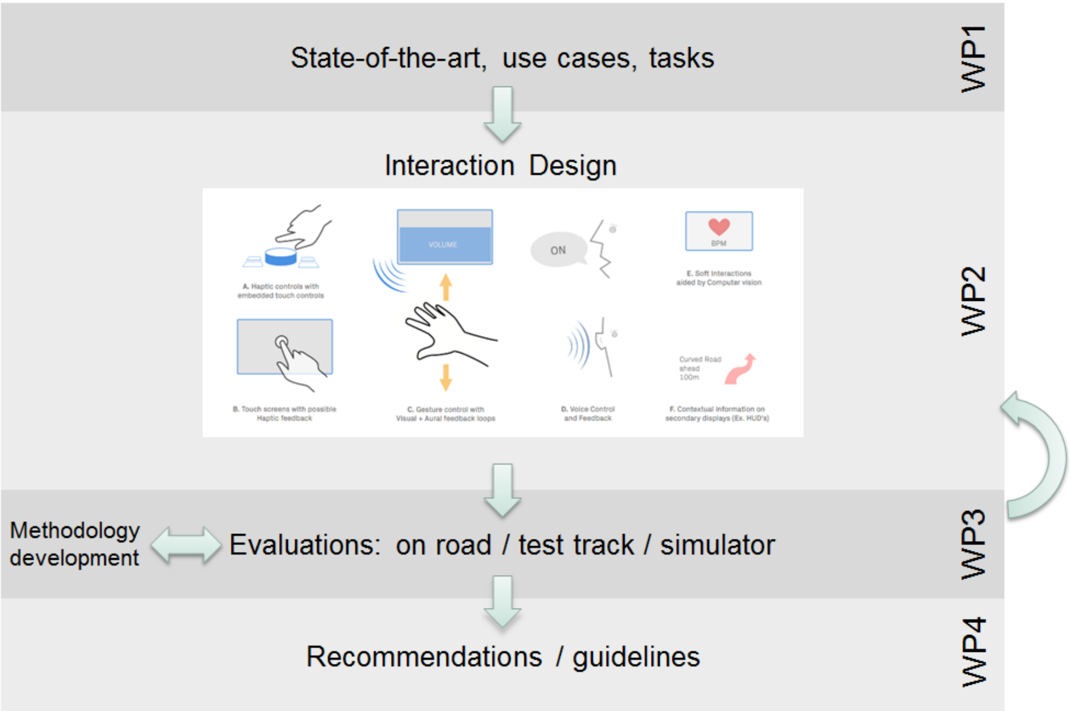
SEER

Seamless, Efficient and Enjoyable inteRaction

Publik rapport



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Project within FFI - Elektronik, mjukvara och kommunikation

FFI Fordonsstrategisk Forskning och Innovation

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Kort om FFI
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1 Summary

The project Seamless, Efficient and Enjoyable inteRaction, SEER, has carried out research and exploration of interaction design and evaluation methods for manual driving and lower levels of automation, i.e. level 2 automation [1]. SEER is a 3-year FFI project in cooperation between Volvo GTT, Semcon, Volvo Cars and RISE.

An impact map has been developed to visualize car- and truck drivers' needs and requirements. A study was performed to provide knowledge on how texting as secondary task should be designed to allow for a simple, seamless and safe interaction while using support systems of level 2 automation in passenger cars and trucks. Results show that the automation seems to have a slightly positive effect on the drivers' experience, and Scribble as interaction method outperforms the competing interfaces (i.e. QWERTY and Qwerty-Swipe) based on ratings from participants.

The ISO method lane change test was used to evaluate two different text output locations, i.e. HUD and SID. The study shows that the driving performance is very similar with HUD and SID in LCT measures (Mean Deviation from optimal path), but task completion time is shorter with HUD output. A new approach on using occlusion to evaluate HUDs, called "Blur", have been tested and evaluated. A SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) of methods used in the project summarizes the reasoning and research results in a methods catalog. An attempt to perform analysis on the potential correlation between established workload measurements and CAN data was also conducted.

