EVALUATION OF PHOTIC COUNTERMEASURES FOR CIRCADIAN ENTRAINMENT OF NEUROBEHAVIORAL PERFORMANCE AND SLEEP-WAKE REGULATION BEFORE AND DURING SPACEFLIGHT

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INTRODUCTION

Prior to short duration space missions, it is critical that the circadian rhythms of astronauts be synchronized to the sleep-wake schedules required for launch in order to minimize potential problems in flight due to circadian disruption, including reductions in sleep quality and quantity, and impairment of daytime performance. Unfortunately, due to constraints imposed by orbital mechanics and operational requirements, space exploration often requires crew members to shift the timing of their sleep-wake cycle as the launch times of lunar sorties may be scheduled at any hour of the day or night. Crewmembers are scheduled to awaken 5-7 hours before these variable launch times, and their circadian rhythms must often be shifted by 6 to 10 hours during the week-long pre-launch quarantine period in order to match the mission schedule. While monochromatic exposure to shorter wavelength light is more effective than equivalent photon exposure to longer wavelength light in enhancing alertness and shifting circadian rhythms, this is not a practical spaceflight countermeasure, because of its adverse effects on color vision. Therefore, we plan to evaluate the effectiveness of short-wavelength-enriched light as a countermeasure for circadian misalignment during lunar missions by developing a cost-effective countermeasure for sleep and circadian disruption.

METHODS

Using a randomized, between-subject study design we are assessing the efficacy of 5 controlled protocol conditions in changing the timing of sleep/wake to 8 hours earlier, relative to each subject’s habitual sleep time. Subjects are exposed to one of five schedules: 1) white florescent ambient light and a gradual shift in which the sleep episode is incrementally advanced over 5 days until an advance of 8 hours is achieved, 2) short wavelength-enriched light and a gradual shift, 3) white light and a slam shift which entails an abrupt advance of 8 hours, 4) short wavelength light and a slam shift, or 5) white and short wavelength light combined and a modified slam shift with 2 short naps scheduled prior to the abrupt advance. We assess each subject’s circadian phase, at baseline and following the shifted schedule in order to evaluate the effectiveness of the protocol conditions in adapting the biological clock to the new sleep-wake schedule. We also assess the impact of these conditions on sleep/wake EEG and neurobehavioral test performance throughout the waking day, in addition to drowsiness during the waking hours and underlying causality of performance impairments.

RESULTS

Forty-three subjects completed the 8-day protocol randomized to 1 of the 5 conditions. We found significantly greater phase advances of the melatonin rhythm in subjects from the combined light and slam shift condition compared to the other 4 conditions (p<0.05). We successfully implemented new infra-red reflectance oculography technologies into the protocol to provide further information on developing sleepiness in real-time and underlying causes of performance impairments during neurobehavioral lapses. Results indicate that these infra-red systems provide valid, real-time indication of developing drowsiness as compared to gold standard laboratory measures.

This strategy of adjusting sleep/wake schedules pre-launch may provide NASA with their first deliverable lighting countermeasure to sleep and circadian disruption for use during space missions that could be incorporated in the proposed CEV’s for Earth orbit and short-term exploration class missions, as well as in lunar habitats as a part of a built-in ambient lighting system.

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