METOHMI Final Report

Project within FFI Fordonsutveckling (Vehicle Development)

Project name:
"Metod- och verktygsutveckling för HMI - METOHMI_C", Dnr 2009-04835
"Metod- och verktygsutveckling för HMI-METOHMI-C-Bas-Tillägg", Dnr 2010-01196

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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

The project METOHMI has, as being part of the umbrella program, performed research on driver interface in passenger cars. The research was performed by the industry parties Volvo Car Corporation and Semcon AB, and the research partners Chalmers University of Technology, Viktoria Swedish ICT, Luleå University of Technology and Swedish National Road and Transport Research Institute (VTI). The project has followed the original time plan and ended on the 31th December 2013. The most important effects of the project have been:

- Establishment of a research cooperation between the automotive industry and academia
- Support to PhD research
- Research and demonstrators of HMI concepts for personalization and multi-modal user interfaces
- HMI concept for energy-efficient planning and driving of hybrid vehicles

The result from the project constitutes a base for both further research within the FFI program and for product development of passenger cars.

2. Background

METOHMI (Methods & Tools Development for HMI) was a research project within in the Swedish FFI (Strategic Vehicle Research and Innovation) partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. Within FFI, METOHMI was part of the FFI Vehicle Development program, sponsored by the Swedish Agency for Innovation Systems (VINNOVA)
The METOHMI project was executed together with other FFI research projects (USI and DRIVI) with focus on the research area HMI (Human Machine Interaction) within the umbrella project EFESOS (Environmental Friendly efficient Enjoyable and Safety Optimized Systems). Of the totally eight research partners in EFESOS the following seven partners were active in METOHMI:

- Swedish National Road and Transport Research Institute (VTI)
- University of Linköping (LiU)
- Luleå University of Technology (LTU)
- Chalmers University of Technology (CTH)
- Semcon AB
- Viktoria Swedish ICT AB
- Volvo Car Corporation (VCC)

This project report covers only the public results. There is also a separate non-public technical report that describes the setup and outcome of the project at a fairly detailed level.

This report covers both the main project “Metod- och verktygsutveckling för HMI - METOHMI_C, Dnr 2009-04835” and the add-on project “Metod- och verktygsutveckling för HMI-METOHMI-C-Bas-Tillägg, Dnr 2010-01196” which both were managed as one project.

3. Objective

METOHMI aimed to develop methods and tools to secure that active safety systems, driver information and infotainment systems developed to increase “safety/green/attractive driving” are in total accordance with the drivers’ cognition and physical limitations to produce optimal effect. The methods and tools developed will serve as a toolkit for the functions developed within the EFESOS project and for further vehicle development. Development of methods will highly contribute to safe, green and attractive competitive cars which contribute to strengthen Sweden on the international automotive market. Powerful methods for verification of HMI early in the process contribute to Swedish Zero Vision and to environmental goal to reduce CO2 emission by facilitating the interaction between the driver and the vehicle with regards to environmental friendly driving.

Objectives were:

- HMI evaluation methodology for the HMI development process, i.e. research, early stages, design verification to increase a safe, attractive and green driving
- Guidelines and measurable goals for driving performance indicators, usability, joy of use and green driving
- A complete cycle of simulations (both HMI simulations and Driving Simulations) for the HMI design development.
- Implementing a holistic approach for HMI development and evaluation.
- A toolkit for open HMI innovation.

