The *e-motion* system: an integrated device to evaluate drivers' functional state in the field

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Research has now provided ample evidence that drivers' functional state should be assessed through multiple recordings from several fields. Drivers' functional state may be studied indirectly through data from the vehicle. Physiological indicators are believed to bring reliable information when available directly and often give anticipated cues about the forthcoming behaviour. A set of bio signals such as electrodermal activity, heart rate or respiratory frequency represent useful and objective data which may be recorded in real time. Indeed, variables of the autonomic nervous system are known to mobilize energy resources of the organism, in response to internal and external milieu demands. The main role of the sympathetic branch is to face up emergency situations. As electrodermal activity (EDA) is under the control of the sympathetic nervous system only, it is closely correlated to arousal and its variation. Recordings from the vehicle and the driver himself through specific systems integrating data on the same time scale should give valuable information for a close estimation of drivers' functional state, its evolution across time and thus to a better understanding of human being functioning.

Many separated systems do exist, each with a specific aim at studying a particular aspect of drivers' behaviour. The main objective of our work is to propose an integrated system, made of several sub-units, each capable of giving valuable solution to a scientific question related to drivers' behaviour.

Specific needs

There is a need to coordinate data from the car to information from the driver himself (physiological and behavioural parameters) and to external data from the environment. Dynamic vehicle parameters provide objective data (speed or command uses). More, some of these parameters give direct information about driver's motor activity (e.g. steering wheel angle or pedal depressions). Physiological analogical signals are recorded from micro sensors placed on the non-dominant hand (the palm is strongly innervated by the sympathetic skin endings, controlling sweat glands). Signals could be processed before being digitized via an acquisition card and analyzed with specific software. Video is aimed at providing data about the driving context and the in-vehicle scene. Data could be compressed easily and recorded on hard disk and bring information from four different scenes (front and rear driving space, drivers' feet position on the pedals and large plan on the driver's face).

Thus, there is a specific requirement to provide synchronization of psycho physiological, video/contextual and vehicle parameters recordings. Such a device must also be car-embeddable. The last stage is to benefit from data files easy to read and analyze with a dedicated and ergonomic tools.

Vehicle parameters: CAN

A CAN bus is available on each car and the CANalyser system (Vector GmbH) is aimed at recording data from the main car systems. These are stored as a CANalyser file, available for further exportation prior to analysis.

Physiological signals recording device

The recording device has the potentiality to record several different physiological signals: skin resistance, skin potential, raw ECG, or nasal air flow temperature. Any other parameter may be selected if needed (skin temperature, skin blood flow). This acquisition device is made to convert analogical voltage measures into relevant digital physical quantities, sampled at 10 Hz. A dedicated software interface called *e-motion* is dedicated to pilot the device. Physiological data are then stored in dedicated files: a new file is created and saved every 5 minutes to prevent accidental data loss.

Video

A quad unit concatenates video flux from four analogical cameras and a frame grabber (Dazzle DVC 80) converts video signal from analogical to digital. The video acquisition software, called *V-motion* compresses video data at a DivX format and stores data in *avi* file-format. The *V-motion* software makes the slaves storing data in the same file directory. The experimenter may have a look on the recordings at any time, date each event by using an event-marker and add any commentary related to the observation of the road scene. Further analysis may then associate cinematic and physiological data with each event and thus bring objective information related to drivers' behaviour.

Contextual data

External events may easily be tagged during data acquisition. The more probable events may be previously predicted and thus pre-written in a specific configuration file (using the *PiloteErgo* software). Unexpected events may nevertheless be added easily during the experiment.

Data synchronization

The *V-motion* software integrates a strip with the time elapsed since start. A reliable time-scale is easily obtained from the core's computer. This time is given as the reference time for all other devices. As shown by Figure 1, the *V-motion* device is the master software that triggers and stops all other acquisitions, including the control of the *e-motion* device driver program, the *CANalyser* control via the *PiloteCAN* software and the setting of *PiloteErgo*'s time for contextual events dating.

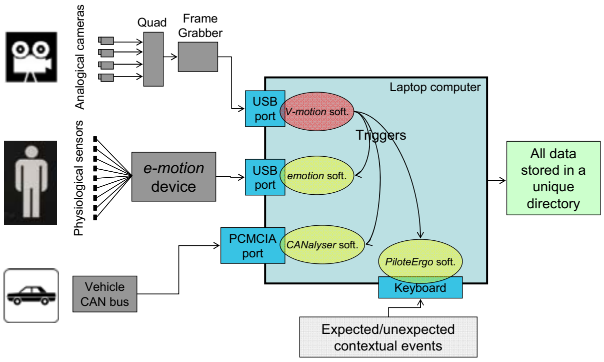

Figure.1. *Schematic representation of the data acquisition device.*

Data analysis

Data analysis is based upon the *LVA* and the *CaroLab* sofware. The *LVA* manages the video movie while the *CaroLab* (*MatLab* - The Mathworks, Inc.) provides the interface displaying both physiological and CAN data with data processing tools. Both display contextual information, thus providing the experimenter meaningful information (particular attention is given to physiological variation related to contextual information. The *CaroLab* software is designed to select any contextual event, to display the events of the same category with the same coloured vertical line and to change the framing as needed.

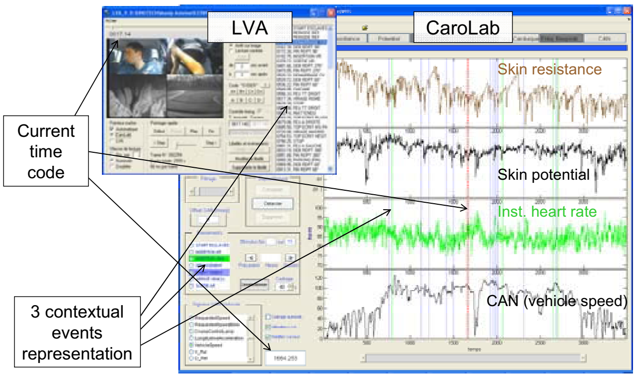

Figure.2. *Schematic representation of the data screens available on the same time-scale.*

Signal Processing

The CaroLab software provides several semi-automatic data processing tools. A butterworth smoothing filter can be applied on raw data before analysis. The software is designed to compute several indicators around each contextual event and to store data in a specific worksheet. The program sets 2 cursors for automatic response detection. The user can move them if the detection does not fit well. Physiological response amplitude, duration, slope, latency, onset value and mean value is thus easily obtainable and associated with behaviour. Future tools should further be developed e.g. heart rate variability and Poincaré plots.

Conclusion

This integrated system provides an effective data acquisition solution, available from field tests in a car-embedded context. During the experiment, any useful contextual information may be tagged in real time to be associated with behaviour and physiological activity attached to it. Thus drivers' behaviour may be assessed through different indicators. This multivariate analysis brings redundant information and is thus aimed at improving reliability.