Finally, HMI recommendations was drawn in the project for design of; I/O devices, Voice Assistants and sound feedback for function awareness.

2 Executive summary in Swedish

Projektet Seamless, Efficient and Enjoyable inteRaction, SEER, syftade till att forska kring design av säkra, effektiva och sömlösa gränssnitt och metoder för att utvärdera dessa under manuell körning och för lägre grader av automation, eg. automationsgrad 2 [1]. SEER är ett treårigt FFI-projekt i samarbete mellan Volvo Group Trucks Technology, Semcon, Volvo Cars och RISE.

Projektet har utfört forskning och design inom området Människa- Maskin-Interaktion. Intervjuer och frågeformulär på sociala medier har genomförts med förare för att samla in behov och krav. En Impact map har skapats för att visualisera behov kring interaktion med sekundära uppgifter. Med stöd från Impact mappen undersöktes olika Input / Output enheter (I/O enheter) för meddelandehantering i olika körscenarion. En studie genomfördes för att ge kunskap om hur textning som sekundär uppgift ska utformas för att möjliggöra en enkel, sömlös och säker interaktion medan man använder kör stödsystem på automationsgrad 2 i personbilar och lastbilar. Resultat från studien visar att automation verkar ha en (något) positiv effekt på förarens upplevelse och att Scribble som interaktionsmodell överträffar de konkurrerande gränssnitten, i den här studien Qwerty och Qwerty-Swipe, baserat på subjektiva skattningar från deltagarna. Ytterligare resultat kommer att delas i kommande artiklar planerade att publiceras, se mer information i kapitel 7. Spridning och Publicering.

Ett problem som undersökts i projektet är en snabb och kostnadseffektiv utvärderingsmetod för att kunna jämföra Head-Up Displays (HUD) med Secondary Interaction Displays (SID). ISO-metoden Lane Change Test (ISO 26022:2010(en) Road vehicles - Ergonomic aspects of transport information and control systems - Simulated lane change test to assess in-vehicle secondary task demand) användes för att utvärdera två olika input/output enheter, eg. HUD och SID. Studien visar att deltagarnas körprestation var lika mellan HUD och SID (medelavvikelse från den optimala banan enligt LCT mätvärde), men uppgiften tog kortare tid att slutföra med HUD input/output.

Ett nytt tillvägagångssätt för att använda ocklusion (för att utvärdera HUD displayer, kallad "Blur", har testats och utvärderats. En SWOT-analys (Styrkor, Svagheter, Möjligheter och Hot) av metoder som används i projektet har sammanställts för att skapa en metodkatalog som sammanfattar resonemang och forskningsresultat från projektet. Ett första försök att utföra analys av den potentiella korrelationen mellan vedertagna arbetsbelastningsmått (t. ex. elektrokardiogram (EKG), Andning (RSP) och pupillstorlek) och CAN-data har också genomförts.

Slutligen har rekommendationer sammanställts i projektet om hur I / O-enheter bör designas för säker, effektiv och tillfredsställande meddelandehantering i lastbilar och bilar med och utan automation, för hur interaktion med röstassistenter bör utformas och hur man kan använda ljudåterkoppling ökad medvetenheten hos användaren om att en funktion är aktiverad.

3 Background

In-vehicle connectivity is becoming more and more important to car- and truck customers. An investigation by McKinsey showed that people are increasingly willing to switch car brands if that would give them full access to apps, data, and media. At the same time, consumers' willingness to pay for this connectivity is also increasing [2].

