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STATE ORGANIZATION AND ACTIVITY IN INFANT CEBID MONKEYS (*CEBUS* AND *SAIMIRI*) IN TWO REARING CONDITIONS

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ABSTRACT: Behavioral states and their organization in 5-week old squirrel monkeys and 8-week old capuchin monkeys was evaluated. Infants at these ages are not quite at the threshold, under species-normal rearing conditions, of independent locomotion. Two age-matched infants of each species were observed continuously for a 5-day period while cared for by their mothers in their natal social groups, or while cared for by humans and housed in an incubator on a stationary support. All four infants spent similar proportions of time sleeping, drowsy, nursing, and awake. Hand-reared infants were more frequently awake and active with their hands, cocked their heads more often, and slept in shorter bouts than their mother-reared counterparts. All infants exhibited a positive correlation during the daylight hours between the duration of time in an alert quiet state and the duration of time being moved by a carrier. In addition to providing detailed information about the temporal characteristics of state organization and activity within subjects, the findings suggest the kinds of alterations in activity which can result in these species when artificial (largely stationary) rearing regimes are experienced. Many of the alterations can be interpreted as compensatory self-stimulation. The alterations are apparently different in the species studied here from those described for other species, principally macaques, experiencing similar artificial rearing regimes.

The focus of this report is the temporal organization of behavioral states and activity in infant monkeys. One aim is to provide some detailed information for species not well represented in this literature. A second aim is to consider in a preliminary fashion if rearing regime (maternal, species-normal; or by humans, called hand-rearing) affects the temporal organization of behavioral states and activity in young monkeys in the short term. We were particularly interested to see if (a) durations and rhythmicity of states and (b) frequency of activity would be influenced by rearing regimes.

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The relationship between rearing condition and the occurrence of head-cocking was of particular interest in this study in regard to the second aim. In head-cocking, an individual rotates its head distinctly about the longitudinal axis of the body while orienting in a fixed direction (Menzel, 1980; see Figure 1). Head-cocking is commonly observed in both species used in this study, as in other small-bodied nonhuman primates such as marmosets and galagos (Rogers et al., 1993; Menzel, 1980). Menzel (1980) suggested that head-cocking, a behavior particularly characteristic of young individuals still carried by another, is influenced by the infant's non-locomotor status. Menzel suggested that this might occur because head-cocking produces self-guided shifts in the visual field that aid the pick-up of visual information. Non-locomoting individuals might obtain visual information from head-cocking that they would be otherwise unable to obtain. If head-cocking is performed to increase the amount of visual information available to an infant that can not readily move the rest of its body, then it ought to be more frequent in hand-reared infants than in mother-reared infants. Hand-reared infants are even less exposed to varying visual stimulation than are passively carried, but frequently moved, mother-reared infants.

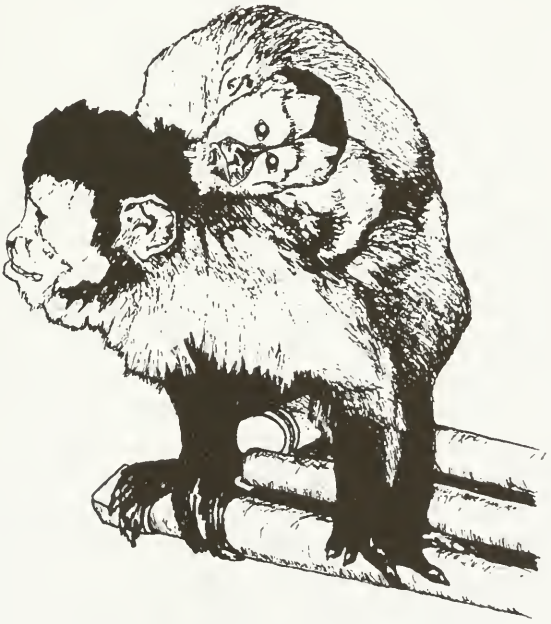

Figure 1. Sketch of a mother-reared capuchin infant displaying head-cocking. Drawn by Deborah Custance from a photograph.

Two species of monkeys (squirrel monkeys, *Saimiri sciureus*, and tufted capuchin monkeys, *Cebus apella*) were studied. These are both intermediate-sized South American monkeys exhibiting similar locomotor and developmental patterns, although motor milestones are reached more slowly in capuchin monkeys compared to squirrel monkeys (Fragaszy et al., 1991). One infant monkey of each species was studied under each rearing condition (hand or mother) in this study. Obviously, this design has limited statistical power. Nevertheless, the findings can alert us to the nature of behavioral consequences one could expect to see in subsequent studies of rearing effects with these species.

