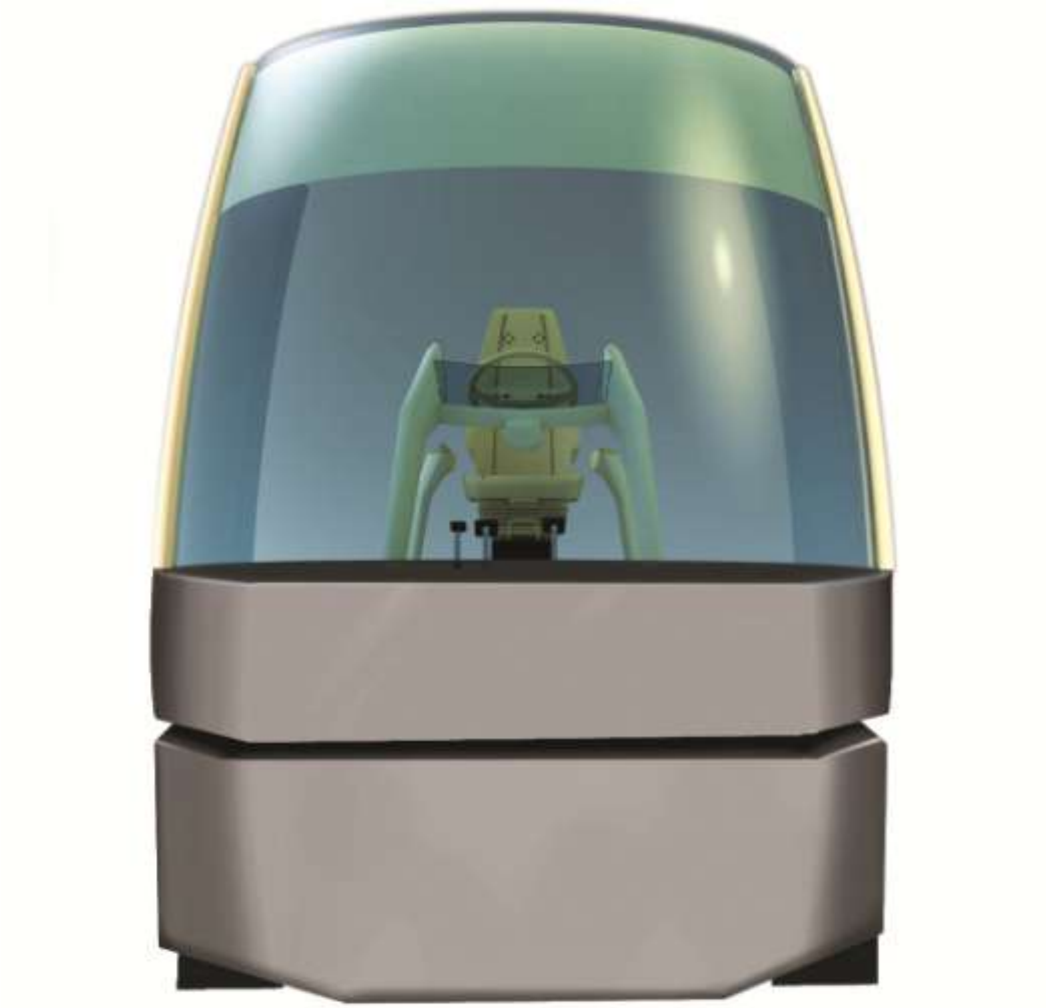
SIDVI – Safe and Integrated Driver-Vehicle Interface



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Vehicle development

Content

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

Safe and Integrated Driver-Vehicle Interface (SIDVI) was a 3-year FFI project in cooperation between Volvo Group and Chalmers University of Technology.

The project focuses on Human Machine Interaction (HMI) for drivers of trucks and buses as well as exploring new HMI technologies that improve the HMI. The goal of the project is to investigate HMI strategies, technologies and test methods.

