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Cage Use and Feeding Height Preferences of Captive Common Marmosets (*Callithrix j. jacchus*) in Two-Tier Cages

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Determining appropriate feeding regimes has important welfare implications for captive primates. This study examined the preference of food bowl heights in 6 pairs of common marmosets (*Callithrix jacchus*) housed in a 2-tier cage system. Given that marmosets are arboreal and spend most of their time in the upper half of their cages, we predicted that the marmosets would prefer a food bowl positioned at the top of the cage over one positioned at the bottom. We further predicted that this would be more apparent for the marmosets housed in lower tier than upper tier cages. Given a choice regarding where to feed, marmosets did prefer the top bowl to the bottom bowl; however, when only 1 food bowl was presented, its position had no significant effect on the marmosets' feeding behavior. In addition, contrary to the prediction, there were few differences in the marmosets' feeding behavior in the upper and lower tier cages. Feeding the marmosets in a bowl at the bottom of their cage did not result in greater cage use. On the basis of this study, we recommend positioning captive marmosets' food bowls high in the cage.

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The issue of two-tier housing is receiving increasing attention. Although this housing system is both financially attractive and space efficient, there are potential serious welfare implications (Reinhardt & Reinhardt, 1999, 2000). These include that (a) lower tier cages are darker, (b) there is no possibility for arboreal primates to show the vertical flee response, and (c) lower tier monkeys receive less attention than upper tier caged monkeys because it is less convenient for personnel to bend down to carry out husbandry procedures. There is good empirical support that lower tier cages are darker (macaques: Schapiro, Stavisky, & Hook, 2000; marmosets: Scott, 1991), a factor shown to affect breeding in marmosets (Heger, Merker, & Nebert, 1986). However, several studies have found no differences in behavior (Crockett, Bowers, Sackett, & Bowden, 1993; Crockett, Shimoji, & Bowden, 2000; Schapiro & Bloomsmith, 2001; Schapiro et al., 2000) or in physiological responses (Crockett et al., 1993; 2000) between lower tier and upper tier caged macaques (*Macaca mulatta, M. fascicularis*, *M. nemestrina*). On the contrary, significant differences have been found between the behavior of upper and lower tier marmosets and tamarins. Box and Rohrhuber (1993) found that upper tier cotton-top tamarins (*Saguinus oedipus*) spent more time in close physical contact and less time in "non-movement" than those in the lower tier. Similarly, Scott (1991) reported less activity in lower tier common marmosets (*Callithrix jacchus*) than in upper tier marmosets. Poole (1990) argued that marmosets prefer to be above care-giving personnel. On the basis of these findings, the National Research Council (1998) advised that marmosets not be housed in two-tier cages.

One overlooked factor of the two-tier housing system is feeding height preferences. In their natural habitat common marmosets sometimes do go to the tops of tall trees, however, they frequent the lower strata of high forests, usually occurring below 12 m (Stevenson & Rylands, 1988). Although often sighted within 1 m above ground level, common marmosets almost never visit the ground except on the rare occasions when they descend to forage in leaf litter or to cross forest clearances (Stevenson & Rylands, 1988). Reluctance to venture onto the ground in wild callitrichids is likely due to an increased perceived risk of predation (Prescott & Buchanan-Smith, 2002).

Similar reluctance to approach the ground has been observed in captivity. McKenzie, Chamove, and Feistner (1986) noted that captive common marmosets spent only 1% (bare floor) to 10% (floor covering) of their time on the floor, leaping up to their perches immediately when startled. Red-bellied tamarins (*S. labiatus*) avoid going to the ground except for brief sorties to pick up food (Buchanan-Smith, 1991). Cotton-top tamarins were hesitant to approach food dishes placed near the floor level of the cage when carrying infants (Snowdon & Savage, 1989). When the dishes were moved to areas of the cage that were at least 1 m above the floor, the tamarins readily approached the dishes to feed. Snowdon and Savage claimed that the success of caring for and rearing infants increased mark-

