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Circadian Rhythmicity of Man Under the Influence of Weak Electromagnetic Fields

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Circadian rhythmicity is of endogenous origin, that is, it is generated within every organism without needing the input of day-night stimuli. Its period is usually close to but not precisely 24 hr. In humans, the free-running period is typically about 25 hr. In fact, in most experiments all rhythms run in synchrony ("internally synchronized"). In a minority of experiments (i.e., 52 experiments to date), the period of about 25 hr is present only in some physiological rhythms (e.g., deep body temperature), whereas the sleep-wake rhythm and other rhythms run with considerably deviating periods (i.e., between 12 and 65 hr) and the rhythms are described as "internally desynchronized."

On the other hand, circadian rhythmicity is modified by external stimuli. Under constant conditions the period and all other parameters of free-running rhythms (e.g., amplitude, wave shape, variability) depend on the magnitude of the relevant external conditions. Furthermore, these external stimuli, when periodic, act as zeitgebers synchronizing the endogenously generated rhythm within a limited range of entrainment. Thus, every external stimulus that can modify circadian rhythms is able to do this both by modifying the parameters of free-running rhythms when given continuously and by acting as a zeitgeber when given periodically (Wever, 1979).

In addition to a variety of other external stimuli, the influence of electric low intensity, low frequency fields (10 Hz square wave, 2.5 V/m) on human circadian rhythms have been tested (Wever, 1967, 1968a). The results of the experiments have importance in three respects. First, the field can be used as a tool for exerting a reproducible external control of human circadian rhythms; hence, its application makes it possible to test properties of the circadian system (Wever, 1968b) that had been predicted originally by model considerations (Wever, 1964). In contrast to light, electric fields are effective independent of the activity state of the subjects, that is, equivalently during wake (with open eyes) and sleep (with closed eyes), and these fields do not influence the behavior of the subject, that is, it is not perceivable consciously. A second aspect of the experiments with electric fields is the special sensitivity of the parameters of human circadian rhythms to subtle stimuli. In this respect, human circadian rhythmicity seems to be a particularly suitable indicator for the evaluation of effects of electromagnetic fields on living matter, in general

M. C. Moore-Ede et al. (eds.), *Electromagnetic Fields and Circadian Rhythmicity*

(Wever, 1971). Third, There are arguments that the still unknown mechanism of the effectiveness of electric fields may play a key role in the generation and control of circadian rhythmicity (Wever, 1977). The search for the mechanisms underlying bioelectric coupling may therefore assist in the enlightenment of basic principles of circadian rhythmicity.

Methods

The relevant experiments were performed in an underground building that was specifically constructed for the performance of human long-term experiments under temporal isolation (Wever, 1979). One of the two available units is shielded against electric and magnetic fields (Wever, 1969,1974). The shielded unit, in addition, is equipped with devices enabling the generation of any kind of electric or magnetic AC or DC fields. Both the shielding and the devices mentioned are mounted in the walls, are invisible to the subjects, and, at least during the first years when most of the relevant experiments were performed, without the knowledge of the subjects. All utilized artificial fields were so weak that they could not be perceived consciously in any way (Wever, 1969, 1974).

Results of Constant Condition Experiments

Effects of Natural Fields

It was first determined that there were significant differences in the results obtained in the two units (the nonshielded and the shielded). These differences are listed in Table 8.1. Under constant conditions (i.e., in the absence of any time cues) the free-running rhythms of the subjects showed longer periods, a larger interindividual variability of the periods, and an increased tendency for the spontaneous occurrence of internal desynchronization (i.e., rhythms with different periods in the same subject) in the shielded than the nonshielded experimental unit (Wever, 1974, 1985b). In cannot be excluded absolutely, however, that these differences are not (or not only) due to the difference in the penetration of natural electromagnetic

TABLE 8.1. Effects of an electromagnetic shielding.

Parameter	Single experiments in the nonshielded room	shielded	Statistical analysis	
Number of experiments	57	80		
Free-running period:				
Mean	24.87 hr	25.21 hr	$t = 2.88$	$p < 0.01$
Standard deviation	±0.45 hr	± 0.80 hr	$f = 1.97$	$p < 0.01$
Number of experiments with internal desynchronization	4 (= 7%)	28 (= 35%)	$p < 0.001$ (exact Fisher test)	