METHOD

Subjects

Four infant monkeys were studied. The two infant capuchins (both females) were observed at 50 through 54 days of age. The two infant squirrel monkeys (hand-reared: female; mother-reared: male) were observed at 36 through 40 days of age. These ages correspond to a similar period in the development of infants of the two species: they occur near the end of the pre-locomotor phase, during which infants are carried continuously. All the infants were in good health, and were phenotypically normal for their species in size, weight, and general behavioral abilities. Locomotor development of the hand-reared infants was in line with that reported by Elias (1977) for nursery-reared infants of these species; none of the infants exhibited competent quadrupedal locomotion during this period.

The mother-reared infants were cared for by their mothers in their natal social groups. The group of squirrel monkeys contained 16 other individuals, in addition to the infant subject; the group of capuchin monkeys contained 6 other individuals. Each group was housed in an enclosure with an indoor room 1.5m x 2.3m x 2.3m, connecting with an outdoor pen 3.5 x 3.5 x 2.3m. Both parts of the cage were fitted with perches at multiple heights, straw bedding, and water and food were available ad libitum. The indoor portion of the home cage was partially lit by natural light, and also had a 12 hour on/12 hour off cycle of fluorescent white lighting. Artificial lighting came on at 7 AM and went off at 7 PM. This study took place in the summer months, so that the natural light cycle was about 14 hours light:10 hours dark. The natural light arrived before, and lasted past,

the artificial lighting. During full darkness, a red light was lit in both indoor and outdoor portions of the home cage for observational purposes. Both groups were fed at about 9 AM and again at about 3 PM, and the cages were cleaned on the same schedule in each group.

The two hand-reared infants were housed in a room with natural lighting through a window, and a similar schedule of artificial lighting as the group-housed infants. The two infants had been born 6 days apart. The capuchin infant was separated from its mother two weeks after birth; the squirrel monkey, 2 days after birth. They lived together in a transparent hospital incubator which was kept at about 29 degrees C. Each infant was placed on a soft, cylindrical, stationary object (a paint roller, with long nap, mounted at a 30 degree angle from horizontal). Each infant was removed from the incubator and held for feeding at 2 to 3-hour intervals around the clock. The hand-reared infants were fed a commercial human infant formula using a pet nurser. During night-time feedings (about 10 min per infant per feeding), a shaded lamp with a 30-watt incandescent bulb was lit. For the remainder of the night, a red light was used. Infants also rode for 10 - 20 minutes at a time several times each day on the caregiver's arm while the caregiver moved about normally with the arm held in a largely horizontal position. This rearing regime had been in place for several weeks before these observations began.

Procedure

A team of trained observers, each conducting a 3-hour shift, observed each infant continuously for a period of five days (120 hours). Using a keyboard data collection device, the observer scored changes in the infant's state (sleeping; drowsy; alert inactivity, called Alert-Quiet; and alert activity, called Alert-Active; see Table 1), the onset and termination of movement by the mother, or by the human caregiver, and the occurrence of manipulative activity and head-cocking by the infant. The data were collected with a temporal accuracy of .6 seconds (1/100 minute). A three-second rule was used to determine transitions in state.

Prior to data collection, observers practiced scoring the behavior of older group-living infants of each species, and conducted simultaneous observations for purposes of determining inter-observer reliability (set at 85% agreement on total duration or frequency per variable over a 30 min session). Subsequent comparisons of data indicated no consistent variation across observers for any subject.

Table 1. Behavioral categories and defining characteristics

Category	Defining characteristics
1. States	
Sleep	Eyes closed, body limp, twitching and change in position possible.
Drowsy	Eyes partly open, eyes may be glazed, some slow postural adjustments possible.
Alert-Quiet	Eyes wide open, head may be up or supported, body supported. May change position of arms and legs, but not of the core of the body.
Alert-Active	Moving the whole body, either in space as in locomotion, or in orientation, and more than a movement equivalent to changing positions on the mother. Also,when the body core is not supported (as in standing).
2. Other activities with durations	
Movement by Mother	Mother reared: Mother locomoting or moving vigorously (as in scratching with a leg). Hand-reared: Riding on a human arm, and the arm is moving.
Nurse	Mother-reared: In the nursing position. Hand-reared: On the nipple
3. Events	
Manipulate	Chew, pull, reach toward, and hold objects. Can occur in Drowsy, Quiet, or Active states.
Head-Cock	Abrupt movement of head about the longitudinal axis of the body. Occurs in visual inspection during Alert states.

