During *deep sleep* (with desynchronized EEG and flattening of nuchal muscles), the TCR became quite stable while the EEG became desynchronized. The integrated value of the TCR was similar, or only slightly reduced, compared with the one seen during light sleep. The ECR was strongly reduced during paradoxical sleep and appeared very similar to the ECR observed during attentive wakefulness (Figure c).

The behaviour of visual cortex responses (VCR), evoked by geniculate stimulation (single shocks at 1/sec, 0.02 msec, 0.8–4 V), was quite different from that shown by TCR and ECR. During *attentive wakefulness*, the VCR markedly fluctuated in amplitude both in its presynaptic and postsynaptic components. An integration of a variable number of them showed an amplitude which was always higher than that seen in light sleep (Figure d).

During *synchronized sleep*, the VCR was very unstable; its integration revealed the lowest values observed (Figure e). As the animal went into an episode of *deep or paradoxical sleep*, the VCR became extremely stable. Its integration showed a dramatic increase in amplitude of both presynaptic and postsynaptic components up to 100% of the values seen during wakefulness and 130–150% of those observed in light sleep (Figure f).

The curve of interaction between transcallosal and geniculate stimulation (transcallosal stimulus preceding the geniculate one) showed a marked facilitation of VCR by callosal stimulation, which appeared always at an interval of 40–50 msec. This facilitation was present during both wakefulness and sleep, although it appeared maximal during deep sleep. During attentive waking and paradoxical sleep, facilitation was usually followed by a short inhibition at 70–90 msec stimulus interval, soon replaced by slight facilitation at an interval of 110–150 msec. During light sleep, on the other hand, the inhibition was much stronger and continued for several msec, reaching its highest value at an interval of 130–150 msec. Interaction was in no case present when geniculate stimulation preceded the transcallosal one. The results suggest that: (a) the excitability of cortical neurons activated by the transcallosal volley is higher during sleep (either slow or paradoxical) than during wakefulness. These results are slightly at variance with those reported by others[5]. (b) The ECR was very similar during both wakefulness and paradoxical sleep. Since the ECR has been shown to be due to activation of mesencephalic neurons[6], which are very active during wakefulness and deep sleep[7], the results obtained may be explained by reticular occlusion. (c) The transition from light to deep sleep was characterized by an augmentation of VCR indicating an increase of thalamic excitability as already reported by others[3,4]. (d) Interaction experiments indicate, moreover, that only during synchronized sleep can a long lasting inhibition of geniculo-cortical pathway by transcallosal volley occur. The inhibition appears to be very short during the most active wakefulness and the deepest stage of sleep.

Riassunto. La TCR è ampia nel sonno (lento e rapido) e ridotta nella veglia. La ECR è massima nel sonno lento e minima nella veglia e sonno profondo. La RCV, minima nel sonno leggero, raggiunge i valori massimi nel sonno desincronizzato. La curva d'interazione tra stimolo transcalloso e genicolato ha rivelato un processo inibitorio prolungato presente soltanto nel sonno leggero.

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[5] E. FAVALE, C. LOEB, and M. MANFREDI, Boll. Soc. ital. Biol. sper. *39*, 1513 (1963).
[6] L. T. RUTLEDGE and T. T. KENNEDY, Exp. Neurol. *4*, 470 (1961).
[7] P. R. HUTTENLOCKER, J. Neurophysiol. *24*, 451 (1961).

Excitability Changes during Paradoxical Sleep in the Rat

It was shown previously[1] that before the onset of paradoxical sleep (PP), a gradual decrease of the excitability of the reticular activating system (RAS) develops. Both direct reticular and external physiological stimulation become progressively less effective. Although the PP is characterized by decreased excitability in the RAS, it always ends with a sudden increase in reticular responsiveness, and, in the majority of sleep cycles, by a spontaneous behavioral (and EEG) arousal not precipitated by any new external stimulus. Thus it may be suggested that variations of activity in the RAS occur during the PP.

