways. Several researchers have reported that animals housed in the lower row show more physiological signs of stress during fear inducing events than animals housed in the upper row (Lilly, Mehlman, & Higley, 1999; Van der Kar, Richardson-Morton, & Rittenhouse, 1991). As Reinhardt and Reinhardt (2000) have noted, this variability in arousal produces an uncontrolled variable that could reduce the validity of data obtained from these animals.

Both the United States Department of Agriculture (1999) and the National Research Council (1998) have recognized these inadequacies of the double-tier system and have recommended that primates not be restricted to the lower row of double-tier cages. However, this solution is not easily implemented in most research facilities because abandoning the lower row of double-tier cages doubles the space required to house animals. In addition to increasing space requirements, relocating animals housed in the lower row requires the purchase of costly new cages. Although a shift away from double-tier housing may be a worthwhile enterprise in the long run, it is critical to consider less costly and more easily implemented options which can immediately improve the living conditions for animals housed in the lower row and help assure reliable data from animals housed in double-tier cages.

The aim of this research was to determine how rhesus and long-tailed macaques respond to the environmental differences between the upper and lower rows of double-tier cages while examining the effect of increasing illumination in the lower row with wall-mounted lighting. Although several studies have investigated whether the sum of the differences between the upper and lower-row cages affects monkeys' behavior (Draper & Bernstein, 1963; Watson & Shively, 1996; Schapiro & Bloomsmith, 2001; Schapiro, Stavisky, & Hook, 2000), no studies have addressed the two most notable differences of light and height individually. In this experiment, we pitted the variables of illumination and cage height directly against one another to determine the relative importance of each. Across two conditions, rhesus and long-tailed macaques were given simultaneous access to both an upper and lower-row cage connected by a transfer tunnel. In condition A, we measured monkeys' baseline preference for the upper and lower-row cage of the apparatus. In condition B, we reversed the lighting environment by limiting illumination in the upper-row cage and increasing illumination in the lower-row cage. Preference for the upper and lower row of the apparatus was then compared between these conditions.

We believe that by using location preference as our dependent measure, our data reveal the environmental conditions in which monkeys feel most comfortable. Compared to simply focusing on the presence or absence of stereotypical behaviors, which may only emerge after significant psychological disturbance, examining preference affords a more sensitive measure of an animal's wellbeing. By considering preference we hope to shift the focus from solely what needs to be done to prevent stereotypical behavior, to what can be done to construct an environment best suited to its inhabitant's preferences.

Method

10 male rhesus macaques (*Macaca mulatta*) and 4 male long-tailed macaques (*Macaca fascicularis*) were each tested under normal (A) and reversed (B) lighting conditions.

The order of conditions was counterbalanced across subjects. In both conditions, monkeys were given simultaneous access, via a transfer tunnel, to the top and bottom cages of a 1-over-1 apartment module. In condition A, the lighting environment of the apartment module was unaltered (figure 1a). That is, the upper-row cage was better illuminated than the lower-row cage. In condition B, the lighting environment was reversed (figure 1b). Illumination was decreased in the upper row by placing a stainless steel bedding pan on top of the apartment module, thus blocking light from entering through the top of the cage. Illumination was increased in the lower row by mounting a fluorescent light behind the cage. This light was identical to those used for overhead illumination of the testing room. To ensure the accuracy of lighting manipulations, illumination measurements were taken at nine different points within each cage and matched to an array of previously recorded averages for those locations. Mean illumination levels for each condition are shown in Table 1.

All subjects were tested in both conditions for 60 minutes. Monkeys were habituated to the apparatus for 30 minutes prior to each session to minimize the influence of preferences for, or aversions to, novelty. Experimental sessions were recorded with a video camera and experimenters remained outside the testing room during periods of data collection. To prevent social factors from influencing behavior, subjects were tested individually and the normally transparent side doors of the experimental apparatus were covered with opaque paper. In order to minimize the influence of other extraneous variables, all food, water, and enrichment devices were removed from the apparatus prior to testing.

