IVSS
Intelligent Vehicle Safety Systems

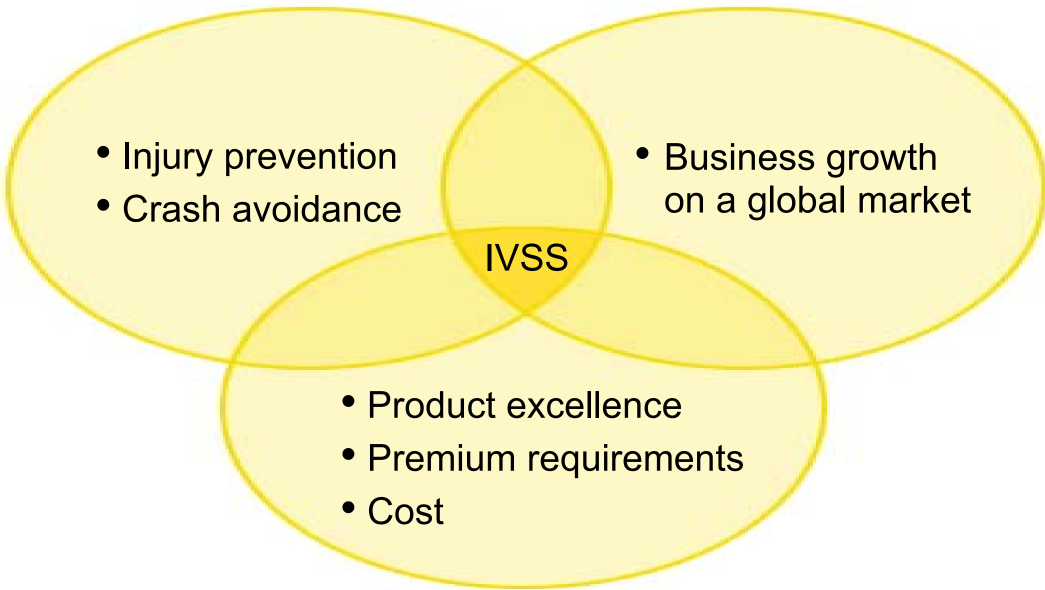
Driver Attention – Dealing with Drowsiness and Distraction

IVSS Project Report

The IVSS Programme

The IVSS programme was set up to stimulate research and development for the road safety of the future. The end result will probably be new, smart technologies and new IT systems that will help reduce the number of traffic-related fatalities and serious injuries.

IVSS projects shall meet the following three criteria: road safety, economic growth and commercially marketable technical systems.



Three interacting components - for better safety, growth and competitiveness:

The human being

Preventive solutions based on the vehicle's most important component.

The road

Intelligent systems designed to increase security for all road users.

The vehicle

Active safety through pro-active technology.

Project Partners:

Title of the report: Driver Attention – Dealing with Drowsiness and Distraction

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SUMMARY

Loss of control is a fact if the driver diverts from the driving task for just a few seconds. A continuous attention to driving is a must in order to drive in a safe way. But it is also known that humans are easily being distracted or drowsy.

The project overall objective was to contribute to traffic safety by promoting an alert and attentive driver by technical means in the vehicle. A Driver Attention system was developed with the purpose to detect and warn the driver in case of visual inattention and sleepiness. By monitoring head- and eye behaviour with a remote eye tracking system, indicators of drowsiness and distraction, such as gaze direction and eye blinks, was measured. An Inattention Detection Algorithm was developed and worked as follows; A "field relevant for driving" was defined that would correspond to the most important road scene. When the drivers' eye gaze was within this field he was considered to be attentive. For the inattention algorithm the driver had a buffer of two seconds which could be spent looking at targets outside the field relevant for driving. When the buffer was empty, a warning was given by vibrations in the seat. The detection of drowsiness was based on the eye blink behavior. The longer the eye blinks were and the more often they occurred, the more drowsy was the driver. The warnings were classified in three levels; slightly drowsy, drowsy and very drowsy, and were given by text- and speech messages.

Field operational tests were done in order to evaluate the system. Seven drivers used an instrumented Saab 9-3 in their daily lives for about a month each, and four professional drivers used a Scania truck in long-haul delivery runs for two weeks each.
In the passenger car, the results of using the system do not show very large effects, but those that appear tend to go into the "right" direction, meaning that a distraction warning could have positive effects on driving safety and does not seem to have negative effects. Drowsiness warnings were not evaluated in the passenger car due to very few warnings and these were not experienced as correct.
In the truck, as a main result, inattention warning turned out to decrease the number of prolonged inattentive periods in drivers. Results also indicate a tendency for drivers to drive drowsier when using a drowsiness warning system. In contrast, the truck drivers exhibited no clear behavioral adaptation effects in response to distraction warning.

