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# The Lower Row Monkey Cage: An Overlooked Variable in Biomedical Research

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A survey of 96 primatological articles revealed that cage location of research monkeys is rarely mentioned, although the environment of upper and lower row-housed animals markedly differs in terms of light quality, light intensity, and living dimension. Not accounting for these uncontrolled variables may increase variability of data and, consequently, the number of experimental animals needed to obtain statistically acceptable results. This study concluded that single-tier housing would be an important refinement of research methodology. Such housing would (a) enable all animals of a room to use the "arboreal" dimension of their enclosure and retreat to "safe" vantage points above the human "predator," (b) offer all animals access to uniform light, and (c) provide more favorable conditions for professional animal care.

Cages of small and medium size nonhuman primates are commonly arranged in double tiers with one row stacked on top of the other (Rosenberg & Kesel, 1994). This housing is financially attractive, but it carries with it serious ethical and methodological implications.

Monkeys are biologically adapted to withdraw in alarming situations and avoid terrestrial predators by taking to the *arboreal*—vertical—dimension of their environment (Chopra, Seth, & Seth, 1992; DeVore & Hall, 1965; Home Office, 1989; Lindburg, 1971; Roonwal & Mohnot, 1977). The presence of cliffs, trees, or other high structures for refuge from predators affects the distribution of monkeys more than the edibility of the vegetation does (Jay, 1965; Hamilton, 1982; Simonds, 1965): "Even macaques, which [sic] some describe as semiterrestrial, spend most of the day in elevated locations and seek the refuge of sleeping trees at night" (National Research Council, 1998, p. 92; cf. Lindburg, 1971; Roonwal & Mohnot, 1977; Wheatley, 1980).



*Figure 1. The standard lower tier cage provides a crepuscular, cavelike living environment, which not only jeopardizes the animals' well-being but also introduces uncontrolled extraneous variables into scientific data collected from upper row- and lower row-caged research subjects.*

In the conventional double-tier system, monkeys in lower rows—unlike those in upper rows—are forced to lead a terrestrial lifestyle. They will sit on perches for a considerable portion of the day (Reinhardt, 1989; Shimoji, Bowers, & Crockett, 1993; Woodbeck & Reinhardt, 1991) to get at least a short distance away from the "unsafe" horizontal dimension of the room (see Figure 1). But even with access to perches, lower row-caged animals are unable to retreat to a safe place above the human predator who periodically captures them and subjects them to both life-threatening situations (Fowler, 1995, Figures 8-11, 19-22; Klein & Murray, 1995, Figures 1,7, 10, 11) and distressing procedures (Fuller, Hobson, Reyes, Winter, & Faiman, 1984; Ives & Dack, 1956; Line, Clarke, & Markowitz, 1987; Line, Morgan, Markowitz, & Strong, 1989; Mason, 1972; Mason, Mougey, & Kenion, 1973; Puri, Puri, & Anand-Kumar, 1981; Schnell & Gerber, 1997). No wonder that caged monkeys show behavioral and physiological fear responses when someone dressed in protective garb enters the room and approaches their cages. Their responses include alarm vocalization, acute diarrhea, fear grinning, fear threatening, crouching in a far corner, stereotypical locomotion, self-biting, increased heart rate, elevated blood pressure, raised core temperature, and pronounced cardiac reactivity (Bowers, Crockett, & Bowden, 1998; Draper & Bernstein, 1963; Malinow, Hill, & Ochsner, 1974; Reinhardt, 1994, 1999b; Reinhardt & Seelig, 1998; Schnell & Wood, 1993).

The situation must be especially distressing for lower row-caged monkeys who "might perceive the presence of humans above them as particularly threatening" (National Research Council, 1998, p. 118). Having no vertical flight option, they are quasi cornered and might experience intensive anxiety in the presence of the looming human predator.

Lower row housing per se does not imply that the animals "suffer behaviorally" (Schapiro, Stavisky, & Hook, 2000, p. 5) but that lower row-caged subjects are likely to be more disturbed (e.g., more intensive fear behavior; higher blood pressure; higher respiration rate; higher levels of norepinephrine, prolactin, and cortisol; higher white blood cell count; Lilly, Mehlman, & Higley, 1999; Van der Kar, Richardson-Morton, & Rittenhouse, 1991) by the presence of fear-inducing personnel than upper row-caged subjects. It is this difference in the acute fear response prior to the actual experiment that introduces an uncontrolled variable, thereby diminishing the validity of subsequently collected research data. The National Research Council (1998) alluded to this problem in its book *The Psychological Well-Being of Nonhuman Primates*, advising that primates should not be housed in double-tier cages. Unfortunately, this advice refers only to marmosets and fails to include other primates who are equally dependent on access to high, safe locations.

