ASSESSING THE IMPACT OF CHRONIC SLEEP RESTRICTION AND ACUTE SLEEP DEPRIVATION ON PERFORMANCE-ASSOCIATED REGIONAL BRAIN ACTIVATION USING NEAR INFRARED SPECTROSCOPY

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NASA astronauts and ground crew must maintain high levels of alertness and cognitive performance to ensure successful completion of space missions and the safety of astronauts. Both astronauts and ground crew suffer sleep loss and circadian misalignment due to extended work hours and shifting work schedules, and are therefore at elevated risk for sleepiness/fatigue-related accidents. A major challenge in devising effective countermeasures to decrease this risk is accurately detecting sleepiness. While subjective reporting is often used as a marker of sleepiness, such reports do not reliably reflect the magnitude of the objective cognitive performance decrements. Therefore, it is imperative to develop reliable and minimally intrusive objective measures of sleepiness as it relates to cognitive performance impairment. A relatively new technology, developed by Drs. Zhang and Strangman with NSBRI support, quantifies hemodynamic changes in oxygenated and deoxygenated blood within the brain using Near-Infrared Spectroscopy (NIRS); these hemodynamic changes reflect alterations in regional brain activity. Sleep deprivation (extended time awake) reduces activation in the prefrontal cortex (PFC), a brain region important for cognitive performance and executive function. The NIRS technology detection of reduced PFC activation offers a novel opportunity for developing an objective sleepiness detection tool. Current methodology for assessing hemodynamic changes requires large, expensive functional magnetic resonance imaging or positron emission tomography techniques that are impractical for use in most work environments, including the International Space Station. In contrast, ambulatory NIRS monitoring is relatively portable, relatively inexpensive, simple to apply and can record over 24 hours of data in a single session. Therefore, this non-invasive method for assessing regional brain activity overcomes the restrictions of other neuroimaging systems and has the additional advantages of multi-hour recordings and ambulatory monitoring.

We are using NIRS to examine PFC activity in experimental volunteers participating in (i) a 32-day inpatient study assessing the affects of chronic sleep restriction (CSR; multiple consecutive days of insufficient sleep) and (ii) a 30-hr acute sleep deprivation inpatient study (ASD; single episode with extended wake) conditions. In these studies, NIRS monitoring occurs during cognitive performance testing and quiet focused wakefulness. In the CSR study, participants are scheduled to live on twenty-four 20-hr days (a forced desynchrony protocol during which sleep and wake occur at different circadian phases); we therefore assess the effects of circadian phase and of CSR on PFC activity. In the ASD study, we evaluate PFC activity during an extended (30-hr) wake episode.

Results from this study will demonstrate the effectiveness of using NIRS to objectively monitor sleepiness related to cognitive performance. These results can also be used to better characterize times of decreased cognitive performance in working populations under real-world conditions for predicting when an individual might be at significant risk of an accident or work-related errors. Furthermore, NIRS may help identify neural targets for monitoring sleepiness and the effectiveness of sleepiness countermeasures. Therefore, the cost-effective and minimally intrusive NIRS approach of monitoring sleepiness may be applicable in diverse work environments ranging from space missions to earth based shift-working populations, including firefighters, pilots, health care providers, truck drivers and military personnel.

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