Chapter 13
Ultradian Cognitive Performance Rhythms During Sleep Deprivation

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Abstract Ultradian rhythms that modulate daytime human behavior and cognitive performance exist. However, their subtleness may make them susceptible to masking effects from heightened arousal, attention, and motivation. Experimental designs using sleep attenuation and total sleep-deprivation appear to unmask certain ultradian rhythms. This chapter reviews the few studies designed to evaluate rhythms in waking EEG and task performances during sleep deprivation. Some EEG studies demonstrate an approximate 90-min rhythm in arousal. No confirmation has been reached for an underlying common basic rest-activity cycle (BRAC) that ties the phases of the nightly 90-min NREM-REM sleep cyclicity to those of any ensuing similar-period wake time alertness and performance rhythms. Studies have also found a slower 4-h rhythm. Other arousal and performance rhythms shorter than 90 min and longer than 4 h have been suggested, but are not as well substantiated. The 90-min and 4-h rhythms seem to dominate the morning and early afternoon circadian rhythm portion during wakefulness, but are attenuated later by the rising circadian rhythm, or perhaps other slower ultradian cycles. Ultradian rhythm expression appears related to a greater susceptibility for reduced arousal and sleepiness. Impairment of cognitive-behavioral performance occurs at times of low circadian influences and increased ultradian fluctuations. These effects, in combination with any amount of sleep deprivation, raise concerns about naturally occurring potentially widespread performance decrements. Concern stems from the widespread increase in chronic partial-sleep loss in cultures deliberately abridging adequate nightly sleep in favor of attempting to maintain a 24/7 mode of existence.

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13.1 Introduction

The large number of research investigations during the 1950s and 1960s saw successful demonstration of a basic endogenous circadian (near 24-h) rhythmicity in nearly all physiological systems in all warm-blooded animals studied in past decades. This was followed later by confirmation of its genetic origins in genes Per, Tim, Cloc and Cry, and their variants in a variety of animals. On the heels of the well-demonstrated circadian cyclicity was the suggestion by Nathaniel Kleitman (1961) of a sub-harmonic wake-time rhythm of the circadian cycle, an approximately 90-min cycle. This rhythm was thought to include basic survival activities of physiology and behavior; he thought it was derived from the NREM-REM cyclic architecture of sleep, discovered by Eugene Azerinsky and Nathaniel Kleitman (1953) and characterized by William Dement (1955) as the cyclical deep sleep-dreaming pattern in nocturnal sleep known today. This 90-min cycle was labeled the basic rest-activity cycle or BRAC. The relationship between waking- and sleep-state activities culminating in a single-system BRAC has not reached the well-substantiated level of the circadian rhythm. Nonetheless, research generated by its attempted falsification has demonstrated a myriad of cognitive and behavioral rhythmic manifestations of varying periods both below and above 90 min. Certain rhythms of arousal and performance appear to relate to the BRAC. Regardless, these rhythms wax and wane with environmental and endogenous physiological changes. This chapter will discuss the effects of extended wakefulness on rhythms of arousal and performance.

13.2 Daytime Ultradian Alertness Rhythms in EEG

Using the reasonable assumption that basic daytime alertness fluctuations influence levels of performance, we reviewed such studies to examine emergence of ultradian rhythms that would precede changes in performance levels. An early EEG rhythms study (Nakagawa, 1980) tested for presence of the daytime BRAC rhythm. Subjects were placed under quiet relatively supine restfulness conditions in minimized natural lighting, sound, and time information. Following an acclimatization night of sleeping in the laboratory, a night of EEG recording was followed by 10–12 h of additional daytime recording. Although subjects were instructed not to fall asleep, the point of the study was to examine the frequency and occurrence of spontaneous napping and any sleep onset REM periods that might occur. While extension into daytime of the nightly approximate 90-min REM-NREM was not found, about 90 min post-awakening a peak in sleep occurred, followed 4 h later by a second peak of group-calculated episodes of napping. Nakagawa concluded no connection of the daytime napping with the prior night’s approximate 90-min NREM-REM sleep architecture and no support for the BRAC rhythm. Instead, the author suggested that a 3–4 h rhythm might be related to the diurnal work-rest rhythm.