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Social Environment and Nocturnal Sleep: Studies in Peer-Reared Monkeys

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Summary: Nocturnal sleep was recorded for a total of 40 nights by means of totally implantable, multichannel biotelemetry from 11 peer-reared pigtail (*Macaca nemestrina*) monkey infants (aged 221 ± 28 days). Fourteen sleep variables were compared to values previously obtained from similar-aged, mother-reared infants living in social groups. Sleep in peer-reared monkeys was more fragmented, contained less drowsy, more stage 2, less REM, fewer REM periods, and longer interREM intervals than sleep in mother-reared infants. It would appear that these effects are not due to a relatively impoverished environment that may accompany peer rearing, as has been reported to be true for rodents, but rather to the disruptive influence of sleeping with a peer in the absence of the organization and control effected by a monkey mother and a social group. **Key Words:** Sleep—Primate—*Macaca nemestrina*—Telemetry—REM sleep—Environmental effects.

Alteration in early rearing experience has been demonstrated to affect sleep patterns in rodents. Young rats raised in enriched environments have been found to have less time awake, more slow wave sleep, more REM sleep, and shortened REM latencies compared to rats raised under standard or isolated conditions (1,2). Whether there are similar relationships between early environment and subsequent nocturnal sleep patterns in primates is not yet clear.

Sleep studies in primates are frequently complicated by the special manipulations required to obtain the data, such as coming to a laboratory or being connected to recording devices. The use of implantable biotelemetry minimizes such problems, and previous studies have used this technology to study nocturnal sleep in young pigtail (*Macaca nemestrina*) and bonnet (*Macaca radiata*) monkey infants living in social groups (3–5).

This report focuses on the nocturnal sleep patterns (obtained by means of implantable biotelemetry) of young pigtail monkeys who were separated from their natural

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mothers shortly after birth and reared with a similar-aged peer. These animals experienced neither normal monkey mothering nor social group interaction. Their nocturnal sleep patterns are reported and compared with sleep patterns previously recorded from animals of the same age and species living in a social group. In addition, the question of whether animals raised and recorded together show evidence of influencing each other's sleep patterns was addressed.

METHODS

Procedures

The present subjects were 11 pigtail monkey infants (7 females, 4 males) born in the Department of Psychiatry Primate Laboratory during the calendar years 1984 and 1985 (see Table 1). All animals were removed from their mothers at a mean age of 5 ± 4 days and subsequently raised with a peer who differed in age by no >15 days. The peer pairs lived in 1 m^2 cages for the first few months of life. Pen temperature was maintained at a nominal 31 ± 1°C. Timer-controlled fluorescent lights, providing 700 lux daytime illumination, were turned off between 2000 and 0700 h. The animals were initially fed ad lib on Enfamil (Mead Johnson Company) formula. Fruit supplements, monkey biscuits, and water were gradually introduced into their diets beginning at ~3 months of age. Gradual weaning from Enfamil began at ~4 months of age and was completed by a mean age of 147 ± 19 days. Biscuit and fruit feeding occurred at 0900 daily and water was available ad lib during and after weaning. Two of the sets of peers were placed together in a common living pen at ~6 months of age.

At a mean age of 199 ± 34 days, the infants were sedated, then anesthetized with sodium pentobarbital (15 mg/kg), and surgically implanted with multichannel biotelemetry systems that transmitted seven channels of physiological data, including electro-

TABLE 1. *Descriptive data characterizing the animals used in this study*

Pair	Animal	Sex	Date of birth	Age at initial separation from mother (day)	Age at implant (day)	Age at data collection (day)
1	23.3.2	F	147-84	4	207	223
	53.6.3	M	148-84	3	150	222
2	17.2.4	M	5-85	2	174	191
	63.2.4	F	20-85	2	159	176
3	32.6	M	48-85	3	191	211
	63.4.2	M	49-85	2	190	210
4	30.3	F	91-85	14	191	210
5	17.3.4	F	145-85	2	207	226
	34.1	F	146-85	3	206	225
6	63.9	F	156-85	13	258	271
	8.10	F	162-85	7	252	265
Mean ± SD				5 ± 4	199 ± 34	221 ± 28

Four consecutive nights of data were available for the first seven animals. The last four animals lived together as a group of four after 6 months of age. Animal 30.3 was a member of a pair in which the other animal's transmitter was nonfunctional.

oculographic, electromyographic, electrocardiographic, body temperature, and three channels of electroencephalographic data (6,7). About 2 weeks prior to implantation, the peer pairs were moved to a larger pen (measuring 1.5 × 2.5 × 3 m) with ample space for climbing and locomotor activities. Both animals in each pair were implanted the same day and recovered from the surgical procedure together. Animal 23.3.2's first transmitter was nonfunctional and was subsequently replaced; 23.3.2's peer was anesthetized during the second implant procedure. The animals recovered from the surgical procedure within 10 days.

Once the implanted telemetry units were turned on, physiological data was transmitted 24 h a day. Data collection began at a mean age of 221 ± 28 days. Individual peer pairs were studied simultaneously. All animals were recorded in pairs and housed together; the eleventh subject (animal 30.3) was a member of a pair in which the second animal's transmitter was nonfunctional. During the lights-off period, data was recorded continuously on a Grass Model 78 polygraph running at 15 mm/s. Daytime naps were also noted by the research assistants, and samples of physiological data were obtained frequently during daytime naps.