However, just delivering connectivity is not sufficient to reach customers' willingness to buy. Most people today are used to high-end consumer technology in everyday life, and their expectations based on the consumer technology world, are not fully met yet in the automotive world [3]. According to the investigation by [3], a successful connected driving experience relies on that the system is Simple, Seamless and Safe. *Simple*, meaning that users of modern vehicles demand out-of-the-box, intuitive usability ("Nobody reads a manual"), *Seamless* meaning that different technology eco-systems need to talk to each other seamlessly ("In a connected world, we don't want our interactions to stop when we get in our car"); and above all *Safe* – since "everyone is ultimately aware that driving is dangerous" [3]

Drivers' increased safety awareness has likely been influenced by the recent years' increased focus on the relation between driver distraction - that is, when the driver is focusing on other things than driving - and traffic accidents. Visual distraction has been shown to be especially risky, e.g. in the study by Victor et al. [4], where a large number of real rear-end collision events was studied and where it was established that crashes occur when the driver looks away from the forward roadway at the wrong moment (the driver has an "inopportune glance") (Victor et al, 2016). There are also scholars that believe that cognitive distraction can be as dangerous as visual distraction, although this has been debated [5]. Distraction guidelines as the ones published by the European Commission [6], National Highway Traffic Safety Administration [7], or Japan Automobile Manufacturers Association [8], stipulating how in-vehicle interfaces should be designed highlight the fact that information displays, media players and other devices that the OEMs equip their vehicles with is part of the distraction problem. From the OEM and regulatory perspective, it might be tempting to suggest that interaction with in-vehicle interfaces while driving should be restricted as much as possible. However, an increasing number of similar "secondary tasks" are also being incorporated in the driving environment by the driver; smartphones, tablets, navigation systems etc. are also calling for the driver's attention. In a recent study it was found that as much as 80% of the drivers use smartphones while driving [9]. If the in-vehicle interface is too restricted the driver will likely prefer carrying out a certain desired task with a brought-in device (even if it's risky). A good OEM strategy is therefore to offer a *safe* way for the driver to perform the desired tasks e.g. by integrating smartphones through Apple Car Play or similar, and/or offering a more desirable, easier-to-use interface than the smartphone interface. Or in other words, driver interface and interaction modalities must be designed to comply with the automotive safety standards, and at the same time meet the customer expectation in terms of connectivity, infotainment and productivity.

Alongside the development of connectivity solutions and solutions to distraction issues, new driving assistance functions that partly take over the driving task are being introduced in both consumer and commercial vehicles. While automatic longitudinal control functions (referred to as adaptive cruise control or similar) have existed some time on the market, active/automatic steering support is today also becoming more and more common, as are increasingly advanced active collision avoidance systems. Such systems are gradually relieving the driver from the primary task of controlling the vehicle, and thus have the potential to change the general behavior of the driver. For example, they may increase boredom and favor secondary task engagement, but there is also evidence that the exposure to critical situations is reduced when driving with these functions [10]. A recent study by Morando et al. [11] suggest that the vestibular/somatosensory cue from the automatically controlled longitudinal deceleration acts as pre warning and allow the driver to make timely responses to critical situations. The potential change in drivers' behavior and the whole driving situation when using driving assistance systems could suggest that the current requirements put on in-vehicle interaction design are no longer valid. As more and more knowledge is gained from the domain of driver-automation interaction, the design of the digital user experience of secondary tasks must follow and make use of this knowledge. Currently, ESoP [6], NHTSA [7], and other guidelines/standards that address secondary task interaction design provide no guidance on how such designs should take into account advanced driver assistance systems, let alone higher degrees of automation.

The FFI project Safe Interaction Connectivity and State (SICS) [12] finished in 2015 in which Volvo GTT and Volvo Cars were involved, investigated how to create safe HMI designs and how to evaluate such designs. The project had great influence on how Volvo GTT and Volvo Cars design and evaluate HMI from a distraction point of view in product development projects.
Several national and international research initiatives, in which the partners are involved in, are working with the design of automation HMI, for example AdaptIVe [13] HATric [14], or user experience (UX) and novel user interaction concepts (e.g. AUX [15] and AIMMIT [16]). However, there is little research that addresses the design of secondary task HMI and UX in the context of driver assistance systems and automation and how to optimize such HMI from safety, comfort and general experience perspectives. The proposed project intends to fill this knowledge gap.