An industrial prospective was carried out in order to guide the continued development of drowsiness and distraction mitigation systems to production readiness.

SAMMANFATTNING

För att säkert framföra ett fordon krävs en kontinuerlig uppmärksamhet på vägen. Redan vid ett par sekunders distraktion kan föraren ha förlorat kontrollen över körningen. Men det är också känt att människor har svårt att upprätthålla koncentration och vakenhet under längre perioder utan att bli distraherade och sömniga.

Det övergripande syftet med projektet var att bidra till ökad trafiksäkerhet genom att med ett tekniskt system i bilen hjälpa föraren att hålla uppmärksamheten på vägen. Ett sådant system utvecklades med syfte att varna föraren vid visuell ouppmärksamhet och sömnighet. Genom att övervaka huvud- och ögonbeteende med ett kamerasystem mättes indikatorer på distraktion och sömnighet, såsom blickriktning och blinkningar. En algoritm för visuell ouppmärksamhets togs fram, där först en ”zon relevant för körning” definierades såsom det vägområde som är viktigt för körning. När förarens blick var inom denna zon betraktades föraren som uppmärksam. Sedan definierades en ”uppmärksamhetsbuffert” som tillät föraren att ha blicken utanför denna zon i två sekunder utan att få en varning. När bufferten var tom fick föraren en varning genom att sätet vibrerade. Detektion av sömnighet baserades på förarens blinkningar. Ju längre blinkningar och ju oftare dessa förekom, desto sömnigare förare. Sömnvarningar gavs i tre nivåer, något sömnig, sömnig och mycket sömnig, i form av text- och talmeddelanden.

För att utvärdera systemet genomfördes fältstudier. Sju förare körde en instrumenterad Saab 9-3 i fyra veckor var ”som om den vore deras egen” och fyra lastbilschaufförer körde en Scania långtradare i två veckor var i vanlig drift. Resultatet av försöken i personbilen visar inga stora effekter av användandet av systemet, men de som finns tenderar att gå i ”rätt” riktning, dvs. att distraktionsvarning kan ha en positiv effekt på körsäkerhet och verkar inte heller ha några negativa effekter. Sömnvarningen utvärderades inte då antal varningar var få och dessutom inte upplevdes som korrekta. I lastbilen så visade resultaten att distraktionsvarningen minskade antalet långa distraktioner. De indikerar också att det finns en tendens att förarna kör mer sömniga när det finns en sömnvarningsfunktion. Däremot syntes inga tecken på att förarna ändrade beteende på grund av av distraktionsvarningen.

I projektet gjordes även ett industriellt prospekt med syfte att vägleda fortsatt utveckling av varningssystemet till industriell tillämpning.

1. Introduction

Loss of control is a fact if the driver diverts from the driving task for just a few seconds. A continuous attention to driving is a must in order to drive in a safe way. But it is also known that humans are easily being distracted or drowsy. These traffic safety problems have received lot of attention lately. Several recent studies indicate that about 10-20 % of all accidents are likely sleepiness-related, and distraction has been a contributing factor of up to 78-80% of all accidents and incidents.

Recently, systems are introduced on the market that will mitigate this problem by managing the drivers' workload (examples: the ComSense in Saab and the IDIS in Volvo). The purpose of these systems is to eliminate or suspend potentially distracting information in high workload situations, and by that avoid secondary tasks to be in conflict with primary driving tasks. These systems can mitigate the distraction originating from the use of in-vehicle systems but can not detect other kinds of distraction.

The intention of this work was to take another step in drowsiness and distraction mitigation by using newly matured remote eye tracking systems. By monitoring head- and eye behaviour, indicators of drowsiness and distraction, such as gaze direction and eye blinks, can be measured.

2. Project objective

The project overall objective was to contribute to traffic safety by promoting an alert and attentive driver by technical means in the vehicle. A Driver Attention system – in this project called 'AttenD' – was developed with the purpose to detect and warn the driver in case of visual inattention and sleepiness.
The following specific objectives were defined:

1) Develop and install a "Driver Attention system" (AttenD) in a Saab car and a Scania truck.
2) Develop measures of system effectiveness and user acceptance.
3) Develop test methodology for "small-scale field operational test.
4) Industrial prospective. How to go from prototype system to industrial application.

