Mini-Symposia Title:

Engineering and Medicine in Extreme Environments - Part I

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Mini-Symposia Speaker Name & Affiliation 1:

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Mini-Symposia Speaker Name & Affiliation 2:

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Mini-Symposia Speaker Name & Affiliation 3:

Anastasiia Prysyazhnyuk, Ontario Tech University

Roman …, Russian Space Agency

Mini-Symposia Speaker Name & Affiliation 4:

Rob Riddell, Canadian Space Agency

Theme:

- ○ 01. Biomedical Signal Processing
- ○ 02. Biomedical Imaging and Image Processing
- ○ 03. Micro/Nano-bioengineering; Cellular/Tissue Engineering & Biomaterials
- ○ 04. Computational Systems & Synthetic Biology; Multiscale modeling
- ○ 05. Cardiovascular and Respiratory Systems Engineering
- ○ 06. Neural and Rehabilitation Engineering
- ◉ 07. Biomedical Sensors and Wearable Systems
- ○ 08. Biorobotics and Biomechanics
- ○ 09. Therapeutic & Diagnostic Systems and Technologies
- ○ 10. Biomedical & Health Informatics
- ○ 11. Biomedical Engineering Education and Society
- ○ 12. Translational Engineering for Healthcare Innovation and Commercialization

Mini-Symposia Synopsis— Max 2000 Characters

Extreme environments, such as naturals (underwater, altitude, space, geographic poles, volcanoes, desert,…) or forced/man-made (extreme sports, emergency forces, armed forces) are conditions where specific physiological adaptations in the human body are triggered to maintain physiological functionality and to ensure survival.

The general goal in the medical and engineering areas can be formulated as: to enhance human comfort, performance and survival in extreme environments.

The Mini-Symposia will present world-leading experts in varying research fields ranging from engineering and medicine in diving, space, tactical forces and other extreme environments to present on their current research fields of device engineering, computer science and medical application scenarios.

This Mini-Symposia is Part I of a two Mini-Symposia in Engineering and Medicine and Extreme Environment at the EMBC'20 Montreal, in combination with a Mini-Symposia Engineering and Medicine in Extreme Environments Part II which is also proposed and organized by T. Cibis, C. McGregor

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Wearable and Intelligent Technology for First Responders

Jeffrey S. Palmer, Brian A. Telfer; MIT Lincoln Laboratory, Lexington MA USA

***Abstract*— First responders working in extreme environments need wearable sensing and intelligent devices to stay safe and maximize human performance. Progress is highlighted in the areas of wearable sensing to avoid physical injury and disease, cognitive monitoring to maximize team performance, and intelligent devices that provide just-in-time training to allow efficient responses in high-pressure situations.**

I. Introduction

First responders include paramedics, firefighters, wildland firefighters, police, and specialized teams that respond to chemical, biological, radiological or nuclear (CBRN) incidents. In the U.S. alone, more than two million people serve in these roles, with numbers ranging from about 1.2 million firefighters to about 18,000 CBRN responders. Although the specifics of their work vary considerably, many first responders share these challenges: 1) the need to wear encapsulating, encumbering, heavy protective equipment for protection against fire, toxins or bullet fire, 2) the need to operate as a team in an unknown, unpredictable, cognitively demanding environment, 3) the need to facilely operate diverse specialized medical or sensing equipment. Wearable and intelligent technology can aid in addressing each of these challenges by: 1) monitoring individual physiological state to avoid physical injury and disease, 2) monitoring individual cognitive state to maximize team performance, 3) providing AI-enabled devices that provide just-in-time training.

II. Applications

As examples of wearable systems to avoid physical injury and disease, three applications will be highlighted. First, to avoid heat injuries, a wearable system prototyped by MIT Lincoln Laboratory and the U.S. Army has been transitioned to industry and has been matured as a product. This system has been tested on over 2,000 subjects in the field. Another wearable system intended to detect early onset of musculoskeletal injury has also prototyped and transitioned to industry. To provide early detection of infection, which can be valuable to Ebola responders and CBRN teams, algorithm is being prototyped and tested.

In order to maximize team performance, it is important to understand the cognitive state of each team member, to understand whether they are cognitively overloaded and sufficiently alert. With this information, team members can rebalance workloads and adjust work-rest cycles. This is important for human teams, but even more so for human-machine teams. Robots are being increasingly integrated with first responder teams. Recent progress in multimodal cognitive monitoring that is suitable for field operation will be reported. Sensing modes include voice, facial video, and eye tracking from wearable electrooculography.

