Evaluation of the Accuracy of Astroskin as a Behavioral Health Self-Monitoring System for Spaceflight

Arun Kumar[1] , Edwin Levin[2] , Patricia Cowings[3] , William B. Toscano[3]

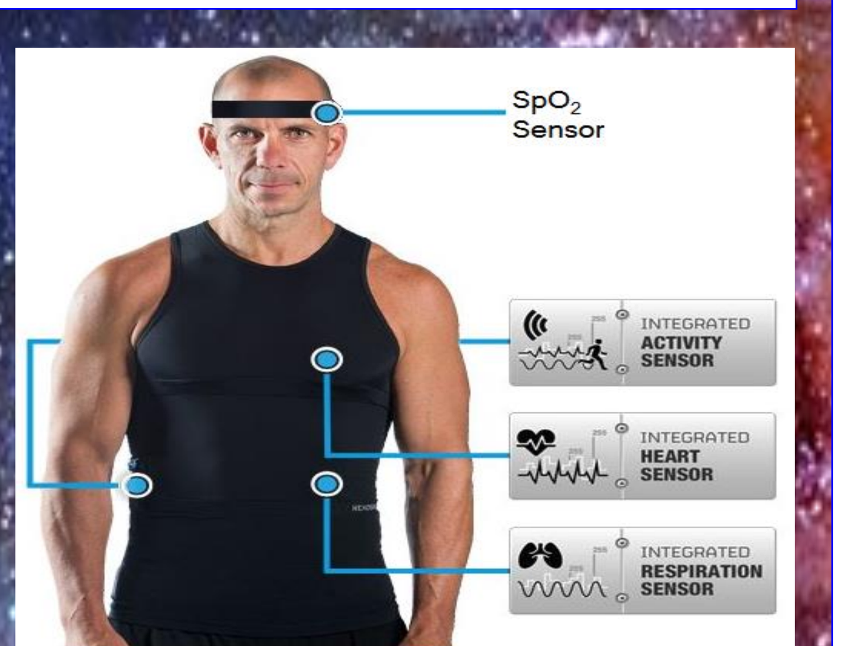
[1]San Jose State University, [2]Hartnell College, [3]Psychophysiology Lab, NASA Ames Research Center

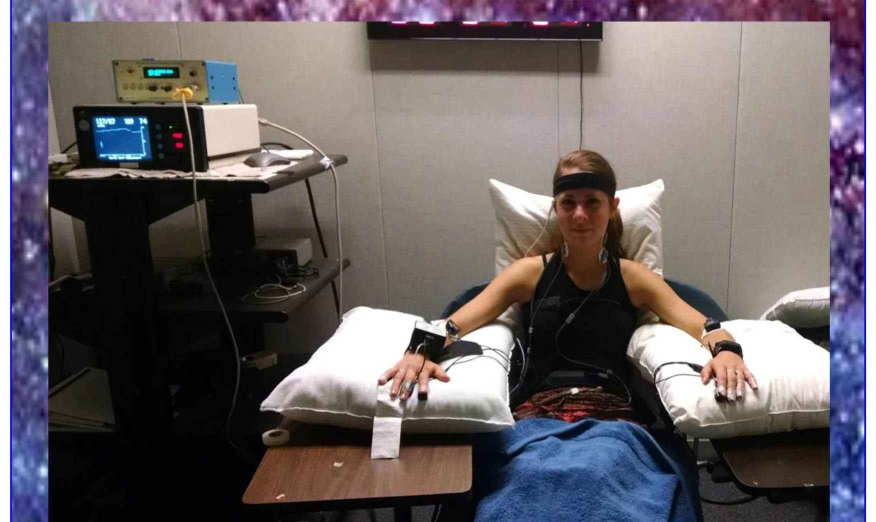
Abstract

In space, there is a need to monitor astronauts' vital signs and assess their readiness to perform specific tasks during a mission. Currently, NASA does not have the capability to noninvasively monitor crew for extended periods of time. The Canadian Space Agency is working with the Psychophysiology Lab at NASA ARC to determine if the Astroskin could be used as a solution to this problem. Astroskin, a commercially available garment with built-in biosensors, can be comfortably worn under clothing or a spacesuit and relay information to the crewman's own mobile device. Data can also be sent wirelessly to the on-board Exploration Medical System. To determine if Astroskin meets requirements for health monitoring, it must first be validated in spaceflight analog environments. In the current study Astroskin data will be compared to traditional biomedical instrument measures of electrocardiography (ECG), respiration rate, and systolic blood pressure. The data will be recorded during Autogenic Feedback Training Exercise (AFTE), which is a type of physiological self-regulation training designed for astronauts. The data will also be recorded during simulations of the Orion spacecraft re-entry. The results to date suggest that Astroskin is a suitable ambulatory monitoring system that allows astronauts to self-diagnose and self-regulate adverse autonomic nervous system responses to sustained exposure to microgravity of spaceflight.