edly because of this simple change in food placement. In line with these findings, captive common marmosets show a preference for feeding bowls situated higher rather than lower in the cage (Hannaford, 1996; Morrissey, 1994). Hannaford presented two food bowls at different height configurations of top, middle, or bottom and recorded the number of visits the marmosets made to each bowl. The top bowl was visited more often than the middle or bottom bowls, but there was no significant difference between the middle and bottom bowls. However, Hannaford noted that the bottom of the cage was not actually on the ground but elevated 1 m from the ground and that this probably affected the results. Morrissey (1994) found that when they had a choice, the dominant pair in a family of marmosets would feed from a higher bowl.

We combined the factors of feeding bowl heights and two-tier housing in this study to see what effect, if any, manipulation of these factors had on the behavior of captive common marmosets. Behavior observed in the wild and in previous studies led us to predict that the marmosets would (a) approach a feeding bowl more quickly when it is presented higher in the cage, (b) visit a higher bowl more often than a lower bowl, and (c) spend more time at a higher bowl than a lower bowl. Furthermore, because marmosets generally spend more time in the upper half of their enclosures (Ely, Freer, Windle, & Ridley, 1998), we predicted that feeding lower in the cage may increase the marmosets' cage use.

METHOD

Study Animals, Housing, and Feeding

We conducted this research on common marmosets, *Callithrix j. jacchus*, housed at the Medical Research Council Human Reproductive Science Unit, Edinburgh, Scotland. Six pairs were observed: two male–male pairings, two female–female pairings, and two male–female pairings. In one of the pairings the two animals were unrelated; in the five others, the animals were from the same family—parent and offspring or two siblings. All the study animals had been born in captivity. Their ages ranged from 15 months to over 6 years old.

The marmosets were housed in two different rooms (2.7 m × 3 m × 5 m) alongside other marmoset groups of varying size. Each pair was housed in either an upper or a lower tier cage (55 cm wide × 95 cm high and 110 cm deep). Lower tier cages were positioned 25 cm off the ground, and upper tier cages were 115 cm off the ground (see Figure 1). None of the pairs studied had a veranda as seen in the lower right-hand cage depicted in Figure 1. One of the male–male, female–female, and male–female pairings studied were housed in each room, either all in the upper tier cages or in the lower tier cages, depending on the experimental condition (see Procedure section). Alternating cage tier

FIGURE 1 The marmoset caging system at the Medical Research Council Unit. The cages of four pairs are shown.

when cleaning the cages is routine practice in this laboratory. This practice of cage rotation follows a recommendation by Ross and Everitt (1988) to alleviate potential welfare implications for lower tier macaques.

The rooms were kept at a temperature of 22 to 24°C, relative humidity of 50%, and the light source was natural daylight supplemented with strip lighting. Each cage contained a nest box, shelves, and larchwood perches. Wood shavings covered the floor, and a plastic water bottle was attached to the outside of the cage door.

The experiment was carried out without any alteration to the marmosets' usual diet. A standard diet of Mazuri Primate Diet (E; Witham, Essex, England) and fresh fruits, such as apples, oranges, tomatoes, pears, grapes, and bananas was given every day. Depending on the day of the week, this was combined with either high-protein porridge or a mixture of peanuts and dried fruits, raisins, and dates. The food was presented in the usual round paper feeding dishes that were placed in the cage at different heights depending on the experimental condition.

Procedure

The monkeys were habituated to the presence of the observer (Carole Shand). Normal preexperimental feeding time involved one food bowl per pair placed on each cage floor. The experimental manipulations of bowl height involved placing the feeding bowls at different heights within the cage: (a) at the top of the cage on a shelf; (b) on the floor as normal; or (c) at both heights simultaneously, with the food divided into two bowls. The experimental procedure was carried out over two time blocks, each lasting for 9 days. Each pair in the two rooms experienced all bowl height configurations when housed in each level of the two-tier cage; we used a counterbalanced procedure to avoid order effects. The bowls always were placed at the front of the cage in a central position.

