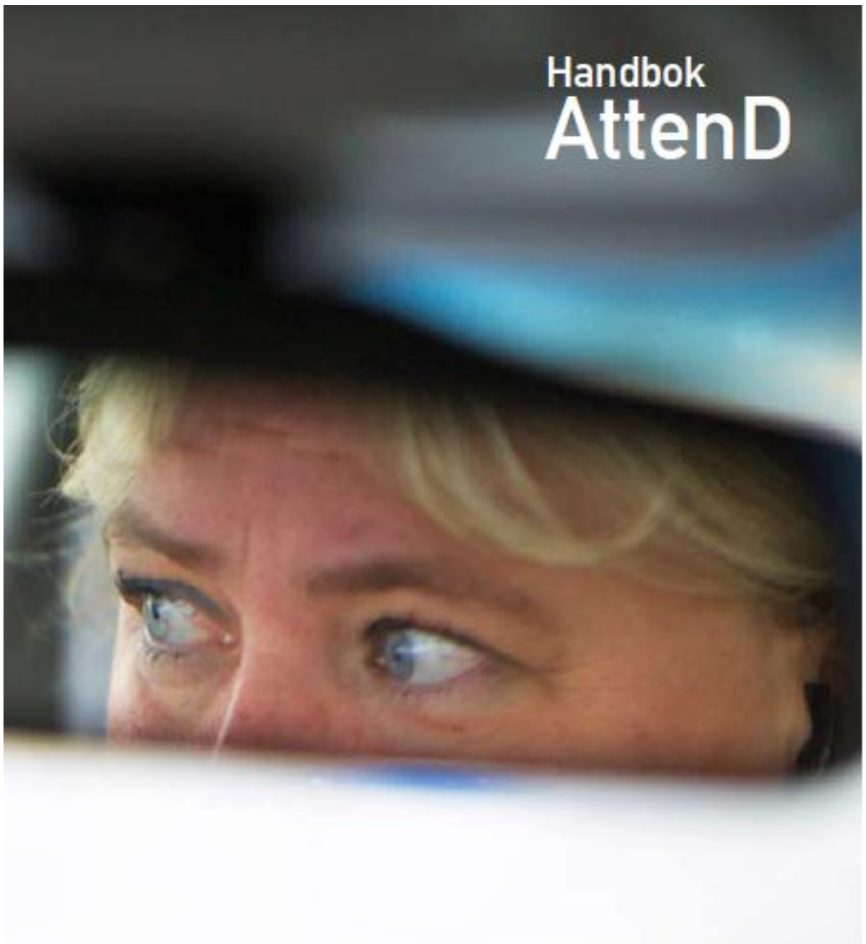
HMI for Active Safety



Picture: Katja Kircher

Project within Vehicle and Traffic Safety/ Dnr 2010-01140 and 2011-03640
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Date: 2013-01-30

FFI

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FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

For more information: www.vinnova.se/ffi

1. Executive summary

The use of active safety systems are increasing in road vehicles. These systems are often of informative type, i.e. the driver gets a warning and is expected to act upon it. This means, for the systems to be successful, they are completely dependent on correct driver actions in time- and safety critical situations. Also, the warnings must be welcome, they should only warn when the drivers have use for them, i.e. in the right situations and in right time. Further, the warnings must be clearly sensed by the drivers but not so strong that it becomes annoying.

In the first part of the project a warning concept for multiple active safety functions was developed. The basic principle in this concept was that warnings should be adapted to both driver state (attentiveness, alertness) and driving situation (speed, location on the road, traffic). The warnings system gave warnings in case of risk for lane departure, forward collision, distraction and sleepiness. The basic system functionality was developed by using the Saab driving simulator and the installed in a real passenger vehicle that could be used on public roads.

In order to tune the system to real world driving conditions and drivers, a field test was done including 38 drivers. Physiological data (EEG, EOG, etc.) was recorded together with vehicle- and trip data and the test leader's notes. Tests were done during both day and night and the driver's self-assessment of sleepiness level was noted. The result was then used in order to optimize algorithms in the system and to set appropriate threshold values for warnings and adaptivity.