Overview

Astroskin is an ambulatory monitoring system for conditions where it may be difficult to collect health data such as in spaceflight missions or space analog environments . The purpose of this experiment is to validate Astroskin as a viable replacement for traditional wet electrodes, blood pressure cuffs, and respiration monitors that are currently being used. The data from the Astroskin and the data from the standard devices for physiological monitoring must have a high correlation. If Astroskin provides high quality data, the system can be further developed for spacesuit integration, extra vehicular space activities and extraplanetary exploration.





Methodology and Materials

For the purpose of this study, ECG, systolic blood pressure, and respiration data from two devices were recorded simultaneously and compared. ECG (wet electrodes), and a respiration strain gauge were connected to a Flexcomp data encoder. Blood pressure was recorded with a Finapres instrument described in the Blood Pressure section. This data was sampled at a rate of 250 Hz. The Astroskin electronics module connected to a garment consisting of integrated textile based sensors. Astroskin's sample rates for ECG, respiration, and systolic blood pressure estimated from Pulse Transit Time were 256 Hz, 128 Hz, and 1 Hz, respectively. The data were also sent wirelessly via Bluetooth to a mobile device for displaying the data.

2 males and 2 females (mean age 30.75±3.59) participated in this study. The participants were studied during an AFTE training session where they were given specific self-suggestion exercises and biofeedback to control various autonomic nervous system responses. In addition, subjects were tested in a rotating chair which elicited motion sickness symptoms similar to what crew experience during spacecraft re-entry.

The raw data, in the form of CSV files, were imported into DADiSP software for post-processing (e.g., visualization, filtering, peak detection).

Electrocardiogram

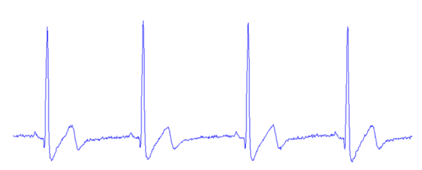


Figure 1, Astroskin ECG

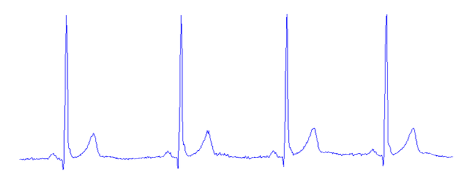


Figure 2, Flexcomp ECG

The raw ECG signals above were measured simultaneously from one male participant using the Astroskin and Flexcomp devices. The data clearly show the QRS complexes with slight variations due to the different positions of the electrodes. DADiSP calculates the heart rate from the raw Flexcomp ECG signal, while Astroskin calculates heart rate using its own algorithm. The 15 second block averages of heart rate showed a high correlation (*r=0.989*). When the Astroskin garment has the correct fit on the body, the heart rate measurements from the two devices are almost identical (Figure 3).

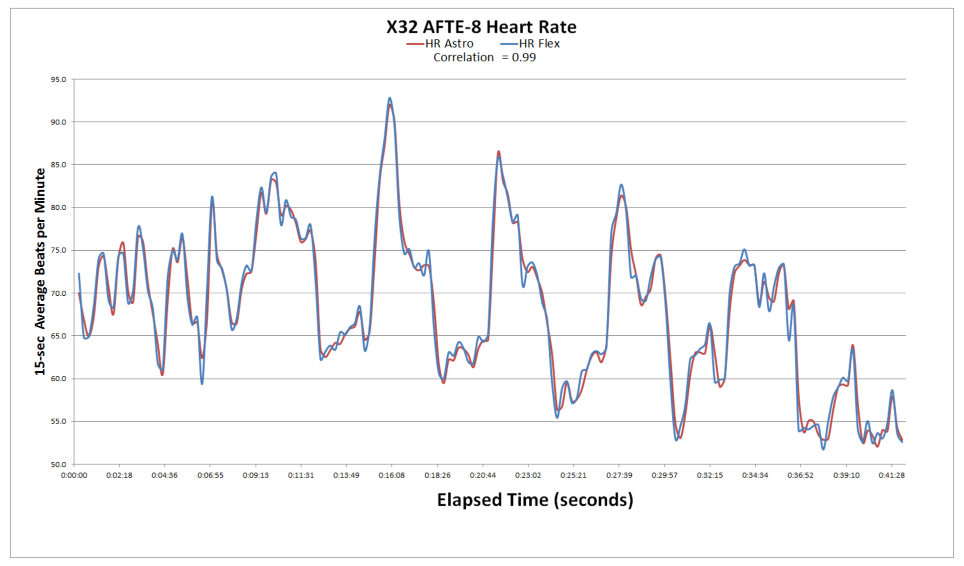


Figure 3

Some data was excluded from this study because of external noise in the ECG signal most likely caused by the electrodes from the impedance cardiograph also located on the subjects thorax. A poor ECG signal would also affect Astroskin's blood pressure measurements, since this is derived from pulse transit time which relies on R-wave peaks.