4 Purpose, research questions and method

4.1 Purpose

The aim of the project is to study user behavior, user experience and the driver distraction problem when combined with driver assistance and automation functions, and specifically how such functions affect the design of secondary tasks for connectivity, entertainment and information.
Interaction design principles will be adapted to driver interaction patterns under selected driving scenarios and form the basis for a ‘context-based’ HMI design. Furthermore, it is intended to investigate how new multimodal HMI technologies and the new scenarios that arise by the advent of ADAS makes it possible and perhaps necessary to rearrange the driver environment in such way as to support the driver/user to the greatest extent possible, and adapt to his/her needs.

The most important results from the project are;

1) increased knowledge about how user behavior and experience of secondary task interaction changes when driver assistance systems are active,
2) design principles and HMI concepts/technologies for secondary tasks in assisted driving scenarios - and
3) evaluation methods for comparing how well concepts using different modalities, fulfill the project goals seamless, efficient, enjoyable and safe.

4.2 Research questions

The following Research Questions (RQs) provide the foundation for the current research proposal:

- **RQ1:** Does drivers’ glancing/interaction behavior change when different driver support systems are active compared to when driving in manual mode? In what way?
    - **RQ1.1:** If the glancing behavior changes, should the interface be adapted, and if so – in what way?
    - **RQ1.2:** Does the cognitive load change during assisted driving, and if so, how? How do we take this into account from a secondary task design perspective?
    - **RQ1.3:** If the cognitive load changes, should the interface be adapted, and if so – in what way?

- **RQ2:** What are the ”best” ways of interacting with digital devices (e.g. a media player) – in terms of safety, efficiency, comfort, and general UX (considering RQ1 and RQ2).
    - **RQ2.1:** Does drivers’ preferred style of interaction with digital devices change with different driver support systems activated, e.g. Adaptive Cruise Control vs. Adaptive Cruise Control+Lane Keeping Assist
    - **RQ2.2:** How can the interaction design support personalization / customization (in order to make people use the in-vehicle interface instead of their smartphones?) Is there a connection to different persona?

- **RQ3:** How can current and future multimodal HMI technologies best be utilized, combined and designed to support the preferred interaction paradigms?

- **RQ4:** What recommendations on interaction design for secondary tasks in more or less automated driving scenarios can be formed based on the answers to the previous RQs?

The outcome of the project will help OEMs design interaction and interface concepts for their in-vehicle infotainment systems and provide recommendations on how to update current in-vehicle HMI regulations, standards and guidelines. These recommendations will give guidance on e.g. how to adapt the interface and interaction design to be optimal for different types of vehicle states and scenarios.

4.3 Method

Research approach
The project has performed User centered and Human factors research as a scientific foundation. User centered research takes the human and the context of work as a starting point for investigation. In the SEER project work is done iteratively starting with exploration of the working context of truck and car drivers, continuing with design of prototype HMI:s that has been tested and evaluated using a variety of evaluation methods from the body of scientific Human Factors knowledge. New methods have been proposed and established methods have been tested in new settings relevant for automated driving. The project is organised in four work packages (WPs).

Research process
The project consists of 4 WPs:

1. WP1 SoA, Use cases, Tasks
2. WP2 Design
3. WP3 Evaluations
4. WP4 Recommendations

Work package 1	**SoA, Use cases, Tasks**
WP leader	VCC
Other participants	GTT ATR, Semcon
Contents	This WP will summarize the state of the art in the area of secondary task interaction behavior while using driver assistance functions.
Method	WT2.1: A State-of-the-art on secondary task interaction behavior while using driver assistance functions will be summarized and continuously updated during the project. Information will be gathered from both past and ongoing initiatives and take into account the most relevant and novel findings. WT2.2: Use cases that represent typical and interesting situations from the car- and truck driver perspectives as well as specific tasks will be selected.
Deliverables	D2.1: State of the art D2.2: Use cases and tasks