3. Functionality of the AttenD system

The primary input to the AttenD system came from a Driver Monitoring System (DMS) consisting of two cameras directed towards the drivers face.

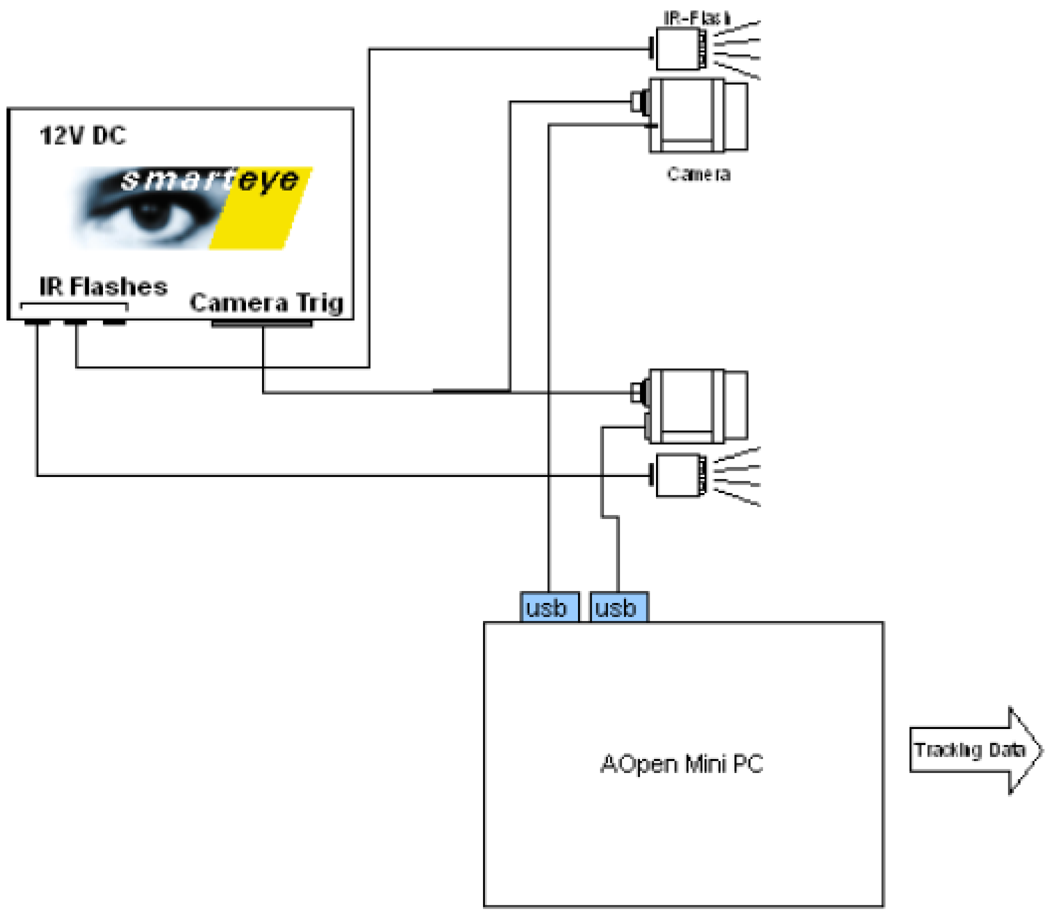

Figure 1. A schematic overview of the Driver Monitoring System (SmartEye Pro).

An Inattention Detection Algorithm was developed and worked as follows; A "field relevant for driving" (FRD) was defined that would correspond to the most important road scene. When the drivers' eye gaze was within this field he was considered to be attentive. For the inattention algorithm the driver had a buffer of two seconds which could be spent looking at targets outside the field relevant for driving. When the buffer was empty, a warning was given by vibrations in the seat. The buffer was filled when the driver looked back at the FRD.

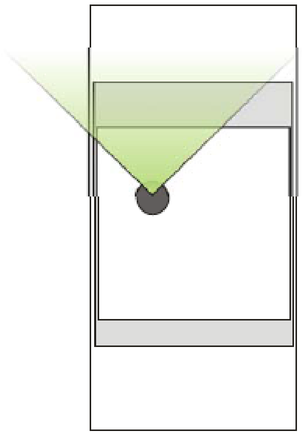

Figure 2. The "field relevant for driving(FRD)" as seen from above, provided that the driver looks through a window.

