stimulation or water can be altered systematically by varying the intensity of the stimulating current.

The administration of the two drugs produced a marked change in the preference for hypothalamic stimulation and water. Statistical analyses demonstrated that the number of lever presses for hypothalamic stimulation was increased by amphetamine and reduced by phenobarbital (Series 1: $\lambda^2 r = 8, p < .02$; Series 2: $\lambda^2 r = 6, p < .05$), whereas the number of lever presses for water was reduced by amphetamine and increased by phenobarbital (Series 1: $\lambda^2 r = 8$, $p < .02$; Series 2: $\lambda^2 r = 6.5$, $p < .05$). Superficially, the change in preference appears to be somewhat greater for the animals in Series 1 than for those in Series 2, but this is due mainly to the duration of stimulation being shorter (0.2 sec as compared to 0.5 sec) so that there was more opportunity for the animals in Series 1 to press the lever which controlled the hypothalamic stimulation.

The electrodes were in the lateral hypothalamus between A 4.6 and A 5.2. They were in the medial forebrain bundle either near the fornix or as much as 1 mm lateral to the fornix.

DISCUSSION

It has been reported that rats will self-stimulate the lateral hypothalamus and neglect basic needs for survival (Morgan & Mogenson, 1966; Routtenberg & Lindy, 1965; Spies, 1965). When the current intensity is optimal for self-stimulation, the motivation for seeking water by pressing a lever is weaker than the motivation-reinforcement consequences of pressing a lever to stimulate the lateral hypothalamus; the animal self-stimulates the hypothalamus and ignores the water lever (Morgan & Mogenson, 1966). If the current intensity is reduced (see Table 1, control) or if the water is made more palatable by the addition of saccharin, glucose, or sucrose (Phillips, Morgan, & Mogenson, 1968), the animal switches from the lever that delivers hypothalamic stimulation of optimal intensity to the one that delivers the liquid reward. Apparently, an animal's preference in these tests is a function of the relative strengths of the motivation-reinforcement consequences associated with the two levers.

In the present study, the preference behavior was changed, presumably because the two drugs employed influenced the motivation-reinforcement consequences of pressing the two levers. Amphetamine has been shown to increase the reinforcement of hypothalamic stimulation (Mogenson, 1968; Stein, 1964) and to decrease the motivation to drink water when it is elicited by deprivation (Epstein, 1959) or by electrical stimulation of the lateral hypothalamus (Mogenson, 1968). Therefore, the animal's preference shifts because of reduced motivation for water reward coupled with an enhanced motivation for hypothalamic stimulation. On the other hand, for phenobarbital, which has little, if any, effect on self-stimulation of the hypothalamus (Olds, Killam, & Eiduson, 1957), the change in preference is apparently due to its enhancing the motivation for water (Mogenson, McLachlan, Wishart, & Stevenson, 1969; Schmidt, 1964). Apparently, amphetamine and phenobarbital both influence the integrative-control mechanisms for the regulation of water balance, whereas amphetamine, but not phenobarbital, influences the mechanisms that subserve brain self-stimulation.

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NOTE

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Length of sleep and length of waking interrelations in the rat[1]

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Across a 24-h period in a confined EEG recording setting, the length of successive sleep and waking episodes in the rat show no direct relationship. These data imply a limitation to a hypothesis of sleep as a simple energy restoration or storage period.

A simple but impelling hypothesis about the function of sleep is that it serves as a period of energy storage or restoration. The sleep period may serve, under such a hypothesis, to dispose of accumulated toxins, restore depleted energy or develop and store energy for expenditure during waking, or serve a combination of these functions. From such a model, it would follow that the energy expenditure during the waking period would predict the length of the subsequent sleep period or, if the sleep period was an energy development and storage state, the length of the sleep period would predict the energy expenditure of the subsequent wake period. If the amount of energy expenditure during the waking periods was essentially equal, then the length of the waking period would be predictable from the sleep period, or vice versa.