Results

Video recordings were scored for the percent of time that animals spent at each level of the apparatus. A repeated measures ANOVA for Condition (normal illumination, reversed illumination) X Location (top cage, bottom cage) revealed a main effect of location, $F(1, 26) = 19.01$, $p < .001$ (Figure 2). Specifically, monkeys exhibited a strong preference for the upper row, spending an average of 68% of their time in the top cage across conditions. Although the average amount of time spent in the lower-row of the apparatus was 7% greater when the lower row had supplemental illumination, the interaction was not significant $F(1, 26) = 0.75$, $p = .39$.

Discussion

Across conditions, monkeys showed a strong preference for the upper-row of a standard double-tier cage. This result is consistent with several other studies which have documented macaques' preference for elevation in other contexts (e.g., Bernstein & Draper, 1964; Reinhardt, 1992; Rosenblum, Kaufman, & Stynes, 1964). Surprisingly, preference for the upper-row cage decreased only marginally when this area was darkened and better illumination was available in the lower row. When pitted against one another, macaques found access to elevated space to be far more important than access to well-illuminated space.

Our results corroborate the importance of housing macaques in the upper row of double-tier cages whenever possible. If financial or spatial constraints require that some animals be housed in the lower row of double-tier cages, we suggest providing these animals with regular access to a multi-level activity module. In our colony room, one activity module is often shared by two pairs of macaques. Every afternoon we rotate which pairs have access to the activity module such that each monkey has access to the unit for 12 hours daily. This arrangement requires only half the space that would be needed to house all macaques in the upper-row yet still provides each animal with daily access to elevated areas.

Although monkeys did not spend significantly more time in the lower-row cage during periods of reversed lighting, we should not conclude that well-illuminated cages are not important to captive macaques. All animals in this experiment were tested without access to social partners, food, or enrichment devices, and this may have eliminated many opportunities to exploit the benefits of a well-illuminated cage. We suspect that illumination is most likely to be important to macaques during grooming, foraging, and visual inspection of manipulanda. Future research should address these issues by providing macaques with access to food, social partners, and manipulanda during similar preference tests. It is also possible that access to vertical space is so important to macaques that it overshadows secondary preferences for illumination. We are currently testing this possibility by investigating how macaques allocate their time when given simultaneous access to horizontally adjacent cages that differ in illumination.

The results of this study demonstrate the importance of providing captive macaques with access to elevated areas. Our data also indicate that the illumination of lower-row cages can easily be increased to match that of upper-row cages with the installation of wall-mounted lights. In addition to potentially increasing the quality of life for animals housed in the lower row, this housing refinement reduces variability in the research environment, which in turn, may reduce the number of animals required for research.

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Table 1.

Mean Light Levels at 9 Positions Within the Apparatus (Foot Candles)

Condition	Cage	Front Left Top	Front Left Bottom	Front Right Top	Front Right Bottom	Back Left Top	Back Left Bottom	Back Right Top	Back Right Bottom	Middle
A	Upper-row	16.77	12.22	14.13	11.48	22.50	36.63	35.22	3.16	2.86
	Lower-row	0.32	1.89	0.39	2.55	2.73	1.77	0.90	0.86	1.94
B	Upper-row	0.48	1.35	0.44	1.56	2.46	1.11	1.08	0.79	1.75
	Lower-row	21.00	5.71	21.19	6.87	27.92	21.07	19.40	8.78	9.11

In condition A (normal lighting), the upper-row cage was better illuminated than the lower-row cage at each of 9 sampled positions. In condition B, the normal lighting environment was reversed and the lower-row cage was better illuminated than the upper-row cage at all 9 positions.

Figure 1. The apparatus under normal (A) and reversed (B) illumination.

