Fiscal Year:	FY 2012	**Task Last Updated:**	FY 01/15/2013
PI Name:	Brainard, George C. Ph.D.		
Project Title:	Blue Light for Enhancing Alertness in Space Missions		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Human Factors and Performance Team		
Joint Agency Name:		**TechPort:**	Yes
Human Research Program Elements:	(1) **BHP**:Behavioral Health & Performance (archival in 2017)		
Human Research Program Risks:	(1) **BMed**:Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
PI Email:	george.brainard@jefferson.edu	**Fax:**	FY 215-923-7588
PI Organization Type:	UNIVERSITY	**Phone:**	215-955-7644
Organization Name:	Thomas Jefferson University		
PI Address 1:	Light Research Program		
PI Address 2:	1025 Walnut St., Room 507		
PI Web Page:			
City:	Philadelphia	**State:**	PA
Zip Code:	19107-5083	**Congressional District:**	1
Comments:			
Project Type:	Ground	**Solicitation / Funding Source:**	Directed Research
Start Date:	09/01/2006	**End Date:**	09/30/2012
No. of Post Docs:	1	**No. of PhD Degrees:**	0
No. of PhD Candidates:	1	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	1	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:	NOTE: End date changed to 9/30/2012 per NSBRI (Ed., 1/27/2012)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):			
Grant/Contract No.:	NCC 9-58-HPF00001		
Performance Goal No.:			
Performance Goal Text:			

The overall goal of this project is to study the efficacy of blue-enriched solid state polychromatic light for acutely enhancing alertness and cognitive performance in healthy men and women. The purpose of this work is to develop in-flight and ground-based lighting countermeasures for enhancing alertness in astronauts and NASA ground crew. This is the final year of this directed research project. This year's aims were reduced due to an unexpected funding reduction. The reduced aims were:

1) Continue the three-day inpatient study of narrowband blue solid state light on alertness and cognitive performance: (a). complete neurocognitive and melatonin data analysis (b). initiate analysis of polysomnography data, completing as much as possible with remaining funds.

2) Complete a pilot study on testing the effect of light emitting surface size on melatonin suppression. (a). finish running

Task Description:

subjects through the test conditions (b). complete blood assays and data analysis.

3) Write a report on the results on items 1 and 2 above.

Two studies have been previously completed for this project using two prototype 122 cm x 122 cm solid-state blue light (peak wavelength 469 nm) exposure systems. A melatonin suppression study has resulted in a peer-reviewed manuscript published in the Journal of Applied Physiology (West et al., 2011). The second study was a three-day inpatient study on the effects of narrowband blue light from light emitting diodes (LEDs) on alertness and cognitive performance.

Per the first aim above, plasma melatonin, alertness, and neurocognitive performance measures have been analyzed. Polysomnographic data from Karolinska Drowsiness Tests (KDTs) was analyzed from 8 of the 22 subjects. Further KDT analysis was not feasible due to the unexpected funding cut. Two presentations were made at international meetings describing the protocol and the preliminary analysis of the melatonin data set (Hanifin et al., 2010a, 2010b). The completed melatonin, alertness, and neurobehavioral data sets are now being written up as a chapter in a doctoral thesis (Hanifin, unpublished) and subsequently are likely to be published as a peer-review manuscript. Importantly, the experimental 122 cm x 122 cm LED light panels we have used in the first two studies for this project are too large to be flight-worthy, although they could be used for lighting countermeasures for ground crew.

