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Hippocampal EEG Changes and the Motivational-Emotional Aspects of the Paradoxical Phase of Sleep

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EEG recordings in the cat made during the paradoxical phase (PP) of sleep in the presence of continuously desynchronized neocortical activity revealed three significantly different hippocampal electrical patterns: (1) desynchronization (fig. la); (2) 0-dominance (fig. lb), and (3) 8-dominance (fig. lc) [7].

During 0-periods there occurred an increase in heart rate and respiration, while during 8-periods a decrease of these effects was recorded (fig. 2). Earlier experiments of Grastyán and his associates [2, 4] suggested that emotional-motivational mechanisms would be active during PP. Since during the PP inhibition of muscular tone and of spinal reflexes makes it impossible to observe actual behavioral changes, correlation of electrohippocampal and vegetative patterns observed in PP and during characteristic motivational states of the awake animal seemed to be the only available way of testing the above suggestion.

In a recent study of Grastyán et al. [3], a strict correlation was revealed between the spatial direction of subcortical stimulation-elicited

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Fig. 1. Electrical activity of different brain structures, the antigravity and the external ocular muscles during wakefulness and sleep in the cat. a initiation of a paradoxical phase (desynchronized period); b hippocampal 0-dominance; c S-dominance. 1 = neck muscle; 2 = visual cortex; 3 and 4 = left and right dorsal hippocampus, respectively; 5 = pyriform lobe; 6 = external ocular muscles; 7 = integrated values of various frequency bands: 8 = 2-4 cps, 0 = 4-8 cps, a = 8-13 cps, ß 1 = 13-20 cps, ß 2 = 20-30 cps. Analysis of EEG, from the visual cortex (first 5 deflections), and of the left hippocampus (second 5 deflections). Calibration: 100 /aV; time = 1 sec [after 7].

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Fig. 2. Correlated changes of the hippocampal electrical activity and the heart rate during the paradoxical phase of sleep (result from statistical analysis of a number of records). Abscissa: time in seconds (continuous records from the beginning of the paradoxical phase of the sleep). Left ordinate: integrated values of the 8- (o-o) and 0(•-•) waves of the hippocampal electrical activity in millimeters (from 5-sec analysis period). Right ordinate: heart rate beats/min. ( A-A).

movements and learned behavior. If stimulation induced contraversive movements (i.e., the cat turned toward the direction opposite to the stimulated hemisphere) positive approach behavior was observed. In turn, after ipsiversive movements (i.e., the animal turned toward the direction of the stimulated hemisphere) aversive, withdrawal-like consequences were found. The main purpose of the present study was to record electrohippocampal and vegetative concomitants of rewarding (i.e., contraversive) and aversive (i.e., ipsiversive) phases of movements in the awake cat and relate them to those seen during PP.

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Fig. 3. Heart rate effects and hippocampal electrical correlates of lateral hypothalamic stimulation in a freely moving cat. a 3 V, 100 cps, 0.3 msec, b 6 V, 100 cps, 0.3 msec. Abscissa: time in sec. Left ordinate: heart rate, beats/min. Right ordinate: integrated values of hippocampal 8- (•-----•) and 9- (o o) waves, in millimeters [5]. Ipsi. = ipsiversive movements, Cont. = contraversive movements.

Low-voltage stimulation of certain hypothalamic loci elicited withdrawal, or ipsiversive movements. A decrease in the heart rate, depression of the 0-output and increase of the 8-output in the hippocampal records accompanied this behavioral pattern (fig. 3a). Higher voltage stimulation of the same loci elicited a pattern opposite to the former one: contraversive
slow circular movements, increase in heart rate, increase of the hippocampal 0-values and decrease of the 8-values. A further increase of stimulation produced contraversive circular running, rage reaction, culminating in a ‘blind’ attack. If stimulation was continued beyond the appearance of these effects, finally a complete relaxation of the animal was observed. The heart rate and the hippocampal EEG showed corresponding changes to the behavioral effects (fig. 3b).

The cessation of stimulation was followed by oscillating after-effects of a rebound character. They consisted of two phases of opposite signs: immediately after the cessation of stimulation an ipsiversive rebound phase appeared, accompanied by sudden decrease of heart rate with arrhythmia and a decrease in the amount of 0-waves, and an increase of the 8-waves in the electrohippocampogram. The second, contraversive rebound phase was accompanied by a sudden rise in the heart rate (and a simultaneous cessation of the arrhythmia) as well as a marked increase of the 6-waves.

Thus, in awake, freely moving animals, there seems to be a strict correlation; on the one hand, we found the functional dominance of the hypothalamic reward (‘contraversive’) elements, hippocampal 0-waves, and sympathetic vegetative signs; on the other hand, there appeared the effects of the aversive (‘ipsiversive’) system, hippocampal 8-activity and parasympathetic visceral manifestations.

Comparison of the vegetative and bioelectrical changes recorded during wake state and PP seem to validate the notion that organized emotional-motivational processes are induced during the PP [6]. The observed facts also support an earlier suggestion mainly based on human observations that the PP of sleep is associated with oneiric functions [1, 2]. A further, perhaps too fanciful, suggestion is offered by the present correlation that the 0- and 8-stages of PP may correspond respectively to dreaming activities of a positive and negative emotional charge.

References

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