First responders are trained to use multiple types of technology, but may not use that technology every day. However, during a high-pressure situation, the responders need to be able to rapidly employ that technology. For example, during a mass casualty event, paramedics need to rapidly triage a large number of casualties and perform life-saving interventions before the patients are taken to the hospital. Artificial intelligence is needed to quickly guide the medics through the triage and interventions. Examples of these technologies that are being prototyped will be described.

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Serious Games for Firefighter Training

F. Michael Williams-Bell, Durham College

Abstract— **Firefighters are required to perform physically demanding tasks in life-threatening situations where they are exposed to physical, psychological, and environmental stressors. This very specialized environment makes it difficult to conduct training with all stressors present. Virtual simulations provide an opportunity to incorporate some of these stressors in a safe and cost-effective manne**r.

I. INTRODUCTION

Firefighting involves physically demanding activities, such as victim search and rescue, that imposes physiological strain and requires the firefighter to maintain cognitive function while performing tasks under conditions of extreme heat and psychological stress [1]. In a burning structure, firefighters can be exposed to temperatures from 38° to 93.3°C [2, 3] and may even exceed 200°C [4]. In addition to the environmental stressors, firefighters are required to wear personal protective equipment (PPE) that is thick and multi-layered, affecting the thermal balance of the body. The thermal insulation of the clothing ensemble is not the only mitigating factor affecting physiological strain on the wearer as the additional weight of the PPE increases metabolism and subsequently increases metabolic heat production [5].

II. FIREFIGHTING AS AN EXTREME ENVIRONMENT

The environmental stressors imposed on firefighters creates a situation of uncompensable heat stress; a scenario where the increase in metabolic heat production exceeds the body's ability to dissipate heat. To combat this, the firefighter must be removed from the extreme environment and into a situation where heat loss exceeds heat storage. In addition, firefighters must wear a self-contained breathing apparatus (SCBA) to combat lethal smoke inhalation during a fire or hazardous material (Hazmat) scenario. The ability to manage air supply with respect to controlling the amount of time in the hazardous area is known as "air management" (National Fire Protection Association, 2006). As of 2013, the National Fire Protection Association standard 1981 was revised to implement an audible low-air alarm that is sounded on the firefighter's SCBA once there is 33% of air remaining (known as reserve air) in their air cylinder. Furthermore, NFPA 1404 (Standard for Fire Service Respiratory Protection Training indicates that firefighters should exit a scenario before consuming their reserve air. Typically, firefighters use a 20-minute work cycle during a residential fire; however, previous work in our lab revealed during simulated large structure firefighting activities (i.e. high-rise buildings, big box stores), low-air alarms could be activated in as little as 10-minutes [6]. Despite this finding, these studies did not include all environmental stressors that firefighters are exposed to. This, in particular, becomes difficult for training purposes as uncontrolled emergency scenarios cannot be replicated during live-fire training.

III. SERIOUS GAMES FOR FIREFIGHTING TRAINING

Unlike working with real fires, virtual simulation allows trainees to make and correct mistakes, while allowing them to experience situations that cannot be recreated in the real-world due to ethical and cost concerns [1]. The majority of existing virtual simulations and serious games have primarily focused on the training and education of incident commanders within an organization and communication of multiple fire personnel at an emergency scene [1]. The next step is to utilize the benefits of the gaming environments in recreating physical and psychological stresses are analogous to a live simulation [1].

IV. DISCUSSION & CONCLUSION

Firefighting is a strenuous occupation that can be conducted in numerous extreme environments making it extremely difficult to train for all possibilities. Virtual simulations may allow for training to incorporate additional stressors that are present in real scenarios while ensuring a safe environment.