Data Collection and Statistical Analysis

Each pair was observed in each condition for 15 min after the food bowls had been presented. All occurrences of visits made by each animal to the feeding bowl and their latency to approach them were recorded on a check sheet. A beeper sounded every 15 sec, and the marmosets' height in cage (top or bottom), whether they were at a food bowl, and whether they were moving were recorded using instantaneous point sampling (Martin & Bateson, 1986).

All food bowls were weighed before being placed in the cages. Approximately 170 g of food were presented in each bowl during single-bowl conditions, and approximately 85 g was presented in each in the two-bowl condition. The food bowls

were removed 90 min after presentation and weighed again so we could calculate the amount of food eaten from each. Then, the remaining food was replaced in the cages. It was not always possible to weigh the food remaining in some of the bowls placed high in the enclosure as their contents had been spilled on the cage floor.

To ensure statistical independence, the mean score for each pair was taken. We calculated the proportion of scores engaged in each particular activity and analyzed them using a two-way within-subject design analysis of variance. We also analyzed the weights of food eaten and latencies to approach by means of analysis of variance. Interactions are reported only if they are statistically significant.

RESULTS

Latency to Approach Each Bowl

During single-bowl presentations, the position of the bowl had no significant effect on the marmosets' latency to approach, $F(1, 5) = 0.65$, $p > .05$; neither was there an effect of cage tier, $F(1, 5) = 4.02$, $p > .05$. In two-bowl presentations, the monkeys were significantly quicker to approach the top bowl than the bottom bowl, $F(1, 5) = 9.5$, $p < .05$, but there was no main effect of tier, $F(1, 5) = 0.16$, $p > .05$. For a summary of the results, see Table 1 (see also Figure 2).

Number of Visits Made to Each Bowl

There was no effect of cage tier, $F(1, 5) = 0.07$, $p > .05$, or bowl position, $F(1, 5) = 3.38$, $p > .05$, for the number of visits the marmosets made to each bowl during single presentations. When given a choice, however, the marmosets visited the top bowl significantly more than the bottom bowl, $F(1, 5) = 28.09$, $p < .05$, but there was no effect of cage tier, $F(1, 5) = 5.06$, $p > .05$ (see Table 1 and Figure 3).

Time Spent at Each Bowl

Cage tier had no significant effect on time spent at each bowl in either single- or two-bowl presentations, Fs(1, 5) = 0.35 and 1.65, ps $> .05$, respectively. There was, however, a significant effect of bowl position in both the single- and two-bowl conditions, $F(1, 5) = 7.01$, $p < .05$, and $F(1, 5) = 92.84$, $p < .001$, respectively. As predicted, the marmosets spent significantly more time at the top-positioned bowl than at the bottom-positioned bowl (see Table 1 and Figure 4). There also was a significant interaction between cage tier and bowl position for single-bowl presentations, $F(1, 5) = 8.63$, $p < .05$; lower tier monkeys spent less time at the bottom bowl and more at the top bowl than upper tier monkeys did (see Figure 5).

TABLE 1
A Comparison of Measures in Single-Bowl and Two-Bowl Presentation in Upper and Lower Tier Housed Marmosets