The project was divided in four different work packages with the above as a common goal:

1. Future scenarios for trucks and buses were written
2. A state of the art research showed what infotainment solutions the car- and truck industry has today and is planning to introduce in the near future. The research also showed the problems and possibilities with a connected car, the possible solutions for connecting a car and what implications and possibilities this means for Volvo. A thesis work was done together with Volvo where a future dashboard for trucks and buses was designed, both the physical, graphical and interaction design. The prototype acted as a platform for new HMI-solutions such as Head Up Display (HUD), voice control, haptic feedback in a knob, and a fully dynamic and graphical cluster for multiple functions.
3. Strategies for active safety features were developed and evaluated. The strategies involved novel types of dynamic visual head up information, haptic feedback through the seat and dynamic auditory information.
4. A toolbox of development and evaluation methods was created. The toolbox was used to evaluate the prototype design above and was also connected to Volvos internal development process.

2. Background

AB Volvo is known as the manufacturer of one of the safest commercial vehicles (trucks and buses) in the world. The passive and active safety features of its commercial vehicles are world-leading and have become the benchmarks of the industry. This reputation is now facing a new challenge in light of the current technological developments. There is a rapidly increasing number of functions – and complexity of these – interacting with the driver in modern trucks and buses. Among others, these include information, entertainment and active safety functions.
A fundamental challenge is posed by the fact that the number of HMI devices (e.g. displays, input devices, remote controls, nomadic devices) is still limited (e.g. by packing constraints and cost) and thus need to be shared among an increasing number of applications. Consequently a single application may use several different HMI devices and, conversely, a single HMI device may be used to control a large number of applications. The design of such an integrated interface is a great challenge facing the automotive industry and involves both human factors and technological issues. A badly designed HMI may lead to confusion and irritation among drivers, thus cancelling out the potential benefits and possibly even further compromising safety by inducing dangerous levels of mental workload and distraction.

3. Objective

For Sweden to uphold its prime status in vehicle technology area, and for Volvo to maintain its leading position in the world as manufacturer of the safest commercial vehicles, there is a strong need for continued focused applied research on safe and efficient automotive HMI.

The project has HMI for trucks and buses as its main focus, more specifically these three points:

1. *HMI strategy* – Development of use case scenarios and HMI design strategies for safe and efficient integration of multiple functions in a unified HMI.

2. *HMI Technologies* – Exploration and exploitation of existing and emerging HMI technologies, their optimal combinations and proper uses to facilitate the driver's interaction with multiple functions.

3. *HMI Test Methods* – Valid, cost-efficient and industrially applicable HMI evaluation methods useful during actual product development work (concept validation to market offering)

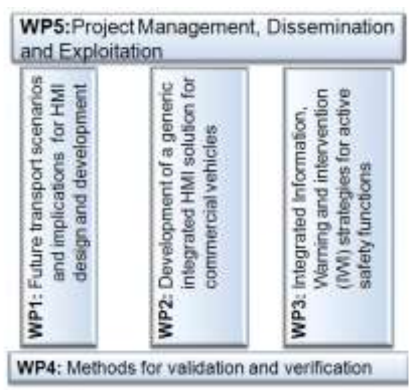

Figure 1 - Project layout

4. Project realization

The project was divided in five work packages. The first three focused on meeting the objectives for HMI strategies and technologies, the fourth work package dealt with the HMI test methods and the fifth contained administrative work for the project.

Work package 1

The objective of WP1 “Future transport scenarios and implications for HMI design and development” was to provide a vision of future transport scenarios and the possible implications for the design of automotive HMI design. The vision was to serve as the basis for the development work conducted in the subsequent WPs.

This was accomplished in three steps. In step one an analysis was carried out, scanning the trends regarding the **S**ocio-cultural, **T**echnological, **E**conomical, **E**cological and **R**egulatory factors of relevance (i.e. a STEER analysis). In a second step, information was gathered from OEMs as well as other sources to create future transport scenarios for bus and truck respectively. The third and final step included an analysis of the implications for future designs of HMI in vehicles.