Nocturnal sleep was scored page by page (20-s epoch) from the paper record using criteria developed previously for monkey infants (3) and included the 14 sleep variables listed in Table 2. Three all-night sleep records were available for all 11 animals; for seven animals, four consecutive nights were available. A total of 40 nights were recorded from the 11 subjects. Pairs were recorded consecutively over a 15-month period, and all subjects were treated in accordance with the policy of the American Physiological Society with respect to animal experimentation.

Data analysis

Data analysis addressed three major areas: (a) a description of normal nocturnal sleep in infants reared and living as peers, (b) a comparison of this new data to similar data previously collected in this laboratory from mother-reared social group living

TABLE 2. *Nocturnal sleep variables scored from polygraph record*

Sleep variable	Comment
Awake	Time awake (min) between sleep onset and final awakening in the morning.
Arousals	Number of arousals >10 s in duration.
Sleep latency	Time (min) from lights-out to the first epoch of sleep.
TST	Total sleep time (min; sum of stages drowsy, 2, 3, 4, and REM).
Drowsy	Total time (min).
Stage 2	Total time (min).
Stage 3 and 4	Total time (min; stage 3 and 4 sleep are not separated).
REM	Total time (min).
REM Latency	Time (min) from sleep onset to start of first REM period.
#REMP	Number of REM periods.
$\overline{X}$REML	Mean length of REM periods (min).
IRI	InterREM interval. Mean value of intervals (min) between beginnings of successive REM periods.
REM eff	REM efficiency. Mean percentage of time from onset of REM period to end of REM period spent in REM sleep.
Sleep eff	TST divided by TST + Awake (%).

Each variable was calculated for each night's sleep for each infant monkey.

TABLE 3. *Nocturnal sleep data*

Animal	Awake	Arousals	Sleep latency	TST	Drowsy	Stage 2
23.3.2[a]	45 ± 7	19 ± 2	14 ± 10	567 ± 50	15 ± 12	293 ± 53
53.6.3[a]	119 ± 44	43 ± 4	6 ± 4	532 ± 51	31 ± 3	263 ± 10
17.2.4[a]	221 ± 61	115 ± 23	24 ± 17	399 ± 63	5 ± 4	221 ± 53
63.2.4[a]	183 ± 72	78 ± 19	25 ± 17	436 ± 76	5 ± 1	262 ± 59
32.6[a]	77 ± 35	35 ± 8	15 ± 9	550 ± 21	3 ± 2	350 ± 26
63.4.2[a]	109 ± 41	53 ± 9	24 ± 16	508 ± 41	16 ± 1	304 ± 51
30.3[a]	99 ± 33	69 ± 13	48 ± 26	516 ± 68	1 ± 1	319 ± 43
17.3.4	129 ± 47	62 ± 39	89 ± 4	430 ± 43	26 ± 22	256 ± 21
34.1	76 ± 29	22 ± 3	88 ± 5	475 ± 34	6 ± 5	282 ± 50
63.9	69 ± 15	22 ± 1	74 ± 23	514 ± 24	3 ± 1	322 ± 18
8.10	95 ± 54	60 ± 17	84 ± 19	469 ± 29	7 ± 2	300 ± 44
Mean ± SD	111 ± 52	53 ± 29	45 ± 32	491 ± 53	11 ± 10	288 ± 36

* Means and SDs of sleep variables by animal, with group means and SD in bottom row.
[a] Subjects for whom 4 consecutive nights of sleep were available, and whose data was compared to mother reared group living infants.

(MRSG) infants, and (c) an examination of correlations between sleep patterns in peer pairs.

The description of normative sleep included means and SDs for all 14 sleep variables in the 11 subjects. Sleep pattern distribution was examined as a function of time of night by calculating percentage of each sleep stage occurring during each hour of the lights-out period.

The nocturnal sleep from the seven peer-reared infants (4 males, 3 females) who had 4 consecutive nights of data was compared with nocturnal sleep previously recorded from seven MRSG infants (4 males, 3 females) matched as closely as possible for age. This subset of peers was implanted at a mean age of 180 ± 20 days, and data collection began at the mean age of 206 ± 17. The MRSG infants were implanted at a mean age of 161 ± 42 days, and data collection began at a mean age of 182 ± 42 days. The implantation and recording procedures in the MRSG infants were identical to those of the peers and have been described in Reite and Short (4). Ambient light intensity (700 lux) and timing and pen temperature were the same for the MRSG and peer-reared group. Sleep variables in the two groups were compared across the means of 4 consecutive nights using two-tailed *t* tests for independent groups. Sleep pattern distribution was again examined by calculating the percentage of each sleep stage occurring during each hour of the lights-out period. Those hours of the night containing the greatest percentage of stages 2, 3 and 4, and REM and the smallest percentage of awake were compared using two-tailed *t* tests for independent groups.

Sleep pattern relationships between animals for the five pairs for whom simultaneous data was available were examined using intra-class correlations calculated from the normative sleep means and SDs for the 14 variables. The night by night correlations of sleep variables in peer pairs were examined by computing a correlation coefficient for each variable for each pair.

RESULTS

Nocturnal sleep variables obtained from the 11 peer-reared infants over a total of 40 nights are presented in Table 3. Mean values and SDs for 3 or 4 nights are presented for