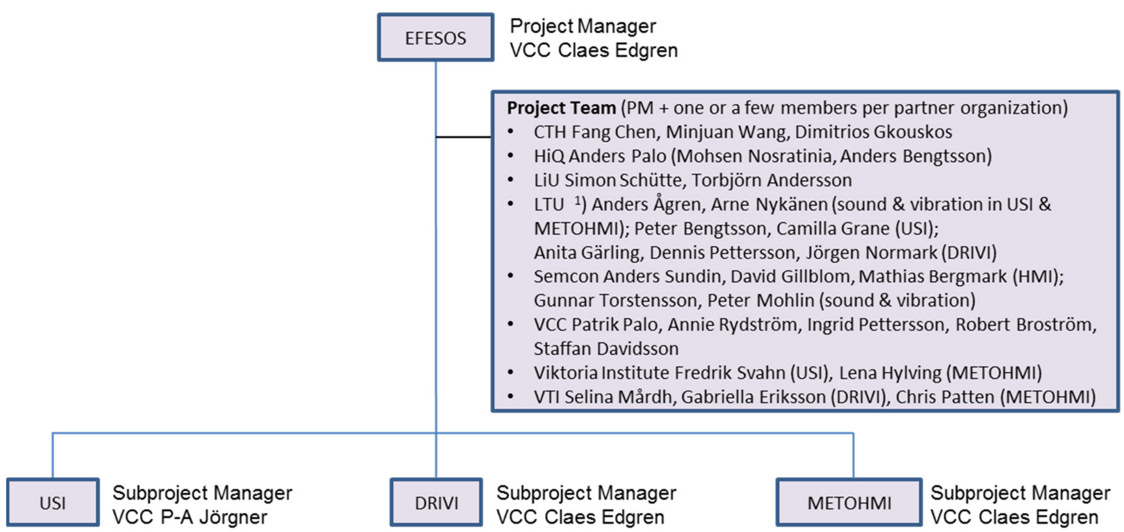
4. Project realization

The FFI decision to start the project arrived in December 2009 and the project started to ramp up its activities shortly after. Since then, the project has been executed with no significant deviations from plans. An addition to the original scope was applied for and granted, labeled as “METOHMI C-bas Tillägg”. In the context of this report, this project is seen as an integral part of METOHMI project and is not separated in any way.
The overall time schedule, start early 2010 and finish late 2013, was not changed during the course of the project.

The way of working in terms of meeting structure, reporting structure was part of the EFESOS infrastructure. Below is an overview of the project meeting and reporting structure.

The METOHMI project organization was part of the EFESOS project organization. Project Manager, EFESOS and USI, DRIVI and METOHMI was initially Patrik Palo VCC and Per-Anders Jörgner VCC, and since March 2013, Claes Edgren VCC.
The EFESOS Management Team (2013) consists of:

- Urban Kristiansson, VCC, Chairman
- Claes Edgren, Project Manager, VCC
- Patrik Palo, VCC
- Patrik Sahlsten, HiQ
- Anders Sundin, Semcon
- Håkan Alm, LTU
- Per-Åke Olsson, Viktoria Institute
- Ola Henfridsson, Chalmers
- Simon Schütte, LiU
- Jan Andersson, VTI



Meetings:

- Monthly project meetings, including at least one representative for each WP and partner organization.
- Workshops on demand, at startup of WP or Task, for problem solving and for sharing results and knowledge
- Internal Conferences, two times per year, and participation in selected external conferences, see further section 6.3 below.

Reports:

- Monthly reports from WP teams to project manager (reviewed and monitored at monthly project meetings)

- Quarterly financial and status reports from each partner to project manager.
- Quarterly PhD student status reports from applicable supervisors to project manager

Status and financial reporting from project manager to FFI via VINNOVA web portal, twice yearly.

5. Results and deliverables

The project consisted of six work packages (WPs), which are described below.

WP 1: HMI process and requirements

Task 1	Offering completeness by affective engineering	LiU, VCC
Task 2	Enjoyment and Safety	CTH, VCC

WP1 Task 1
Traditional product development mostly starts with the definition of a product specification list. Those specifications are usually technical and based on customers' demands. To customers, cars however, do not only fulfill functional needs, but increasingly also intangible needs such as image value and status.
The aim of Work Package 1 Task 1 was to develop, test and apply a method for affective evaluation of car interior and in this way offering an affective completeness of driver experience.
The task was broken down into three sub-tasks with one delivery each. Firstly, a tool-kit was developed for prioritization of infotainment and HMI information. Traditionally In-drive information is presented on LCD displays and manipulated by menus using keys or knobs. This area is well described in HMI literature; a number of tools were found and documented. However, currently the area is undergoing a paradigm shift towards touch screen displays. Hence task 1.1 was enhanced with at study in LiU's car simulator were drivers were asked to perform actions on touch screens as well as conventional displays. It was found that the drivers' behavior is much different with touch based screens. Since they do not deliver tactile feedback the accuracy is lower, which in turn means that the attention on the driving task is reduced. As a side effect it was found that the rapid visual change between the road (simulator screen) and the touch screen frequently leads to simulator sickness.
The second task was to develop a tool kit for affective engineering evaluations of vehicle interior. There are several instruments in existence measuring those needs, but few being able to connect them to physical properties and even less which can generate product specifications based on customers' affective needs. Kansei Engineering is a method which can measure and quantify user feelings and give concrete suggestions for future product specifications. A step-by-step procedure for carrying out such studies was added.
In the final part an analysis was done on the importance of affective evaluations in car-industry. Different methods were compared theoretically and presented according their usefulness in car-interior applications.

WP1 Task 2

In-car systems offer an astounding array of functions that are meant to improve the experience of using a car in a multitude of ways. While most in-car systems development focuses primarily on safety, there has been very little work on exploring the experience of interacting with a vehicle from a car user perspective. User experience is much more than just safety, and in this fact lie immense opportunities for improving automobiles. In order to develop vehicles that support positive interactions the industry must obtain a meaningful understanding of the needs, desires and wishes of car users. The vehicle user need dimensions are a first, crucial step towards shifting perspectives from a technology-first approach, towards the creation vehicles that support human needs in an essential way and thus facilitate positive user experiences.