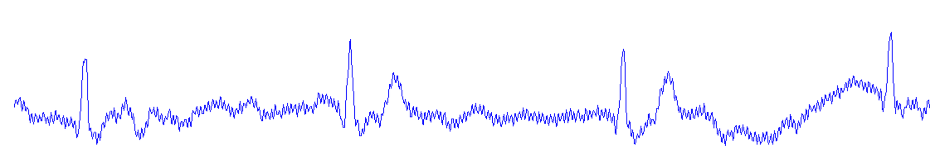


Figure 4, Noise in ECG

Respiration

Lungs filled with air

www.hexoskin.com

Lungs empty

Astroskin uses dual respiration channels to measure respiration rate. These sensors are positioned on the chest and abdomen. Inhalations and exhalations are detected from thorax expansion, and the time between each breath is measured.

The Flexcomp respiration data was measured with a strain gauge sensor placed around the chest. Astroskin's data showed a smoother respiration curve while the Flexcomp had spikes. The Astroskin algorithm uses the last 8 inspirations in a moving average to estimate the respiration rate while all Flexcomp data is block averaged. Both systems showed a moderately high correlation (*r=0.709*) which could be improved if the Flexcomp curve was smoothed.

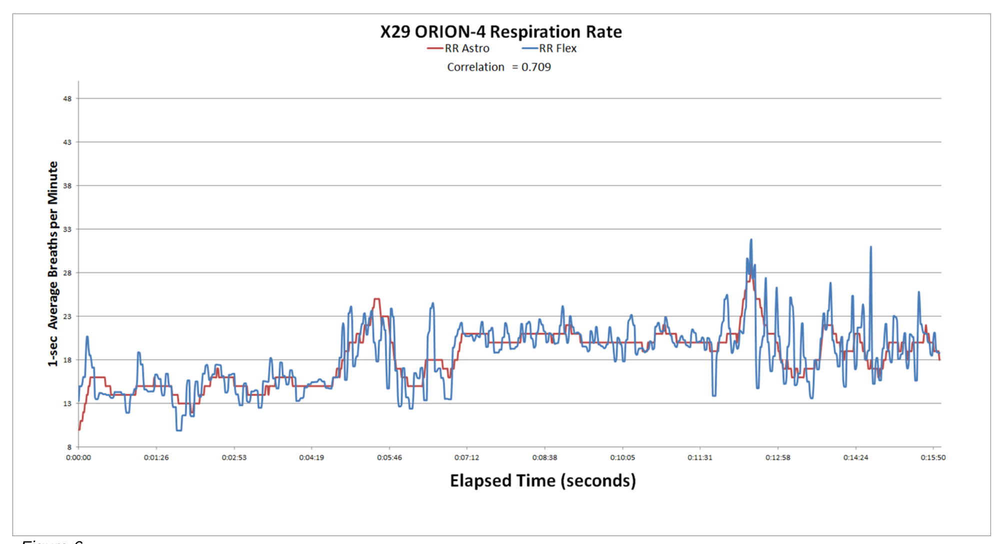


Figure 6

FlexComp data was shifted 9 seconds backwards to be properly aligned with elapsed time

Blood Pressure

The Finapres system utilizes the clamp method with a cuff measuring arterial pressure in the middle finger, while Astroskin uses photoplethysmography at the forehead and derives systolic blood pressure from pulse transit time. Blood pressure measurements obtained from the Finapres were significantly higher than measurements from the Astroskin which may be due to a positional effect of the sensor (finger versus forehead) relative to the heart. The blood pressure data from both instruments during an AFTE session is shown in Figure 5. The participant was trained to raise (arousal) and lower (relax) blood pressure at set intervals, and this can clearly be seen on the graph. Astroskin's algorithm seems to smooth the sharp changes in blood pressure and provides a better means of visualizing trends and analyzing changes in blood pressure in real time.