Analysis

Most analyses were done by individual subject. The data were first divided into 120 50-min blocks. Subsequently, the data were plotted by 24 hour units, pooling across days, for visual inspection. Spectral analyses and Box-Jenkins time series analyses (using the BMDP statistical package) were run on the duration variables expressed as % total time per block to identify periodicities in the occurrence of behavioral states. Head cock and manipulation were omitted from these analyses, as they had no meaningful duration. Spectral analyses indicate how much of the temporal variability across the 120 hours derives from multiple cycles (say, from 2 hour cycles interacting with 24 hour cycles). We first plotted the unfiltered data, and re-plotted it using filters to smooth out 24-hour cycles. The values reported below were obtained with a filter band width of .0583.

Box-Jenkins analyses indicate the strength of various temporal cycles in a particular behavior by using a correlational approach. A preliminary analysis using an autoregressive model on the original data indicated that the data were not stationary. Therefore, a 24-hour differenced series (moving average model) was derived for each variable. Last, Pearson product-moment correlations were used to examine the relationship between the proportional duration of passive movement and the infants' activity over the 120 blocks, and over the 60 daylight blocks.

Average durations per bout for the 6 duration variables (four states, plus Nurse and Movement by Mother) and the frequency of bouts for all 8 behavioral variables were graphed for visual inspection. Comparisons between hand-reared and mother-reared infants of the same species for frequency and duration variables are descriptive only; inferential comparisons are not appropriate as the frequencies in each class (subject) are drawn repeatedly from the same subjects.

RESULTS

Time budgets

Each infant's overall time budget is displayed in Figure 2. Overall, certain similarities are evident: all 4 infants spent about 40% of all their time asleep, about 7% of their time drowsy, less than 5% of their time nursing, and the remainder (nearly 50% of their time) in an alert state. Neither of the hand-reared infants engaged in stereotypical body-rocking at any time.

The capuchin mother moved during one-third of her time; the squirrel monkey much less (about 13%). The hand-reared infants were passively moved about 6% of the time, less than half the amount of time that either of the two mother-reared animals experienced movement. Even so, this amounts to one hour and 45 minutes of movement per infant per day, which is substantially more than would be experienced by a monkey infant in a standard nursery setting in which infants are not moved passively except during feeding and cleaning procedures. In this sense, our rearing regime represents a half-way point between no movement stimulation and mother-rearing.

Periodicities

The time budget data are displayed across 24 hours in Figure 3. Visual inspection of these graphs suggest that all infants exhibited

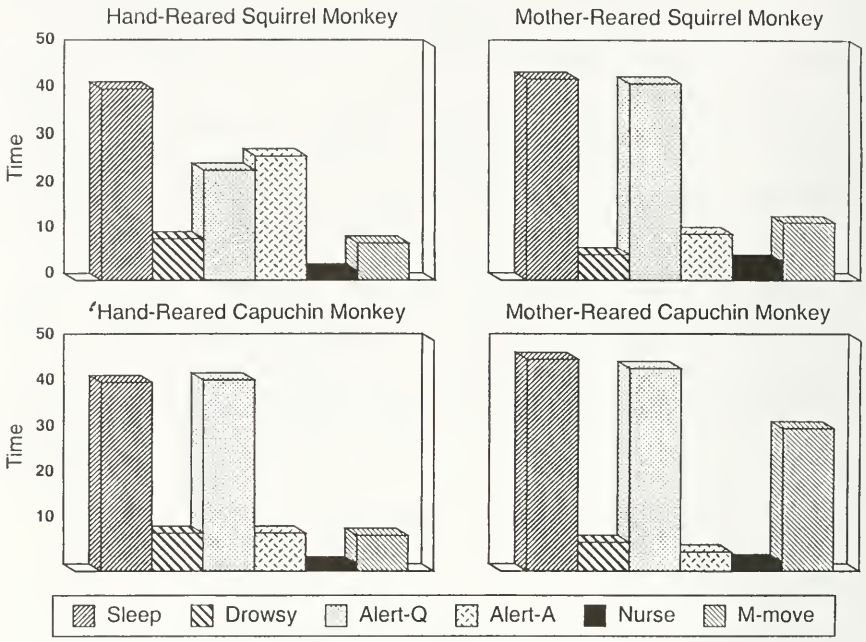

Figure 2. The distribution of time over 120 hours of observation per infant among the four states (Sleep, Drowsy, Alert-Quiet, and Alert-Active) and to two other (non-exclusive) categories (Movement by the mother or carrier, and Nurse).