The majority of nonhuman primates used in biomedical research are diurnal animals. In the traditional double-tier system, however, monkeys of the bottom row are forced to live in the crepuscular shade area of the upper row (see Figure 1). The indirect light they receive is reflected and its spectral distribution altered, depending on the colors of the surrounding walls. Because cage illumination often is poor, a flashlight is needed to identify and inspect the cage occupants correctly—tattoos and general health check, respectively—as well as to properly illuminate the cage interior (e.g., waste material in back corners of cage) and the drop pan (e.g., feces indicative of shigellosis; Reinhardt, 1999a). Inadequate animal care and insufficient cage hygiene often result. The National Research Council (1996) addressed this dilemma in the *Guide for the Care and Use of Laboratory Animals*, stipulating that lighting should provide sufficient illumination to allow good housekeeping practices and adequate inspection of animals, "including the bottom-most cages in racks" (p. 34). The United States Department of Agriculture (1999) made a similar observation and suggested that "it is also helpful to redesign rooms so primates are not kept in darkened lower-tier cages" (p. 43). Unfortunately, there are no recommendations for accomplishing this (Reinhardt, 1997).

That lower row-caged monkeys live in a much darker environment than those kept in upper rows is no secret but has been documented repeatedly—although without intention—in the scientific literature (Abee, 1985, Figure 1; Anonymous, 1973, Figure 2; Coid, 1967, Figure 1; Gay, 1957, Figure 3; Gengozian, 1969, Figure 5; Bonjo, 1985, Figure 2; Kemnitz, 1980, Figure 1; King & Norwood, 1989, Figure 1; Klein & Murray, 1995, Figure 7; Milhaud, Klein, & Merkel, 1980, Figure 2; Ohto, 1993, Figure 1; Valerio et al., 1969, Figure 18; Weed, Baker, Barbaugh, & Erwin, 1995, Figure 2). A recent study demonstrates a statistically significant difference ( $p < .001$ ) in mean light levels of upper row and bottom row monkey cages at nine different positions within the cage (Schapiro et al., 2000). This observation validates the notion that "intensity of light in animal cages is likely to be the most variable environmental factor in the average animal room" (Clough, 1982, p. 512).

The influence of direct versus indirect light on biomedical parameters has not yet received any attention in the primatological literature. A few publications evaluate the impact of light intensity. Isaac and DeVito (1958) and Draper (1965) reported that decreased illumination is accompanied by decreased activity in single-caged rhesus macaques. Schapiro et al. (2000) scored a more than two-fold higher incidence of abnormal behaviors and a more than five-fold higher level of inactivity in six long-tailed macaques housed in relatively dark lower row cages than in three long-tailed macaques housed in relatively bright upper row cages; the comparison did not reach statistical significance, probably because of the small sample size. Scott (1991) observed that locomotor activity is lower in pairs of marmosets kept in dark lower tier cages than in pairs kept in bright upper tier cages. Box and Rohrerhuber (1993) noted that pairs of tamarins housed in (presumed to be relatively dark) lower tier cages engage in less amicable behavior and are less active than pairs housed in upper tiers.

Beger, Merker, and Neubert (1986) underscored that pair-housed female marmosets excrete abnormally low levels of steroid hormones and show prolonged ovulatory cycles associated with substantially reduced fecundity when kept in dim lower row cages rather than in bright upper row cages.

These findings indicate that illumination is an important variable that both may influence animal well-being (National Research Council, 1996; United States Department of Agriculture, 1991) and potentially decrease research quality (Bellhom, 1980; Clough, 1982; Mulder, 1971; Ott, 1974). The International Primatological Society (1989) and the United States Department of Agriculture (1991) aptly stipulated that illumination should be not only sufficient but also *uniform*.

To bend or kneel down while inspecting monkeys in lower tiers is less convenient than standing in an upright position while checking monkeys in upper tiers. Consequently, monkeys in lower rows tend to receive less attention by animal care personnel (e.g., Ross & Everitt, 1988). The daily check of both their well-being and the cleanliness of their cages may be so haphazard that developing health and hygiene problems go unnoticed.

