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Effects of Outdoor Housing on Self-Injurious and Stereotypic Behavior in Adult Male Rhesus Macaques (*Macaca mulatta*)

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We examined the effects of outdoor housing on self-injurious and stereotypic behavior in adult male rhesus macaques with a history of self-wounding that were previously singly housed indoors for at least 4 y prior to the study. Baseline behavioral observations were collected over 2.5 mo. In phase 1, animals were relocated outdoors in 1 of 2 experimental conditions, group-housed (n = 8) or single-housed (n = 5), for 6 wk. In phase 2, group-housed animals were observed outdoors for an additional 6 wk. Behavioral observations were done using focal sampling techniques. In phase 1, rates of self-biting and self-directed stereotypies and time spent displaying idiosyncratic self-directed stereotypies decreased significantly when group- and single-housed animals were housed outdoors. Rates of yawning and scratching were significantly decreased for group- and single-housed animals and, for group-housed animals, self-grooming decreased with outdoor housing. In phase 2, rates of self-biting, time engaging in idiosyncratic self-directed stereotypies, and yawning remained significantly lower during weeks 7 through 12 (outdoor housing) compared with those under indoor housing. Rates of scratching and time spent self-grooming decreased significantly during the first 6 wk but then returned to baseline levels. Our findings suggest that self-biting and self-directed stereotypic behavior in rhesus macaques with a history of self-injurious behavior is significantly reduced by outdoor housing regardless of whether animals are socially or individually housed.

Abbreviations: SIB, self-injurious behavior

In rhesus macaques, prolonged individual housing, particularly if initiated at an early age, is implicated as a leading contributing factor to the development of self-injurious behavior (SIB).[11] Therefore, several studies have examined the effects of socially housing animals that exhibit SIB. Mitchell[13] attempted to pair juvenile social isolates with adults, age-mates, or infants in a playroom for 15-min intervals, but he found that exposing juveniles to adults or age-mates did not significantly reduce SIB. However, the exposure was probably too brief to realistically evaluate any positive effects of socialization on these animals. Bayne, Dexter, and Suomi[2] compared animals that were housed individually indoors with those that were housed in outdoor groups in either runs or corncribs and found that animals housed socially in corncribs exhibited significantly lower rates of SIB than those among monkeys housed individually indoors. Reinhardt[15] showed that in 7 rhesus monkeys paired with same-sex partners, rates of SIB decreased immediately in 3 animals, whereas they diminished gradually over a 2-mo period in the remaining 4 animals. Finally, Weed and colleagues[21] paired vasectomized monkeys with females and found that instances of SIB were "markedly reduced" in the males.

Overall, these studies suggest that social housing may have ameliorative effects on rates of SIB. However, it is unclear whether housing animals in an outdoor environment contributes to the effects of group housing. Therefore, we investigated whether housing animals outdoors reduces rates of SIB and amount of time displaying stereotypic behavior more than does group-housing alone.

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Materials and Methods

Subjects. The study included 17 adult male rhesus macaques (*Macaca mulatta*) aged between 6 to 13 y (mean ± 1 standard deviation, 9 ± 2.05 y) with a history of at least 1 episode of self-wounding requiring veterinary supervision (Table 1). All of the animals had been housed individually for at least 4 y (5.76 ± 1.03 y) prior to our study. All animals were maternally reared and weaned at 6 to 9 mo of age; available postweaning data are presented in Table 1. Study animals were fed a commercially available primate diet twice daily, and water was provided ad libitum. Additional fresh fruit and foraging devices were provided 5 d per week for enrichment. All animals were provided with manipulanda, which included commercially available toys and wood.

The animals were serologically negative for simian retrovirus, simian T-cell leukemia virus, simian immunodeficiency virus, and herpes B virus (*Cercopithecine herpesvirus 1*). All experimental procedures were approved by the institutional animal care and use committee. The University of Louisiana at Lafayette–New Iberia Research Center operates in full compliance with federal guidelines and is accredited by the Association for the Assessment and Accreditation of Laboratory Animal Care, International. During the baseline period, animals were housed indoors in 2 adjacent animal rooms in 1-tiered 0.56-m^2 cages, with the exception of 1 animal (weight greater than 15.0 kg) that was housed in two 0.56-m^2 cages to ensure compliance with federal regulations regarding cage specifications. The rooms exclusively contained animals on this study.

During the outdoor experimental condition, social groups (composed of 2 or 4 animals) were housed in 'corncribs'—steel outdoor enclosures (floor area, 10.5 m^2; height, 3.7 m)—each with 3 satellite 'mini-corncribs' (floor area, 1.2 m^2; height, 2.1 m)

Table 1. Ages and numbers of previous incidents of severe self injurious behavior (SIB) of male rhesus macaques in this study

Animal	Age (y) at study inception	Colony-born?	Age (mo) at transfer to Colony	Years singly housed	No. of incidents of severe SIB during the previous 5 y	Months since last incident of severe SIB
A	13	no	52	5	2	63
B	8	no	25	5	6	19
C	9	no	6	8	3	13
D	8	no	22	6	1	16
E	8	yes	0	7	1	27
F	8	yes	0	6	1	27
G	10	no	21	7	2	9
H	8	no	18	5	1	21
I	13	no	52	5	4	19
J	9	no	25	6	4	18
K	8	no	25	5	1	27
L	8	no	24	5	1	27
M	6	yes	0	5	1	13
N[a]	8	yes	0	4	1	26
O[a]	8	no	25	7	1	41
P[a]	13	yes	0	6	2	38
Q[a]	9	no	26	6	2	14

[a]Subject excluded from analyses because of fighting (n = 2), injuries (n = 1), or degenerative joint disease (n = 1).

attached. Single-housed animals each occupied a mini-corncrib. The corncribs were located in 2 adjacent rows on a concrete slab such that all of the animals had visual access to each other. No other animals were housed on the slab. The concrete slab was surrounded by a 2.1-m high cinder-block wall to prevent direct exposure to wind. The corncribs were equipped with a radiant heat source located on the top of the crib that was activated when environmental temperature fell below 7.2 °C; the satellite mini-corncribs had no heat source. All cages were equipped with perches and toys.