This year's second aim was concerned with testing the consequences of reducing the size of the light-emitting surface to a more flight-worthy size. This pilot study used the acute melatonin suppression response as its dependent variable for quantifying how different size light-emitting surfaces influence this neuroendocrine response. A pilot study protocol was designed and approved by the Jefferson Institutional Review Board (IRB). Two new exposure systems were designed, constructed, and equipped with blue-enriched broad-bandwidth LEDs (6,500 K) for this study. Of note, this blue-enriched LED light source is similar to one of the LED sources being specified for the Solid-State Light Assembly (SSLA) that is being proposed for replacing the current fluorescent General Luminaire Assemblies (GLA) onboard the International Space Station. Eight healthy male and female subjects were recruited, screened, and enrolled in an experiment that employed a within-subjects design. Subjects were seated comfortably with their head resting in an ophthalmologic head holder facing the light source at a distance of 90 cm. The volunteers' pupils were freely reactive during the light exposure that was given between 2:00 and 3:30 AM. Subjects were exposed to a 122 cm x 122 cm exposure area or a much smaller 3.81 cm x 3.81 cm exposure area at an equal surface irradiance and a dark control exposure (with at least one week between each exposure). The volunteers have completed all 24 study nights and their plasma samples have been quantified for plasma melatonin content. The resultant data support the hypothesis that light source size is a critical factor in the design of SSLA lighting that can be used to serve as an in-flight countermeasure for circadian disruption and sleep during long duration space exploration. A follow up study testing a range of light emitting surface sizes including the surface size of the SSLA (approximately 11 cm x 54 cm) was planned but not initiated due to the unexpected funding cut. The ultimate goal from this work is to develop a lighting countermeasure that enhances alertness and cognitive performance in ground crew members and astronauts.

This year's results ultimately will impact the NASA Human Integration Design Handbook and the Space Flight Human Systems Standard, NASA-STD-3001, that provide guidance for supporting crew health, habitability, environment, and human factors in human space flight. Our progress addresses NASA Human Research Program Integrated Risk Plan (2011) risk area 22 (Sleep 5, 9, and 10) Critical Risk areas. These areas concern countermeasures that will optimally mitigate health, performance and safety problems due to circadian, neuroendocrine, and neurobehavioral disruption, for flight, surface, and ground crews.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:

The knowledge gained from this research, though focused on space flight, also may benefit people on Earth. The circadian disruption experienced by astronauts during space flight can be considered a threat to the success of space missions (Longnecker and Molins, 2005; NASA Human Research Program Integrated Risk Plan, 2011). The resulting physiological and behavioral changes caused by circadian and sleep disruption can lead to diminished alertness, cognitive ability, and psychomotor performance (Dijk et al., 2001). Over 45% of all medications taken in space are sleep aids taken as a measure to counteract sleep deficits (Putcha et al., 1999). Although the studies in this project are focused on developing a non-pharmacological lighting countermeasure for space exploration, it is anticipated that there will be benefits to civilians. A significant portion of the global population suffers from chronic sleep loss and/or circadian-related disorders. Evidence for disease or illness due to a circadian disruption has mounted significantly. Nearly 22 million Americans do shift work that interferes with a biologically healthy nocturnal sleep cycle (U.S. Bureau of Labor Statistics, 2007). Shift workers have been shown to be more likely to suffer from a wide variety of ailments, including cardiovascular disease, gastrointestinal distress, and cognitive problems. Furthermore, epidemiological studies of female shift workers have shown that they are more likely to suffer from breast cancer and colon cancer compared to day shift workers. The World Health Organization has identified shift work as a probable risk for cancer (The International Agency for Research on Cancer, 2007). This past year the American Medical Association acknowledged the harmful effects of widespread electrical lighting at night (Council on Science and Public Health Report Report, 2012). Our laboratory is involved in testing the hypothesis that night time exposure to light suppresses melatonin and contributes to cancer risk (Blask et al., 2005; Mao et al., 2012).
Aside from evidence of a breakdown in physical health, the effects of circadian disruption and sleep loss have long been known to have potentially dangerous behavioral effects. Mental fatigue, diminished alertness, loss of psychomotor coordination, and decreased physical performance are all commonly found in individuals with sleep loss, sleep debt, or circadian misalignment. Many people also experience the same effects after air travel across several time zones. The impact of these deficits affects many industries, including transportation, manufacturing, communications, medicine, and homeland security. It has long been a source of concern for the military, as well. In the past, the U.S. Air Force has supported our laboratory to study the acute alerting effects of light (French et al., 1990; Brainard et al., 1996). Our past work for NIH (National Institute of Health) has continued this effort (Lockley et al., 2006).