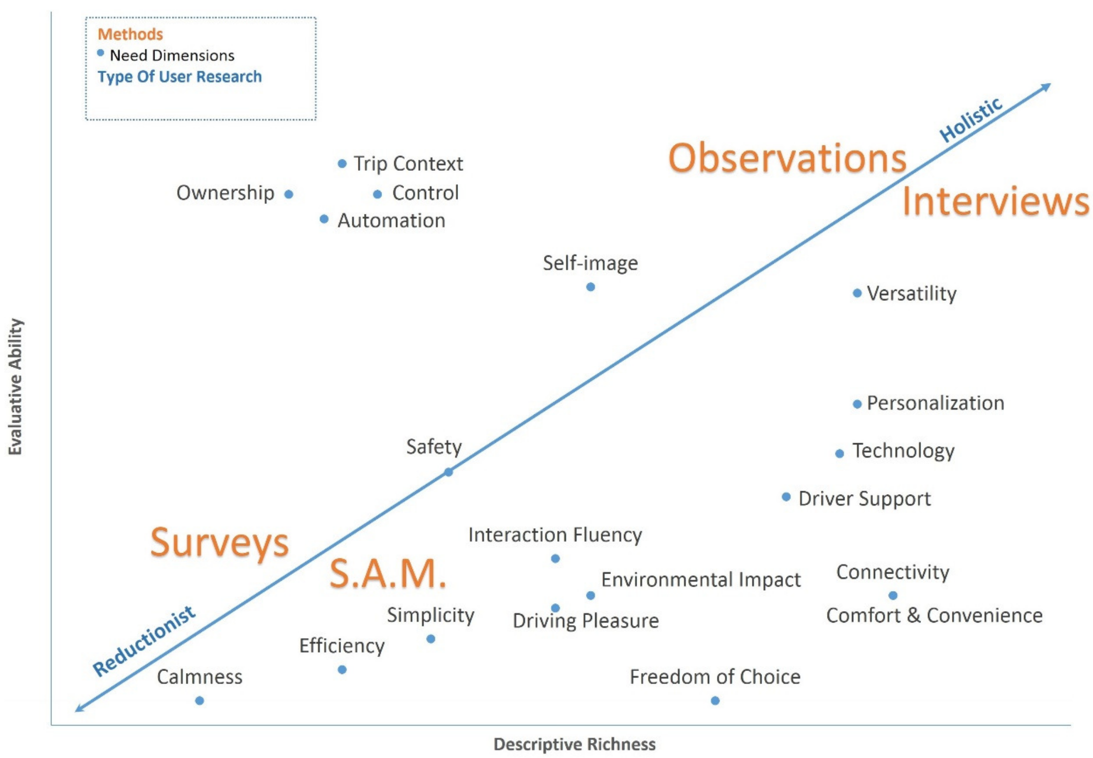


Figure 1: The Need Dimensions and their use in User Research

The figure above displays the vehicle user need dimensions along with their positioning respectively to two important characteristics: their evaluative ability, and their descriptive richness. Each user need dimension has two data points; the first one is the dimension's evaluative ability. Dimensions with a low percentage of evaluative ability contain constructs that do not express a semantically clear preferable state and have a higher place on the vertical axis, whereas dimensions with a high percentage of evaluative constructs have a lower place on the vertical axis. Thus, dimensions with a low evaluative

ability are placed on the top part of the graph. A low evaluative ability reflects that the dimension does not have an obvious preferable pole and should be researched using holistic, ethnographic methods that can capture fine nuances and details that may give a deeper insight into the participant's wishes.
Each dimension also has a descriptive richness percentage, which reflects the diversity of constructs within that dimension. A descriptively rich dimension may reflect diverse values, is placed on the right side of the graph, and should be explored using holistic, ethnographic methods. Correspondingly, a need dimensions with a low percentage of descriptive richness is more homogenous and can be explored using reductionist user research approaches such as Likert scales or closed answer questionnaires. Figure 1 can be of great value when determining the user research approach that is most suitable to explore a certain dimension. For more details regarding the need dimensions, see Gkouskos, Normark & Lundgren (2013) published in the international journal of design.