Experimental procedure. Baseline data were collected over a 2.5-mo period while animals were housed indoors. At 36 d after baseline observations were completed, the animals were categorized according to room number (1 or 2) and location within the room (left or right side) and then randomly were placed into group- versus single-housed conditions to ensure that none of the animals in the group-housed condition had direct visualization of each other prior to group formation. Subsequent *t* tests confirmed that neither rate of biting nor duration of self- or environment-directed stereotypies varied significantly between the 2 experimental conditions (data not shown). All social groups were composed of animals exclusively on this study. The single-housed animals (n = 5) served as our control for group-housing effects.

For phase 1 of our study, we examined the short-term effects of outdoor housing on group- and single-housed animals for 6 wk. We placed 3 groups with 4 animals in each group in corncribs, 2 at a time. Placement of the animals into each social group required less than 1 min to complete.

Of the initial 3 social groups, 2 animals were removed from 2 separate social groups after the initial 3 d because of injuries inflicted during fights. In addition, 1 animal was removed from a social group of 3 after 2 wk because of injuries (trauma to incisors, which may have been self-inflicted as a result of head banging). After 6 wk, another animal was removed from the other group of 3 because of degenerative joint disease. None of the animals removed from the social groups were used in the analyses (Table 1). The remaining social groups consisted of 2 pairs and a group of 4. At the end of phase 1, all of the single-housed animals were moved indoors because of unusually cold temperatures (lows lower than 0 °C). All of the group-housed animals remained outside in large corncribs equipped with radiant heat.

In phase 2, which began once the nighttime lows had risen above 0 °C (after 5 d), group-housed animals were observed for an additional 6 wk to evaluate the long-term effects of social housing.

Behavioral observations. Baseline observations were conducted over 2.5 mo. Animals were observed during three 2-wk periods with 1-mo intervals between them. Animals were relocated outdoors 36 d after completion of baseline observations, and observations resumed 5 d after relocation. Animals were observed daily for the presence of wounds. When animals were group-housed outdoors, self-inflicted wounds were recorded only if they were directly observed at the time of occurrence or if the wound was noted at a body site that the animal had self-wounded previously.

Behavioral observations were done using focal sampling techniques (for baseline data, 20-min sessions twice weekly per animal; for outdoor conditions, 10-min sessions 4 times weekly per animal) and were balanced for time of day. Thus the total observation time for each animal was 4 h during each experimental condition (baseline, outdoor weeks 1 through 6, and outdoor weeks 7 through 12). Morning observations were done between 0700 and 1015, and afternoon observations were done between 1200 and 1515.

Behaviors recorded were classified as SIB, stereotypic, and general (Table 2). The SIB category distinguishes between self-biting that does not cause injury and self-wounding. The stereotypic category consists of repetitive nonpurposeful behaviors, which are further divided into self-directed, environment-directed, and whole-body stereotypies.[11] The general category includes behaviors that are species-typical. Although classified as general behavior, scratching, yawning, self-grooming, and other self-directed behavior may be indicative of anxiety.[1,3,16,17,20]

Behaviors that occurred nearly instantaneously were classified as events and calculated as rates.[9] Behaviors that occurred over a period of time were classified as states and calculated as percentage of total time.[9] Behaviors were averaged over

Table 2. Ethogram for adult male rhesus macaques

	Definition	Unit of measure
Self-injurious behaviors		
Self-wound	Self-inflicted wound that results in puncturing or tearing of the skin and that may require veterinary attention.	no. incidents/h
Bite (no injury)	Vigorous biting of animal's own body without tearing or puncturing of the skin.	no. incidents/h
Stereotypic behaviors		
Self-directed stereotypies	Hair pluck, head toss, salute, eye poke, abnormal masturbation, self-grasp, or abnormal posture.	no. incidents/h
Self-directed stereotypies (idiosyncratic)	Repetitive, abnormal self-directed behaviors not previously listed. Examples include hitting or kicking self, cheek pouch manipulation, and repetitively touching of animal's own body.	% time
Pacing	Repetitive locomotion.	% time
Environmental-directed stereotypies	Repetitive behavior directed towards environment, such as compulsively rubbing hands on cage; biting, licking, sucking, picking at cage; and nonpurposeful grabbing at objects in the cage.	% time
Stereotypic body movements	Swing, rock, bounce, body-flip, and 'floating' limb.	% time
General behaviors		
Neutral	Maintenance of static position with no simultaneous behavior; withdrawn with head down or sitting upright while looking up with chin resting on cage.	% time
Manipulate	Use or investigation of enrichment device with hands, nose, mouth, or teeth.	% time
Rest	Sitting with eyes closed or lying down, with or without eyes closed, in a relaxed state.	% time
Scanning or watching	Observing in a sweeping motion or watching attentively.	% time
Locomote	Nonstereotypic walking, running, climbing, or other major positional change.	% time
Self-groom	Normal self-directed picking or spreading of fur with hands or mouth.	% time
Yawn	Inhalation of air through an open mouth with teeth exposed.	no. incidents/h
Scratch	Deliberately brushing fingers or toes across skin.	no. incidents/h
Investigate	Exploration of surroundings with hands, nose, or mouth.	% time
Masturbate	Genital manipulation with hands or limbs; often followed by the animal eating semen if ejaculation occurs.	% time

2-wk periods, creating three 2-wk time periods for each condition: baseline, outdoor weeks 1 through 6, and outdoor weeks 7 through 12. All data were collected using a personal data recorder (Workabout, Psion Teklogix, Erlanger, KY) and The Observer software (Noldus Information Technology, Leesburg, VA). For the baseline period there were 3 observers. Intraobserver reliability was assessed at a Cohen κ of greater than 0.75. One of the initial 3 observers (MW) collected all of the data from animals housed outdoors.