strong cyclical variations in activity. Time series analyses revealed that all infants exhibited significant 24-hour periodicities in Sleep (correlation = .35 to .48). [The sign of the correlation is uninformative, and is omitted; all of these values exceed a 95% confidence interval.] As shown in Figure 3, across all five days the mother-reared infants appeared to have sleep cycles more in synchrony with day/night cycles, in that the hand-reared animals shifted the peak of sleeping from midnight to mid-day. This is most evident in the hand-reared capuchin monkey.

Other behaviors showing 24-hour periodicities were Alert-Quiet (.30 to .45), and Manipulation (.26 to .46). Three of the four monkeys exhibited a 24-hour periodicity in Alert-Active (.40 - .56). The fourth, the hand-reared capuchin monkey, did not. The two monkey mothers exhibited strong 24-hour periodicity (.55, squirrel monkey, and .59, capuchin monkey) in moving. The human carriers also showed 24-hour periodicity in carrying, although it was not as strong for movement by the monkey mothers (.33 to .38). Nursing

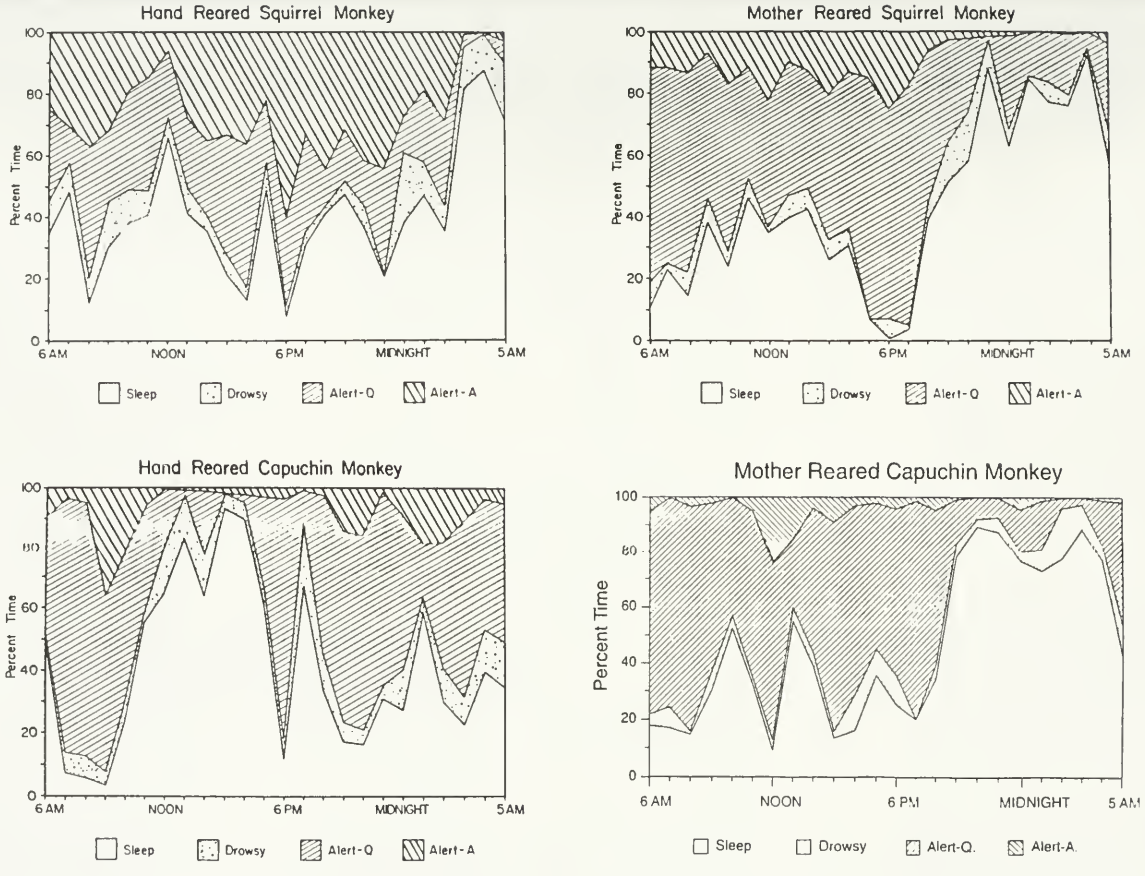

Figure 3. The distribution of time per infant among the four states across 24 hours.

showed a 24-hour periodicity for two animals, the mother-reared squirrel monkey and the hand-reared capuchin monkey. Overall, Nursing was the least periodic of all the behaviors in terms of the Box-Jenkins analyses. All four subjects exhibited 2 or 3 quite short periodicities of 2 to 5 hours in the spectral analyses of nursing.

