Fiscal Year:	FY 2014	**Task Last Updated:**	FY 12/24/2013
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Project Title:	Assessing the Impact of Chronic Sleep Restriction on Sleep and Performance-Associated Regional Brain Activation Using Near-Infrared Spectroscopy		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Human Factors and Performance Team		
Joint Agency Name:		**TechPort:**	No
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Human Research Program Risks:	(1) **BMed**:Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders		
Space Biology Element:	None		
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Space Biology Special Category:	None		
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Zip Code:	02115	**Congressional District:**	8
Comments:			
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COI Name (Institution):	Klerman, Elizabeth (MENTOR/ Brigham and Women's Hospital) Strangman, Gary (Massachusetts General Hospital)		
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Task Description:	POSTDOCTORAL FELLOWSHIP NASA astronauts and ground crew need to maintain high levels of physical and cognitive performance to ensure successful completion of space missions and the safety of astronauts. Astronauts and ground crew are exposed to sleep loss arising from shifting and extended work schedules commonly associated with their missions. As a result, many astronauts and ground crew are at risk for fatigue-related accidents that can endanger the success of space missions and personal safety. A major challenge in combating fatigue is accurate diagnosis. Subjective sleepiness is reported significantly less often than observed objective performance decrements, indicating that self-diagnosis is inaccurate. Recent evidence suggests that sleep deprivation reduces activation in the prefrontal cortex (PFC), a brain region known to be important for executive function and cognitive performance. A recently-developed technology, developed substantially by co-mentor Dr. Strangman with NSBRI support, allows for the quantification of hemodynamic changes in oxygenated and deoxygenated blood within the brain using Near-Infrared Spectroscopy (NIRS). NIRS detects regional brain activity alterations associated with these hemodynamic changes. Current methodology for assessing hemodynamic changes requires large, expensive functional magnetic resonance imaging or positron emission tomography techniques that are impractical for use in space or most work environments. 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 prohibitive restrictions of other neuroimaging systems and has the additional advantages of multi-hour recordings and ambulatory monitoring. We are using NIRS technology to examine PFC activity in experimental volunteers participating in chronic sleep restriction (CSR) and acute sleep deprivation (ASD) protocols. NIRS monitoring during these protocols will allow us to address our specific aims: 1) To test the hypothesis that hemodynamic responses in the PFC to the psychomotor vigilance task (PVT) will exhibit a circadian rhythm. 2) To test the hypothesis that hemodynamic responses in the PFC to the PVT will be reduced during CSR. 3) To test the hypothesis that hemodynamic fluctuations in the PFC associated with delta wave sleep activity will increase in frequency following a 30-hour ASD. In the past year, we have developed standard operating procedures to implement NIRS monitoring of the PFC during cognitive performance testing. We have successfully collected NIRS recordings from 400 cognitive performance testing sessions at multiple circadian phases in 4 participants on the CSR protocol, and should complete collection from a 5th participant in October 2013. We also modified our 3rd specific aim to conduct NIRS monitoring of PFC during sleep in volunteers immediately after a 30-hour ASD. We are developing the standard operating procedures to monitor PFC hemodynamic changes during sleep. We are concurrently amending the data analysis methods originally developed by Dr. Strangman to address our specific aims. These data analyses involve block-averaging, power spectral density, and deconvolution methods. In the upcoming year, we plan to record and analyze NIRS data from an additional 5 participants on the CSR protocol, and 12 participants on the ASD protocol for a total of 22 participants by November, 2014. Results from this study will inform future use of NIRS technology to objectively monitor sleepiness and reduce fatigue-related accidents. Our results may lead to the improved identification and prediction of sleepiness and decreased performance in shift-working populations, including astronauts, ground crew, firefighters, pilots, health care providers, truck drivers, and military personnel.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Our current funded project is important not only to the space program, but to the general population. Astronauts and ground crew face challenges during a space mission that disrupt sleep and circadian alignment that can lead to increased risk of fatigue-related accidents. Sleep loss and circadian misalignment are prevalent amongst the 15% of the US labor force that participates in shift work, including rotating, evening, and/or night shifts. Ground-based professions that require shift work schedules include health care professionals (e.g., physicians, nurses, pharmacists), air traffic controllers, pilots, and commercial drivers, all of whom frequently perform tasks that require high levels of attention and cognitive function under conditions of sleepiness. Fatigue impairs attention and increases risk of accidents that can result in injury, death, or significant monetary loss. Therefore, fatigue-induced cognitive impairment poses a serious risk to the success of space missions and ground-based operations. Understanding and diagnosing such impairment would be of great benefit in many critical operations on Earth. Results from this study can inform use of Near-Infrared Spectroscopy (NIRS) to objectively monitor sleepiness and reduce fatigue-related accidents. The prefrontal cortex (PFC) brain region is easily accessible to NIRS imaging. This study will investigate the impact of chronic sleep restriction (CSR) and delta wave activity during sleep on the PFC using NIRS imaging. Increased delta wave activity occurs after extended wakefulness or acute sleep deprivation (ASD) that causes high homeostatic sleep pressure. The results from this study may lead to the improved identification of times of decreased performance or high homeostatic sleep pressure in working populations susceptible to fatigue-related accidents. Sleep loss and circadian misalignment impact both ground-based shift workers and astronauts with potentially severe consequences on both the maintenance of high levels of cognitive performance and the risk of fatigue-related accidents. The proposed protocol is the first study to examine activity in the PFC with NIRS during wake-time performance testing while an individual experiences CSR and during sleep following ASD. The results from this study may lead to brain region-specific targets for fatigue monitoring and countermeasures, and demonstrate the potentially low-cost, effective use of NIRS to detect sleepiness with applications for NASA space missions and the general population.
Task Progress:	During the first funded year, Dr. Lee has made substantial progress in addressing the specific aims. Specific Aims 1 and 2: Standard operating procedures were developed and tested to use Near-Infrared Spectroscopy (NIRS) during the 32-day chronic sleep restriction (CSR) study. These were required both to collect data cleanly but also to ensure no other data collection (e.g., polysomnography) for the CSR study were negatively affected. We have collected NIRS recordings from over 400 cognitive performance testing sessions (from 5 participants) during an inpatient forced desynchrony (FD) protocol with CSR in which participants complete cognitive tests across all circadian phases. We have modified analysis software developed by Dr. Strangman for use in our experimental conditions. Preliminary assessment of the hemodynamic response to individual psychomotor vigilance task (PVT) trial presentation reveals an immediate decrease in oxygenated blood, followed by a larger increase, while deoxygenated blood shows an inverse response. This pattern of hemodynamic response has been described in the visual cortex in previous studies using visual stimuli and demonstrates the operational success of the data collection thus far. We will continue data collection on 5 additional participants. For specific aim 1, analyses of the NIRS data and relative to melatonin phase (a circadian marker) will quantify the circadian rhythmicity in the hemodynamic response in the prefrontal cortex (PFC) in response

	to PVT presentation. For specific aim 2, comparisons of hemodynamic responses to PVT from the beginning of the CSR protocol compared to responses at the end of the CSR protocol and between CSR and control participants will allow us to quantify the impact of CSR on brain activation in the PFC. Specific Aim 3: We redesigned Aim 3 to investigate the impact of a 30-hour acute sleep deprivation on PFC activity during the following recovery sleep. NSBRI approved this change. We are developing the standard operating procedures necessary to conduct NIRS monitoring during sleep, and plan to implement these procedures in October.
Bibliography Type:	Description: (Last Updated: 08/25/2020)