Temperature. The study was conducted from November through February, during which ambient outside temperatures averaged 14.8 °C (range, 0 to 27.8 °C). To assess the effects of environmental temperature on behavior, we designated morning observations that were done when the lowest daily temperature was less than 7.2 °C and the highest was less than 18.3 °C as 'cold'; all others were designed as 'warm' (Figure 1). During the baseline period, highest and lowest daily temperatures in the room were recorded by use of a max–min thermometer (model 5458, Taylor, Oak Brook, IL). Daily outdoor temperatures for the local area were obtained from the National Weather Service.

Statistical analysis. For phase 1, we used 2 × 3 × 2 repeated-measures analysis of variance with location (indoor versus outdoor) and time (three 2-wk periods) as within-subjects variables and housing (group-housed versus single-housed) as a between-subjects variable. To determine the effects of temperature on behavior, we used 2 × 2 repeated-measures analysis of covariance with Housing as a between-subjects factor and temperature (warm versus cold) as a within-subjects factor. Behavior averaged over baseline was the covariate. All significant interactions were analyzed using univariate contrasts. All statistical procedures were done using the software package Statistica (Statsoft, Tulsa, OK).

For phase 2, we used 3 × 3 repeated-measures analysis of variance with time (three 2-week periods) and location (indoor, outdoor weeks 1 through 6, and outdoor weeks 7 through 12) as within-subjects factors. The effects of temperature were analyzed by use of 2 × 2 repeated-measures analysis of covariance with time (outdoor weeks 1 through 6 versus outdoor weeks 7 through 12) and temperature (warm versus cold) as within-subjects factors and behavior averaged over baseline as the covariate. All significant results were analyzed further by use of univariate contrasts.

We used Friedman analysis of variance to calculate changes in the incidence of self-wounding from baseline to outdoor weeks 1 through 6 and outdoor weeks 7 through 12.

Results

Phase 1: effects of outdoor and social housing. ***Self-wounding.*** We found no significant main effects or interactions on the incidence of self-wounding (Figure 2).

SIB and stereotypic behavior. We found that rates of self-biting with no injury (Figure 3 A; F [1, 11] = 7.42; $P < 0.05$) and self-

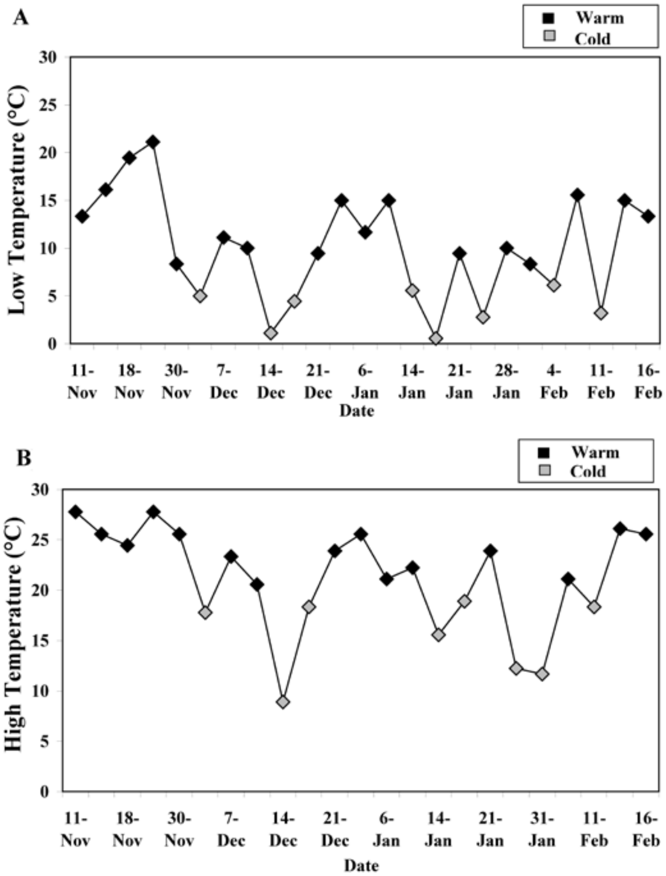

Figure 1. (A) Date of morning observations versus corresponding lowest daily temperature. (B) Date of afternoon observations versus corresponding highest daily temperature.

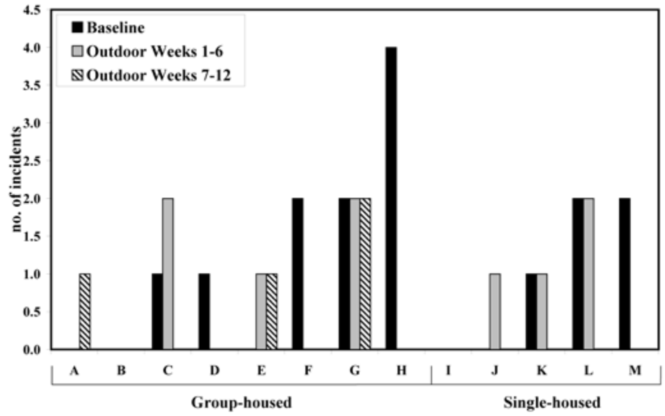

Figure 2. Number of incidents of self-wounding.

directed stereotypies (Figure 3 B; F [1, 11] = 5.62; $P < 0.05$) and percentage of time spent performing idiosyncratic self-directed stereotypies (Figure 3 C; F [1, 11] = 5.48; $P < 0.05$) all decreased when animals were housed outdoors.