Bipolar electrodes were implanted in the frontal cortex, dorsal hippocampus, mesencephalic reticular formation and, in some cases, in the caudate nucleus and nonspecific thalamic region in 11 rats.

More than 100 sleep cycles were analyzed. It was found that after the beginning of the regular ϑ-activity (4–7/sec) in the hippocampus, which is a very typical EEG manifestation of the PP, the cortical EEG (Figure 1) usually exhibited well developed spindle activity (9–14/sec). The amount of spindling gradually decreased and almost disappeared by the end of the first minute of the PP (Figure 2). This spontaneous spindling was present also in cases where cortical spindles did not occur frequently in the slow wave sleep phase (SWSP). In these cases a gradual increase in the amount of cortical spindles was observed during the last minute of SWSP (Figure 2). However, when the cortical spindles were well developed during the whole SWSP it was difficult to determine whether the amount of spindling was increased before the end of SWSP. Often a few cortical spindles were observed during the last seconds of the PP before the behavioral arousal reaction (and hippocampal desynchronization in the EEG) following the PP. The frequency of the hippocampal ϑ-activity showed phasic ranges during the PP similar to those evoked in waking animals by changing the intensity

[1] E. ROLDÁN, T. WEISS, and E. FITKOVÁ, EEG clin. Neurophysiol. *15*, 775 (1963).