WP 2: Evaluation methodology

Task 1	Generic methods and tools for the evaluation of active safety systems	VTI, CTH, VCC
Task 2	Generic methods for the evaluation of infotainment systems and services	VTI,VCC, Semcon
Task 3	Generic methods for the evaluation of environmental impact - DRIVI and USI	VTI, VCC
Task 4	Modelling driver performance	VTI, VCC
Task 5	Customer centric evaluation of in-vehicle information systems	Semcon

VTI, Semcon, VCC, CTH have worked together in this horizontal MetoHMI work package that was in part designated to support the vertical subprojects (USI and DRIVI) within EFESOS. WP2 has focused on evaluation methodology.
The twenty-one deliverables in MetoHMI WP2 are a combination of practical approaches for testing and evaluation, compendiums of methods employed in the two main sub-projects DRIVI and USI, and tools for choosing appropriate methods. The different reports reflect different aspects of an evaluation that may include planning, or tailoring of the test methodology or metrics for optimizing the development process.
There were five main research areas in WP2. The first area discussed methods enabling evaluation of new driver support HMIs with the main focus on safety. The second area discussed methods enabling evaluation of innovative information and entertainment systems and services. The third area discussed methods enabling evaluation of new eco-driving supports. The fourth area discussed driver modelling by predicting driver performance and drivers' usage of support systems. The fifth area discussed ways of evaluating Customer Willingness to Pay (CWTP).
WP2 provides a test environment guide for researchers and design engineers. There are many considerations and decisions that require careful consideration when attempting to evaluate a driver's interaction with an advanced system. These considerations must attempt to balance requirements of cost-efficiency and validity (internal and external) in the product development process. In conclusion, the overriding recommendation for the

researcher or the design engineer is that he or she should follow a scientific approach whenever possible.

WP 3: Test environments

Task 1	Review and value of test environments	VTI, CTH, VCC
Task 2	Virtual proving ground	VTI,VCC, Semcon

VTI, Semcon and CTH have worked together in this horizontal MetoHMI work package that was in part designated to support the vertical subprojects (USI and DRIVI) within EFESOS. WP3 has focused on test environments.

The seven deliverables in METOHMI WP3 can be likened to chapter in evaluation manual or hand book. The different reports reflect different aspects of an evaluation that may include planning, or tailoring of the test environment for optimizing the development process.

The methods used in METOHMI WP3 have predominately comprised literature searches as well as apply expertise from senior human factors researchers. The methodological focus was based on statistical and scientific research methods when studying human behaviour. It was important that the methodological focus was on human behaviour in particular because these methods are particularly responsive to variance in behaviour-data.

This work package also aims at investigating test environments available for evaluation of in-car devices and HMI. The considered test environments are lab, virtual (video, computer, simulator) and real traffic (naturalistic, FOT) environments. The work includes finding synergies between and complementary usage of the different environments, i.e. how they can benefit from and contribute to each other. The work package collected and coordinated methods produced in EFESOS.

WP3 provides a test environment guide for researchers and design engineers. There are many considerations and decisions that require careful consideration when attempting to evaluate a driver’s interaction with and advanced system. These considerations must attempt to balance requirements of cost-efficiency and validity (internal and external) in the product development process.

WP 4: User Involvement

Task 1	Open Innovation Strategy	Viktoria
Task 2	Review of established HMI design	Viktoria
Task 3	Open HMI design	Viktoria

Digital innovation is an activity that involves the creation of new combinations of digital and physical components to produce novel products. Such innovation is becoming progressively important for VCC to enhance the functionality and capabilities of their produced cars. However, the study shows that it is difficult for an established firm, like VCC with plenty of dominant design, to accomplish digital innovation.

Features of digital technology such as programmability and reproducibility stimulate to create new ways of innovating cars. In this regard, digital innovation shapes established processes and product designs. However, the processes aligning the tasks required to realize an innovation and its product design also influence digital innovation via its manifestation of VCC's dominant design. Also, it is not enough to focus on technological solutions, but to as much look at organizational implications of implementing new technology; what processes are needed to develop the digitized car, what external resources can and should be used, how do the marketing logics change etc.

The analysis highlights the need to develop a layered digital architecture and a coupled organizational structure in order to reap the benefits of flexibility associated with digital innovation, open innovation and thereby possibilities for user involvement. However, it also highlights the challenges VCC are experiencing in the development of this architecture, particularly the necessary cross-organizational structures that needs to be established. This is obvious when the protocols that unambiguously define the interfaces between the layers are being developed.

In sum, VCC has difficulties in implementing possibilities for user involvement. Some foundational changes have to be established to develop progressive strategies for digital and open innovation and enable possibilities for successful user involvement. For one, recognition of the influence dominant design has on digitalization and secondly, improved understandings of a layered architecture along with its organizational implications are necessary.

WP 5: Methodology for audio design of information, entertainment, warning and feedback

Task 1	Develop methodology to design information and warning sounds and vibrations functioning inside a vehicle in operation	LTU, CTH, LiU, Semcon
Task 2	Develop methodology for subjective-affective evaluation of audio and vibration quality	LTU, CTH, LiU, Semcon
Task 3	Develop methodology for brand sound and vibration design	LTU, CTH, LiU, Semcon

Task 1: Develop methodology to design information and warning sounds and vibrations functioning inside a vehicle in operation, and Task 3: Develop methodology for brand sound and vibration design.