Out of 54 periodicities exceeding the 95% confidence interval calculated by the Box-Jenkins analyses of all behaviors, 5 were for periods from 25 to 28 hours; all the rest were for 24 hours or less. For example, all four infants displayed 3 or more periodicities in Sleep of 12 hours or less with correlations of between .2 and .3. Clear differences in the extent of periodicity between hand-reared and mother-reared infants were not evident.

Correlation between infant's activity and passive movement

Strong negative correlations (r_{xy} = -.34 to -.71, n = 120, $p < .002$) were evident for all subjects for the duration per hour spent sleeping and being moved, and strong positive correlations between Alert-Quiet and being moved (r_{xy} = +.32 - +.73, n = 120, $p < .001$, all cases). Nursing was strongly positively correlated with movement for the hand-reared infants, reflecting the caretaker's typical pattern of feeding the infant and then carrying it for a time afterward (r_{xy} = +.30 - +.40, n = 120, $p < .001$, both cases). No other clear trends were evident in the correlational data for being moved with other variables. When the data for the daylight hours only (6 AM to 6 PM) were considered, the strong correlation between Alert-Quiet and movement was retained, and the values were highest for the two mother-reared individuals (r_{xy} = +.49 and +.51, mother-reared; +.35 and +.39, hand-reared; n = 60, all cases).

Short-term organization of behavior: Duration and frequency of bouts

The average durations per bout of the 6 state variables are given in Figure 4, and the frequency of bouts per day for all variables in Figure 5. The similarities across infants are more apparent than the differences. However, a striking difference between mother-reared and hand-reared infants is evident in the duration of sleeping bouts: Hand-reared infants sleep in shorter bouts than mother-reared infants. Also, bouts of Alert-Quiet were shorter in the hand-reared capuchin infant than her mother-reared counterpart. Surprisingly, the duration per bout of passive movement was nearly the same for all infants. The similarity of durations per bout for infants of the same species for