	Single-Bowl Presentation								*Two-Bowl Presentation*							
	Upper Tier				*Lower Tier*				*Upper Tier*				*Lower Tier*			
	Top Bowl		*Bottom Bowl*		*Top Bowl*		*Bottom Bowl*		*Top Bowl*		*Bottom Bowl*		*Top Bowl*		*Bottom Bowl*	
Measure	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Latency to approach[a]	19.4	7.8	22.0	5.9	6.9	0.7	15.0	4.0	12.1	5.6	187.8	86.8	8.2	2.9	266.8	138.6
No. of approaches/ 15 min	9.2	1.9	6.4	1.8	8.5	1.4	6.3	1.1	7.5	0.9	1.2	0.4	5.6	1.2	1.2	0.4
% of point samples at bowl	30.7	2.9	23.4	8.5	36.6	3.1	11.4	5.4	30.3	2.8	2.9	1.5	39.6	4.7	7.8	7.2
Weight eaten from bowl[b]	110.6	12.1	76.2	11.8	86.2	13.4	69.7	8.5	57.6[c]	10.1	20.1	6.6	59.8[d]	6.5	17.4	4.3
% of time in top half of the cage	91.2	1.2	71.5	13.0	84.3	3.7	73.4	5.9	79.9[e]	9.0			74.4[e]	6.3		
% of time in bottom half of the cage	8.8	1.3	28.5	9.6	15.7	3.0	26.6	5.8	20.1[e]	9.1			25.6[e]	5.3		
% of point samples spent moving	5.7	0.9	4.5	0.9	8.4	1.1	8.1	1.8	4.8[e]	1.4			4.1[e]	1.1		

[a]Given in seconds. [b]Given in grams. [c]Total for top and bottom bowls = 77.75. [d]Total for top and bottom bowls = 77.21. [e]Only one value is presented as the top and bottom bowls were presented simultaneously.

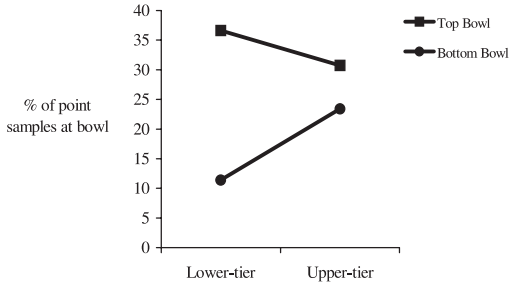

FIGURE 2 Latency (in seconds) to approach the top and bottom bowl in single- and two-bowl presentations.

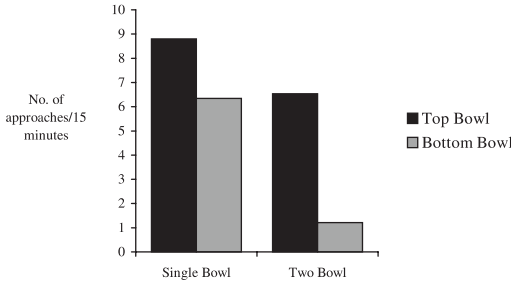

FIGURE 3 Mean number of approaches per 15 min to the top and bottom bowls in single- and two-bowl presentations.

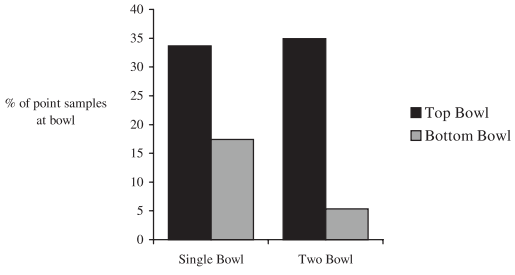

FIGURE 4 Mean percentage of point samples spent at the top and bottom bowls in single- and two-bowl presentations.

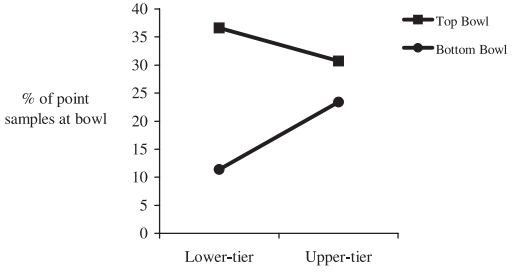

FIGURE 5 Percentage of point samples spent at the top and bottom bowls for upper and lower tier marmosets, for the single-bowl presentation.