Work package 2

Work package 2 consisted of two parts;

1. A state of the art report which explained the different infotainment platforms existing today and the different solutions for connected services used in an infotainment platform. The report also contained descriptions of different brands’ infotainment platforms and their solutions. The report ended in a discussion on what could be a solution for Volvo for connectivity and infotainment.
2. A prototype of a future truck and bus dashboard with all its content was physically, graphically and interaction-wise designed, built and implemented. This was done by three thesis workers in cooperation with Volvo.

Work package 3

The focus of Work package 3 was to investigate the efficiency of different strategies for warning the driver in near-collision situations and as part of this investigation, two simulator experiments were conducted. Experiment 1 was targeted towards a truck application, longitudinal warning systems and focused specifically on the effect of multisensory looming (i.e. giving the sensation of something approaching you) signals while experiment 2 focused on bus applications, lateral warning systems and the specific acceptance issues related to the bus environment. Both experiments were conducted in Volvo ATR’s fixed-base simulator which contains a truck cab and a large FOV visual screen.

Experiment 1: Looming auditory-visual stimuli for longitudinal warning systems

In experiment 1, warning design for systems warning for rear-end collisions was the main focus. 22 participants took part in the study. The scenario consisted of driving on a rural road while following a lead vehicle. At certain points in time (unknown to the participant), the lead car would brake to stand still and a warning would then be triggered. A navigation task was used to distract the participant (typing addresses on a keyboard placed to the below-right of the steering wheel).

Six different warnings were presented to the drivers in the hazardous situations (in randomized order): Static sound, static image, static image+ sound, looming sound, looming image, looming image + sound.
The visual image was a symbol of a car seen from behind. The symbol was projected onto the windshield slightly below the driver's line of sight, using a small computer projector. The sound was the sound of a car horn played through loudspeakers placed directly in front of the driver. For the looming conditions, the size of the visual image increased over time, and the sound increased in level. For the static conditions, the visual image size and the sound level were held constant. All warnings had a duration of 1.5s. The main measures used were brake reaction time (BRT) and emotional response.

Experiment 2: Multimodal stimuli for lateral warning systems

In experiment 2, two lateral warning systems intended for the bus market were tested, Lane Change Support (LCS, a blind spot warning system) and Lane Keeping Support (LKS, a run off road warning system). Two different warning concepts were tested for each system. For the LCS Concept 1 was based on using sound and light on the windscreen and Concept 2 was based on using seat vibration and light on the windscreen. For the LKS Concept 1 was based on using only seat vibration and Concept 2 on using seat vibration and light on the windscreen.
36 participants took part in the study. The LCS concepts were tested on a highway section, where there were two critical events when an overtaking car appeared from behind just as the participant was about to change lanes. The LKS concept was tested on a rural road section where the bus was pushed off the road by the test leader when the participant was looking down performing a distraction task. The main measures for both LCS and LKS were steering reactions and various subjective measures of acceptance and trust.

Work package 4

Work package 4 consisted of three tasks;

1. A state of the art research was performed to provide a general overview of existing HMI evaluation methods and tools as a basis for the toolbox development in SIDVI WP4.
2. The toolbox development was the main part of the WP and consisted of several sub-tasks to correlate with the results from the state of the art report. Evaluation methods were identified and categorized according to these topics:
    a. Usability assessment methods
    b. Assessment of user acceptance and emotional response
    c. Driver distraction
    d. Assessment of information, warning and intervention strategies
    e. Toolbox integration
3. The toolbox was evaluated by applying it to two use-cases; "*Evaluation of Volvo's new infotainment system for 2020*" and "*Evaluation of the new bus LDWS system*".

5. Results and deliverables

The results are divided according to the four work packages.