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Physiological Monitoring in Space from First Manned Missions to the Future on Mars

Anastasiia Prysyazhnyuk and Carolyn McGregor,
Ontario Tech University

***Abstract*— The first manned space mission was completed over half a century ago. Since then, the field of space travel and exploration has seen revolutionary advancements of science and technology, redefining the limits of the human mind and body, while enabling the humankind to continue exploration of extreme habitats within the solar system, putting a man on the Moon, and on Mars in the near future. Human space exploration necessitated development of human space healthcare, as a separate field of medicine, to monitor, diagnose, preserve, and intervene, whenever possible, to preserve health and well-being of astronauts. This paper presents a brief overview of physiological monitoring in space from first manned space missions to the future on Mars, highlighting the future space healthcare needs required to develop capacity to support deep space exploration.**

I. INTRODUCTION

The first manned space flights were pioneered by the former Soviet Union and date back to the early 1960's, when very little was known about the effects of spaceflight environment, such as weightlessness, confinement, isolation, radiation exposure, acceleration, solar flares, etc [1]. The knowledge acquired from animal spaceflights and terrestrial simulation experiments was used in order to investigate the various effects of spaceflight environment and how they might impact physiological performance and well-being of a human [1].

The initial health monitoring of astronauts in space was based on the principles adapted from aviation medicine, which further served as a foundation of space medicine. Physiological monitoring of astronauts is performed pre-, in- and post-flight. The pre- and post-flight monitoring is very comprehensive, mainly attributing to availability of complex state-of-the-art terrestrial biomedical monitoring modalities. However, the biomedical capacity in-flight is significantly reduced due to physical space constrains, user-interface and system operability, lack of communication with the terrestrial Mission Control Centres, delays in transmission, limited crew medical expertise and other specifics of spaceflight environment that greatly limit the availability of medical monitoring modalities in-flight. Wearable technologies have been introduced on the ISS since the end of 2018 [2], yet Holter-style monitoring devices are still in-use [3]. Current in-flight medical monitoring is scheduled, fragmented and heavily relies on terrestrial telemedicine support, necessitating development of comprehensive autonomous medical decision support systems.

II. METHODS

Big Data analytics framework, known as Artemis, is being proposed for in-flight use, to enhance medical autonomy and diagnostic capability of the crew. Figure 1 summarizes the overall architecture of the proposed platform.

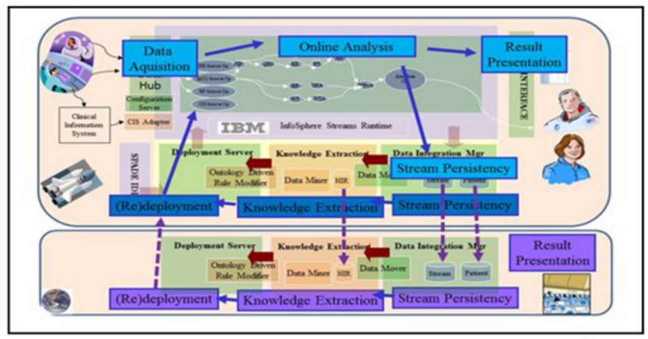

Figure 3. Online health analytics platform during spaceflight [7]

Figure 1. Artemis in-flight big data analytics platform [3].

III. DISCUSSION & CONCLUSION

Deep space exploration necessitates development and implementation of innovative biomedical monitoring modalities in-flight, to enhance crew's medical capacity, establish autonomy and enhance diagnostic capacity. The proposed Big Data analytics platform has the capability to function as an in-flight self-sufficient autonomous clinical decision support system and support prognosis, diagnosis and offer clinical intervention guidance, with no or minimal support from the Mission Control Centres.

Acknowledgment

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Lunar Exploration Health Initiatives from Long Range Missions and those in Medically Remote Communities

Rob Riddell, Canadian Space Agency

***Abstract*— Providing healthcare to astronauts on long duration health missions and medically remote Canadians is a complex and challenging task. In this talk Dr Riddell will present the vision of the Lunar Exploration Health Initiatives for long duration missions and medically remote Canadians.**

I. INTRODUCTION

Providing healthcare to astronauts on long duration health missions and medically remote Canadians is a complex and challenging task. Lunar Exploration Health Initiatives aims to find home-grown medical solutions that will not only be essential to astronaut health on long duration missions but contribute significantly to the health of medically-remote Canadians including those living in Arctic communities.

In this talk Dr Riddell will present the vision of the Lunar Exploration Health Initiatives for long duration missions and medically remote Canadians. Dr Riddell was selected as the a Flight Surgeon in the Operational Space Medicine Group at the Canadian Space Agency after finishing in the top 4 in the 2017 Astronaut Recruitment Campaign. He was Deputy Crew Surgeon for Astronaut David Saint-Jacques' long-duration mission to the ISS in 2018/2019.