Industrial design covers the design of products taking all senses into account. In addition, design for creation and preservation of brand identity is often central throughout the product design process. However, most literature on product design has focused on vision and visual design and there is a lack of tools for handling product sounds and vibrations in the design process. Buxton (2007) identified sketching as one of the most central tools in industrial design, and Schon and Wiggins (1992) defined the design work as a seeing-moving-seeing process. Designer uses a sketch to see a problem, then tries a solution by suggesting a new sketch (moving) and finally evaluates the solution by visual inspection (seeing). The same process is utilized by a composer or sound designer when working with music or sounds, hearing-moving-hearing, and should be utilized when designing vibration signals, feeling-moving-feeling. Today, few dedicated tools for sound design exist. Commonly tools for music composition and production are used. These tools allow the composer/designer to interact with the media in a hearing-moving-hearing way. However, such tools are more complicated than a pen and a paper. This is especially apparent in phases of product design which involve non-experts in sound design, e.g. decision makers and jury groups.

Within METOHMI WP5 a tool for quick real time sketching by a product development team was developed and evaluated. This allowed a hearing-moving-hearing process utilized by the whole product design team, facilitating interaction and development of ideas and thoughts. Further, sketching of vibrations was studied using combinations of low frequency sound and shakers allowing designers to feel the signals during the design process.

Three case studies have been conducted in these two tasks:
1. Development of welcoming sounds/sound logotypes for a Volvo car.
2. Development of combined sound and vibration signals for turn instructions for a navigation system.
3. Development of sketching tools for combined sound and vibration signals.

Part of the project focused on identification of properties making synthetic 3D sounds work in a car compartment and assessment of performance of 3D signal sounds. Previous studies have shown that attention may in some cases be enhanced and distraction decreased by proper placement of sounds in space. In cases when loudspeakers cannot be placed in the desired positions, 3D sound reproduction can be achieved by binaural synthesis. The use of synthetic 3D sound is known to result in higher localization blur and front-back confusion rates than real life listening. Therefore, it is important to have methods for design and evaluation of this kind of sounds. In METOHMI Bhat & Lai (Bhat & Lai, 2013) developed a design and evaluation methodology that can be used to test the acceptance of 3D sounds in in-vehicle auditory information systems. Zedigh (Zedigh, 2013) studied how a unidirectional sound source movement along an orbit in the horizontal plane affected front – back confusion and localization errors. Both the conducted Master’s thesis (Bhat & Lai, 2013) and Bachelor’s thesis (Zedigh, 2013) have shown that sound source movement in the horizontal plane may reduce front-back confusions, although the statistical significance of the results were not tested. Future studies could investigate the movement speed.

Lundkvist et al. (Lundkvist, Nykänen, & Johansson, 2011) developed and tested a crosstalk cancellation algorithm intended for use in car compartments in combination with sound signals specially designed for use in combination with the algorithms. Different loudspeaker positions were compared and the study resulted in recommendations on where loudspeakers should be placed in a car compartment in order to achieve good synthetic 3D sound.

Task 2: Develop methodology for subjective- affective evaluation of audio and vibration quality

A tool for subjective evaluation of sounds have been developed and applied to evaluate the sounds designed for an early warning system. By following the sound sketching method, several sounds were designed and evaluated by jury groups. The jury group evaluations provided valuable information which helped in improving the sound sketches. The emotional responses of designed sounds were evaluated using Self-Assessment Manikin (SAM) scales (Margaret M. Bradley and Peter J. Lang, 1994) and open discussions.

The SAM scale is an effective tool for measuring existing feeling states, relating them to other indices of emotional response, and assessing changes due to time, therapeutic intervention, or other processes affecting reactions to contextual stimuli. SAM ranges from a smiling, happy figure to a frowning, unhappy figure when representing the pleasure dimension, and ranges from an excited, wide-eyed figure to a relaxed, sleepy figure for the arousal dimension. Thus, the results can be mapped in a plot, which uses pleasantness as x - axis and arousal as y - axis. The results showed that by using the sound sketches method, the emotional responses to sounds had moved to the desired top right quadrant of SAM plot (arousal/pleasantness scale).

A study was conducted by Schütte (2013) to demonstrate the development of new sound characteristics using affective engineering methods (Kansei Engineering). Kansei Engineering is a proactive product development methodology, which translates customers' impressions, feelings and demands on existing products or concepts into design solutions and concrete design parameters. Psychological impressions intended for a future product are put into a Kansei Engineering System (KES), which in turn delivers the required product design parameters evoking the impression being aimed for. The Kansei Engineering method was applied to evaluate sound sketches designed for welcoming sounds in vehicles. The results showed that the Kansei Engineering is an appropriate method to obtain the emotional demands of customers and map different sound accordingly. The results also showed that sounds containing less elements are easier to rate by the listeners.