FFI

Work package 1

STEER analysis

Some of the identified **socio-cultural** factors to consider include:

- *Digitalisation*. A future society will be a connected society. People will be connected everywhere and all the time which means that also commercial drivers are and/or are expected to be the same;
- *Urbanisation*. Urbanisation results in cities growing larger and denser, at the same time as the areas in between cities become more rural and more sparsely populated. Future driving environments may hence be characterized by on the one hand no traffic and low complexity and on the other large amounts of traffic and high complexity;

Recognized **technological** factors comprise, for instance:

- *Connectivity*. With increased digitalisation, people (including drivers) will have access to more and more dynamic information which will pose new requirements for the design of the HMI in the vehicles but also change the character of the driver's work.
- *Integration*. Whether technology push or demand pull, future technical functions (Internet, GPS, mobile phone, etc.) will become integrated into one or a few devices. There will be in-vehicle systems and nomadic devices;
- *Multimodality*; New technology will allow for more and more reliable multi-modal interaction (touch, speech, etc.) between users and HMI;

Evidently also the **economic** development will affect the transport area. The future will carry with it waves of recession and advance but the cycles will probably be shorter. For the transportation area this means increased flexibility. The economic development will pose demands for higher efficiency and quality in terms of lower fuel consumption, just-in-time deliveries, tracking of goods, etc.

The **ecological** trends can be expected to continue as there is a strong push for sustainability, not least the transport area. Thus, from an economic but also from an environmental perspective future transportation will demand adaptations of vehicles to new fuels, and new cleaner technology as well as new ways of driving, i.e. eco-driving.
Regulatory and political factors include rules and regulations. From a transport business perspective new EU and US directives on e.g. emissions, traffic safety and security are of particular interest.

Use scenarios

A future scenario was developed for city bus, long-distance coach, city distribution, and long-haul respectively. From a work task perspective, handling the vehicle and manoeuvring the vehicle are common tasks for which certain functions (and HMI) are required. An increase of different systems to support drivers, partly 'replacing' drivers, is anticipated. However, a bus driver's as well as a truck driver's task extends to other work-related tasks. The design of future HMI needs to consider basic cluster functions, different advanced driver support functions, information and communication to support complex work-related tasks, as well as the need for social interaction and infotainment. It needs to consider different traffic contexts. It needs also to consider differences between drivers, for instance education and familiarity with different ICT devices.

Driver's tasks	City Bus	Distribution	Functions/information
Level 1: Handling the vehicle	√	√	ACC, ABS Automation
Level 2: Manoeuvring the vehicle	√	√	LDW, BLIS, Eco-driving, Automation
Level 3: Navigating	Follow route, and timetable	Plan, follow and/or change route	Navigation support Traffic info Eco-driving
Level 4a: Other work related task	Check vehicle status Inform/communicate with passengers	Check vehicle status Plan and execute loading/unloading	Communication with traffic mgmt./ dispatcher/customers
Level 4b: Social tasks	(√)	√	Infotainment Communication (with other drivers etc.)

Implications for HMI based on STEER

The implications for future HMIs are several, for instance that future designs must handle:

- increased complexity – increased interaction with different sources of information (internal and external to the vehicle);
- the introduction of new driver assist and safety functions as well as different levels of automation;
- increased use of nomadic devices (smartphones, pads) as application platforms;
- requests for flexibility, tailoring solutions to different users (drivers), different contexts as well as different customers;
- increased demand for easy-to-use interfaces, little time can be spent on learning how to interact with and use new functions;

However, future design of HMI must also monitor and deal with increased HMI regulation. The designs must be consistent with existing authority guidelines applicable on main markets.

Work package 2

The results of WP2 are divided in two parts; a state of the art report and the prototype.

