Wearable sensor system for long-term monitoring of psychological health in extreme, operational environments

Mental health issues are a risk for workers in isolated, confined, and extreme operational environments. These populations include astronauts, warfighters, polar explorers, and many others. Astronauts, in particular, in transit to far-away destinations, such as the Moon and Mars, will be at risk of developing mental issues and far from traditional support networks. For this reason, it is important to develop a method of pre-screening workers for risk of developing mental illness. One method of measuring quantifiably the effects of psychological stress is by monitoring a set of physiological signals that are correlated with mental state. This concept is known as “psychophysiology”, and is a promising way to move psychological care away from purely qualitative metrics. Additionally, monitoring must move out of the clinical/laboratory environment to measure these psychophysiological signals long term. Wearable sensor systems that allow comfortable, un-intrusive, and non-stigmatizing monitoring are essential for monitoring patients in the wild. The goal of this work is to design, develop, and test a wearable system for long-term psychophysiological health monitoring and is split into four specific aims:

1) Define a system architecture for psychophysiological monitoring of subjects in operational, high-stress environments
2) Design, develop, and evaluate the feasibility of a wearable sensor system and survey administration device
3) Develop and characterize a data analysis protocol to select important features from acquired physiological and subjective assessment data
4) Conduct a functional assessment of the system in an operational environment to evaluate wearability and data accuracy

This presentation will cover the work completed to date toward system definition, prototyping, garment design, and data analysis. The system consists of three different sensors to detect the electrodermal activity (EDA), electrocardiogram (ECG), and photoplethysmogram (PPG) signals that will be monitored during sleep. EDA is measured through the conductance across the skin, which corresponds to the amount of sweat present. This is a good indicator of stress that can be measured with a simple electrode. ECG is measured through an electrode on the skin that picks up electrical signals that correspond to heart activity. While ECG contains a lot of information about the heart’s activity, PPG just measures the pulse and is a good way to cross-check the accuracy of the ECG signal. PPG is usually measured through a pulse oximeter that shines a light on a vein and measures changes in light absorption. PPG sensors are integrated in many commercially-available wrist-mounted devices, so this is a convenient way to check ECG signals obtained with a sensor system developed in-house. These three signals were chosen because they have been found to be correlated with changes in response to stimuli and sleep interruption exhibited in patients with PTSD and depression. They are also measured on the skin using relatively unobtrusive sensors, which makes them ideal for a long-term wearable system. The most compelling option for integrating sensors into a wearable garment is to create smart textiles – fabrics that have electronic elements incorporated directly into their structure. ECG and EDA sensors consist of a set of electrodes, and there are several options for iterating upon the design of a traditional electrode. This can be done by weaving conductive threads in specific patterns on a loom or sewing conductive thread onto a commercially manufactured textile. Both of these options have
been explored and will be presented in detail along with the overall system architecture and planned testing.