A Multimodal Database for Mental Workload, Stress, and Fatigue Assessment of Ambulant First Responders

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I. Background

Ambulant first responders, such as police officers and paramedics, are deployed in various situations with high uncertainty and, sometimes, high risk. Assessing ambulant first responders physical and mental state can help support coordination of units and can help provide real-time support to those in need. In the last years, researchers have proposed models to detect mental states of individuals based on their physiological response [1], [2]. However, these models might not be able to detect differences between some combinations of states, such as mental workload, stress, or fatigue [3]. This limitation implies that we cannot differentiate someone focusing efficiently on his/her task (mental workload) from someone potentially needing assistance (stress) or fatigued. Furthermore, these models are often trained to detect mental states when the user is stationary, which is not representative of the work environment of first responders [1]. To ensure models are able to detect multiple combinations of different mental states and to assure they are robust to physical activity, new databases must be introduced to the scientific community. In this project, we present a multimodal physiological database intended to modulate multiple state detection models in ambulatory settings.

II. Methods and Materials

This project is divided into 3 distinct data collection phases. In the first phase of the project, 48 participants performed an experiment in which mental workload and physical activity were jointly modulated. The task used was the Revised Multi-Attribute Task Battery (MATB II) [4]. In this computerized task, participants must simultaneously monitor changes in gauges, maintain a moving crosshair near its target position and balance a set of fuel reservoirs (see Figure 1. Mental workload was modulated at 2 levels (easy, hard) by changing the difficulty of these three subtasks. Participants performed the task either on a treadmill or on a stationary bicycle (see Figure 2). Physical activity was modulated by changing the speed they had to maintain during the task. These levels were: no physical activity, medium physical activity (treadmill: 3km/h, bike: 50 rpm) or high physical activity (treadmill: 5km/h, bike: 70 rpm). All combination of workload and physical activity were completed by participants (for a total of 6 trials, each lasting

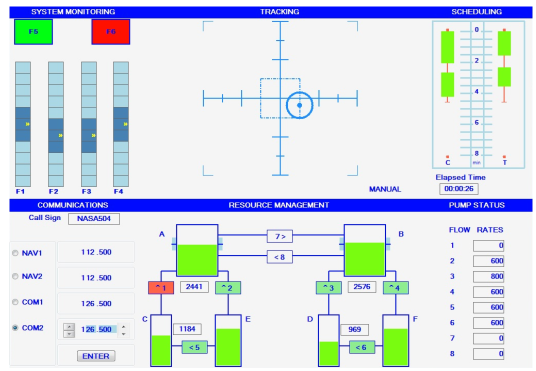

Fig. 1. Screenshot from MATB-II.

10 minutes). The condition order was counterbalanced across participants. The NASA Task Load Index (NASA-TLX) and the Borg Questionnaire were recorded after each trial [5], [6]. A short pause was also introduced between each trial. During the trials, physiological activity was recorded using three devices. Electrocardiographic and breathing activity was recorded using a Bioharness 3 chest strap (Zephyr, USA). Electrodermal activity, skin temperature and blood volume pressure were recorded with an E4 wrist band (Empatica, USA). Finally, electroencephalographic activity was recorded using an Enobio 8-channel wireless headset (Neuroelectrics, Spain).

During the second phase, 48 participants performed an experiment in which stress and physical activity were jointly modulated. Stress was modulated on a two level scale. In the low stress condition, participants played the computer game *TIMEframe* (Random Seed Games). TIMEframe is an exploration game in which a player must retrieve artifacts in an abandoned city. There is no threat in this game (players cannot die) and it features some relaxing elements (such as a peaceful soundtrack). In the high stress condition, participants played *Outlast* (Red Barrel). Outlast is a survival game in which players must navigate an eerie asylum and escape its dangerous inmates. The game features stressful elements such as scary sceneries and horror-like sound effects. All participants performed this experiment on a stationary bike. Condition order was counterbalanced across participants. Physical activity was again modulated on a three level

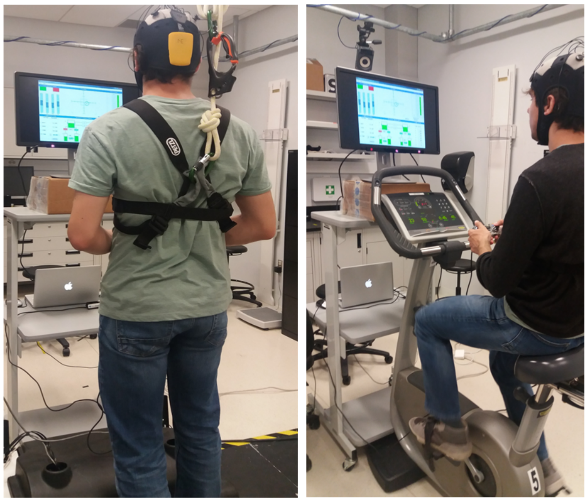

Fig. 2. Treadmill (left) and stationary bike (right) setup.

Fig. 3. Screenshot from TIMEframe.

scale (same as phase 1). Participants also performed all six combination of stress and physical activity (trials also lasted 10 minutes each). NASA-TLX and Borg questionnaires were administered after each trials. Physiological activity of the participants was also recorded with a Bioharness 3 and an E4 wristband. Neurological activity was recorded using a Muse 4-channel EEG headband (Muse, Canada).

The third phase of the project was done in partnership with the Quebec Province Police Academy (french: *École Nationale de Police du Qubec*, ENPQ), and physiological activity of police trainees were recorded while they performed real-life shooting exercise. These exercises included typical accuracy training, but also decision-making during

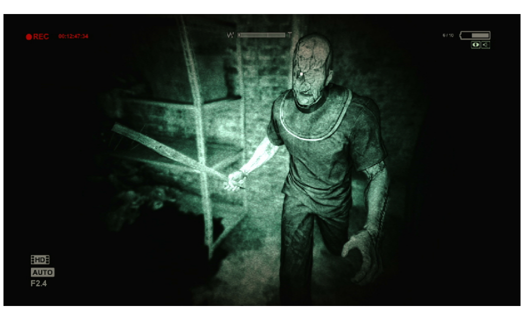

Fig. 4. Screenshot from Outlast.

use of firearms, displacement and team cooperation. Some of the exercises were performed in a shooting range. Exercises performed in this range were done with real firearms. The rest of the exercises were performed inside a realistic shooting simulator. This shooting simulator was used to simulate interactions between police trainees and suspects/victims. These exercises were performed with electronic firearms. Participants were donned with a Bioharness 3 chest strap during all exercises. Participants also wore a Fitbit (Fitbit, USA) during the full duration of their 15-week semester. NASA-TLX and Borg questionnaires were also recorded after each exercises.

III. Database Availability

The three datasets described herein will be made available to the public at `http://musaelab.ca/resources/`. The raw and pre-processed physiological signals along with the questionnaire answers will become available by the end of 2019.

IV. Conclusion

This abstract has summarized the creation of three databases developed to allow researchers to investigate physiological and neurophysiological responses of individuals performing both mental and physical tasks concurrently. It is hoped that the database will allow for the development of operator functional state models that that into account factors such as stress, mental workload, and fatigue, thus providing real-time support to first responders. Moreover, the database can be used to develop physiological signal enhancement algorithms, as well as to train machine learning algorithms robust to physical activity. The database will be available publicly online to interested researchers.

V. Acknowledgements

The development of these database was only made possible via the funding support from NSERC Canada, PROMPT Quebec, MITACS, and Thales Canada. The authors would like to thank the ENPQ for their contribution to this project.

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