The system was evaluated in a Field Operational Test (FOT) where 10 drivers had the vehicle for one week each to use as if it was their own. The only requirement was that they should also use the vehicle to commute to their work place. The system existed also in a non-adapted version and the participants drove both, but were not aware of that there were two versions.

The result shows that the adapted system issued a lot fewer warnings than the non-adapted for most of the drivers. But there was a large variation between drivers and some did not get any warnings at all in the adaptive system.

There were no observations of unfavourable driving behaviour as a consequence of a warning, neither in the adaptive system nor in the non-adapted. Though, there were two exceptions, both sleepiness warning, where the drivers continued to drive but the instructions was to make a safe stop and rest.

The vast majority of all warnings were sensed by the drivers, implying that the way the warnings have been issued has been successful. Though, the drivers liked the idea with an adaptive warning system but pointed out that it must perform better than the system they had been driving. Important was that false warnings must be reduced.

In the second part of the project, automated driving was explored from the driver's point of view. Four focus groups were carried out where the participants were encouraged to reflect and discuss about different aspects of automated driving.
The discussions were much about to which drivers automation is addressed and how much it will cost. Different views on safety and security were discussed such as data security and how drivers can cope with sleepiness and distraction. As a conclusion, two different driver expectations could be seen. Some drivers would like automation to help them with long and boring driving (for comfort reasons) while others would like automation to help them in difficult driving situations (for safety reasons).

2. Background

The use of active safety systems are increasing in road vehicles. These systems are often of informative type, i.e. the driver gets a warning in case of risk for e.g. lane departure (LDW) or forward collision (FCW). This means, for the system to be successful, it is completely dependent on the driver actions. The driver needs to act agile and correct as these warnings usually are given in time critical situations. Even if several systems warn at the same time, or in near proximity, and some warnings may also have higher priority than others, the driver must act quickly and correctly. Also, these warnings must be experienced as relevant to the situation. If the warning is issued to early it can be annoying and if too late the driver has no use of it. What would be regarded as an "appropriate" timing for a warning is not an easy question as the answer contains many contributing factors. These factors could be linked to the driver's state (attentive/distracted, sleepy, etc.), to driving style (conservative, aggressive), to the road conditions (friction, curves, etc.) or to other kinds of "threats". Last but not least is that the way the warning is brought to the driver must be carefully designed. The warning may not startle the driver or be annoying to the driver and passengers, it could result in that the driver turns off the system. The warning may not be too weak so it could be missed or be obscured by other things in the vehicle. Also, it must not be confused with other type of signals that could appear in a vehicle.

The above is dealing with warnings in critical driving situations, where the driver is expected to act on a given warning. The next step in this area is to develop systems where the vehicle acts on its own by for example braking if risk for a collision or steer back in case of risk for a lane departure. This means that parts of the driving task will be automated. Also here, the drivers opinion of the system are important. The vehicle actions must be seen as relevant.

3. Objective

The project had two objectives:
a) To develop a warning concept for active safety systems, that gives optimal effectiveness and driver acceptance. This will be reached by;

- adapt the warnings to driver state and driving situation, so that drivers that for example are distracted or sleepy are getting the warning earlier if they are close to a vehicle ahead, or later if there are no "threats" present.
- manage warnings from several systems by coordination and prioritization
- design the warnings so that drivers experience them as relevant and make correct actions.
- design the warnings in such way that they will not annoy drivers or passengers.