Work package 2	Design
WP leader	Semcon
Other participants	VCC, GTT ATR
Contents	The purpose of this WP is to translate the findings from WP1 to adequate HMI concepts in an iterative fashion, according to established (emotional) design process principles and knowledge regarding HMI issues, such as driver distraction, vehicle automation, usability and user experience.
Method	WT2.1: HMI Concept creation based on established iterative interaction design processes, taking current context-specific knowledge into account. Multiple concepts will be designed and prototyped. WT2.2: A final concept will be designed and prototyped, based on WT2.1. The final concept may consist of one single concept, or a combination of those above. The same iterative design processes will be used in order to assure the quality of the outcome.
Deliverables	D2.1: Multiple HMI concepts D2.2: Final HMI concept

Work Package 3	**Evaluation**
WP leader	GTT ATR
Other participants	VCC, Semcon, RISE
Contents	The purposes of this WP are to: WT3.1) develop/establish evaluation methodologies appropriate for the scenarios/use cases and applications/concept designs under study and WT3.2) perform evaluations of the concept designs prototyped in WP2. Evaluation will take place in either simulator or test track, depending on use case under study.
Method	WT3.1: Currently existing methods for user evaluation will be reviewed and the appropriate ones will be selected for inclusion in a methods catalogue. Adaptation of methods will be performed if necessary. An exploration of novel methods will be carried out. WT3.2-4: Concept designs from WP2 will be evaluated using the methods developed/selected in WT3.1. Results from the evaluation will be fed back to WP2 to refine the concept designs and also to WT3.1 so that the methods catalogue can be adapted/improved if needed.
Deliverables	D3.2 Results from evaluation loop 1 (feedback to WP2 and WT) D3.3 Results from evaluation loop 2 (feedback to WP2) D3.4 Final evaluation
Milestones	M3.1 Draft methods catalogue M3.2 Final methods catalogue

Work package 4	**Recommendations**
WP leader	GTT ATR
Other participants	VCC, Semcon
Contents	The purpose of this WP is to summarize the findings from WP2 and 3 into a set of recommendations on HMI design and evaluations that can be used by the project partners and others in their development of future products.
Method	As an initial task, a draft recommendation document will be written, based on state-of-the-art from respective partners. The results from WP2 and 3 will be used to update to this draft document during the project and eventually release this as the final deliverable.
Deliverables	D4.1 HMI design and evaluation recommendations
Milestones	M4.1 Draft HMI recommendations M4.2 Final HMI recommendations

5 Objective

The objectives for this project have been:

- A set of methods for evaluation of secondary tasks in assisted driving scenarios. Specific use cases, which have been identified as problematic to evaluate from the industries, have been targeted and evaluated with suggested evaluated methods. Results are compiled in a SWOT analysis in the results section 6.3 WP3 Methods Catalogue.

- HMI concepts (prototypes) for passenger cars and trucks, evaluated in realistic driving scenarios; with special attention to messaging in various driving scenarios with different levels of cognitive demand. Further results can be found in 6.2 WP2 Use cases and 6.3 WP3 Methods catalog.

- At least 6 peer reviewed publications in scientific journals or conference proceedings. As a result from the two major studies performed in the project three articles are pending submission. One oral presentation [46] was made at the 6th Driver Distraction and Inattention conference (2018), Gothenburg, Sweden. The target of 6 peer reviewed publications was not fully reached. A decision was taken in the project to focus on less studies with more qualitative content rather than quantity.

- 5 MSc theses have been conducted focusing on I/O devices when performing secondary task interaction, sound as function enhancement and voice assistant guidelines.

- HMI design and evaluation recommendations have been drawn and can be found in the result section 6.4 WP4 HMI recommendations.