For the purpose of exploring these predictions, the sleep of the laboratory rat provides an ideal paradigm. The rat's sleep and waking is quite episodic across a 24-h period, with widely varying lengths of these episodes. For the nine animals reported in this study, the mean number of episodes of sleep was 67.0, with a range from 45 to 87

Table 1
Lengths of Wake Episodes Followed by Lengths of Sleep Episodes and Sleep Episodes Followed by Wake Episodes

	Closed Environment N = 5				Open Environment N = 4			
	Light Period		Dark Period		Light Period		Dark Period	
	W-S*	S-W**	W-S	S-W	W-S	S-W	W-S	S-W
short-short	11	17	21	22	14	11	18	13
long-long	16	12	21	22	7	11	17	20
medium-medium	17	14	27	30	11	13	14	13
short-medium	20	9	24	25	8	8	13	16
medium-short	15	17	23	26	5	11	14	19
long-medium	10	19	26	18	10	8	20	7
medium-long	12	14	25	25	13	4	20	13
short-long	18	14	25	23	10	11	12	14
long-short	18	16	26	27	12	9	12	11

* *Wake followed by sleep*
** *Sleep followed by wake*

Table 2

	Dark		Light			
	W-S	S-W	W-S	S-W	W-S	S-W
short-short	48	51	77	77		
long-long					125	128
short-long	58	50	75	75		
long-short					133	125

episodes. The sleep periods varied in length from 1 min to 105 min, and the waking periods varied from 2 min (a criterion imposed by the Es) to 82 min in length. Furthermore, the energy expenditure during the waking period could be considered essentially low and homogeneous. Recordings were done in relatively confined recording areas, with no variation in stimulation or specific task demands.

The purpose of this study was to determine if the length of the waking periods and the length of the sleeping periods were successively interrelated.

METHOD

Nine male Long-Evans strain rats were implanted stereotaxically with bipolar steel recording electrodes in the hippocampus, and with two cortical screws placed unilaterally over frontal and parietal areas. These were crimped into amphenol miniconnector pins embedded in a plastic block that was chronically cemented to the skull. After surgery, there was at least a 1-week recovery period and a 1-week habituation to the recording situation. Ss were recorded in 18 cm (deep) x 18 cm (diam) plastic canisters. Food and water were available at all times. At 140 days of age, electroencephalogram recordings were obtained for 24-h periods. The records were visually scored in 1-min units as either wake, sleep, or paradoxical sleep.

For other experimental purposes, the animals had been raised since weaning in the attached cage of Wohlmann activity wheels (25 x 15 x 12 cm area). Four of the Ss had access to the activity wheel at all times; five were restricted to the cage area. These groups are reported separately.

The animals were raised under a 12-h light/12-h dark regime.

RESULTS

The relative lengths of the sleep and waking episodes differed considerably between Ss and between dark and light periods. Furthermore, the individual S's periods were variously skewed. For the purposes of analyses, each animal's sleep and waking periods were separately ranked, relative to length, and divided into thirds of sleep and waking length. For each animal, each episode was then designated as "short," "medium," or "long." Beginning with the first wake episode, and serially across the 24 h, each wake period (coded as "short," "medium," or "long") was tallied in terms of the coded characteristic of the succeeding sleep period. This was then done for each sleep period beginning with the first sleep period. These tallies were done by the two separate rearing conditions and by light and dark periods. These results are reported in Table 1. Table 2 presents summary statistics derived from Table 1. None of the columns or combinations of the two tables result in a significant χ^2.

In simple summary of these tables, a sleep period of a given coded length (short, medium, or long) had an equal probability of being followed by a period which was short, medium, or long. Similarly, a wake period of a given length had an equal probability of being followed by a period of the same length or the other two coded lengths. This was true during either light conditions or dark conditions.

DISCUSSION AND CONCLUSIONS

During a 24-h period, under circumstances in which there is no stimulus demands on the length of the waking or sleep periods (other than diurnal periodicity), the length of these episodes varies widely. The hypothesis that the sleep period is a simple and direct energy restoration or storage period is not sustained by the data of this report. These data do not speak to circumstances of high or sustained energy demands. Indeed, there is evidence that such conditions do affect the quality of the sleep response (Baekland & Lasky, 1968; Hobson, 1968; Matsumoto et al, 1968). Furthermore, even in this limited situation, there may be complex "entrainments" of the sleep and waking responses reflecting an energy-sleep relationship (although we have not yet been able to decipher them). However, in this "free-running" and low-energy-demand paradigm, we must seek bases other than period length or a simple energy expenditure output for prediction of sleep and waking period lengths.

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NOTE

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