With reference to the above, the following research questions were identified:

A. Will a warning adapted to driver status and driving situation lead to higher effectiveness and acceptance than a non-adapted warning?
B. Will an adapted warning lead to that the driver experiences it as correct and makes a correct counteraction more frequently than if the warning is non-adapted?
C. Is an adapted warning experienced as less annoying than a non-adapted warning?
D. Is an adapted warning used more frequently than a non-adapted warning?

b) Gain knowledge on automated driving seen from a driver's perspective by having group discussions. Questions asked were:

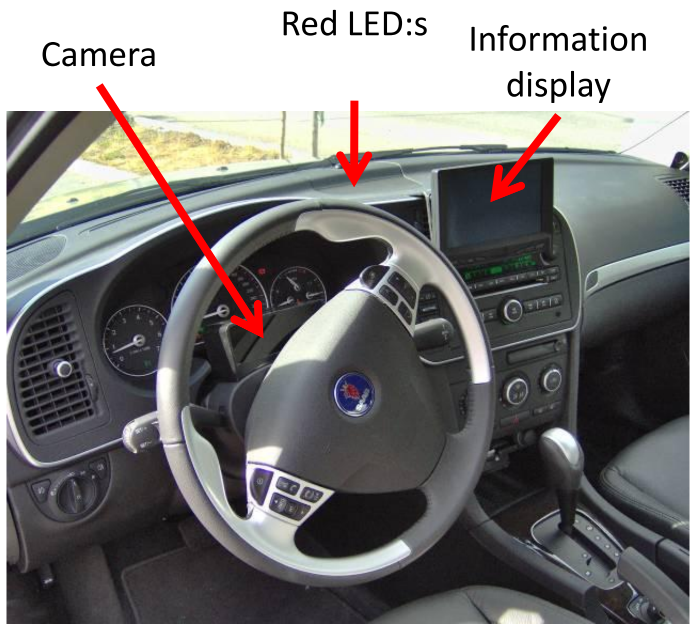
- What do you see when thinking about automated driving?
- What are the reasons for introducing automated driving?
- What kind of functions would you like to have in automated driving? Do you see any pros and cons with automated driving?
- What are your thoughts on trust, safety and security?

4. Project realization

Development of a warning concept.

A passenger vehicle was equipped with a warning system that included the following:

- Sleepiness warning: Warns if the driver shows signs of sleepiness (based on both physiological changes and changed driving behaviour).
- Distraction warning: warns if the driver is visually inattentive.
- Lane departure warning: warns if the vehicle is about to leave the lane if not the driver's intention
- Collision warning: Warns if the safety margin to the vehicle in front is too short.
- Adaptivity: Adapts the warnings to driving situation and driver status.
- Warning actuators: Visual warnings are displayed as red LED reflected off of the windscreen and as symbols and text on a screen mounted on the centre of the dash board. Tactile warnings are given as a jerk in the seat belt and as vibrations in the seat. Sound warnings are given in a small loudspeaker.
- Owner's manual describing the system.

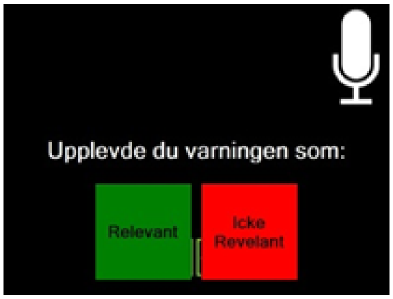


Picture 1. Location of driver monitoring camera, red LED:s and information display.

The basic system functionality was developed by using the Saab driving simulator. In short, the logic of the system was as follows:

- If the driver is inattentive, LDW and FCA will be issued at an earlier stage.
- If the vehicle is close to lane markings or close to the safety margin to the vehicle in front, the distraction warning will be issued at an earlier stage.
- If the driver is sleepy, all warnings will be issued at an earlier stage.
- If more than one warning calls to be issued at the same time or in near proximity, the warning with the highest priority will be issued and the other warnings will be inhibited.
- When a warning has been issued there will be no more warning of the same kind or warnings of lower priority for a while, no matter if any of the warning criteria of these will be fulfilled.