WP 6: VCC Advanced Engineering and Research

Task 1	Methodology of the HMI requirement process	VCC
Task 2	Collect needs and methodology results of USI, DRIVI and METOHMI	VCC
Task 3	Establish VCC Usability lab, evaluate and apply methods	VCC

The process of developing the laboratory was started in 2009. Extensive research was made, defining the usage of the laboratory, the requirements of facilities and equipment,

investment alternatives and suitable suppliers. The investment was made in spring 2010, and the driving simulator was fully functional by September 2010. A number of departments within VCC were involved in the project to ensure quality of the facilities, cockpit build and integration of the driving simulator.
The laboratory contains several integrated systems. The two main parts are the driving simulator and the cockpit. They constitute terrains for driving scenarios and a fully functioning cockpit. Data is collected by data measurement units, for examples cameras and a three camera eye tracking system. All parts in the simulator set up can exchange information and in some cases control each other when needed.

The font vision consists of a 180 degree round screen, where the image is provided by 5 projectors. The resolution is 1900x1080 pixels. Rear vision is provided by three 12" TFT screens serving as rear view mirrors. Surround sound of road, wind and engine noise is provided by a 5.1 sound system. A low frequency speaker is installed under the driver seat for road vibration.

The simulator's API is possible to use to extract information from the driving simulator. If needed, data such as GPS position, distance to other objects etc can be extracted. Signals are also sent on a CAN interface to be able to communicate with production systems brought into the cockpit, such as an existing speedometer. Examples of CAN communication from the cockpit are accelerator, brake pedal, gear, steering wheel position, light and direction indicators. Examples of CAN communication to the cockpit are steering force, RPM and speed.
The driving simulator consists of 6 computers handling visual processes, and one main computer handling the driving scenarios, dynamics etc. The main computer is connected to a VCC storage disc for storing of large amounts of data.

A flexible solution was of high priority when developing the lab, especially a plug-and-play solution for interchangeable HMI systems. Rapid integration of new hard ware and software was an absolute requirement. The cockpit rig was constructed to integrate Adobe Flash simulations of interfaces as well as fully functioning pre-production systems (i.e. infotainment systems and driver information modules).

Examples of infotainment system installations

Due to the need of flexibility and rapid simulations, a fixed base driving simulator construction was preferred. The Norwegian company AutoSim was chosen because of the simulator's flexibility and ease of use. The company provides high quality visual driving terrains and a wide range of driving scenarios, with graphical user interfaces for easy scenario programming.

The driving terrains range from city and suburb driving to highways and country roads. Both day and night conditions can be simulated, as well as different weather and road surface conditions. A large number of vehicles, bikes, animals and pedestrians can run simultaneously. The traffic can run autonomously if needed, following traffic lights and rules, or different scenarios that can be programmed to perform actions at specific conditions. These can for example be used for creating a potentially dangerous driving situation.

The simulator will serve as a complement to more advanced driver simulators like the VTI simulator IV. There, tests with higher demands of timing and fidelity will be performed.

5.1 Delivery to FFI-goals

Volvo cars: METOHMI has, together with USI and DRIVI, created capabilities for building competence within the automotive HMI area. The funding from VINNOVA has made it possible to employ engineers within research and development, whose results have partly been scheduled for market and product introduction. Further, METOHMI has contributed in the effort to create an organizational structure for cooperation between academy, research institutes, service providers and Volvo Cars, which facilitates further research and innovation.

Viktoria Swedish ICT has contributed with insights on how organizations must adapt to take advantage of the potential and possibilities of digitalization. Necessary increase in competence for enhanced innovation capability within the area of HMI follows the proposed corporate re-organization. The effects of Viktoria's contribution can especially be seen in organizational changes and an increase of digital innovation awareness and competence.

Semcon: METOHMI developed the methods applied in the DRIVI and USI subprojects. New methods for the design and evaluation of warning and information sounds and vibrations have been developed. Subjective responses of designed sounds for an early warning system were tested. The culture differences were taken into consideration during the design. METOHMI provided an opportunity to strengthen and improve the design methodology of sound and vibration signal. METOHMI also created a valuable chance for Semcon to collaborate with academia and research institutes in developing vehicle HMI. The knowledge from previous research at the universities and the experience and practical knowledge from the industry were combined in the project and the collaboration will promote further research.