We identified a location × housing interaction (Figure 3 D; F [1, 11] = 9.40; $P < 0.01$) for percentage of total time spent pacing. The results of subsequent univariate analysis showed that group-housed animals paced significantly more than did single-housed monkeys during the baseline, indoor period (F [1, 11] = 10.65, $P < 0.01$). When outdoors, percentage of total time spent pacing declined significantly for group-housed animals (F [1, 11] = 18.02; $P < 0.001$). However, there was no significant difference in percentage of total time spent pacing between group- and single-housed animals while animals were housed outdoors.

We found no main effects or interactions on percentage of total time spent displaying environmental-directed stereotypic behavior or stereotypic body movement.

General behaviors. A summary of the significant effects of location and housing on general behavior states is shown in Table 3.

We found that percentage of total time spent in neutral behavior (F [1, 11] = 16.51; $P < 0.01$) and manipulation of toys and enrichment devices (F [1, 11] = 34.20; $P < 0.001$) decreased and percentage of total time spent resting (F [1, 11] = 23.33; $P < 0.001$) increased when animals were housed outdoors.

We identified a location × housing interaction for percentage of total time spent scanning (F [1, 11] = 4.87; $P < 0.05$) and locomoting (F [1, 11] = 17.86; $P < 0.05$). We compared single-housed with group-housed animals and found that only group-housed animals spent more time scanning (F [1, 11] = 34.00; $P < 0.001$) and locomoting (F [1, 11] = 40.62; $P < 0.001$) when housed outdoors.

We found a location × housing × time interaction for percentage of total time spent self-grooming (F [2, 22] = 6.00; $P < 0.01$). We examined the contrast between group- and single-housed animals by using data collapsed over the 3 time points in the location condition and found that percentage of total time spent self-grooming decreased for the group-housed animals only when they were housed outdoors (F [1, 11] = 12.50; $P < 0.01$).

We found that rates of yawning (Figure 4 A; F [1, 11] = 12.19; $P < 0.01$) and scratching (Figure 4 B; F (1, 11) = 15.19; $P < 0.01$) decreased significantly when animals were housed outside.

We found no main effects or interactions for percentage of total time spent investigating or masturbating.

Temperature. Results of repeated-measures analysis of covariance indicated a significant temperature × housing effect on percentage of total time spent scanning (F [1, 6] = 6.94; $P < 0.05$). Single-housed animals scanned significantly less during cold days than warm days (F [1, 6] = 6.46; $P < 0.05$). No further effects of temperature on SIB, stereotypic behavior, or general behavior were identified.

Phase 2: effects of outdoor housing for group-housed animals over 12 wk. ***Self-wounding.*** We found no evidence that housing had an effect on the incidence of self-wounding in group-housed animals (Figure 2).

SIB and stereotypic behavior. We found that rates of self-biting with no injury decreased significantly outdoors (Figure 5 A; F [2, 14] = 7.81; $P < 0.01$) during weeks 1 through 6 (F [1, 7] = 7.28; $P < 0.05$) and remained significantly lower during weeks 7 through 12 (F [1, 7] = 8.71; $P < 0.05$) compared with rates associated with indoor housing.

Group-housed animals spent significantly less time engaging in idiosyncratic self-directed stereotypies while housed outdoors (Figure 5 B; F [2, 14] = 8.24; $P < 0.01$) during weeks 1 through 6 (F [1, 7] = 7.19; $P < 0.05$) and weeks 7 through 12 (F [1, 7] = 11.35; $P < 0.01$). In addition, group-housed animals spent significantly less time pacing outdoors (Figure 5 C; F [2, 14] = 13.54; $P < 0.001$) during weeks 1 through 6 (F [1, 7] = 12.16; $P < 0.01$) and weeks 7 through 12 (F [1, 7] = 19.09; $P < 0.01$).

Stereotypic body movement was decreased after outdoor housing (Figure 5 D; F [2, 14] = 4.35; $P < 0.05$) during weeks 7 through 12 (F [1, 7] = 6.73; $P < 0.05$).

No significant main effects or interactions were found for rates of self-directed stereotypies or percentage of total time spent displaying environmental-directed stereotypic behavior.

General behaviors. A summary of the significant effects of location on general behavior states is shown in Table 4.