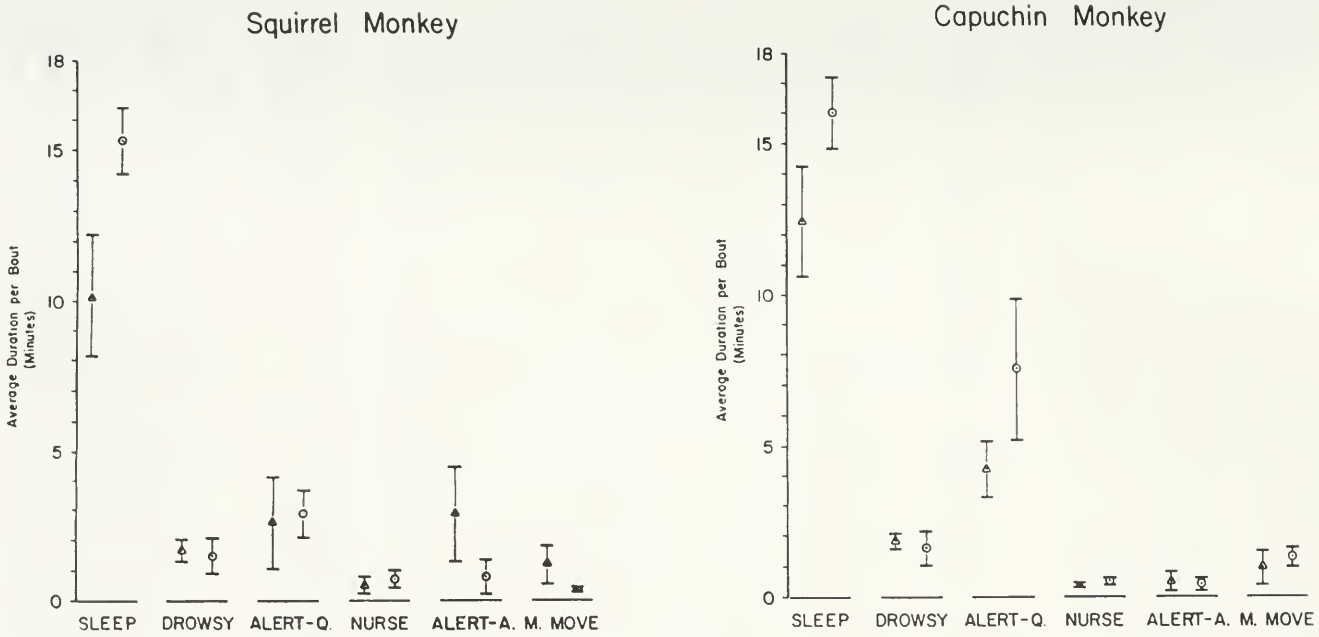

Figure 4. Average duration per bout for each activity or state per infant. Bars indicate standard deviation. Circle = mother-reared. Triangle = hand-reared

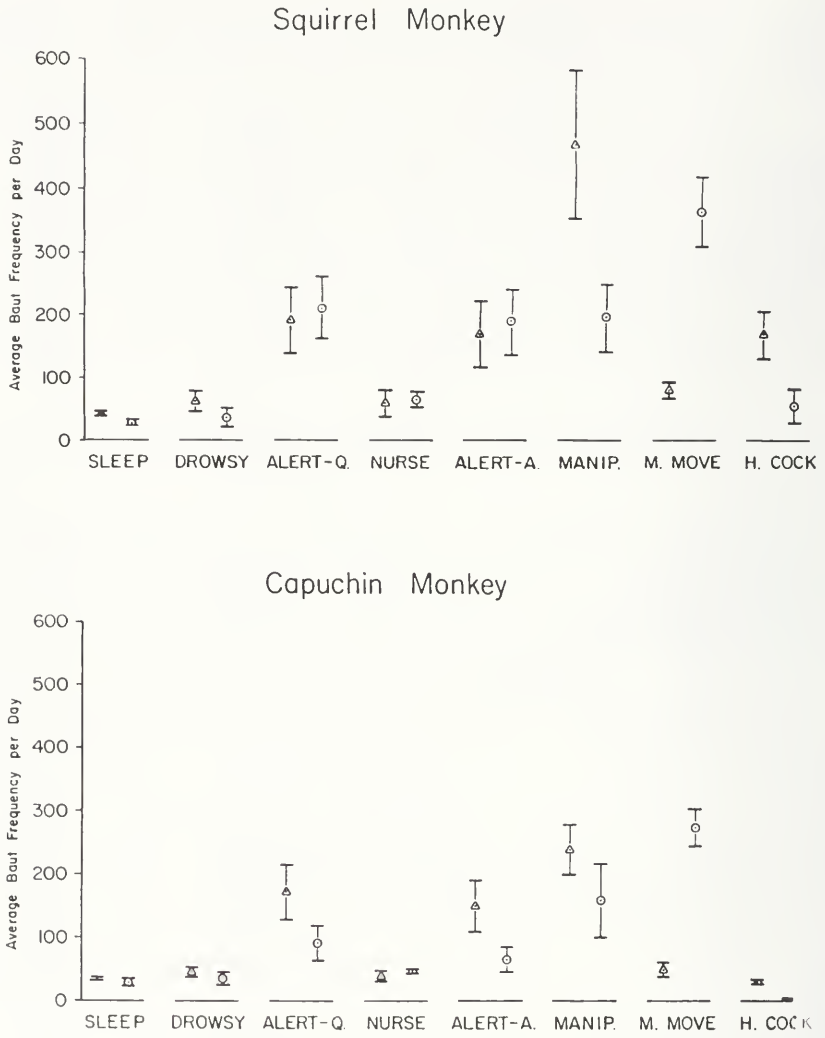

Figure 5. Average frequency per day for bouts and events per infant. Bars indicate standard deviation. Circle = mother-reared. Triangle = hand-reared.

all variables except sleep suggests that cycling through activities while awake is relatively stable in infants.

Frequencies of bouts varied in different ways than duration of bouts. The greatest differences between the capuchin infants occurred in Alert-Quiet, with the hand-reared infant entering this state more

frequently (but as we saw above, for shorter durations) than the mother-reared infant (167 vs. 85 times per day) . The hand-reared infant also entered an Alert-Active state more frequently than the mother-reared infant (150 vs. 65 times/day). The mother-reared infant was moved passively much more frequently than the hand-reared infant (272 vs. 50 times/day).

