Comparative assessment of drivers' stress induced by autonomous and manual driving with heart rate variability parameters and machine learning analysis of electrodermal activity

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Background: Nowadays research on Autonomous Driving Systems (ADS) and attention towards novel technology allowing real-time assessment of car drivers' psycho-physiological status is growing, to quantify driver's stress during semi-autonomous or autonomous driving assistance and to investigate human reaction to different types of ADS. We present a system for automatic stress detection with combined machine learning analysis of Skin Potential Response (SPR) and electrocardiographic (ECG) recordings to compare the driver's stress reaction during both manual and autonomous driving sessions carried out in a dynamic professional drive simulator (PDS).

Methods: All data were acquired after informed consent from 14 healthy volunteers (HVs) in the Vi-grade (Udine) PDS. Two SPR signals (one from each hand) and three chest ECG leads were recorded. A Motion Artifact (MA) removal algorithm was used to remove motion artifacts from SPR signals. A cleaned, single SPR signal, obtained as the RMS value by combining the two original signals, was then sent together with the time-variation of heart rate (HR) to a Machine Learning (ML) classification algorithm, i.e., a Support Vector Machine (SVM), based on some specific features of this signal. The output of the SVM provides a series of labels, that indicate the presence or lack of stress episodes during the driving experiment. Stress occurrence was also independently quantified with heart rate variability (HRV) analysis in the time (TD) and frequency (FD) domains and with non-linear (NL) methods.

Results: All participants completed the driving protocol consisting of two subsequent sessions, one with conventional manual (MD) and the other with autonomous (AD) driving settings, along a highway where some unexpected events occurred, inducing different level stress response.
Figure 1 shows an example of time variant changes of the RMS SPR signal and of the HR of one tested individual during both experimental settings. A simultaneous increase of both SPR and HR signal is apparent during the stress episodes correctly identified by the SVM (gray shadows). Discriminant analysis of FD (VLF, LF and HF) and NL (SD1, SD2, Entropy and Recurrence Plot) HRV parameters, independently assessed by two researchers blind to SVM results, differentiated between stress induced by MD and AD (accuracy: 88,4% cross-correlated) in good agreement with automatic SVM assessment. In general stress level was lower during the AD, being all HRV parameters not significantly modified from baseline rest. SPR amplitude eventually increased also during AD, but SVM efficiently differentiated between AD and MD stress anyhow.

Conclusions: The proposed method for automatic assessment of stress reactions of car drivers with SVM of SPR and HR signals is reliable, in both MD and AD scenarios. The results seem to evidence that MD is in general more demanding than AD inducing higher activation of sympathetic nervous system, especially in critical situations.

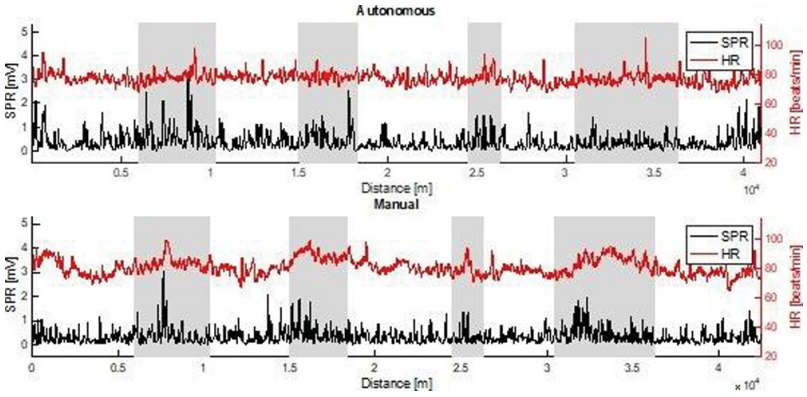

Figure 1. Time variance of SPR and HR.