Tunable Somatosensory Stimulation for Selective Sleep Restriction Studies in Rodents

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Many methods for sleep restriction in rodents have emerged in the literature, but most are intrusive, lack fine control, and induce stress in the animal. A versatile, nonintrusive means of sleep restriction that can alter sleep in a controlled manner could be of great value in sleep research. In previous work, we proposed a novel system for closed-loop somatosensory stimulation based on mechanical vibration and applied it to the task of restricting Rapid Eye Movement (REM) sleep in mice. While this system was effective, it was a crude prototype and did not allow precise control over the amplitude and frequency of stimulation applied to the animal. This paper details the progression of this system from a binary, "all-or-none" version to one that allows dynamic control over perturbation to accomplish graded, state-dependent sleep restriction. Its preliminary use is described in two applications: 1. Deep sleep restriction in rats, and 2. REM restriction in mice.

Effect of Temperature on Sleep Regulation in an Animal Epilepsy Model

7b

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Besides recurring seizures, disordered sleep is common in individuals with epilepsy and may present as reduced sleep depth, altered proportions of different stages of sleep, intermittent arousal, and other phenomena. Sleep loss can in turn precipitate seizures, thus sustaining a vicious cycle. It is well known that changes in ambient temperature elicit thermoregulatory responses that alter the dynamics of sleep. As a first step toward therapeutic sleep modulation for epilepsy, we assessed the effect of elevated ambient temperature on sleep dynamics and seizure yield in the chronic pilocarpine mouse model of temporal lobe epilepsy. The results in a small sample indicate that temperature does in fact significantly alter the proportions and durations of each vigilance state in this model, with possibly correlated changes in seizure incidence. Manipulation of ambient temperature therefore offers a simple and relatively unobtrusive way of titrating sleep quality and perhaps alleviating the seizure burden in epilepsy.

A Mathematical Model of Ultradian Sleep-Wake Regulation in Rodents

8a

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Rodent models are widely used for the experimental analysis of sleep. While this is motivated by similarities in brain circuitry and electrophysiological rhythms, unlike the circadian sleep-wake cycle in humans, rodent sleep is polyphasic, containing multiple bouts of sleep and wake minutes to hours in duration over the course of a day. Each sleep bout is punctuated by several brief arousals several seconds to minutes long. Physiologically motivated mathematical models replicate the shorter timescale of arousal within sleep, but not the longer one representing prolonged wakefulness. Here, we adapt a previously published ``flip-flop'' model of human sleep to capture the ultradian alternation of sleep and wakefulness in mice on the longer timescale. The resulting model reproduces both the mean durations of alternating sleep and wake bouts as well as the circadian trends in their bout durations documented in our experiments on mice.