Driver Workload Monitoring

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Abstract. Modern information and communication systems within a vehicle are drawing more and more attention of the driver towards secondary tasks. This paper presents a valuable approach to overcome the problem of information overload by introducing an adaptive man-machine interface. In situations with a high mental workload information from secondary tasks like an incoming telephone call will not be presented to the driver. A prototype system was implemented and evaluated in the S.A.N.T.O.S project.

1. Introduction

The rapid technical development in the market for consumer electronics is responsible for a steadily increasing number of information and communication devices available within a modern vehicle. All these devices are drawing drivers' attention ignoring the fact that "driving" remains the main task for the driver. On the one hand the new devices have the potential to enhance comfort and even efficiency and safety, if they are used sensibly. On the other hand ergonomists and psychologists are warning against the problem of distraction and information overload (Verwey 1993). The classic example of an additional task that impairs driving performance is a mobile phone conversation. A simulator study carried out by the Transport Research Laboratory TRL in Berkshire, UK (Direct Line 2002) found a spectacular result. The experiment showed by measuring the reaction time to a signal, driving performance under the influence of alcohol (80mg/100ml) was significantly worse than in normal driving, but significantly better than in driving while using a mobile phone (Figure 1).

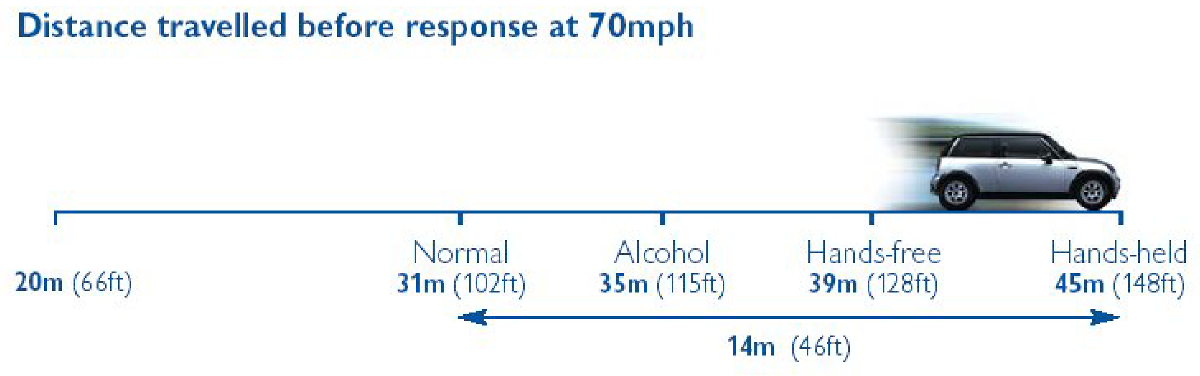

***Figure 1**: distance traveled in relation to the reaction time to a signal in different driving conditions.*

Using a mobile phone while driving represents a potential risk and therefore, in Germany, it is only allowed in a hands free modus. But most drivers will probably not accept further regulations in this area on the long run.

Therefore there is a need to investigate possible solutions to avoid the mental overload of the driver caused by secondary tasks. The idea of an adaptive man-machine interface that presents information to the driver according to the currently available resources seems to be a valuable approach. It was born in the DRIVE Project V1041 Generic Intelligent Driver Support GIDS (Michon 1993) and further prosecuted within the S.A.N.T.O.S* Project (König et al. 2000).

2. Methods

Within S.A.N.T.O.S the approach was to predict the mental workload of the driver and to influence the presentation of data within the vehicle according to the results of the prediction. Postponing or even canceling less important messages can reduce additional workload resulting from displays or other signals.

2.1 Technical Realization

The static road environment like sharp turns or intersections is a first indication to the mental workload of the driver. During the preparations for the experiments a predefined route for the test drives was classified in different road situations according to the Fastenmeier Taxonomy (Fastenmeier 1995), which were stored in a geographical database. The relative workload induced by these road situations was measured using a secondary task paradigm. Since the glance frequency is a sensitive measure of drivers' visual workload, the number of glances per second devoted to a secondary task can be used as an indicator for the complexity of the traffic situation.

While driving on the predefined route the exact position of the vehicle can be determined using differential GPS. With the current speed and the changes of the position the system calculates a prognosis of the oncoming road section (Schraut 2000) and the expected basic workload. The basic estimation can be adjusted using signals form the onboard sensors of the vehicle. For an example, a leading vehicle and short time headway, detected by a radar sensor, will increase the workload as well as rain, detected by an onboard raining sensor.

As a result of the estimation an incoming phone call was not signaled to the driver in situations with a potentially high workload. This is called adaptive telephone behavior within the document.

2.1 Experimental Set-up

The system was tested in a field evaluation experiment with 12 subjects, 6 of who were experienced drivers (holding a driving license for 6.7 years on average), and 6 of who were novice drivers (possessing a driving license for 50 days on average). Each subject drove the experimental route 3 times; the sequence of experimental conditions was permuted within groups. None of the subjects was familiar with the experimental route. The experimenter provided standardized route guidance instructions throughout the whole experiment. The experimental conditions (within subjects variable) were driving without driver assistance (Reichart et al. 1995), driving with adaptive cruise control (ACC) and heading control (HC), and driving with ACC, HC and adaptive telephone behavior.