6 Results and deliverables

The most important result from the project is the increased knowledge of how driver behavior and experience of secondary task interaction, changes when driver assistance systems are active.

More specifically, the results include:

6.1 WP1

- Literature review; secondary task interaction and interaction changes when driver assistance systems are active.
- Use cases and tasks; impact map.

6.2 WP2

- HMI concepts (prototypes) for passenger cars and trucks, evaluated in simulated driving scenarios; focusing on messaging text input/output, information suppression strategies and interaction design for HUDs, design of Voice assistants and "Make-no-sound" concepts.

6.3 WP3

- SWOT analysis of methods used in the project and their usefulness for evaluating secondary tasks in assisted driving scenarios; WP3 Methods Catalogue.

6.4 WP4

- A summary of HMI design and evaluation recommendations from the research conducted in the project.

Results publications and theses

- 1 peer reviewed Conference presentation,
- 1 submitted Conference presentation
- 3 papers pending submissions to scientific journals. For more information contact the authors of the reports since the papers currently are pending submission.
- 5 MSc theses

6.1 WP1 State of the Art and Use cases

State of the Art (SoA)

General knowledge on AD

"The ironies of automation concerning the unsuitability of a human operator to undertake such a role of monotonous monitoring are long established" (Bainbridge quoted in [34]).

Decreased mental workload can affect the situation awareness negatively

Reduced situation awareness can have many negative effects, such as delay in breaking response when ACC has failures, delay in action caused by malfunction of lane keeping systems
Passive role of monitoring an automated system is less satisfactory
Mental underload can be equally hazardous to road safety as mental overload.

We need an optimum level of automation, better feedback in the systems and suitable secondary tasks [34].Stanton and Young [24] identify a number of arguments in favor of automation, for example, it can improve the driver's well-being, it can improve road safety and it can enhance product sales. Main automation concerns:

- drivers will become over-reliant upon the automated systems
- drivers will evoke the systems in situation beyond their original design parameters
- drivers will fail to appreciate that the system is behaving in a way that is contrary to their expectations [24].

Important aspects when assessing driver's behaviour in ACC: Trust, situation awareness, mental model, workload (There is still some controversy about whether ACC reduces workload or not), and driver's stress [26].

Behavioural adaptation/Personality driven adaptation to AD

The degree to which behavioural adaptation (BA) affects the effectiveness of a device, may depend not only on the individual technology but also on intrinsic characteristics of the drivers.
There are two central psychological measures - LOC (locus of control) and SS (sensation-seeking) - as well as the concept of trust in automation, which can explain people's behaviour and their willingness to overtake the control, when AD is introduced.

Despite the potential benefits of ACC, negative BA could occur with its introduction. Drivers may use any freed visual, cognitive and physical resources to engage in non-driving tasks that they perceive as improving their productivity. In reality, however, these tasks may reduce their vigilance and attention to the primary driving task, which could result in driver distraction, and a failure to detect and respond to critical driving situations [25].

Four cluster of users were formed, from those who rarely use ACC, to those who use it almost all the time (also in inappropriate situations). Older users and those who were confused on how to use the cruise speed settings, don't use ACC often. The drivers with an overall higher use of ACC, were keen to use the system in situations that can be considered distracting or risky [23].

Research in other domains suggests that people with an internal locus of control, generally perform better than individuals with an external locus of control [26] Drivers who like to drive fast are less positive to ACC (both regarding comfort and usefulness) [31].

Situational awareness (SA)

Both ACC and HAD (Highly Automated Driving) can result in improved SA compared to manual driving if drivers are motivated or instructed to detect objects in the environment. However, if drivers are engaged in non-driving tasks, SA deteriorates for ACC and HAD compared to manual driving. In almost all studies HAD (and to a lesser extent ACC) gives rise to a reduction of workload. The results clearly suggest that a proper feedback system could alleviate much of the concerns of low workload and low SA of HAD [33].