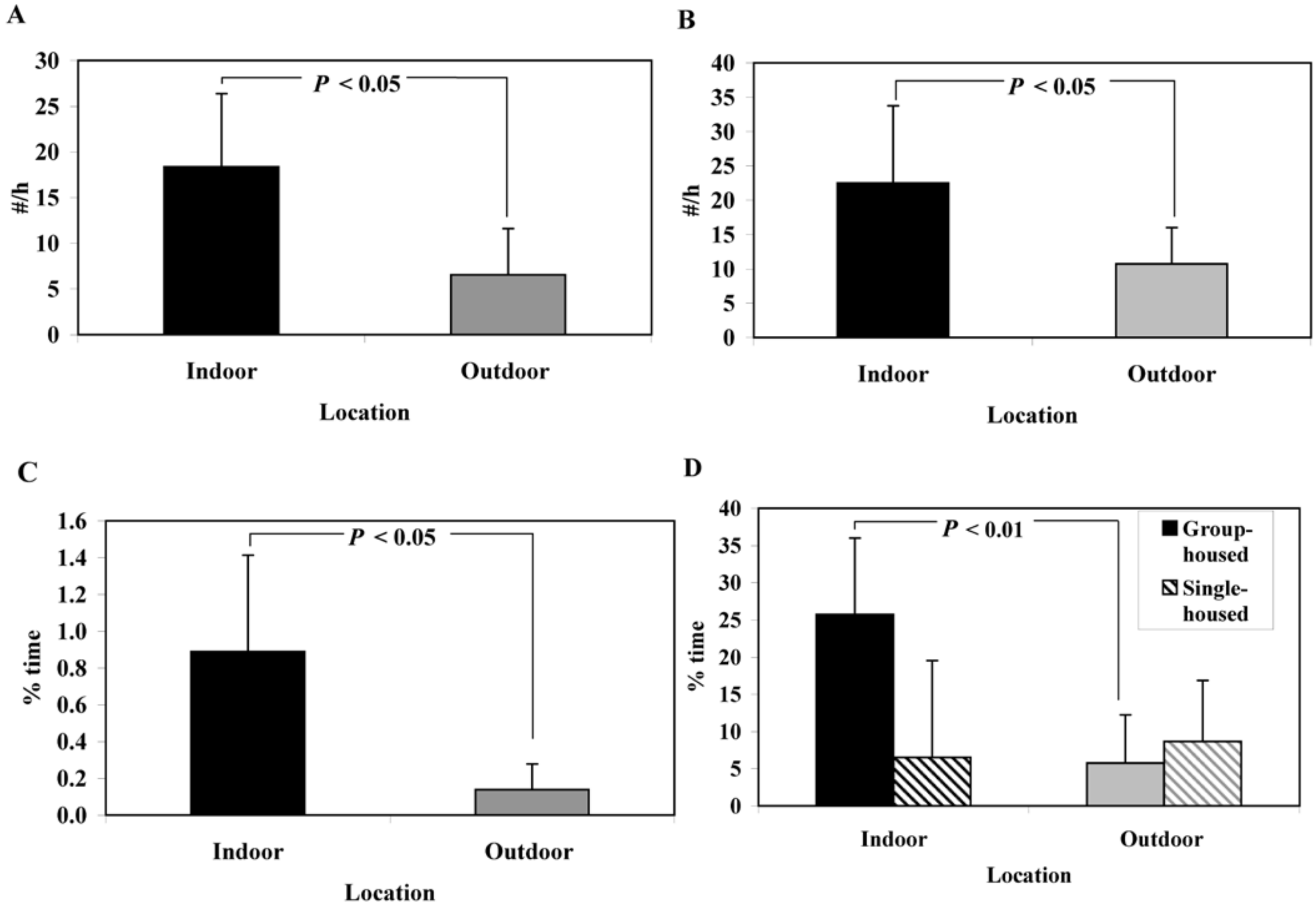

Figure 3. Rates of (A) self-biting and (B) self-directed stereotypies and percentage of total time spent (C) displaying idiosyncratic self-directed stereotypies and (D) pacing during phase 1. Data are presented as mean ± 1 standard error.

Table 3. Effects of location and housing on behavior during phase 1

Behavior	Effect	Location	Mean % of total time (1 standard error)		
Neutral	Housing ($P < 0.01$): indoor > outdoor	indoor	9.12 (2.72)		
		outdoor	3.31 (1.06)		
Manipulate	Housing ($P < 0.001$): indoor > outdoor	indoor	6.49 (1.68)		
		outdoor	0.97 (0.51)		
Rest	Housing ($P < 0.001$): indoor < outdoor	indoor	4.12 (1.86)		
		outdoor	11.36 (3.25)		
Scan	Location × Housing ($P < 0.05$):		Group	Single	
	group-housed indoor < group-housed outdoor	indoor	43.21 (7.23)	48.63 (9.14)	
		outdoor	66.07 (4.69)	57.54 (5.93)	
Locomote	Location × Housing ($P < 0.05$):		Group	Single	
	group-housed indoor < group-housed outdoor	indoor	0.59 (0.15)	0.55 (0.19)	
		outdoor	3.37 (0.94)	1.73 (1.19)	
Self-groom	Housing × Time × Condition ($P < 0.01$):			Group	
	group-housed indoor > group-housed outdoor		week 1	week 2	week 3
		indoor	14.15 (2.66)	12.61 (2.15)	10.10 (2.43)
		outdoor	8.03 (2.49)	3.76 (2.15)	3.64 (2.27)
				Single	
			week 1	week 2	week 3
		indoor	8.92 (3.37)	5.59 (2.70)	15.68 (3.08)
		outdoor	11.64 (3.14)	7.36 (2.72)	7.71 (2.87)