Existing therapeutic lighting interventions stand to benefit from enhancing our understanding of how different wavelengths of the spectrum affect human circadian and neurobehavioral regulation (Byrne and Brainard, 2012). A more efficient intervention with increased potency and/or fewer side effects could result. One such disorder currently being treated with bright white light is Seasonal Affective Disorder (SAD). It is estimated that as many as 1 in 5 Americans suffer from SAD or its milder version, sSAD (Lam and Levitt, 1999). Similar bright white light interventions also are used to treat jetlag. Side effects from exposure to bright white light for these and other therapies

	include: hypomania, headache, vision problems, nausea, dizziness, and anxiety. Optimizing the light spectrum for specific affective and/or circadian-related disorders could deliver the same medical impact with lower levels of light intensity and, potentially, with fewer side effects. Our group has completed Phase I testing of light therapy with blue solid-state lighting for patients with SAD (Glickman et al., 2006).
Task Progress:	This is the final year of a directed research project that had reduced aims due to an unexpected funding reduction. The goal is to study the efficacy of blue or blue-enriched white solid-state light for enhancing alertness in men and women as a basis for developing an in-flight lighting countermeasure for enhancing alertness in astronauts and NASA ground crew. For this project, we have four 122 sq cm solid-state light sources: two with narrow-bandwidth (peak 469 nm) LEDs and two with broad-bandwidth blue-enriched LEDS that emit white-appearing light with a Correlated Color Temperature (CCT) of 6,500 K. These units provide a large, uniform light-emitting surface with intensity modulation. An independent safety analysis of both LED light sources based on national (American Conference of Industrial Hygienists (ACGIH)) and international (The International Commission on Non-Ionizing Radiation Protection (ICNIRP)) criteria has been completed. James Maida of Johnson Space Center (JSC) and Charles Bowen, Ph.D., of Lockheed Martin (retired) have confirmed that the blue LED units meet NASA's safety standards (West et al., 2008). A melatonin suppression study was conducted with the narrow bandwidth blue LED units to characterize their biological potency and to guide the selection of the light intensity for the multiday alertness study. Healthy subjects (N=8) completed a total of 84 nighttime melatonin suppression experiments. Data analysis was completed showing that the blue LED light evokes a dose-response melatonin suppression, and permitting the calculation of a target intensity for the alertness study. The data also indicate that blue LED light is stronger than 4,000 K white fluorescent light for suppressing melatonin. A peer-review manuscript has been published on these results (West et al., 2011). Over 300 individuals volunteered to be screened for a 3-day alertness study with the blue LED light units. From that pool of volunteers, 26 subjects completed all medical, psychological, and ophthalmological examinations as well as screens for stability of sleep-wake cycles and drugs of abuse. Of the 24 subjects that entered the study, 22 completed the three-day inpatient alertness protocol. Analysis of plasma melatonin, subjective alertness, objective alertness, and neurobehavioral data was finalized this year. Due to reduced funding, only a partial analysis of polysomnography data was completed. Two presentations have been made at international meetings describing the protocol and a partial analysis of the resultant data set (Hanifin et al., 2010a, 2010b). Preliminary testing of visual performance and color discrimination has been done with selected intensities of the narrow bandwidth blue LEDs with 8 healthy subjects. A pilot study on the consequences of reducing the size of the light-emitting surface to a more flight-worthy size was designed and approved by the Jefferson IRB. Two exposure systems with broad-bandwidth blue-enriched LEDS (6,500 K) were used for this study. Eight healthy male and female subjects completed all 24 nighttime experiments for this study.
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