State-of-the-art

The aim for this report was to give an overview of the rapidly changing market of automotive infotainment and telematics. Currently available standards, possible strategies and state of the art implementations were included. The infotainment results were divided in four different solutions;
In the **embedded system** everything is run in the vehicle, so the OEM has full control of the content but has a higher development and update cost.
Smartphone tethering means that the drivers' smartphone is used for connectivity. The OEM gets no control, but has lower development and update costs but at high data consumption.
Cloud services theoretically provide always up-to-date content for the driver with a low development and update cost for the OEM.

Smartphone integration brings the content of the smartphone to the embedded infotainment system, the different solutions for this are Mirrorlink, VNC, iPod out, ARPEGGiO and Remote skin.
In the end of the report, the implications for Volvo will be discussed with suggestions on changes in the HMI system architecture.

Human machine interaction

As more and more features enter the vehicles, it puts a higher demand on the HMI-solution for controlling these features. In the US, NHTSA guidelines have introduced an ongoing debate about distraction and how to minimize it while driving. NHTSA speaks highly of voice control as a way of controlling the infotainment system. It requires less visual distraction to be used compared to manual-visual interaction. The technology lets the driver speak commands and dictate text as input to the system.

The prototype

-Driver in central power position
-Holistic design
-Increase visibility
-Minimize distraction
-Simplicity
-Assist when needed

Image 1 - Thesis main focus

Three thesis students – Kristoffer Munk, Thomas Flygenring and Marius Amadeus Koppang – from Architecture & design at Aalborg University did a physical, graphical and interaction design of the prototype together with Volvo.
In short the thesis workers designed a prototype together with Volvo. The main focus in the design is described in the figure above (figure 1). The design included a physical (figure 2), graphical (figure 4) and interaction design of the dashboard (figure 3).
Several iterations were made which included joining a truck driver on the road to see how the vehicles were handled, cutting down on the physical content of the dashboard to increase visibility and minimize the distraction while using the system by a holistic design with HMI technologies such as haptic feedback, voice control and HUD.

Image 2 - Physical design

Image 3 - The built prototype

Image 4 - The graphical layout

A haptic feedback was given to the user via a knob when scrolling through menus. For instance, when trying to continue to scroll in a menu even after the last item has been reached, the knob hits a “wall” and cannot be turned any further. This, together with a specific sound depending on where in the menu the driver was located, enabled the driver to know where in the menu he was without looking at the screen.
The voice control enabled the driver to give commands to the system without looking away from the road and without taking his hands of the steering wheel. Voice control features that were included in the prototype were playing music, calling a contact and dictating a text message.
A HUD projects an image on the windshield which means that the driver does not have to look down on the dashboard to get the information. This decreases the visual distraction compared to a traditional screen attached to the dashboard. It is a challenge to fit a HUD to the windshield of a truck due to the steep angle of the windshield, compared to a passenger car where it is much easier to use a HUD since the reflection on the windshield is easily seen by the driver if fitted on top of the dashboard. The HUD used in SIDVI used a direct projection technology that enabled it to be used in trucks. However the focus of the image was where the windshield was, instead of 2 meter in front of it as other HUDs on the market for passenger cars.

Work package 3

The results of WP3 are divided in two parts; Experiment 1 which focused on longitudinal warning systems and experiment 2 which focused on lateral warning systems.
Results, experiment 1

The main measure was Brake Response Time (BRT) which was defined as the time from warning onset until the time when 50% of maximum brake pressure had been applied. The analysis showed that the multimodal (sound + image) looming warning resulted in faster BRTs than the static multimodal warning. This analysis also showed that the multimodal looming condition resulted in faster BRTs than the image looming warning and the sound+image static warning. The mean BRTs are shown in Figure 2 below.
Participants also rated their emotional response after being exposed to each warning. Also here, the analysis showed that the multimodal looming warning seems to differ from the other warnings in the way that it was perceived as being more positive than the other warnings.

