Manifestations of "Activated" Sleep in the Rat

Abstract. A sleep phase similar to feline "activated" sleep was found to occur regularly in normally sleeping rats. However, at these times the electroencephalogram differed from the waking or "activated" pattern in being dominated by 6- to 8-per-second waves. Instead of assuming a very relaxed posture, as cats in "activated" sleep do, the rats tended to undergo shifts in muscle tone, occasionally of considerable magnitude.

Recent evidence indicates that the sleep-wakefulness cycle of the cat includes a second distinct phase of sleep in which the large electroencephalogram (EEG) waves typical of ordinary sleep are replaced by the low-amplitude fast activity usually associated with the waking state. In addition to the occurrence of the waking EEG pattern during behavioral sleep, this feline "activated" (*1*) or "paradoxical" (*2*) sleep is characterized by irregular breathing, twitching of the vibrissae and extremities, and loss of postural tone. In order to investigate further the generality and possible phylogenetic significance of this phenomenon, relevant data from another common laboratory animal, the rat, were examined.

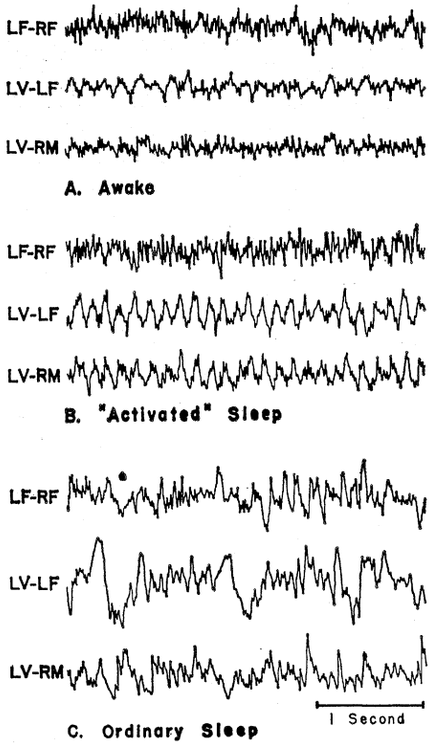

Fig. 1. A comparison of electroencephalographic recordings from a rat during wakefulness, "activated" sleep, and ordinary sleep. Abbreviations: LF, left frontal; LV, left visual; RM, right motor cortex. Areas approximated from Krieg (*9*).

Five male rats, under light ether anesthesia, were provided with chronically affixed steel or silver cortical electrodes. After electrode implantation the rats were removed to a glass-sided observation cage and connected to a Grass IIID EEG console. Data were collected at irregular times beginning after the animals had fully recovered from the anesthetic and occurring up to a week postoperatively.

Generally the EEG patterns of wakefulness and ordinary sleep corresponded well with those described by Caspers (*3*). In addition, a third state similar in many respects to feline "activated" sleep appeared in all five subjects. The rats differed from cats, however, in that their EEG at these times exhibited a distinct 6- to 8-cycle component either absent (two rats) or barely recognizable (three rats) in the waking state (Fig. 1). The magnitude of 6- to 8-per-second activity also seems to be more or less related to the degree of electrode asymmetry. Thus, in Fig. 1 (*A* and *B*), it can be noted that 6- to 8-per-second waves are the most salient in recordings made from the visual-frontal leads; somewhat less so from the visual-motor electrodes; and absent from the symmetrical frontal leads. In another rat with two symmetrical sets of electrodes, simultaneous recordings from the various possible combinations evinced 6- to 8-cycle waves in all bipolar pairs except the two symmetrical ones. The "activated" type of sleep in the rats, as in the cat, was always entered by way of ordinary sleep. This transition, like spontaneous arousals from ordinary sleep, was typically adumbrated by trains of sleep spindles. At times other than these two transitions, spindles were not prominent features of the rat EEG.

Behaviorally the rats resembled cats during "activated" sleep in having a highly irregular rate of breathing and in the frequent twitches occurring in their vibrissae and extremities. On the other hand, although the cat in "activated" sleep is reported to assume very relaxed postures (*4*) accompanied by a loss of electromyogram activity in the neck muscles (*2*), the corresponding state in the rats was characterized by shifts in muscle tone. These perturbations varied widely from the usual slight relaxation or stiffening of the musculature to an extreme of sudden and complete loss of tone or gross myoclonic jerks. In several instances the loss of tone caused the animal to fall over onto his side, completely relaxed.

Unfortunately, the frequent occurrence of extraneous noises during the recording sessions precluded a completely satisfactory analysis of the time relationships in the course of normal rat sleep. Day to day fluctuations in temperature and the great variability of even the best data further compounded this difficulty. Roughly speaking, however, one episode of the "activated" phase occurred in about every 10 minutes of undisturbed sleep. The duration of these episodes varied considerably about a mean in the order of 1 to 1.5 minutes. Periods of ordinary sleep, terminating either in a brief desynchronization or in a run of "activated" sleep, were of comparable length.

Jouvet (*2*) has localized the structure responsible for the triggering of "paradoxical" sleep in the pontine reticular formation, from which he records 6- to 8-per-second spindles during that phase in cats. It seems plausible that the 6- to 8-cycle cortical activity of rats in the "activated" type of sleep may emanate from that region of the pons, although this possibility has not yet been tested.

The present data indicate that the rat enters a state homologous to "activated" sleep in cats. However, since the EEG of rats in this state differs from the truly "activated" or waking pattern, it does not seem entirely accurate to speak of "activated" sleep in the rat. Nor, for a like reason, does "paradoxical" seem suitable. Whether this phase of the sleep-wakefulness cycle now reported to occur in rat, cat, and recently in rabbit (*5*) is related to similar conditions in monkey (*6*) and man (*7*) has not been decided with certainty (*8*).

JOHN E. SWISHER
Department of Psychology, University of Florida, Gainesville

References and Notes

1. W. Dement, *Electroencephalog. Clin. Neurophysiol.* **10**, 291 (1958).
2. M. Jouvet, *Ciba Foundation Symposium on The Nature of Sleep* (Little, Brown, Boston, 1960), pp. 188–205.
3. H. Caspers, *Z. Ges. Exptl. Med.* **124**, 176 (1954).
4. C. F. Essig and H. G. Flanary, *Exptl. Neurol.* **3**, 149 (1961).
5. J. Faure, *J. Physiol. Paris* **54**, 333 (1962).
6. E. D. Weitzmann, *Electroencephalog. Clin. Neurophysiol.* **13**, 790 (1961).
7. W. Dement and N. Kleitman, *ibid.* **9**, 273 (1957).
8. This work was supported in part by grant No. M-3881 from the National Institutes of Health.
9. W. J. S. Krieg, *Quart. Bull. Northwestern Univ. Med. School* **20**, 199 (1946).

10 October 1962