The system described above was called an adaptive warning system.
The same warnings could also be issued without adaptation, e.g. the warnings were given independently of each other. This was called a non-adaptive warning system.
When a warning had been issued the driver could tag it as “relevant” or “not relevant” by pressing buttons on a touch display, and also do an oral comment.



Picture 2. The driver could tag the warning as relevant or not relevant on the touch display and give an oral comment.

The equipped vehicle could be driven on public roads without restrictions. The vehicle was also equipped with a data logging system, an extra brake pedal at the passenger seat and a fire extinguisher.

Data collection, field study.

The purpose for this activity was to collect data in order to optimize the system to real driving conditions and to different drivers. 38 participants drove on a public motorway and physiological data (EEG, EOG, etc.) was recorded together with vehicle- and trip data. Tests were done during both day and night and the driver's self-assessment of sleepiness was recorded together with the test leaders rating. The drivers also answered questionnaires on sleep habits etc. The result from the field tests was used for optimizing algorithms and for setting appropriate threshold values for warnings and adaptivity.

Picture 3. Photo of the entering point at the motorway (Linköping West) heading north.

User study; FOT (Field Operational Test).

Ten drivers participated in a user study where the driver had the vehicle during a whole week "as their own". The only study requirement was that they should use the vehicle to drive from their home to their work Monday to Friday. By this there would be comparable road stretches to be used during the analysis. Each driver drove both the adaptive system and the non-adaptive system but did not know that the system could appear in two versions. The two first days were used for familiarization of the system and the vehicle. Analysis was done on the data from the last five days driving.

Picture 4. Warning symbols for collision, lane departure, distraction and sleepiness, displayed on the screen mounted in the dash board

<u>Focus groups – automated driving.</u>

28 people participated in the study, divided into four groups (one with young participants, one with old, one with only men and one with only women). In the first part of the discussion the moderator asked some open questions about automated driving, and the participants were encouraged to reflect and discuss about these. In the second part a couple of film clips from "YouTube" was shown, exemplifying different concepts of automated driving, which was then discussed in the group. After the discussions the participants filled out a questionnaire. The purpose for this was to capture each participants' thoughts and opinions as well as to see if the answers from such a questionnaire can be used for information to be used in system design.

5. Results and deliverables

5.1 Results from executed studies

<u>Sleep detection.</u>

Data from earlier studies with the same vehicle and equipment was also used in these calculations. As a method for optimizing detection, Fuzzy logic was used together with evolutionary algorithms.
The best result for sleepiness detection in this study was to use information on the drivers' eye blink behaviour together with time of day and time on task. The detection could be further improved if the driver was known and previous individual data used. Information from steering wheel activity and lane position did also improve the detection, but at the same time it was seen that also distraction influenced the drivers steering behaviour and lane position. Steering wheel activity and lane position was also very dependent on road type, which makes it difficult to use these if the context is unknown.

Field Operational Test.

The adaptive warning system issued a lot fewer warnings than the non-adapted for most of the drivers. This was expected as it is a consequence of the system design. But there was a large variation between drivers and some did not get any warnings at all in the adaptive system.
There were no observations of unfavourable driving behaviour as a consequence of a warning, neither in the adaptive system nor in the non-adapted. Though, there were two exceptions, both were sleepiness warning, where the drivers should have stopped or done some other action, but instead continued to drive.
The vast majority of all warnings were sensed by the drivers, implying that the way the warnings have been issued has been successful.
When it comes to driver acceptance the non-adapted system showed somewhat better result, which is opposite to the expected. The study does not provide any clear explanation for this. It could be that the data set is too small or that the adaptive system is experienced to be more confusing.
All in all, the drivers liked the idea with an adaptive warning system but pointed out that it must perform better than the system they had been driving. Important was that the number of false warnings must be reduced, especially when it comes to distraction warning.

Focus groups – automated driving.

The discussions were much about to which drivers automation is addressed and how much it will cost. Different views on safety and security were discussed such as data security and how drivers can cope with sleepiness and distraction when not actively driving. As a conclusion, two different driver expectations could be seen. Some drivers would like automation to help them with long and boring driving (for comfort reasons) while others would like automation to help them in difficult driving situations (for safety reasons). Both these expectations should probably need to be implemented in the future.