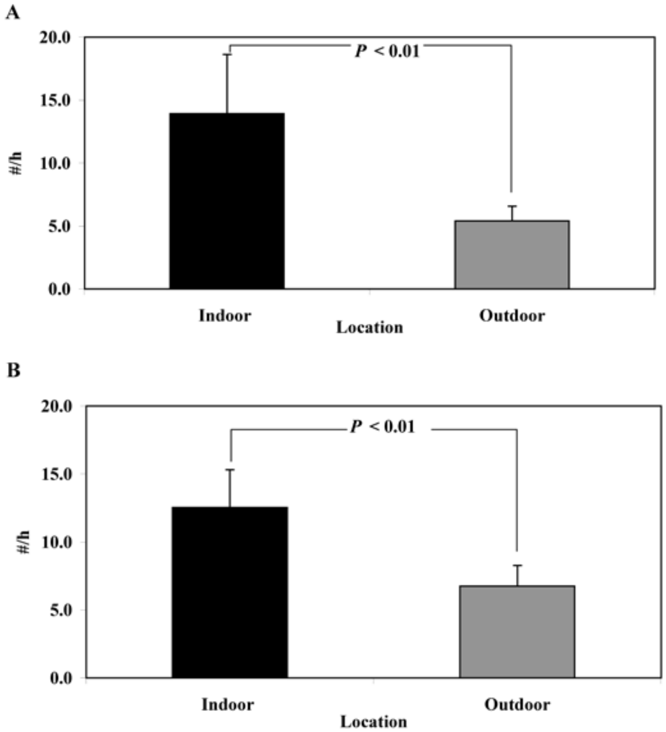

Figure 4. Rates of (A) yawning and (B) scratching during phase 1. Data are presented as mean ± 1 standard error.

Group-housed animals spent significantly more time displaying neutral behavior (F [2, 14] = 7.13; $P < 0.01$) while housed indoors than during outdoor weeks 1 through 6 (F [1, 7] = 10.15; $P < 0.05$). During weeks 7 through 12, the percentage of total time spent in neutral behavior returned to baseline levels.

The percentage of total time that animals spent manipulating toys decreased significantly (F [2, 14] = 19.61; $P < .001$) while they were housed outdoors during weeks 1 through 6 (F [1, 7] = 15.64; $P < 0.01$) and weeks 7 through 12 (F [1, 7] = 29.38; $P < 0.001$). The percentage of total time that animals spent resting increased (F [2, 14] = 11.92; $P < 0.001$) while they were housed outdoors during weeks 1 through 6 (F [1, 7] = 14.12; $P < 0.01$) and weeks 7 through 12 (F [1, 7] = 15.51; $P < 0.01$) compared with that during indoor housing.

The animals spent significantly more time scanning (F [2, 14] = 27.30; $P < 0.0001$) during weeks 1 through 6 (F [1, 7] = 28.48; $P < 0.001$) and weeks 7 through 12 (F [1, 7] = 33.35; $P < 0.001$).

When housed outdoors, animals spent significantly more time locomoting (F (2, 14) = 33.84; $P < 0.0001$) during weeks 1 through 6 (F [1, 7] = 34.79; $P < 0.001$) and weeks 7 through 12 (F [1, 7] = 41.45; $P < 0.001$) compared with that during indoor housing.

Group-housed animals spent significantly less time self-grooming (F [2, 14] = 4.35; $P < 0.05$) during outdoor weeks 1 through 6 (F [1, 7] = 9.69; $P < 0.05$); however, percentage of total time spent self-grooming returned to baseline (indoor) levels during outdoor weeks 7 through 12.

We found that rates of yawning decreased significantly (Figure 6 A; F [2, 14] = 6.04; $P < 0.01$) while animals were housed outdoors during weeks 1 through 6 (F [1, 7] = 7.13; $P < 0.05$) and weeks 7 through 12 (F [1, 7] = 5.49; $P = 0.05$).

Rates of scratching were significantly effected by outdoor housing (Figure 6 B; F [2, 14] = 4.22; $P < 0.05$). We found that rates of scratching decreased significantly during outdoor weeks 1 through 6 (F [1, 7] = 7.56; $P < 0.05$) compared with the baseline rate, followed by a significant increase in rates of scratching during outdoor weeks 7 through 12 (F [1, 7] = 6.18; $P < 0.05$). No significant difference was found between baseline and outdoor weeks 7 through 12.

We found no main effects or interactions on percentage of total time spent investigating or masturbating.

Temperature. Results of repeated-measures analysis of covariance indicated that animals spent more time in neutral behavior during cold versus warm days (F [1, 6] = 5.88; $P < 0.05$).

No other significant effects of temperature on SIB, stereotypic behavior, or general behavior were identified.

Discussion

In phase 1, we found that when housed outdoors, regardless of social housing, animals displayed significantly ($P < 0.05$) lower rates of biting and self-directed stereotypic behavior and spent significantly ($P < 0.05$) less time displaying idiosyncratic self-directed behavior. Group-housed animals spent less time pacing. However we had no evidence that outdoor housing had an effect on self-wounding. In phase 2, we found that rates of biting, percentage of total time spent displaying idiosyncratic self-directed stereotypies, stereotypic body movement, and pacing decreased over 12 wk of outdoor housing. Again, we found no evidence that self-wounding was decreased in group-housed animals over the 12-wk period.

In phase 1, rates of yawning and scratching and percentages of total time spent manipulating toys and in neutral behavior decreased and the amount of time spent resting increased when animals were housed outdoors. For animals housed in groups outdoors, the amounts of time spent pacing and self-grooming decreased whereas the percentage of total time spent locomoting and scanning increased.

In phase 2, group-housed animals spent more time scanning, resting, and locomoting and less time manipulating toys when housed outdoors throughout the 12-wk period. Rates of yawning outdoors remained lower than indoor levels. However, percentages of total time spent self-grooming and in neutral behaviors as well as the rate of scratching returned to baseline levels.

The absence of effects of housing on self-wounding could be related to our relatively small sample size combined with observations that self-wounding occurs only rarely and sporadically among animals that self-bite. Lutz and colleagues[11] found that although 25% of the 362 monkeys they examined engaged in self-biting, only 11% had a veterinarian record of SIB. Although we found evidence that stereotypic behaviors and self-biting were decreased in the present study, further research is required to determine the effects, if any, of outdoor housing on self-wounding.