Linköping University: Many methods within affective product development like Kansei Engineering originate from Japan. Even if Kansei Engeineering has there been used within the automotive industry, some adaptation to European industry was necessary, concerning aspects of organization as well as the function of the method. For the research group within LiU there has been an important learning on how fast and effective this adaptation can be done. This finding can also be applied within other areas of automotive industry and adjacent sectors.
Luleå University of Technology has contributed to the project with knowledge on how perception of sounds affects human-machine-interaction in cars and how methods developed for industrial design can be used for development of multisensory user interfaces in cars which both strengthen the brand identity and increase traffic safety. The project has made it possible for LTU to develop their network of partners, both within the academy and within the automotive industry. This network has been a prerequisite for the development of methods and tools for vehicle design made within the project. Research and method development have been made in close cooperation with many of the partners within METOHMI. The project has resulted in good prerequisites for future research within the research area in close cooperation between academy and industry, and has already led to new research projects within vehicle development (e.g. FFI financed 3D Sound Design).

Chalmers: Through participating the project METOHMI, together with DRIVI and USI, the department of Interaction design at Chalmers, has got the opportunity to have deep cooperation with industry, different research institutes and other universities. We are able

to make further development, from both theoretical and methodological, in the corresponding research areas into the world's leading position and made unique contributions from the entire design process from requirement study, interactive design methods and evaluation methods. The unique cooperative research environment provided us the possibility to take the industrial perspective into the research work on developments of the methods, so they would not only have the academically value, but also practical value.
Another important contribution is that we took the multi-culture perspective into consideration and specially focus on China. We managed to have deep cooperation with two high ranked universities, Tsinghua and Tongji technical universities, in China. This cooperation will open up broad opportunities in the future for both vehicle research work, and even for broad cooperation between our department and Chinese universities.

VTI: The EFESOS/MetoHMI project goals and objectives focused on providing evaluation for green, safe and attractive properties of in-vehicle technologies through test regimes that prescribe reliable, repeatable and verifiable methods; the scientific approach to evaluation. The prescribed evaluation approaches address the different needs inherent to the position of the HMI solution in the development process. The tailoring of evaluation approached endeavoured to aid the researcher/engineer in finding a practical balance between evaluation needs and cost effectiveness; i.e. not using a sledge-hammer to crack a walnut.

6. Dissemination and publications

6.1 Knowledge and results dissemination

During the course of the project, results from research have been disseminated through PhD theses, Master theses, articles in scientific journals and project-internal technical reports. Further, dissemination has been done by project members' participation at external seminars and conferences. Within the project, internal seminars have been conducted twice a year to spread information and findings to other project members and their organizations.

6.2 Publications

The journal and conference papers are listed below
2010:

1. Broström, R., Bengtsson, P. and Axelsson, J. (2010). Correlation between safety assessments in the driver-car interaction design process, Applied Ergonomics, Volume 42, Issue 4, Applied Ergonomics and Transportation Safety, pp. 575-582.

2011:

2. Broström, R., Rydström, A. and Bengtsson, P. (2011). Difference in Usability and Safety when using touch screen and rotary control while driving: A simulator study.
3. Lundkvist, A., Nykänen, A. & Johnsson, R. (2011). 3D-sound in car compartments based on loudspeaker reproduction using crosstalk cancellation. In proceedings of the 130th AES Convention, London, UK.
4. Andersson T., Warell A., Holmlid S., Ölvander J., Desirability in the development of In-Car Infotainment Systems, Interact 2011 - 13th IFIP TC13 Conference on Human-Computer Interaction, September 05-09, 2011, in Lisbon, Portugal.
5. Andersson T., Holmlid S., Warell A., Exploring the concept of Gist as a mean to find the Current Product Sign, Nordcode 2011 conference, September 28-30, 2011, in Roskilde, Denmark.

2012:

6. Svahn F., Henfridsson, O (2012) The Dual Regimes of Digital Innovation Management, HICSS-45, Hawaii, USA.
7. Gkouskos, D., Chen, F., 2012, The use of Affective Interaction Design in Car User Interfaces, The 18th World Congress on Ergonomics - IEA 2012, February 12-16, 2012, in Recife, Brazil.
8. Normark, C. J. & Gkouskos, D. (2012). Exploring user Needs in Automobiles. International Design Conference - Design 2012. Dubrovnik - Croatia, May 21 - 24, 2012.
9. Gkouskos, D.; Chen F. (2012). The challenge of evaluating pleasure-of-use in vehicle interfaces. NES 2012, Stockholm Saltsjöbaden, Sweden.
10. Svenson, O., Eriksson, G., Salo, I, & Peters, E. Judgments of mean speed and predictions of route choice. (2011). Transportation Research Part F: Traffic Psychology and Behaviour, 14(6), 504-511.
11. Eriksson, G., & Svenson, O. (2012). Driving faster or slower? Biased judgements of fuel consumption at changing speeds. Accepted for presentation at the Applied Human Factors and Ergonomics 2012 - AHFE 2012, 1st International Conference on Human Factors in Transportation.
12. Svensson, J., Kleiven, S., Mohlin, P., Mannegren, M (2012). Designing multimodal stimuli for in-vehicle information systems. NES 2012 conference, Stockholm Saltsjöbaden, Sweden, August 2012.
13. Wang M., Yi Ci, Li, Chen, F (2012) How Can We Design 3D Auditory Interfaces Which Enhance Traffic Safety for Chinese Drivers? AutomotiveUI 2012, Portsmouth NH, October 17th – 19th 2012.
14. Hylving, Lena and Selander, Lisen, "Under the Guise of Openness: Exploring Digital Innovation in User Interface Design " (2012). ECIS 2012 Proceedings. Paper 37.