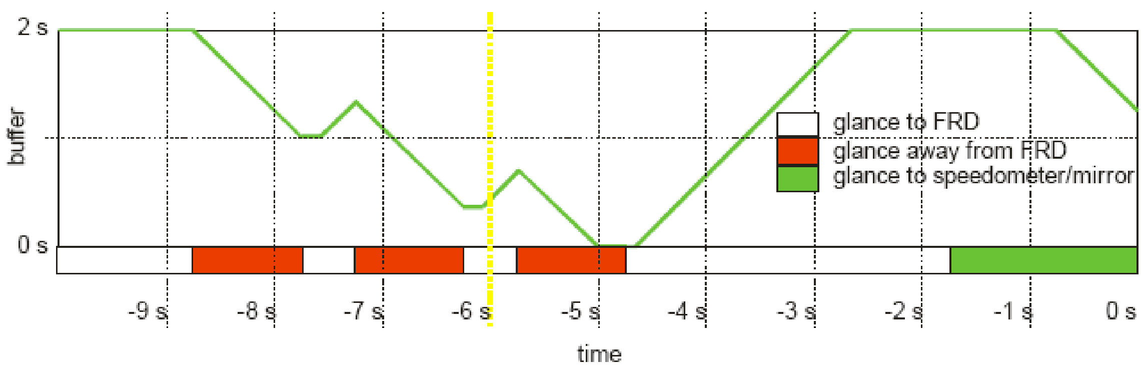

Figure 3. Representation of the decrease of the attention budget for three consecutive one-second glances away from the "field relevant for driving" (FRD), marked red, with half-second glances back to the FRD in between. Warning is activated at -5 s.Between -1.8 s and 0 s a 1.8-s-glance to the mirror or speedometer is shown, where a delay in buffer decrease is allowed as it is a driving related task.

The detection of drowsiness was based on the eye blink behavior. The longer the eye blinks were and the more often they occurred, the drowsier was the driver. The warnings were classified in three levels; slightly drowsy, drowsy and very drowsy, and were given by text- and speech messages.

The AttenD system also included a warning management function with the objective to "filter out" unnecessary warnings, such as avoid repeating the same warning, or to inhibit warnings when the driver is doing excessive maneuvering like hard braking or steering.