One possible explanation for the reduction in self-biting and self-directed and other stereotypic behavior is suggested from the results of Novak,[14] who found that SIB could be elicited by exposure to stressful procedures such as husbandry routines or veterinary procedures. At our facility, outdoor housing provides more space for animals to avoid close contact with care staff, and husbandry routines are less labor intensive. In addition, veterinary procedures typically are not done outdoors. Insofar as yawning, scratching (phase 1), self-grooming (phase 1), and self-directed behavior reflect levels of anxiety,[1,3,16,17,20] decreases in these behaviors suggests that outdoor housing was less stressful during the first 6 wk. Among group-housed animals in weeks 7 through 12 of phase 2, scratching and self-grooming returned to baseline levels and may reflect increased tension among or between the social groups.

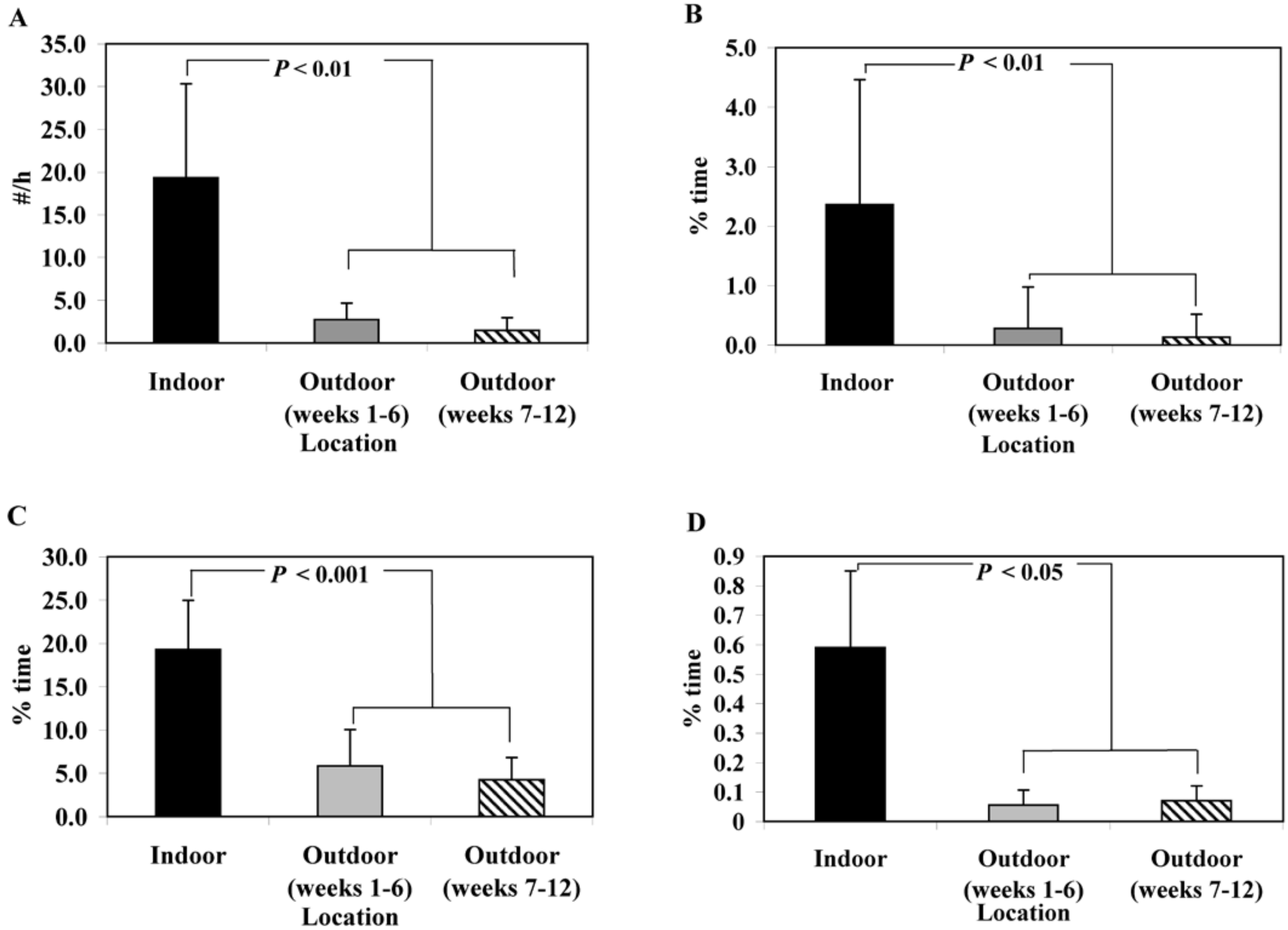

Figure 5. (A) Rate of self-biting and percentages of total time spent (B) displaying idiosyncratic self-directed stereotypies, C) pacing, and (D) displaying stereotypic body movement during phase 2. Data are presented as mean ± 1 standard error.