2013:

15. Eriksson, G., Svenson, O. & Eriksson, L. (2013) The time saving bias in static-cognitive and dynamic-driving judgements. In U. Ansorge, E. Kirchler, C. Lamm & H. Leder (Eds.) 55th TeaP Conference, Vienna, Abstract, p.73.
16. Lundgren, S; Gkouskos, D (2013): Escaping The Obvious: Skewing Properties of Interaction. Conference paper. Presented in NORDES 2013

17. Hylving, L., Schultze, U. (2013) Evolving the Modular Layered Architecture in Digital Innovation: The Case of the Car's Instrument Cluster. Conference paper. Presented at ICIS 2013, Milan.
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7. Conclusions and future research

Volvo cars: The project has given VCC tools and methods that we now take for granted and are completely integrated in the product development, for instance the HMI simulator. Further, the momentum of HMI research fueled by EFESOS concerning connections between industry and academia is utilized in new FFI projects and thesis works. The area of affective product development is now explored further in a dedicated FFI project "Automotive User Experience", chaired by VCC, with partners from industry and academia. Interaction modalities that were briefly investigated in EFESOS is now subject of specific projects, e.g. "3D Sound Design" and the freshly started "AIMMIT" project.

Viktoria Swedish ICT: The increase of digital infrastructure, in the car as well as outside of the car, renders possibilities for non-traditional stakeholders to be involved in the development process of HMI. The technology and knowledge exist to involve people from outside of VCC, and even outside of the automotive industry, such as end users. However, existing organizational processes limit these possibilities. This needs to be further understood to overcome challenges originating from existing and institutionalized development processes.

Linköping University: The research field of affective product development is a growing field both internationally and locally. Swedish industry has become more aware of the related issues and is more open to consumers' new affective demands. However, it can be stated that established methods to connect subjective consumer demands and product specifications are often missing. What is needed in the future is further development of methods and a practice to apply and validate them.

Chalmers: Cooperation with industry is always one of the important issues for Chalmers. The outcomes from research projects should not only have its academically contribution but also have practical contribution to the industry, for which this project has achieved both goals. The achievements from this project bring a brought future for this research team as their work is heading into future vehicle design with high degree of automation and new challenges of positive user experience. We will further develop our research, and it will surely lead to future project application towards national and international projects.

As an example, Volvo and Chalmers together with Tongji University and RIOH established a traffic safety research center in China, and our team is part of it. We carried out the first research project in this center.

Semcon: The collaboration between the universities and the industry combined the knowledge from previous research with more practical knowledge and experience. The results can be applicable to both industrial and academic research. The project also contributed to further development of sound design for in-vehicle infotainment, warning systems and user feedback.

VTI: The EFESOS and the MetoHMI projects have resulted in the development of methodological papers that have aided doctoral and master's students on a practical and theoretical level. MetoHMI has also provided VTI with the opportunity to work closely with industrial partners in exploring the bounds of various evaluation methods and techniques. It is important to find connections between the theoretical/academic side of research and the practical/industrial side of product development which MetoHMI has facilitated. Moreover, the MetoHMI project has provided a very beneficial research platform where research engineers can work alongside research psychologists. The research methodologies are profoundly different where for instance research in to human behavior (of drivers) requires the evaluator to measure between-group and also within-group (individual) variances in performance. Engineering sciences on the other hand can calculate and predict non-human mechanics with amazing precision. The EFESOS and MetoHMI projects have been mutually beneficial in the development of advanced driving systems and their respective HMIs.
The future of motor vehicle research lies in part, in the development of increasingly advanced and increasingly autonomous vehicles. The truly autonomous vehicle will of course not require any driver interactions and will no doubt be superior the cars of today in terms of fuel efficiency, road traffic safety and mobility. Full automation of all road traffic vehicles is possibly on a very distant horizon, but in the meantime, partial automation is just around the corner and high automation is not far away, for some of the vehicle fleet. The advancement of autonomous systems are therefore improving but are currently not mature enough to have the driver completely locked out of the vehicle control. VTI predict that the more advanced the partial and high autonomous systems become, the greater the need for increasingly more sophisticated HMI solutions to help drivers re-engage in driving themselves.

8. Participating parties and contact persons

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