Scientific investigators should be concerned about the traditional lower row cage arrangement because it not only jeopardizes the research subjects' well-being but could also affect the validity of research data collected from them.

## METHOD

A survey was conducted of all scientific articles published since inception in the *Journal of Medical Primatology* (Vols. 1-28) and the *Journal of American Primatology* (Vols. 1-48). These two journals were chosen because it was assumed that primatologists are more knowledgeable than other scientific professionals of the characteristic needs of nonhuman primates. Investigations—dealing with possible stress-sensitive or illumination-sensitive parameters and using small or medium size primates in cages—were screened for descriptions of the research subjects' cage location.

## RESULTS

We examined 96 articles that investigated reproduction (53), stress (20), blood composition (11), behavior (6), and body growth (3) in macaques (75), vervets (7), marmosets (5), squirrel monkeys (3), capuchin monkeys (3), tamarins (1), mangabeys (1), and patas monkeys (1).

Cage location is mentioned in 2 of the 96 articles but not in the remaining 94 (see Table 1). Description of the research subjects' housing conditions usually follows a cliché formula such as "All animals were housed in standard cages in a controlled environment."

## DISCUSSION

Only 2% of the scientific articles surveyed take notice of the research subjects' cage location, and 98% make no reference to whether all or some research subjects were housed in upper row, lower row, or single row cages. This omission suggests that "most investigators think only briefly about the care and handling of their animals" (Traystman, 1987, p. 108). Therefore, they presumably are not aware of the gross differences in the microenvironment of upper versus lower row-caged primates. Not accounting for these uncontrolled variables may increase data variability and, consequently, the number of experimental animals needed to obtain statistically acceptable results. It also makes it problematic, if not impossible, to either reliably test research findings in another laboratory or compare the findings with those of another laboratory. Research data of different laboratories will vary, resulting in discrepancies in the scientific literature.

**TABLE 1**  
**Survey of Scientific Articles Published in Two Primatological Journals**

RESEARCH FIELD	NO. OF ARTICLES SURVEYED	LOCATION OF CAGE IS MENTIONED	LOCATION OF CAGE IS NOT MENTIONED
Reproduction <sup>a</sup>	56	0	56
Stress <sup>b</sup>	20	1	19
Blood composition <sup>c</sup>	11	0	11
Behavior <sup>d</sup>	6	1	5
Body growth	3	0	3
Total	96 (100%)	2 (2%)	94 (98%)
<sup>a</sup> Estrogen, progesterone, testosterone, FSH, LH, reproductive performance. <sup>b</sup> Cortisol, ACTH, prolactin, heart rate, immune response. <sup>c</sup> Hemogram, serum chemistry. <sup>d</sup> Abnormal behavior, response to environmental enrichment.			

From the statistical point of view, to overlook the variable "cage location" would be acceptable only if it has been demonstrated first that upper and lower row housing do not influence the physiological and behavioral responsiveness of the research subjects during the experiment. As far as we know, this has never been done. Yet, it is taken for granted that research monkeys live in a strictly controlled microenvironment.

There are two solutions to problems associated with the double-tier system:

1. Monkeys are housed in single tiers in well-structured cages (perches or shelves at different levels) that reach close to the ceiling of the room. This assures that all cages of a room are directly and equally illuminated, and that all animals of a room have equal opportunities to access the arboreal dimension of their environment and to retreat to safe vantage points above human eye level (cf. International Primatological Society, 1993).
2. Editors of scientific journals should require that authors describe the caging arrangement of research monkeys in such detail that the investigation can be duplicated reliably in another laboratory (cf. Canadian Council on Animal Care, 1993; Davis et al., 1973).

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**Erratum**

In the following sentence [page 114, paragraph 3]

"Schapiro et al. (2000) scored a more than two-fold higher incidence of abnormal behaviors and a more than five-fold higher level of inactivity in six long-tailed macaques housed in relatively dark lower row cages than in three long-tailed macaques housed in relatively bright upper row cages..... "

"... and a more than five-fold higher level of inactivity....." is an erratum.

The **correction** is:

Inactivity of animals housed in lower row cages was less than  
a fifth ( $0.4 \pm 0.7\%$ ) of that of animals housed in upper row cages ( $2.3 \pm 2.3\%$ ).