NENS Exchange Grant Final Report

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Project Title: EEG during stress and aggressive behavior: Identification of candidate neuro and physiological signatures for EEG feedback protocols
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1. Introduction

Aggression is often perceived as a harmful social interaction to inflict intentional damage or other unpleasant behavior upon another individual. One of the primary questions in the aggression literature is whether there are biomarkers that reliably predict aggressive behavior? Many studies have demonstrated the potential for using machine learning tools to identify objective biomarkers useful for diagnosing, monitoring, and eventually predicting stress and aggressive behavior. With this study, we aim at identifying neuro and physiological biomarkers associated with aggression during an aggression paradigm done in virtual reality (VR) and to build a machine learning algorithm that can reliably predict aggressive behavior based on a set of physiological biomarkers and some behavioral analysis.

2. Methods and results

In this experiment, stress responsiveness and behavior in VR are investigated to find out how do personality traits and individual differences in stress responsiveness affect physiological and behavioral responses to different tasks. During the aggression task, participants compete against an opponent in a speed trial, for several trials. They can choose to improve their chances of winning by either making the task easier or delivering a mild electric shock to the opponent. Aggressive behavior is estimated from the sequence of choices participants made. Behavioral and physiological responses are recorded during each phase of the experiment.

The primary goal of our study is to build a machine learning algorithm that, once trained on a dataset using the variables extracted from physiological signals collected in real-time, will be able to predict aggression. This study is focused on analyzing four physiological biomarkers associated with aggression during an aggression paradigm performed in virtual reality (VR): skin conductance, which is a measure of sympathetic nervous system activation; electrocardiogram that measures sympathetic nervous system activation and parasympathetic counterbalance; respiration rate, which can indicate sympathetic nervous system activation and parasympathetic counterbalance; and Photoplethysmography which can reflect neurohypophysis activation, HPA axis activation, sympathetic nervous system activation, and parasympathetic counterbalance.

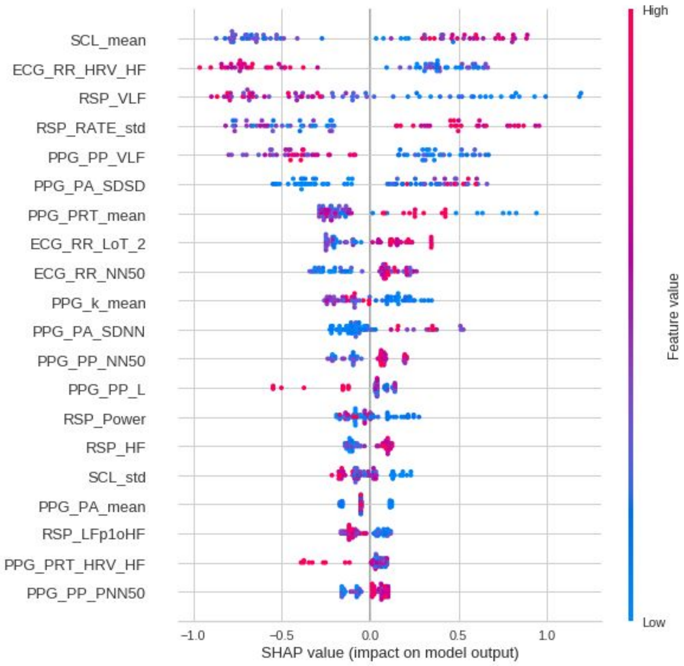

Figure 1. SHAP summary plot for the aggression dataset using XGBoost model

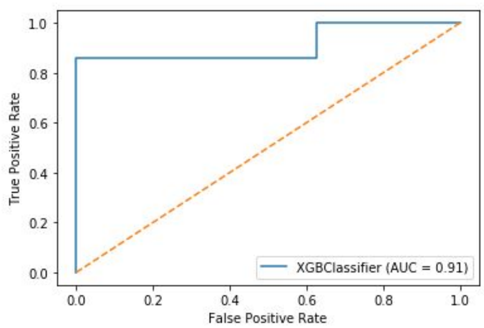

Figure 2. Classification result for the aggression dataset (labeled stress versus control group) using XGBoost model with an area under the curve of 91%

In this analysis, we examined stress and aggression responses of healthy participants using multiple physiological signals. We selected the most informative biomarkers for the model based on SHAP values (Figure 1). Then, we built two optimized models and trained the algorithms on a majority subset of our datasets, and tested the learning performance through a cross-validation procedure. We also evaluated the performance of our trained models on an unseen test set. By combining selected features from these different measures using a machine learning-based algorithm, stressful states could be identified from non-stressful states with up to 95% accuracy. Moreover, our machine learning models suggest that participants can be classified by the type of aggressive behavior with accuracies of up to 90% (Figure 2). We are going to publish these results soon in a relevant journal.

3. Acknowledgments

The NENS Exchange Grant provided me with the opportunity to experience a training period in an enriching international environment at the Laboratory of Behavioral Genetics at the EPFL, under the supervision of Carmen SANDI, where I not only learned about behavior, stress, and aggression but it also allowed me to finalize my master’s in Neurosciences. I would like to thank my supervisor and all the team members as well as the NENS Committee of Higher Education and Training for providing me with this magnificent opportunity.