The two squirrel monkeys displayed similar bout frequencies for most variables, except for frequency of bouts of passive movement. The differences in the frequency of bouts of passive movement were roughly the same as for the capuchins: Much greater frequencies were observed in the mother-reared infant than in the hand-reared infant (360 vs. 75 times/day).

Frequency of head-cocking and manipulation

The mother-reared capuchin infant was rarely seen to cock its head (.1 times per hour while the infant was awake). This behavior occurred regularly (2.6 times per hour while the infant was awake) in the hand-reared capuchin infant. The hand-reared infant also engaged in manipulation somewhat more frequently than her mother-reared counterpart (12 times per hour for the mother reared infant; 17 for the hand-reared infant, for the time spent awake or drowsy).

A large difference was evident between the two squirrel monkeys in the frequency of manipulation and head-cocking (each more than twice as frequent in the hand-reared infant as in the mother-reared infant). Head cocking was much more frequent in both of the squirrel monkeys than in either capuchin (4 times per hour, hand-reared squirrel monkey, and 14 times per hour, for mother-reared squirrel monkey, for hours awake or drowsy). Manipulation occurred 33 times per hour while awake in the hand-reared squirrel monkey, and 14 times in the mother-reared squirrel monkey.

DISCUSSION

Although the single-subject design of this study limits the strength of the conclusions to be drawn, a few findings stand out. The four young monkeys in this study exhibited similarly strong rhythmicity in states and in overall time budgets, despite variations among them in species and rearing conditions. These aspects of behavior may reflect intrinsic regulatory processes which are impervious to all but the most extreme environmental variations. Undoubtedly, however, they

undergo dramatic developmental change; this aspect of variation warrants its own investigation (Fragaszy 1989, 1990b; Wolff 1987).

Second, the infants varied more substantially in the frequency of particular activities and in the duration and frequency of bouts of active states than in rhythmicity or overall time budgets. Considering rearing differences first, the species-atypical rearing regime experienced by the two hand-reared infants in this study, while relatively "enriched" with regard to the extent of contact with an animate caregiver and the provision of passive movement, was still associated with significant alterations of the infants' behavior and experience of movement. Infants reared with their mothers engaged in fewer bouts of manipulation and head cocking, and longer bouts of sleeping than their hand-reared counterparts, and they experienced more passive movement and more frequent bouts of passive movement.

Although the absolute frequency of head-cocking observed in this study in mother-reared infants was much lower than in Menzel's (1980) study, the difference between the species were the same as he observed: Capuchins head-cocked less frequently than squirrel monkeys. Two infant squirrel monkeys observed longitudinally by Menzel exhibited their greatest frequency of head cocking at 6 and 8 weeks of age. Thus it seems likely that we sampled the squirrel monkeys' behavior at an optimal age to observe this behavior. We are able to rule out the possibility that the difference between infants of the two species in this study is a function of when observations occurred in relation to a developmental pattern of waxing and waning of this particular behavior. Head cocking has been observed in a capuchin infant as early as 4 weeks of age, and two capuchin infants followed longitudinally from 6 weeks through 24 weeks head-cocked in all weeks at rates similar to those observed in the mother-reared infant in this study (England et al. unpublished data). Differences between the frequencies observed in this study in the squirrel monkeys and those observed by Menzel (1980) may be a function of the rate at which novel objects or other interesting visual stimuli came into view in the two studies. Rogers et al. (1993) show that the novelty of the object to be viewed strongly affects the occurrence of head-cocking in galagos (*Galago*).

The more important result, however, for the present purpose is that head-cocking occurred significantly more frequently in the hand-reared infant of each species than in its mother-reared counterpart. Hand-rearing apparently elicits atypically high frequencies of this species-normal behavior in both species. This

finding is consistent with Menzel's (1980) hypothesis that head-cocking is a behavioral mechanism to increase visual acuity while in a static posture through self-guided shifts in the visual field. Head-cocking also provides vestibular stimulation, which could be pleasureable in its own right, particularly if such stimulation from other sources is limited.

Manipulation was also more frequent in the hand-reared infants than in the mother-reared infants. Manipulation is more likely to be liberated by hand-rearing than elicited, as head-cocking seems to have been. Postural constraints faced by young infants riding on an unpredictably moving carrier limit the individual's ability to let go of the supporting surface and to reach away from the carrier towards objects in the near environment. However, when supported on a stationary surface, infants of both species exhibited precocially high frequencies of manipulative activity. These findings are reminiscent of those by Thelen and colleagues (Thelen and Ulrich, 1991) and Rochat and Bullinger (in press), among others, with human infants. Given appropriate postural support, human infants in the first 6 - 12 months of life have displayed motor coordination in walking movements and reaching for objects that, in older infants, are enabled by maturing postural control.