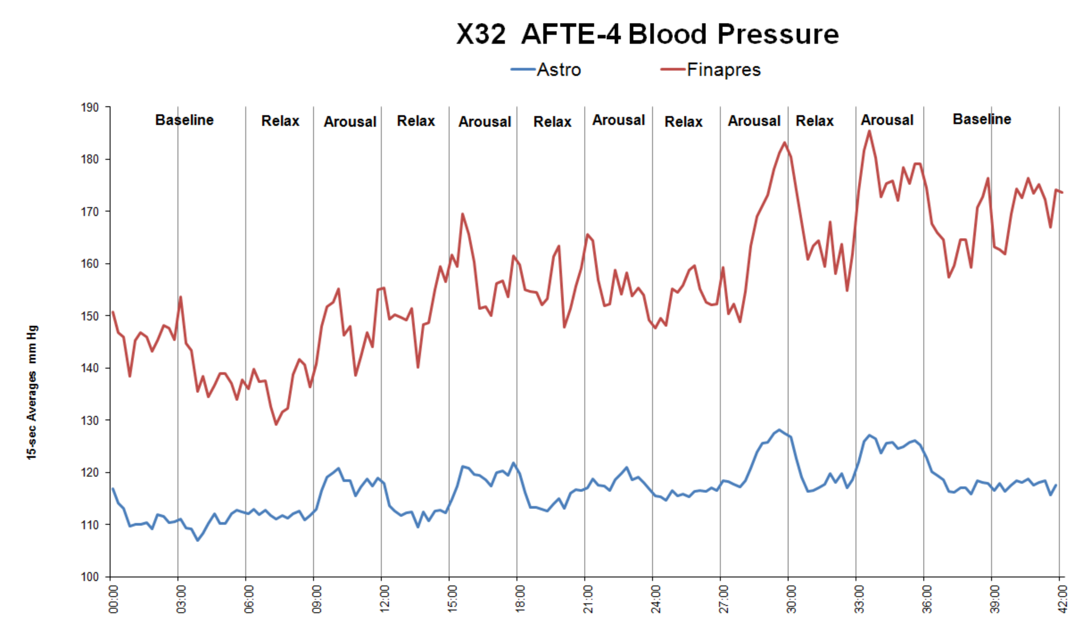
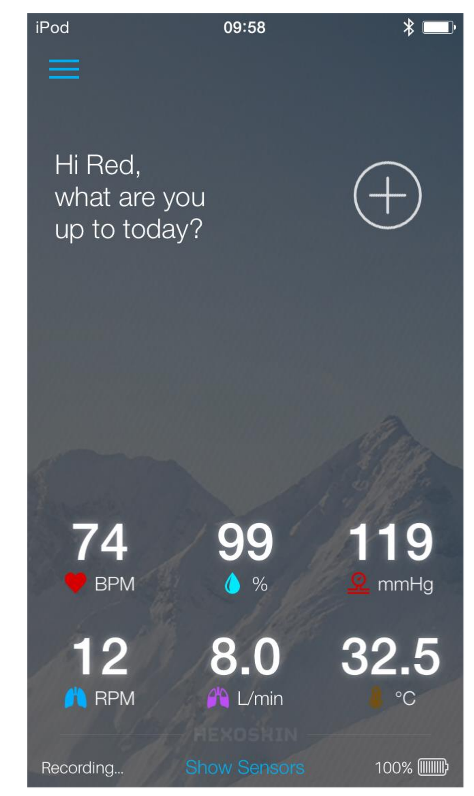


Figure 5

Conclusion

This study showed that Astroskin can be a valuable tool for astronauts. The sensors are able to produce high quality data without being invasive or obtrusive. This makes Astroskin more acceptable for monitoring astronauts for long periods of time. Astroskin can record data for more than 14 hours on a single battery charge, and the garment is <100 grams. It provides vital signs data immediately available to crew at any time. Given this information crew may learn to be more aware of their physiology and manage space-related symptoms. Future applications of Astroskin can include behavioral health monitoring during spacecraft re-entry, extravehicular activities, and exploration missions.

Astroskin's mobile application can provide all the health data from the biosensors wirelessly via Bluetooth. The data is updated in real time and can easily be seen on the display by the astronaut. In addition to the vital signs discussed in this study, Astroskin also displays oxygen saturation, volume of air inspired per minute, and body temperature.



Astroskin home screen

References

M. . Acromite, C. . Davis, P. S. Cowings, & W. B. Toscano (**2011**) **Operational Applications of Autogenic Feedback Training Exercise as a Treatment for Airsickness in the Military**, *Proceedings of the International Workshop on the Psychophysiological Aspects of Flight Safety in Aerospace Operations, 29-32, Warsaw, Poland, September 2011*

Carre Technologies inc (Hexoskin). (n.d.). Retrieved July 13, 2015.

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For further information

Please contact:

Arun Kumar: arun.kumar@sjsu.edu

Edwin Levin: edwinmlevin@student.hartnell.edu