5.2 Delivery to FFI-goals

Traffic safety: A concept for issuing warning addressing the areas driver distraction, sleepiness, lane departure and rear end collisions has been developed. The warnings were clearly sensed by the drivers and did not result in any unfavorable behavior. The negative comment on the tested system is that it has too many false warnings. This must be solved as it has a big influence on acceptance of the whole system.

Industrial competitiveness: Unfortunately, Saab went bankrupt in year 2011 and could not participate at the end of the project. It meant that complementary test driving could not be performed because the test vehicle was taken out of operation. All project result though has been shared with all project partners, so no result has disappeared with Saab. Autoliv and VTI will use the project result in their coming activities.

Innovation and production: The technologies used in this project (sensors, actuators, sensor fusion methods) are still under development and more work is needed to adapt them to real life conditions regarding vehicles and traffic environment. But the project has shown how a limited set of components can be used to realize several different functions, and this is in favor of product cost and weight.

Research- and innovation cluster: The project has gathered competence and partners from several actors in the innovation system – from research (VTI) via system providers (Autoliv) to vehicle manufacturers (Saab).

Demonstrator: The vehicle equipped with the active safety warning system has been useful in the design, test and evaluation work. It has been a valuable asset for all parties in the project.

Sleepy driver database: The database is world unique regarding quality and quantity. It will be most valuable in the future research on sleepiness and in driver sleepiness diagnosis and product development.

6. Dissemination and publications

6.1 Knowledge and results dissemination

The project reports and the seminars held will be used primarily by the project partners in their business respectively. Knowledge and other learnings will contribute to continued development of active safety warning systems and to methodology on how to execute tests on public roads (field tests and field operational tests). Also, the developed concept – including monitoring of driver status and driving situation – will be of great use in the development of systems aiming at automation of the driving task. This will be addressed in the near future.

6.2 Publications

Anund, A., Fors, C., Nåbo, A. (2012). Evaluation of correct counteractions and driver experience during a FOT – a pilot study with in HMI4AS. *VTI PM*. Project restricted.

Anund, A., Karlsson, J.G., Fors, C., Nåbo, A. (2012). AS HMI, Driver warnings in time- and safety critical situations. Report from test November 2010 & April 2011. *VTI PM*. Project restricted.

Anund, A., Fors, C., Nåbo, A., Karlsson, J.G. (2012). Fokusgrupper - automatiserad bilkörning. *VTI Report*. Public.

6.3 Associated papers

a) Ahlstrom, C., et.al. (2013). Fit-for-duty test for estimation of drivers' sleepiness level: Eye movements improve the sleep/wake predictor. *Transportation Research Part C 26 (2013) 20–32.*
b) Anund, A., et.al. (2012). Observer rated sleepiness and real road driving: an explorative study. *Plos one.*
c) (Planned) Anund, A. et.al. (2013). Evaluation of an Adaptive warning system with help of a miniFOT - A pilot study. *3rd International Conference on Driver Distraction and Inattention, September 4-6, 2013, Gothenburg.*
d) (Planned) Nilsson, B., et.al. (2013). Driver sleepiness detection. *3rd International Conference on Driver Distraction and Inattention, September 4-6, 2013, Gothenburg.*

7. Conclusions and future research

The number of issued warnings was lower for the adaptive warning system compared with the non-adapted.
The concept for active safety warnings did not cause any unfavorable driving behavior.
In practice, the drivers have sensed all warnings. Thus, warning modality and strength have been effective.
Unfortunately, the system produced too many false warnings and this probably influenced the evaluation of driver acceptance.
The following research will, besides refining the current warning concept, look into drivers' status and driving situation in the development of automated driving. Further, the database on sleepy drivers will be used in future studies.

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8. Participating parties and contact person

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