Incoming telephone calls were only blocked in the workload estimation condition when the workload estimate exceeded a threshold value. In all conditions, the driver was required to

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respond to ten mental arithmetic tasks via a hands-free telephone. Subjects answered the phone by pressing a button integrated in the steering wheel. The arithmetic tasks consisted of adding 12 to a number in the range of 11 to 93 and saying the answer aloud. This phone task simulated a short real-life telephone conversation with a medium level of complexity. In the workload estimation condition, the caller required up to 64 attempts to place the ten calls, as the workload estimator rejected up to 54 incoming calls. The mental effort was measured for all three experimental runs using objective (electrocardiogram, electromyogram) and subjective measures (offline ratings from observers watching video scenes, NASA TLX self-report scale).

3. Results

The objective workload measures were subjected to a 2 (experience, within subjects) x 3 (condition, within subjects) repeated measures ANOVA. A decrease in the heart rate variability (HRV) is known to indicate an increase in the mental effort invested by the subject. Furthermore an increase of the heart rate (HR) can be used as indictor of an increase in drivers' workload (Hering 1999), though HR is not diagnostic to discriminate between mental and physical effort (Manzey 1998). Thirdly, the lateral frontalis electromyogram (EMG) level rises when exertion increases (Fridlund et al. 1986), (De Waard 1996).

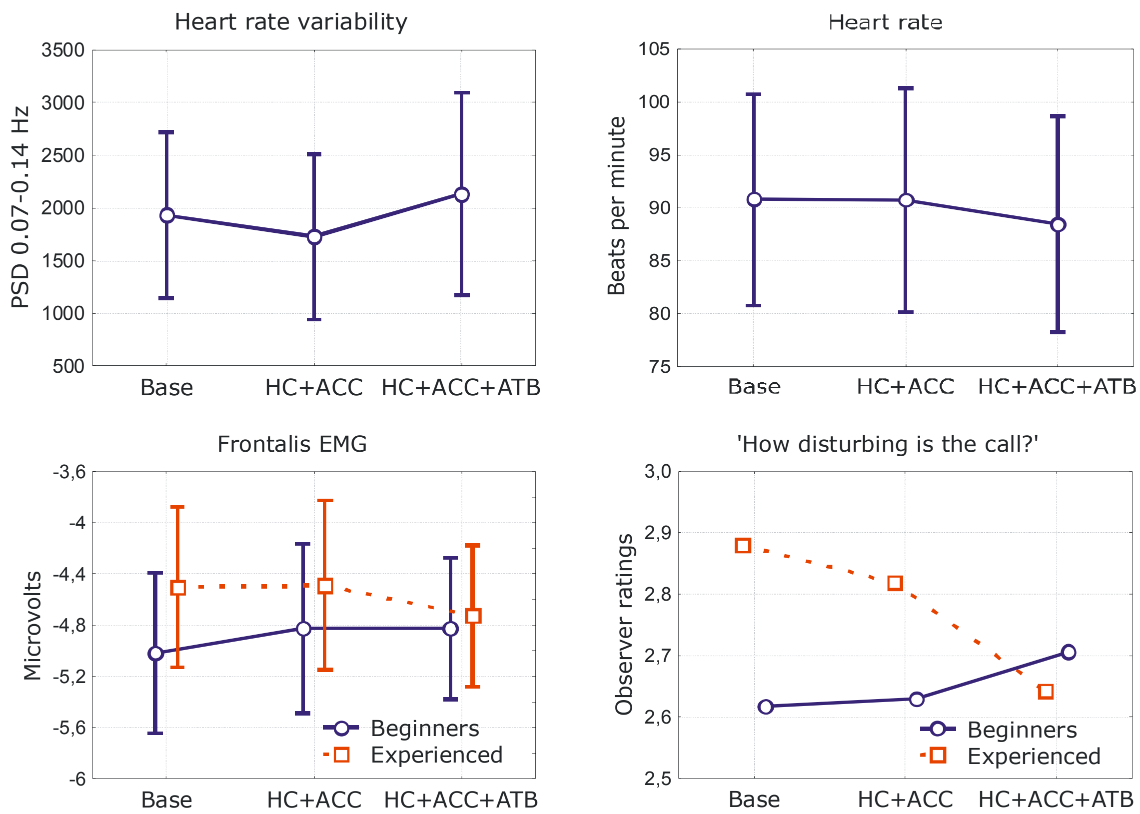

***Figure 2**: Physiological measures (95% confidence intervals) and mean observer ratings (lower right) Experimental conditions are driving without any assistance (base), driving with heading control and adaptive cruise control (HC+ACC) and driving with HC, ACC and adaptive telephone behavior (ATB).*

None of the psychophysiological measures revealed statistically significant results (Figure 2), but they show tendencies in favor of a workload reduction in the ATB condition. A much bigger group of subjects would be necessary to base the evaluation of the described workload estimator on psychopsysiological measurements.

According to the NASA TLX self-report scale there is only a marginally significant difference between the experience groups, i.e. beginners feel a higher mental strain than experienced drivers. The video ratings show that the workload is reduced significantly within the group of experienced drivers, but that is not the case within the group of beginners. Some observations within this group suggest that novice drivers have a lack of situational awareness, they seem to allocate to many resources to secondary tasks regardless of the traffic situation.

4. Discussion and Conclusions

When judging what was really achieved in these experiments, it is important to understand and to appreciate that the goal of the reported work was to explore and to demonstrate the possibilities of creating a functional 'situation-aware' vehicle by means of a synthesis of human factors knowledge and state-of-the-art technology. While there is still an overwhelming amount of unresolved questions that require in-depth analysis, the SANTOS workload estimator is at least one further step towards producing real-time estimates of workload for drivers in real traffic. Situation-adaptive automotive applications could become a dream come true in the near future if the methods and technology in this area are developed further. An additional necessary prerequisite for this vision is the flawless integration of the new technologies or devices into the man-machine interface of the vehicle.

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