SA and workload from eye-movement: HAD drivers are less likely to gaze at the road center than manual drivers, which indicates that they have lower workload and altered SA. Eye movement differences are inconclusive. SA measured with object detection and comprehension: Both ACC and HAD can result in improved SA. This appears to be the case if the drivers are motivated or instructed to detect objects in the environment. However, if the drivers are engaging in non-driving tasks, SA deteriorates for HAD. SA measured by voluntary uptake of tasks unrelated to driving: HAD drivers are strongly inclined to engage in non-driving tasks, such as watching a DVD or even sleeping. ACC drivers are less inclined to engage in non-driving tasks than HAD-drivers.

SA measured with critical events: HAD and ACC evoke long response times and an elevated rate of (near-) collisions in critical events as compared to manual driving. If the automation fails unexpectedly with very little time for the human to respond, then almost all drivers crash, but if drivers receive a timely warning then almost all drivers will safely avoid collision [33].

Workload

Self-reported workload (questionnaire): 32 studies. ACC resulted in lower workload than manual driving in 22/24 studies. HAD resulted in lower workload than manual driving in 15/15 studies. ACC results in a relatively small reduction of workload and HAD results in a large reduction of workload, compared to manual driving [33].

Workload assessment

Occurring confusion over workload assessment motivated the authors to suggest a model of workload where attention towards a secondary task is not taken as a measure of workload. They suggest attention ratio, which is a measure of attention capacity, which can be distributed differently between tasks [20].

Workload varies for different AD systems

ACC is more demanding than AS (auto-steering). AS can lower workload more than ACC [20, 22]. Longitudinal support is largely a feedback task. Lateral control also has a major feed-forward element (adapting to the road ahead to determine yaw input) [32].

Mental underload

Automation could relieve mental workload (MWL) to such an extent that drivers experience underload, which is considered to be at least as serious as overload. Moreover, automation can lead to skill degradation over time, such that operators do not know how to reclaim control when necessary [22]. By automating the task, the driver may become under loaded and thus reduce the level of attention devoted to the task as the driver is removed from the control loop [24].
AD brings a new task of monitoring the AD system
ACC removes some tasks but at the same time it brings a new one, which is monitoring the ACC system [24].

Understanding of AD systems limitations

For ACC to be effective, drivers need to understand the capabilities of ACC, which depend on both braking and sensor limitations [27]. Previous studies have shown adaptive cruise control (ACC) can compromise driving safety when drivers do not understand how the ACC functions, suggesting that drivers need to be informed about the capabilities of this technology [28].

More feedback than in manual driving

Studies with FCW systems have shown that a warning alone was not enough for a driver to be able to avoid the accident. Thus, an additional braking intervention by such systems could be necessary [33]. In general, more feedback could help to understand the situation.

Continuous presentation of driving conditions
(e.g. relative speed to lead vehicle - LV)

Concerning design and safety of automated systems, authors in [21] suggest that relative speed to LV should be presented continuously. Authors in [28] suggest that providing continuous information regarding the state of the automation does not necessarily overburden the operator. Providing continuous visual information about the state of the automation is a promising alternative to the more common approach of providing imminent crash warnings when it fails.

The suggested solution is EID (ecological interface design) display. It provides continuous information on the relationship between the driver's vehicle and the LV using an object, whose shape and position continuously changes to reflect the speed and distance between the two cars [28].

Secondary task (ST)

Drivers of a highly automated car, and to a lesser extent ACC driver, are likely to pick up tasks that are unrelated to driving [33]. There is a large variety of secondary tasks in literature. In this project we should carefully choose and justify secondary tasks for our experiments, since different secondary tasks affect workload in different ways.