Table 4. Effects of location on social behavior (phase 2)

Behavior	Effect	Location	Mean % of total time (1 standard error)
Neutral	Location ($P < 0.01$):	indoor	7.39 (2.59)
	indoor > outdoor weeks 1–6,	outdoor (1–6)	2.56 (0.94)
	outdoor weeks 7–12	outdoor (7–12)	6.53 (1.51)
Manipulate	Location ($P < 0.001$):	indoor	15.52 (8.45)
	indoor > outdoor weeks 1–6,	outdoor (1–6)	2.88 (3.42)
	outdoor weeks 7–12	outdoor (7–12)	1.00 (1.40)
Rest	Location ($P < 0.001$):	indoor	2.2 (1.01)
	indoor < outdoor weeks 1–6,	outdoor (1–6)	8.17 (2.40)
	outdoor weeks 7–12	outdoor (7–12)	10.35 (1.5)
Scan	Location ($P < 0.0001$):	indoor	43.21 (5.33)
	indoor < outdoor weeks 1–6,	outdoor (1–6)	66.01 (3.62)
	outdoor weeks 7–12	outdoor (7–12)	61.51 (3.75)
Locomote	Location ($P < 0.0001$):	indoor	0.59 (0.02)
	indoor < outdoor weeks 1–6,	outdoor (1–6)	3.73 (1.06)
	outdoor weeks 7–12	outdoor (7–12)	3.42 (0.85)
Self-groom	Location ($P < 0.05$):	indoor	12.29 (3.40)
	indoor > outdoor weeks 1–6 <	outdoor (1–6)	5.14 (2.30)
	outdoor weeks 7–12	outdoor (7–12)	8.95 (3.93)

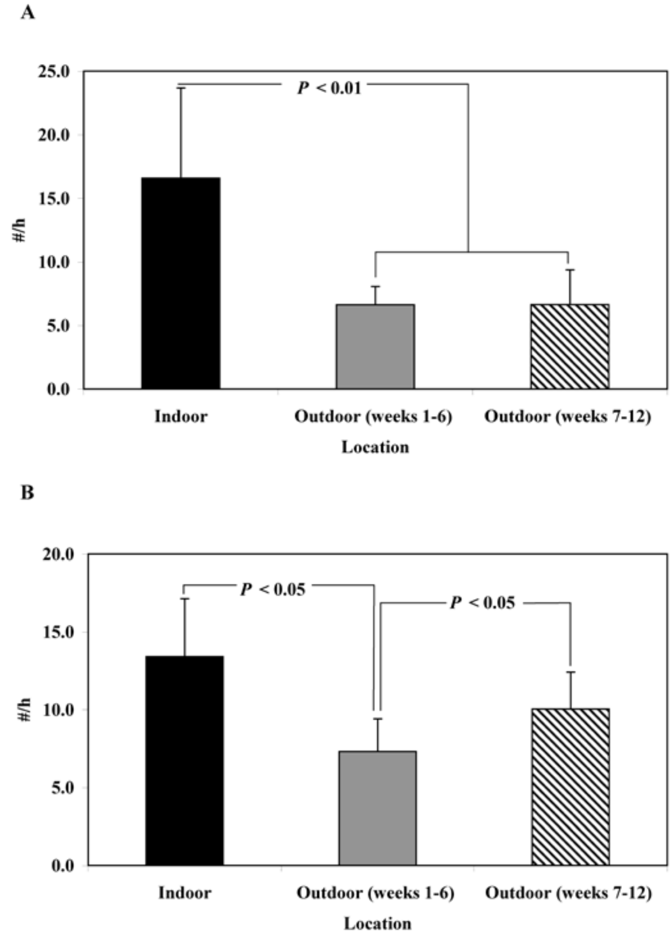

Figure 6. Rates of (A) yawning and (B) scratching during phase 2. Data are presented as mean ± 1 standard error.

In our study, outdoor housing provided a 114% increase in floor area for single-housed animals and a 364% to 837% increase in floor area for group-housed animals; these increases could have contributed to changes in physical activity. Although previous research found that reductions in cage size to 20% of that specified by US Department of Agriculture regulations led to decreased locomotion, increasing cage area to 148% of the mandated size had no effect on either abnormal or normal behaviors of pigtailed macaques (*M. nemestrina*).[5] Similarly, in long-tailed (*M. fascicularis*)[4] and rhesus macaques,[8,10] increasing cage size did not have an effect on abnormal behavior or activity level. It should be noted that all of these studies compared cage size effects on behavior in an indoor environment. We found that group-housed animals, which received the largest increase in cage area, had significant increases in locomotion and scanning and decreased pacing, whereas these behaviors did not change significantly in single-housed animals. These results may have been influenced by increased cage space. A follow-up study examining outdoor housing in cages equivalent in dimension to indoor cages is required to adequately differentiate the potential effects of changes in cage area from outdoor housing on behavior.

In addition to increased space, outdoor housing exposes animals to natural perceptual stimuli such as sunlight, dusk–dawn transition, natural sounds, and temperature variation. Our observations were done during the winter months (November through February) when temperatures averaged 14.8 °C (range, 0 to 27.8 °C), whereas indoor temperatures were relatively constant (range, 22.2 to 26.7 °C). Macaques may budget their activity in order to save energy when environmental temperatures are relatively low.[7] Therefore relatively cold environmental temperatures may promote increases in energy-conserving activities such as resting, scanning, and locomotion, and decreases in activities such as pacing. We found that environmental temperature altered scanning in single-housed animals during phase 1 and neutral behaviors in group-housed animals in phase 2. However, we found no evidence that temperature affected SIB, stereotypic, and most of the general behavior examined. Seasonal studies with a larger sample size would be required to fully examine the potential role of environmental temperature.

The results of our study generally support Bayne, Dexter, and Suomi,[2] who found that animals socially housed in corncribs exhibited less abnormal behavior compared to animals housed individually indoors. However, further studies are needed to determine whether the frequency of self-wounding would be decreased by a change from indoor to outdoor housing. Overall, our results suggest that self-biting and self-directed stereotypic behavior in rhesus macaques with a history of SIB is significantly reduced by outdoor housing, regardless of whether animals are socially or individually housed, and that, when possible, such a change in housing improves well-being. As an adjunct to outdoor housing or when outdoor housing is not possible, pharmacological treatment may be necessary.[6,12,18,19,22]

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