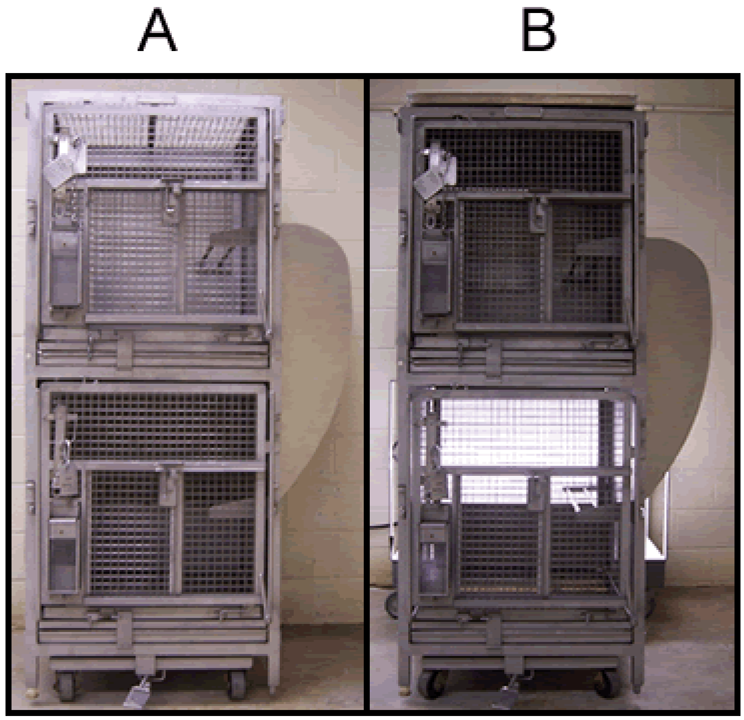
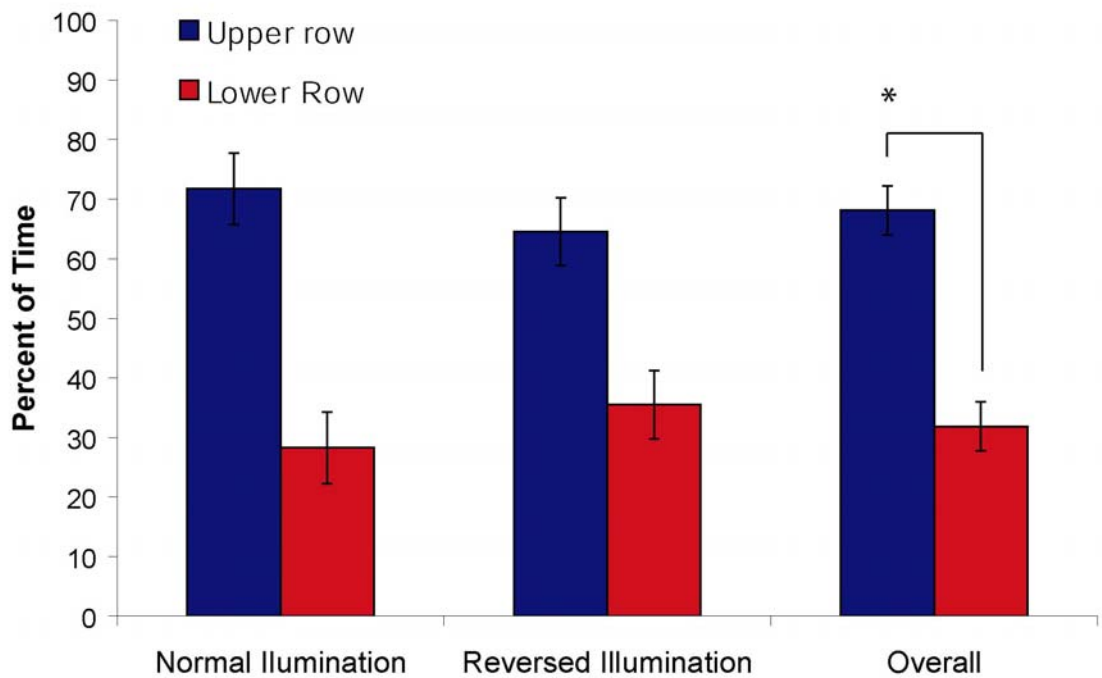


Figure 2. Mean percent of time in the upper and lower row of the apparatus.



* $p < .05$