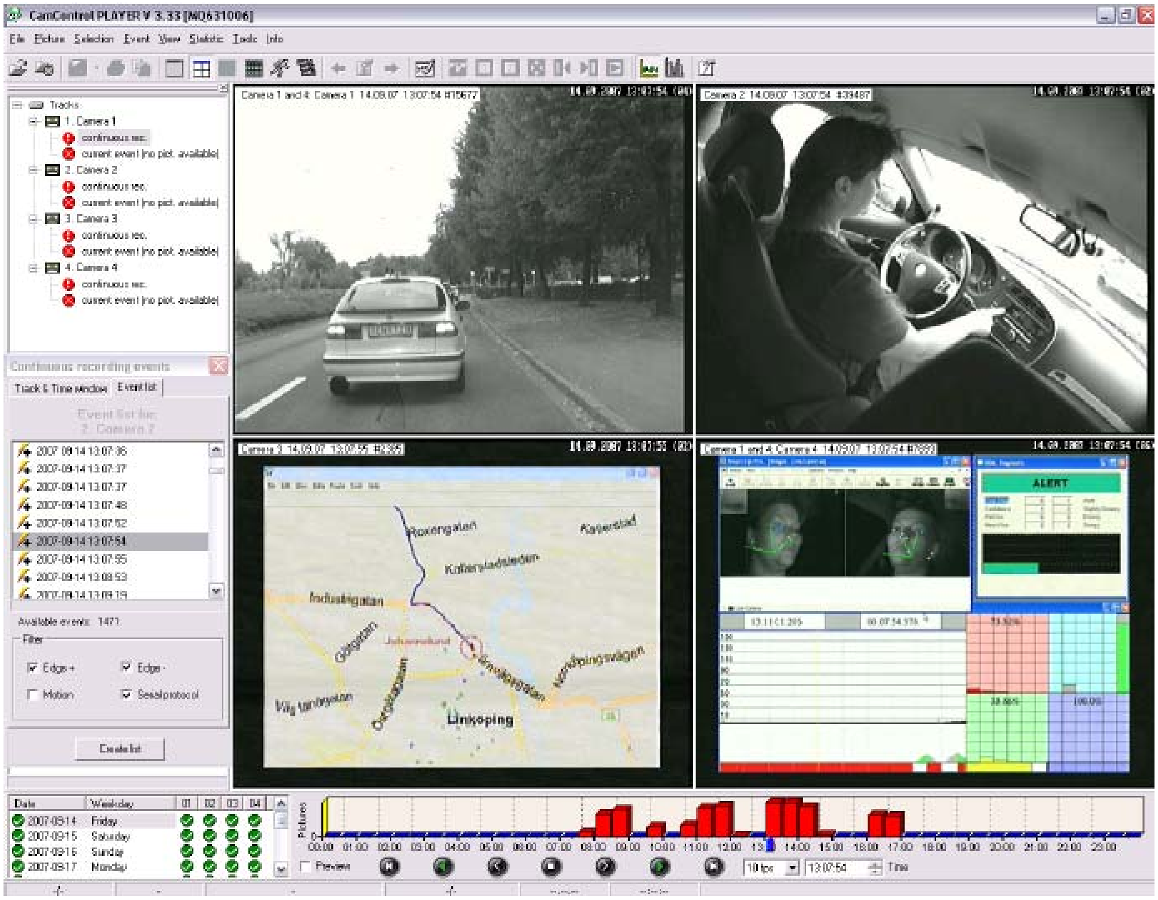

Figure 4. Video recording, actual example from test drive. Upper left; view from front camera on road scene. Upper right; camera view on driver and instrument panel. Lower left; map showing the location of the vehicle. Lowe right; Screen shot from the logging computer showing status of system and history of log data.

4. Field Operational Test

Simulator studies have shown that it is difficult to attain “true distraction” in an artificial setting and researchers who have performed such tests recommend using a field test for further evaluation of distraction mitigation systems. This recommendation led to the decision to perform a field test, using the general methodological setup of a field operational test (FOT), but on a smaller scale than common for this type of test.

Seven drivers (4 males and 3 females) used an instrumented Saab 9-3 in their daily lives for about a month each. During the baseline phase, which consisted of the first approximately 10 days, the driver was not given any feedback on his behaviour; the car “behaved” just like a normal car. The driving behaviour, including warnings that would have been given, was logged. During the treatment phase, which lasted for the remaining approximately 20 days, logging continued, and warnings for inattention and drowsiness were not only logged but also given to the driver. The drivers' subjective opinion about the warning system and their expectations and experiences were obtained via a set of questionnaires and by interviewing the drivers.

Four male drivers, from two transportation companies engaged in long-haul delivery runs, participated in the Scania field tests. The experiments were run for one week per condition (without and with warnings to the driver), a total of two weeks for each participant, which yielded around 40-50 hours of total driving time per participant. As a comparison, the Saab-study generated similar amounts of driving hours per participant. The same data as in the Saab study was collected.

5. Results

Generally the method used in the present study appears to be suited for investigating driver distraction. A substantial number of distraction cases were logged. The automatic eye tracking worked well over a prolonged time period without intervention by the experimenter. The quality of the tracking was constant over time, and the very varying lighting conditions did not adversely affect tracking. The data acquisition system worked as planned in principle, even though stability issues have to be solved in future studies, and a better power management is required for further and more large-scale studies.

Passenger car:

Generally, the experiences with the participants were positive, and the procedure used seemed to have worked for all involved. The large variation between participants for many of the analysed performance indicators shows clearly that the number of participants was too low to draw any definite conclusions about the effect of the distraction warning system. The data from the present study suggest that the warnings do not have an immediate effect such that the driver looks up faster after having received a warning than without warning. It does not appear, either, that drivers try to avoid the warnings, because for most of the drivers the warning frequency did not decrease measurably. There is no increased concentration of glances in the field relevant for driving, or an increase in PRC values (Percent Road Center) in the treatment condition. Neither does the distribution of gazes change from the baseline to the treatment phase. The only possible change could be found for the duration of individual glances, where it seems like the percentage of very long glances decreased in the treatment phase. Furthermore, the number of times the attention buffer returned to zero before filling up completely after a warning appears to have decreased.
Thus, the results do not show very large effects, but those that appear tend to go into the "right" direction, meaning that a distraction warning could have positive effects on driving safety and does not seem to have negative effects. The few effects that appeared did not change much over time. This might indicate that there is no noteworthy

learning curve, even though it is too early for a definite statement on this question. The absence of a learning effect implies that the distraction warning has approximately the same effect already during the first experiences with the warning as it has later on.
In the passenger car study there are no analyses of the drowsiness data because the drivers received only very few drowsiness warnings, and they reported that they did not experience those as correct.