After the frequencies of head-cocking and manipulation, perhaps the largest difference between hand-reared and mother-reared animals occurred in the timing of sleeping. Mother-reared animals slept mostly at night; hand-reared animals slept more during the daylight hours. Some increase of sleeping in the daylight hours is to be expected given that the hand-reared animals were on a two-hour feeding schedule around the clock, and our feeding procedure required that we waken the infant sufficiently to bottle-feed it. We did not know when we began the study whether mother-reared infants of these ages normally go through the night without nursing. Our findings on the periodicity of nursing suggest that in natural situations they do nurse at night about as often as we fed the hand-reared infants, but our sleeping data suggest that they wake only briefly to do so.

These findings suggest that some elements of behavioral organization are more labile than others in response to the complex of features varying between mother-rearing and hand-rearing as we practiced it. Except for differences in the duration of sleeping bouts and when sleeping occurred, the labile elements (frequency of manipulation, head cocking, and bouts of Alert-active and Alert quiet; duration of bouts of Alert-active and Alert-quiet) share the common

theme of more frequent self-produced stimulation on the part of the hand-reared infants. Differences in movement stimulation are likely to be one important source of the differences between mother-reared and hand-reared infants in the frequency of self-stimulatory activities. This hypothesis awaits direct experimental verification. The differential availability of objects and surfaces to contact close at hand (probably greater for hand-reared animals) or in the appearance of novel visual stimuli (probably greater for mother-reared animals) may be other sources of the differences in the distribution of manipulation and head-cocking. These alternate hypotheses could be tested.

Perhaps one reason why the short-term consequences of altered rearing evironments on the organization of activity in infant monkeys have not been given more attention is the virtual restriction of data on this topic to one genus (*Macaca*). Activity differences between hand-reared and mother-reared macaques are not striking. In both rearing settings, young macaques begin to move independently in the first to second week of life, and in both settings they habitually pick up objects in the mouth until postural control enables a hand to be used for this purpose. Buccal prehension appears at about 7 days of age in Japanese and crabeating macaques *(M. fuscata* and *M. fascicularis*, respectively; Poti, 1989). Rhesus infants without external postural support are able to reach through an aperture and prehend small objects such as string within the first three weeks of life (Mason, Harlow, and Reuping, 1959). Schneider and Suomi (1992 b) report that the composite scores for activity (obtained at several points during the first month of life) did not vary across groups of rhesus infants undergoing varying hand-rearing regimes. Similarly, Schneider et al. (1991 a) report that different hand rearing conditions did not influence activity in the home cage in rhesus infants across the first year of life, although they did affect reflexes, muscle tone, and irritability. Comparisons of hand-reared and mother-reared macaques do not suggest obvious differences in age at reaching various motor milestones (compare Hinde et al., 1964 with Castell & Sackett, 1973 or Mowbray & Cadell, 1962). In short, the similarities of behavioral organization and form in macaque infants reared in varying circumstances do not invite further study of the short-term alterations of behavioral organization produced by nursery rearing, as few alterations are noticeable.

The findings of this study suggest that hand-rearing impacts behavioral organization in the short run in infant squirrel and capuchin monkeys in ways that have not been mentioned for infant macaques (see also Fragaszy 1990a, 1990b). It is not clear that these impacts

are not evident in macaques, because they have not been sought specifically, but the general picture of infant activity during hand-rearing provided by earlier studies does not suggest their presence. If they are not present, it is probably in part because of the different affordances of artificial rearing environments for macaques than for New World monkeys. Infant macaques can locomote much sooner after birth, and for the first few months of life are less reliant than New World monkeys on external postural stability to enable prehensile activity. They also exhibit an alternative method (buccal prehension) of grasping objects while postural control is limited. Thus frequency of tactile or prehensile exploratory activity is less likely to be affected in macaques than in New World monkeys by movement or postural support conditions. For all these reasons, and perhaps others not considered here, macaques can be expected to exhibit fewer or less obvious immediate behavioral adjustments to largely stationary rearing regimes than are New World monkeys.

The most general conclusion to be drawn from these findings is that when species-normal behavior in infancy is desired, careful consideration should be given to the implementation of rearing regimes for infant monkeys during the period in which they are unable to locomote, and for New World monkeys, this can be several months. For non-locomoting infants, movement stimulation is an obvious feature of the rearing environment to consider.

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