Weight Eaten From Each Bowl

We calculated the weight (in grams) of food eaten from each bowl by subtracting the weight of the food left in the bowl after 90 min from the weight of the food in the bowl on presentation. There was no significant difference in the amount of food eaten from the top and bottom bowls in the single-bowl presentation conditions, $F(1, 5) = 2.75$, $p > .05$, and cage tier had no effect, $F(1, 5) = 1.13$, $p > .05$. Because of missing data, it was not possible to analyze the two-bowl data, but there is a clear trend that the marmosets ate more from the top bowl than the bottom bowl (overall 58.7 g vs. 18.9 g; see Table 1).

Use of Enclosure

The number of point samples recorded for time spent in the top half of the cage did not differ significantly across conditions. For single-bowl presentations, cage tier had no significant effect, $F(1, 5) = 1.07$, $p > .05$; neither did bowl position, $F(1, 5) = 4.90$, $p > .05$. For two-bowl presentations, the pattern is the same, with cage tier having no significant effect, $F(1, 5) = 0.29$, $p > .05$. It is, however, clear from the data in Table 1 that the marmosets spent substantially more time stationary in the top half of the cage than in the bottom half (overall 79% vs. 21%). The number of point samples recorded for time spent moving was not affected by the experimental manipulations. There was no significant effect of cage tier for single-bowl presentations, $F(1, 5) = 5.46$, $p > .05$; or two-bowl presentations, $F(1, 5) = 0.12$, $p > .05$; or of bowl position in single presentations, $F(1, 5) = 0.26$, $p > .05$.

DISCUSSION

When given a choice, marmosets prefer not to venture to the floor to feed. When there is no alternative, however, they do feed from the floor. These findings are in line with those of both Hannaford (1996) and Morrissey (1994) and strengthen their recommendation to feed marmosets high in the enclosure. Regardless of the feeding condition, they spent similar amounts of time in the top half of the cage. This suggests that the rationale for feeding marmosets on the floor to increase cage use is not warranted. Cage tier had no significant effect on most of the measures recorded; however, the lower tier marmosets spent less time at the bottom bowl and more at the top bowl than did upper tier monkeys during single-bowl presentations. This suggests that cage tier affects them differentially and that lower tier marmosets are more reluctant to spend time on the floor. Prescott and Buchanan-Smith (2002) argued that reluctance to venture

onto the ground in wild callitrichid is probably because of an increased perceived risk of predation. The welfare of lower tier marmosets that are forced to live close to the ground may be compromised because of their predisposition to avoid the ground in the wild and, when given a choice, in captivity.

Because of potential differences in upper and lower tier primates, Reinhardt and Reinhardt (2000) argued that "editors of 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" (p. 146). Furthermore, we argue that if cage tier location is not counterbalanced across experimental conditions in studies on marmosets, then it should be analyzed as a factor to determine whether it is affecting the results.

An even more pronounced preference of upper half cage use has been reported in other callitrichid species. *S. labiatus* spent 90% of their time in the upper half of their cages (186 cm high) when observations were made from a hide—see below for the significance of the hide (Buchanan-Smith, 1991). Although the cages at the Medical Research Council Unit are larger than minimum Home Office requirements, which state a floor area of 1350 cm^2/monkey with a height of 80 cm, that marmosets restrict themselves to the upper half for nearly 80% of the time is of some concern. In this case, it effectively means that they are spending most of their time in less than 0.3 m^3. Ely et al.'s (1998) more detailed study on cage use in common marmosets found a similar, but less pronounced, pattern of cage use in taller enclosures (180 cm high). Although clearly the marmosets preferred the upper half of their enclosures, temporarily reducing cage breadth—while keeping depth and height constant—reduced use of the upper half from 72% to 65%. Ely et al. suggested that this indicates that cage occupancy is a trade-off between height from the ground and available running distance. They also examined the effect of observer position. When the observer sat, the marmosets spent about the same amount of time in the top and bottom halves (53% vs. 47%), compared with 69% in the top half when the observer stood. The presence of a standing observer in our study reported here may have affected the findings.

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