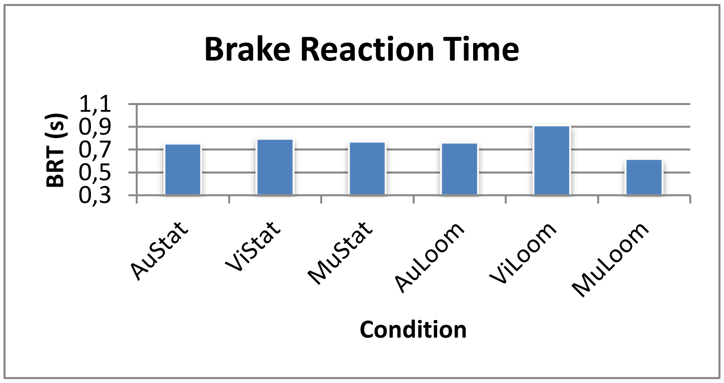

Figure 2: Means of brake reaction time (BRT). Au= sound only, Vi= image only, Mu= sound + image.

The finding that sound+ image looming warnings resulted in faster brake reaction times than the other warnings is particularly interesting and is supported by recent neurophysiological research. The use of multisensory looming warnings in automotive interfaces thus seems to be promising both since they may result in faster reactions and that they may, due to their less intrusive nature, gain higher acceptance from drivers.

Results, experiment 2

The analysis of the objective measure from the LCS evaluation did not show any statically significant difference between the two concepts, which can be interpreted as if the two concepts have the same level of efficiency in terms of the driver's reaction time. However, the analysis of the subjective ratings shows that Concept 2 Vibration + Light received higher satisfaction scores than Concept 1 Sound + Light.

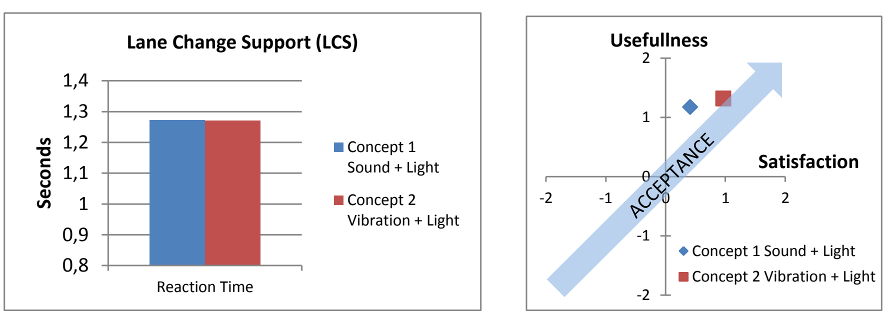

Figure 3. Reaction time (left) and acceptance rating results for LCS concepts.

The analysis of the objective measures from the LKS evaluation showed a trend of Concept 1*only* Vibration resulting in faster reactions. A possible explanation of this result could be that the combination Vibration + Light was not coherent enough with the actual event taking place (i.e. driving off the road). The analysis of the subjective acceptance ratings showed that Concept 1 *only* Seat vibration received a better satisfaction score.

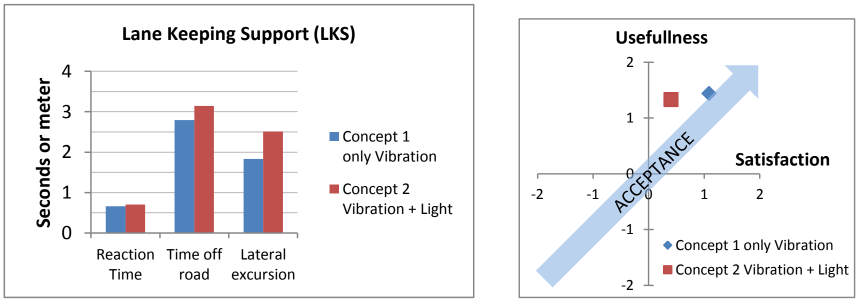

Figure 4. Objective measures (left) and acceptance rating results for LKS concepts.

