Executive Report

Project Title: Using Smart-textiles and Virtual Reality for Artificial Intelligence Enabled Monitoring and Management of Sleep, Fatigue and Mental Health for Deep Space Exploration

Solicitation No.: WS3927164898

Contractor: Myant Corp.

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1 Introduction

This report summarizes the development of a cutting-edge health monitoring system funded by the Canadian Space Agency (CSA). The project focused on creating an autonomous system to monitor and manage the sleep, fatigue, and mental health of astronauts during deep-space missions. The technology leverages smart textiles, machine learning (ML), and a user-friendly dashboard to provide insights regarding mental well being of users by leveraging physiological data. These insights are then used to recommend VR well being exercises on an instrumented VR headset for detecting the benefits of the sessions. This system is designed for both space medicine and terrestrial healthcare applications, offering a self-contained solution that ensures data sovereignty and eliminates ongoing operational costs.

2 Technical Objectives

The primary technical objectives of this project were to:

- Develop and validate protocols for collecting physiological data related to stress, fatigue, and sleep using smart-textile-based solutions.
- Create and evaluate machine learning models to predict stress, fatigue, sleep quality, and physical health metrics from the collected data.
- Integrate these models into a comprehensive analysis pipeline.
- Develop an interactive dashboard to visualize the health metrics and provide insights for users.
- Develop neurobiofeedback exercises on a VR platform that can provide unsupervised mental health intervention and management exercises.
- Monitor mental states (relaxation, engagement and focus) using an instrumented VR headset (developed by Kaptics) while performing neurobiofeedback exercises

on the bWell (developed by National Research Council of Canada) platform.
- Advance the Technology Readiness Level (TRL) of the integrated system from TRL 4 to TRL 6.

3 Approach / Project Tasks

The project was executed in five distinct phases:

- **Protocol Design and Data Collection:** Four studies were designed to collect data using Myant's Skiin smart-textile garments:
    - **STAR (Stress and Tiredness Assessment in Real World):** Collected daily stress and fatigue labels alongside continuous multimodal physiological data.
    - **MARS (Morning Assessment Restful Sleep):** Monitored overnight physiology and collected subjective sleep quality data.
    - **PSG (Polysomnography) Study:** Collected clinical-grade sleep data to develop a sleep staging model.
    - **Physical Health Assessment Study:** Quantified exercise kinematics using textile-integrated IMU sensors.
- **ML Modelling:** A robust pipeline was created for preprocessing raw sensor data and extracting relevant features. Both classical machine learning (e.g., LightGBM, SVM) and sequential deep learning models (e.g., LSTM, TCNN, Transformer) were developed to predict health outcomes.
- **Model Evaluation:** Models were rigorously evaluated using appropriate metrics (e.g., Balanced Accuracy, Cohen's Kappa, or quaternion angular error) and a hold-out test set to ensure generalizability and minimize optimistic bias.
- **Dashboard Development:** An interactive dashboard was built using Apache Superset and containerized with Docker. It provides visualizations for daytime and nighttime reports, on-demand physical health assessments, and 7-day trend summaries.
- **Prototype Integration:** All components (wearable hardware, analysis software, and the dashboard) were integrated into a single, functional prototype system.

4 Accomplishments

- Successfully collected unique datasets for real-world stress, fatigue, and sleep quality as well as sleep staging from over 20 participants in the STAR and MARS studies.
- Developed and validated multiple ML and DL models for health monitoring, with the classical stress model comparable to state-of-the-art solutions.
- Created a novel dataset and model for real-world fatigue and subjective sleep quality detection, an area with limited existing research.
- Collected a clinical sleep dataset from 40 participants in a Polysomnography (PSG) study to serve as ground truth for a sleep staging model.

- Developed a deep learning model for sleep staging that optimized for deep sleep detection, which is crucial for rest and recovery.
- Engineered a deep learning model for estimating body orientation from gravity-free IMU data, a critical capability for microgravity environments, with results comparable to existing literature.
- Built a fully integrated, end-to-end prototype system, from data collection to visualization, packaged within a Docker container for easy deployment.
- Combined mental state insights from a VR instrumented headset into neurobiofeedback exercises for mental well being.
- Successfully advanced the technology from TRL 4 to TRL 6, demonstrating a functional prototype in a relevant environment.

5 Technology

5.1 Description / Status of Technology

- **Initial TRL:** 4 (Component and/or breadboard validation in laboratory environment).
- **Targeted TRL:** 6 (System/subsystem model or prototype demonstration in a relevant environment).
- **Actual TRL at Completion:** 6 (System/subsystem model or prototype demonstration in a relevant environment).

5.2 Innovative Aspects

One of the most novel aspects of the system is its approach to unobtrusive physiological monitoring. The sensing platform is seamlessly embedded into Skiin garments, which are light, comfortable, and machine-washable. This textile-integrated design allows for long-term, continuous monitoring without disrupting daily activities, making it highly suitable for both terrestrial and space-based applications.

Another key innovation lies in the use of real-world data for model development. Rather than relying solely on controlled or laboratory data, the system's algorithms were trained and validated using data collected in everyday conditions. This approach captures natural fluctuations in stress, fatigue, and sleep quality, leading to more generalizable models.

The system also employs multimodal analysis, integrating multi-lead ECG signals with inertial data from accelerometers. This fusion of physiological and kinematic data enhances the robustness and accuracy of health predictions by capturing both internal and external manifestations of physiological states.

A particularly unique innovation is the development of a gravity-free kinematic analysis model. This deep learning model infers physical health metrics in gravity-independent scenarios. Such functionality is critical for monitoring astronaut biomechanics in space, where traditional IMU-based kinematic cues are unreliable.

The system is designed as an autonomous, self-contained unit, eliminating the need for cloud-based computation or data transfer. All sensing, analysis, and reporting occur locally, which ensures both data privacy and operational reliability in bandwidth-limited or isolated environments such as deep space missions or rural healthcare settings.

5.3 Application Fields

This technology holds significant promise in space medicine, where it enables autonomous monitoring of astronaut health, stress, and performance during long-duration missions. Its unobtrusive and self-sufficient design makes it ideal for communication-limited conditions.

In remote healthcare, the system facilitates continuous patient monitoring in geographically isolated or underserved communities. It allows clinicians to assess patients' physiological and physical conditions without requiring frequent in-person visits or complex infrastructure.

The system is equally applicable in occupational health, especially in professions characterized by high physical or psychological stress, such as first responders, law enforcement, and aerospace personnel. Continuous monitoring supports early detection of fatigue or physiological anomalies, enhancing both safety and performance.

In the consumer wellness domain, the technology offers a high-fidelity tool for individuals seeking to track their fitness, recovery, and stress levels with clinical-grade precision, seamlessly embedded into everyday clothing.

Finally, the platform is well-suited for clinical research, enabling high-resolution, longitudinal data collection across diverse populations and settings. This capacity supports the generation of rich datasets for studying chronic conditions, behavioral health, and intervention outcomes over time.

6 Business Potential, Benefit, and Impact on the Company

This project has significantly advanced the company's technical capabilities in autonomous health monitoring systems. Through this project, the team has developed specialized expertise in edge computing architectures, autonomous database management, and real-time physiological data processing. The successful implementation demonstrates an ability to build mission-critical systems that operate reliably in resource-constrained environments. The successful demonstration of a TRL 6 prototype opens opportunities for further collaboration with space agencies and for commercialization in terrestrial markets.

7 Ownership of Intellectual Property

The intellectual property generated during this project is owned by Myant.