Wearable Biosensor Monitor to Support Autonomous Crew Health and Performance

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Abstract

During future human exploration missions, spaceflight crews will encounter adverse health outcomes and decrements in performance during the missions and for long term health. The Psychophysiological Research Lab is currently conducting a technology demonstration of a prototype wearable biosensor system (Astroskin) on astronaut surrogates during 30 day missions within NASA's Human Exploration Research Analog (HERA). HERA, located at Johnson Spaceflight Center, represents a flight analog for simulation of isolation, confinement and remote conditions of mission exploration scenarios. Astroskin is a prototype wearable biosensor monitor developed by the Canadian Space Agency (CSA). It consists of an intelligent garment for the upper body and a headband fitted with sensors, and associated software and hardware that can measure, transmit and store vital signs (ECG, respiration, blood pressure, etc.), sleep quality and activity level of the wearer. One of the main goals of the technology demonstration is to evaluate the performance of the Astroskin system (i.e., data quality), hardware/software usability, and crew comfort. This work supports the Exploration Medical Capabilities (ExMC) element within NASA's Human Research Program.

Introduction

NASA needs a health monitoring system composed of hardware that is compact, fully interoperable with an integrated data management system, and requires minimal consumables with the ability to measure, store and transmit physiological parameters during operational and ambulatory scenarios. Parameters of interest are key physiological signals that indicate crewmembers' workload and other physiological parameters, including ECG, heart rate, and blood pressure. The current method of measuring physiological data on the ISS is via the "BP/ECG Kit", which includes capabilities to measure ECG, HR, and blood pressure. The kit is bulky, heavy and uses a lot of energy. To address limitations of the current systems the ARC ExMC project team is collaborating with CSA on evaluations of a prototype wearable biosensor garment that may meet requirements for future ISS and exploration class missions. Evaluation on board HERA is necessary to demonstrate operational feasibility including long-term crew health monitoring (24-hours) capabilities, during exercise sessions as a measure of crew fitness and exercise intensity, crew comfort and usability, and Bluetooth communication in this environment.

Method

Participants

8 participants (4 men and 4 women) were recruited and selected as crew for HERA Campaign 3 Missions 1 and 2 (each 30-days). Four participants were assigned to each mission.

The Human Exploration Research Analog (HERA) located at Johnson Spaceflight Center represents a flight analog for simulation of isolation, confinement and remote conditions of mission exploration scenarios.

Equipment

1. Astroskin, biosensor garment, that provides physiological measures including:
   - 3-axis accelerometer
   - Electrocardiogram/heart rate
   - Respiration rate and volume
   - SPO2 - oxygen saturation
   - Systolic blood pressure
   - Skin temperature
2. iPod (used by crew to verify status of data)
3. laptop (used by crew for downloading data)

Left: *Astroskin garment and headband;* ***Middle:*** *a participant exercising on ergometer while wearing the AstroSkin;* ***Right:*** *Mission 2 crew before egress in to HERA*

Procedure

Pre-Mission Baseline – 1 day continuous 24-hour physiological monitoring

- training on hardware/software, exercise equipment, and survey

Mission – 4 days continuous 24 hour monitoring (MD1, MD15, MD19, MD29)

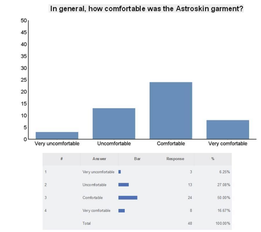
- 1 high workload day
- 1 low workload day
- 2 days that include submaximal exercise on cycle ergometer
- post-session online survey (10 minutes)

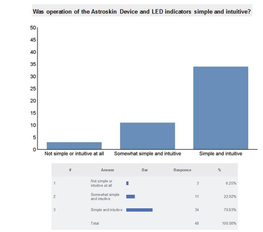
Post-Mission Baseline – 1 day continuous 24-hour physiological monitoring

- crew debrief and survey

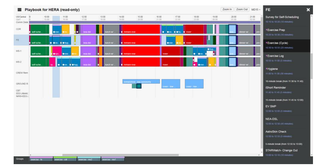
Results

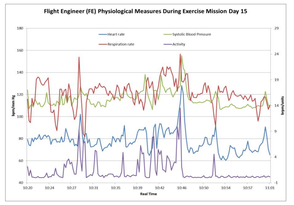
AstroSkin biosensor garment provides good quality physiological data during 24-hour monitoring periods (wake and sleep); it can be used for evaluation of crew fitness during exercise protocols, it is comfortable and user-friendly, and the Bluetooth communication protocol used for data verification is reliable in the analog environment.

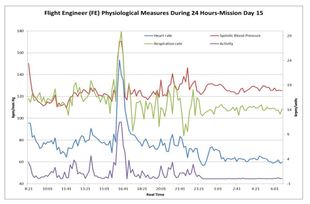




Above: *Sample crew survey questions with results from the HERA Mission 1 and 2.*
Right: *'Playbook' timeline of scheduled activities for each crew member on a single mission day.*
Below: *Physiological data of one crew person on mission day 15. The graph on the left is a 30-minute exercise session with data plotted as 15 second means. The graph on the right is a 24 hour recording with data plotted as 10 minute means.*







Discussion

The current method of measuring physiological data on ISS is a bulky and heavy kit that does not fit the standards envisioned of exploration-class mission hardware. This technology demonstration of the Astroskin system on crews in a spaceflight analog is a good step towards finding a suitable device that can be used by crews on ISS and other long duration missions planned in the future. Data from the two HERA missions indicate that the AstroSkin system is user friendly and can be used by autonomous crew for health monitoring, evaluating countermeasure efficacy, and fitness evaluations. A few important comments were provided by HERA crew: 1) female garments need to be re-designed to provide better support and improve signal quality. 2) The SPO2 headband caused significant discomfort when worn over extended periods (up to 24-hours) and the sensor cable interfered with crew mobility. An alternative option would be to relocate the sensor on the wrist or provide a wireless sensor attached to the forehead with a foam pad. Additional data will be collected from HERA crews during mission 3 (underway) and mission 4 in September. Obtaining results from these missions will help us better understand the advantages and disadvantages of the AstroSkin and its potential as a candidate biosensor system for future flight crews.

Acknowledgements

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