Overall the participants seemed to think that it is important that the passengers in the bus do not notice the warning signal. They find it embarrassing if someone else sees or hear the warning and are afraid that the passengers would lose confidence and think that they are bad drivers. That could explain why the LCS concept 2 Vibration + Light and the LKS concept 1 *only* Vibration got a better acceptance result.

Work package 4

Task 1 – State of the art

The methods and tools were grouped in the following general categories: Assessment of (1) usability, (2) user acceptance and adoption, (3) experience and emotional responses, (4) attention demand/driver distraction, (5) workload and driver distraction and (6) information, warning and intervention (IWI) strategies of advanced driver assistance systems (ADAS).
It was concluded that there exists an abundance of usability assessment methods applicable for present purposes and, hence, no novel developments were needed in the present project. The same conclusion was reached for methods assessing attention demand/driver distraction.
With respect to user acceptance and adoption, and experience and emotional response, fewer methods were identified, and some of the existing methods were judged to be somewhat problematic. Thus, it was suggested that some further development is needed in this area.
In the area of ADAS information, warning and intervention assessment, it was concluded that a well-defined methodology for experimental ADAS HMI evaluation is lacking, although some initial steps have been taken in US- as well as European projects. The same can be said about design guidelines for warnings and interventions. Thus, it was recommended that novel developments of such methodologies would be needed in the project.

Task 2 – Toolbox development

As mentioned above, this task, which comprised the main part of the work in the WP included a number of sub-tasks.
Usability assessment methods

While the term usability could be viewed as encompassing any of the methods addressed in the project, this sub-task addressed more generic usability methods deriving from the field of Human-Computer Interaction. Since these methods were considered relatively mature, this work mainly involved testing the applicability of the methods in on-going product development projects at Volvo. Based on this, a subset of the methods identified in the state-of-the-art review was selected for inclusion in the toolbox. The following usability methods were selected:
1.Hierarchical Task Analysis (HTA), 2.Cognitive walkthrough, 3.Heuristic evaluation, 4.Layout analysis, 5.Usability tests, 6.Interviews, 7.Focus group interviews, 8.Observation, 9.Think aloud methodology and 10.SASSI (Subjective Assessment of Speech System Interfaces).

Assessment of user acceptance and emotional response

The traditional approach to user acceptance evaluation is the van der Laan scale. However, this method was deemed non-satisfactory. It was thus decided to develop a new instrument for acceptance evaluation in the project. This resulted in the Strömberg-Karlsson Acceptance Scale (SKAS), which was developed and initially tested in several on-going product development projects. It is based on a questionnaire containing 20 items, comprising the four general areas trust and control, perceived benefit, perceived effort, and compliance. These are further broken down to a set of more specific aspects, which increases sensitivity compared to previous methods. The final result is a score of the acceptance level of the HMI in under evaluation.
In addition, two existing methods for measuring emotional responses were selected for inclusion in the toolbox; 1.Self-assessment manikins and 2.Hesselgren's scale.

Driver distraction

The third sub-task addressed methods or assessing attention demand and driver distraction. The focus was on well-established methods linked to existing distraction-related guidelines, in particular the European Statement of Principles and the NHTSA Driver Distraction Guidelines in the US.
The methods chosen for assessing the visual-manual aspects of distraction were visual occlusion and eye-glance based measurement. The Detection Response Task (DRT) was chosen as the method for assessing cognitive distraction and the updated version of the TRL checklist was selected for general assessment against ESoP. The visual occlusion method, as specified in the NHTSA guidelines, was applied in an evaluation of the visual demand of selected HMI features of the new Volvo FH truck.
This work also included a study on a simplified version of the tactile DRT which involved a static (non-driving) setup rather than a driving simulator or a test vehicle. The study was conducted as part of a larger set of coordinated studies on the DRT, conducted under the ISO framework with the purpose to support the DRT standardisation. The results indicated that the static set-up yielded similar results as the simulator set-up. An illustration of the DRT set-up is given in Figure .