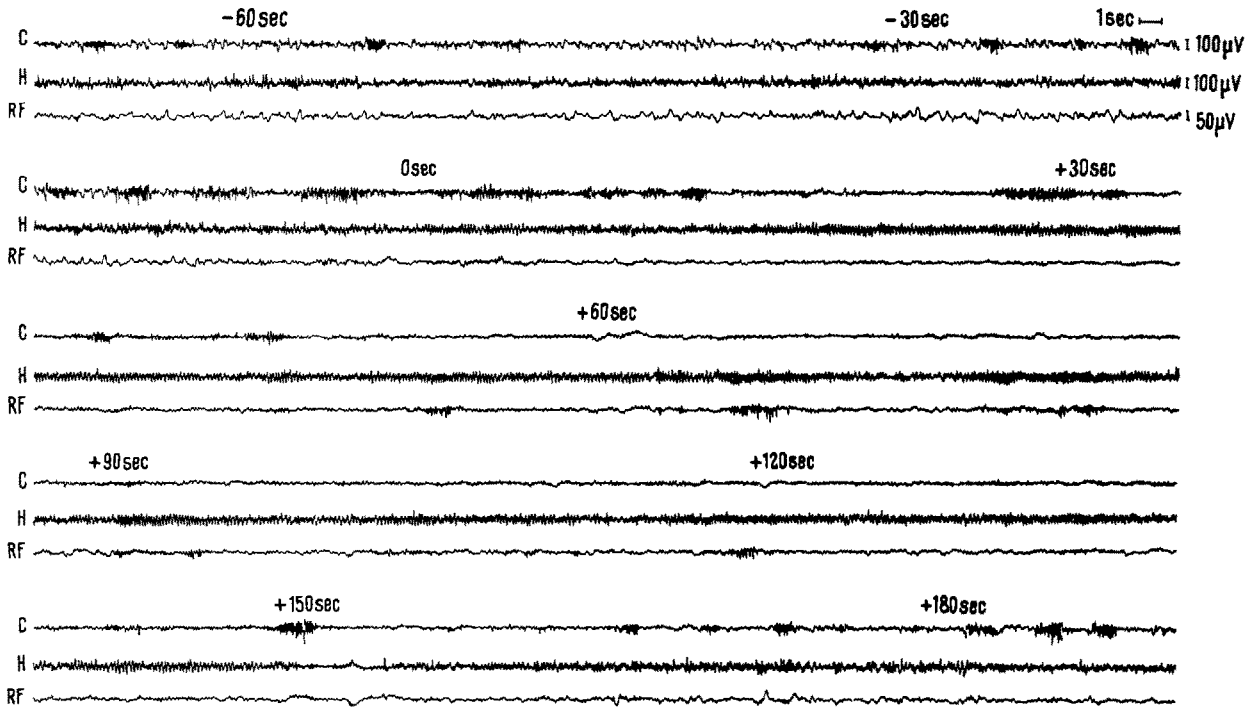

Fig. 1. EEG record from the frontal cortex (C), dorsal hippocampus (H), and the lower portion of mesencephalic reticular formation (RF). Time is measured for the beginning of paradoxical phase to the right from zero, and to the left for the slow wave sleep phase. Arousal in 150 sec.

of reticular stimulation, thereby eliciting an attention reaction. Up to now no apparent relation was found between the occurrence of cortical spindles and the ranges of the frequency of the hippocampal ϑ-activity during the PP.

Alternation of sleep phases was observed also in cats in which forebrain influences were eliminated by sectioning the brainstem[2]. However, our findings suggest that in normal conditions forebrain mechanisms responsible for the generation of cortical spindles[3] are involved in the mechanism of switching from one sleep phase to the other. In animals with the forebrain removed the intervals between PP become considerably longer[2]. This could be explained for instance by a hypothesis supposing the existence of two pacemaker systems determining the sleep phase alteration: (a) of a 'rapid' pacemaker (of which the forebrain is a part) and of a 'slower' 'reserve' pacemaker (unrelated to the forebrain) which is normally always activated from the former (analogous to the control of the Tawara-Aschoff node by the Keith-Flack node in the heart). The dynamic changes observed in the EEG show that the PP is probably not a homogeneous phenomenon characterized by a stable level of function in the participating brain systems[4].

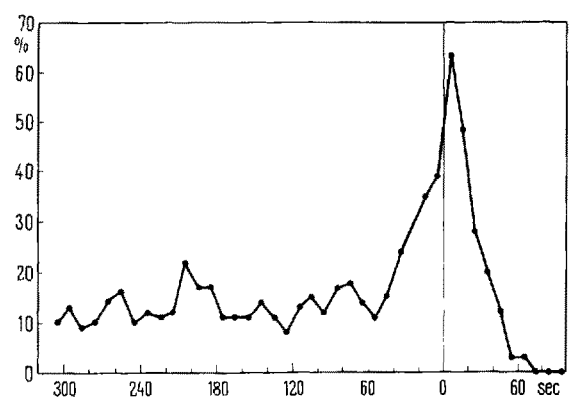

Fig. 2. Averaged incidence of cortical spindles in 15 sleep cycles of a rat, expressed as a percentage of an epoch of EEG record lasting 10 sec. Vertical line (time 0) marks the beginning of hippocampal activity. The paradoxical phase is located to the right of the line, the slow wave phase to the left.

Résumé. Le passage de la phase de sommeil avec ondes lentes à la phase «*paradoxale*» et souvent aussi du sommeil paradoxal à l'éveil, sont accompagnés chez le rat d'un commencement ou d'une accentuation de l'activité dite «spindling» dans l'écorce. Des changements phasiques de la fréquence des ondes ϑ dans l'hippocampe se produisirent pendant les périodes paradoxales. Nous n'avons pas remarqué de corrélations entre ces phénomènes.

T. Weiss[5] and W. R. Adey

Brain Research Institute, University of California at Los Angeles (USA), August 28, 1964.

[2] M. Jouvet, Arch. ital. Biol. sperim. *100*, 125 (1962).

[3] H. H. Jasper, in *Handbook of Physiology, Neurophysiology II* (American Physiological Society, Washington 1960).

[4] This work was supported in part by the US Public Health Service (grant NB-01883) and in part by the US Air Force Office of Scientific Research (grant AF-AFOSR 246-63).

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