*Abstract*

**Neurochemical and Functional Changes During NREM and REM Sleep for Learning and Memory in Humans**

The roles of NREM and REM sleep in learning and memory remain unclear. In procedural learning, it has been suggested that NREM sleep plays a role in performance improvements (offline performance gains), while REM sleep makes learning more resilient to interference (stabilization). These suggest that plasticity of learning increases for offline performance gains during NREM sleep, while it decreases for stabilization during REM sleep.

To test this hypothesis, in visual perceptual learning (VPL) using magnetic resonance spectroscopy in asleep human subjects, we measured the excitation/inhibition (E/I) ratio which represents the amount of plasticity of learning during sleep by simultaneous magnetic resonance spectroscopy and polysomnography measurements. Performance deteriorated significantly after NREM sleep without REM sleep. The E/I ratio increased during NREM sleep while it decreased during REM sleep. The E/I ratio during NREM sleep was correlated with offline performance gains, while the E/I ratio during REM sleep was correlated with stabilization. Furthermore, by utilizing temporary sleep disturbances, known as the first-night effect (FNE), we find that the E/I ratio and performance improvements are significantly impaired when the FNE occurred. These results suggest that NREM and REM sleep play complementary roles for learning, which are reflected by significantly different neurochemical processing, and that the quality of sleep matters for such processes to occur.