Figure 5 The Tactile DRT tactor (left) and response button (right). The basic idea behind the tactile DRT is to measure the cognitive load of an in-vehicle HMI in terms of the ability to respond to tactile stimuli (vibrations) generated by the actor.

Assessment of information, warning and intervention strategies

Since the state-of-the-art review indicated a lack of mature methods in this area, two novel methods were developed in the project. They were the *Volvo Active Safety Evaluation Checklist (VASEC)* and the *Volvo Active Safety Experimental Evaluation Methodology (VASEEM)* which is intended as a general step-by-step guide for how to design experimental studies for assessing IWI strategies of active safety systems. VASEEM was based on previous work in the FICA2 VINNOVA-funded and InteractIVe EU-funded projects.

Toolbox integration

The objective of the fifth sub-task was to put together the results from the parallel sub-tasks reviewed above into a first version of the SIDVI toolbox. The toolbox consisted of (1) the V&V plan guidance document and (2) descriptions of all included methods, based on the common template and (3) other material needed to apply the methods. This also included a general mapping of the included methods onto the Volvo Global Development Process.

Finally, a decision tree was developed to enable selecting the correct method from the toolbox depending on where in the development process one is.

Task 3 – Toolbox evaluation

When the toolbox was used to evaluate the two use-cases, the first being the prototype developed in WP2, it was found that the toolbox worked well for its intended purpose. A number of improvements were identified and the toolbox will be updated accordingly.

5.1 Delivery to FFI-goals

Within the Vinnova-program Vehicle development, the following was contributed from SIDVI:

Vehicle concepts

SIDVI developed future innovative and safe vehicle HMI concepts. WP2 developed a prototype for future truck and bus concepts by using new HMI technologies such as HUD, voice control and haptic feedback. WP3 developed HMI strategies for active safety functions. Both the WP2 and WP3 prototypes were verified in WP4.

Methods for development

WP4 created a toolbox of methods to be used when evaluating HMI concepts, specifically developed to be used in product-projects to make the development more efficient and improve the results of it.

6. Dissemination and publications

Even before the projects dissemination it was decided to continue research of selected parts of the projects. On the 27th of February 2013 dissemination was held for both Volvo and Chalmers to share the results of the project.

7. Conclusions and future research

Work package 2

The state of the art research showed some interesting alternatives for Volvo regarding connectivity and infotainment options. The report has been further developed since, and will hopefully continue to be updated in the future. The different options described in the report are further investigated internally at Volvo to see which one suits our needs best.
The prototype has been used to demonstrate and evaluate the new HMI-technologies installed there. The plan is to further develop the content there and treat it as a future infotainment platform for Volvo commercial vehicles. Voice control and HUD will be the areas most focused on in further research.

Work package 3

Experiment 1 showed that dynamic, multimodal warnings can be beneficial for improving the driver's reaction time in critical situations. In experiment 2, the issue of acceptance was in primary focus and it was shown that vibrations can in some cases replace sound to gain higher acceptance ratings without impairing the behavior significantly. Hence, when designing an integrated interface for safety critical information and warnings, both reactions and subjective opinions should be taken into account and the parameters of the interface need to be optimized with respect to the targeted users. It is foreseen that the concepts developed and tested within WP3 will be further developed in currently ongoing and future projects.

Work package 4

It is foreseen that the toolbox will be continuously updated in order to address new types of vehicle functions and incorporate future advancements in methods and tools development. One particular area not addressed in SIDVI is that of automated driving which should be further developed. The ultimate goal should be to develop a general user-centred design (UCD) process, integrating both evaluation methods and various levels of product representations (e.g. desktop simulations, simulator mock-ups etc.), into the different phases of the GDP. The SIDVI HMI evaluation toolbox can be seen as a first step towards this goal.

8. Participating parties and contact persons

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