Truck:
The AttenD system proved to operate well in the field tests. As a main result, inattention warning turned out to decrease the number of prolonged inattentive periods in drivers [1].
Results also indicate a tendency for drivers to drive drowsier when using a drowsiness warning system[2]. In contrast, drivers exhibited no clear behavioral adaptation effects in response to distraction warning.

6. Industrial prospective

An industrial prospective was carried out in order to guide the continued development of drowsiness and distraction mitigation systems to production readiness. This is the content of the report (21 pages, restricted to project partners).

[1] We found one exception with the last driver that was tested: This driver happened to drive during night when systems were turned off, and drove during daytime when the systems were turned on.
[2] The last driver exhibited more drowsiness in the systems-off condition, when driving during night.

7. Fulfilment of IVSS objectives

Road safety: Regarding system performance it shows indications on positive results (less inattentive drivers when using the system). However, the design of the field test was not optimal in terms of evaluating system effectiveness, as it was difficult to identify what were correct alarms, false alarms and misses. This is a draw-back in performing field tests (no - or little control of what is happening). To study system effectiveness requires a more controlled experiment set up. (This was identified as important follow-up activities.)
The system tested shows good potential for user acceptance. Most drivers were positive to the system and the experience of using it. This shows a good potential for high usage when the system is put on the market.

Economic growth: As all partners were actively engaged in the project work it has resulted in continued development and planning within each organisation respectively. Also, a number of new joint projects that build from the result of this project has been identified and started at Swedish competence centres and research programs (ViP-VisualEyes and FFI-Driver Drowsiness- and Distraction Detection by SensorFusion.)

Commercially marketable technical systems: One part of the project was an industrial prospective. Besides pointing out the most important system performance requirements, it also described other quality- and production issues, such as how to integrate the systems in the vehicle and how to plan for production. (See chapter 6.)

8. Conclusions and recommendations

Conclusions:
The results do not show very large effects, but those that appear tend to go into the "right" direction, meaning that a distraction warning could have positive effects on driving safety and does not seem to have negative effects.
The automatic eye tracking worked satisfactory for the test period, but improvement of its performance is highly recommended for the specific conditions that were found.
The test procedures for the passenger car were successful in contrast to the truck test procedures that were less successful. In particular, the truck instrumentation turned out to be under-dimensioned, with frequent overload of the USB-connections and resulting signal loss.

Recommendations:
For field operational test it is recommended to have a greater number of vehicles running in parallel in order to collect more data on more test participants and to better control for seasonal variations.

Another learning is that robust power management for test systems and data logging systems is needed. The best would be to use automotive specifications for these components.
Analysis of the collected data on a more detailed level would be beneficial. Due to resource limitations this was not done within the scope of this project.
Regarding system performance it was concluded that improvement of the distraction algorithm in order to decrease the overall number of warnings and of course especially the false and nuisance warnings have to be found.

9. Publications

Boverie, S. et.al. (2008). Driver Attention - Dealing with Drowsiness and Distraction: Industrial prospective. Restricted report. Toulouse, France: Continental Corporation.

Kircher, K. (2007). Driver distraction: A review of the literature (VTI Report No. 594A). Linköping, Sweden: VTI (Swedish National Road and Transport Research Institute). http://www.vti.se/templates/Report____2796.aspx?reportid=8034

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Kovordányi, R., Kollegger, P., Claezon, F., Granlund, R. (2008). IVSS Driver Attention - Dealing with Drowsiness and Driver Distraction: Field Operational Test of two Warning Systems using an Instrumented Scania Truck. Linköping, Sweden: Department of Computer and Information Science, Linköping University.

10. Presentations

Swedish-American Chambers of Commerce. Lidköping. August 21, 2006.
Transportforum 2008. Linköping. January 9, 2008.
Press Event with test driving. Södertälje. October 23, 2007.
IVSS and V-ICT Temadagar. Göteborg. December 10, 2007.
IVSS Temadag. Göteborg. March 27, 2008.

BilSweden ”Den olycksfria bilen” Seminar. Stockholm, April 4, 2008.
NORBIT 2008
Driving Assessment Conference 2009.

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