Visual ST

Workload measured as performance on a self-paced in-vehicle display task: 12 studies. In 9/10 studies, more secondary tasks were completed with ACC than with manual driving. In 9/9 studies, more secondary tasks were solved with HAD than with manual driving. In other words, when using ACC, drivers are able to complete approximately 12% more tasks on a visual display than when driving manually. However, for HAD, drivers are able to complete over 2.5 times as many tasks as when driving manually [33]

Non-visual ST

Workload measured as performance on a non-visual task: No significant differences, however small number of experiments [33].
Reaction time to ST
Workload measured as reaction time to artificial visual stimuli: ACC frees up mental capacity so that drivers respond faster to artificial visual stimuli than manual drivers. However, for HAD, it seems that drivers are susceptible to drowsiness, so that reaction times are slower than during manual driving.

Glancing

Participants were glancing at DIM after the warning sound, probably to understand the meaning of the signal. Important is to design more self-explanatory signals [19].
In general, when using automated systems participants spent less time looking at the road. The higher the automation level, the time spent looking on the road decreases [32]. This leads to lowered situational awareness. When participants were asked to detect objects in HUD, the SA increased [33]. Blinking frequency patterns were more consistent for manual than automated driving, but were generally suppressed during conditions of high workload [36].

Over-reliance

While drivers often have a choice of whether, when, and how long to take their attention away from the roadway, over-reliance on automation can influence these choices [30].

Physiological measures

Workload measured through physiological measurements: HAD reduces skin conductance, increases eye-blink rate, and increases the percentage of time that drivers close their eyes.
Heart rate for HAD versus manual driving: Both ACC and HAD tend to reduce heart rate as compared to manual driving, indicating a reduction of workload. However, not all studies are consistent in this respect [33].

CAN data as an indication of high or low mental workload and distraction

Semmens et al. [42] in their article *Is Now A Good Time?* Analyzed several car data to monitor the preferred time to present voice prompts. They presented prediction models which considered vehicle speed and steering wheel angle, change in vehicle speed and change in brake pressure, as well as vehicle speed and change in brake pressure. Even though the models' predictive power was not very high, the work presented potential of the CAN data. We believe that to improve the predictive power of the models we will need to use more than two types of data.

De Waard [43] tested standard deviation of steering-wheel movement (SDSTW), standard deviation of lateral position (SDLP), time-to-line crossing (TLC) and delay in following of speed changes of a lead car. He showed that SDSTW changes in conditions of increased task complexity and as a result of time-on-task. Additional tasks lead to a decrease in SDLP and SDSTW, while an increase in complexity of the environment, increases both values. Increase in SDLP can be the result of being overloaded as well as of driver deactivation. TLC decreased in the vigilance conditions. Delay in car-following (as a built-in secondary task) was found to be a sensitive measure, reflecting the mental workload.

For building a model of driver distraction using machine learning, Tango et al. [44] qualified speed, time to collision, time to lane crossing, steering angle, lateral position, position of the accelerator pedal and position of the brake pedal as promising CAN data to use. From an operator to a supervisor With the addition of a greater number of Advanced Driver Assistance Systems in vehicles, the driver's role is likely to alter in the future from an operator in manual driving to a supervisor of highly automated cars [36].

Solutions for distracted situational awareness

HUD

Recent research links time with eyes off of the road, to increased chance of accidents, a problem that could be diminished when using HUDs [37]. The HUD performed worse on the NHTSA eye glance test than the HDD did; however, the driving performance measures were superior when driving with the HUD. There were no significant differences in the secondary task performance between the two displays. Therefore, the NHTSA standard may not adequately assess HUDs in vehicles [37]. Authors in [38] introduced T9+HUD, a text entry method designed to decrease visual distraction while driving and typing. T9+HUD combines a physical 3×4 keypad on the steering wheel with a head-up-display (HUD) for projecting output on the windshield. While driving, the T9+HUD text entry rate was equal compared to a dashboard-mounted touchscreen device, but it reduced lane deviations by 70%. Furthermore, there was no significant difference between T9+HUD and baseline driving in lane-keeping performance. T9+HUD decreased glance time off road by 64% in comparison to the touchscreen QWERTY [40].

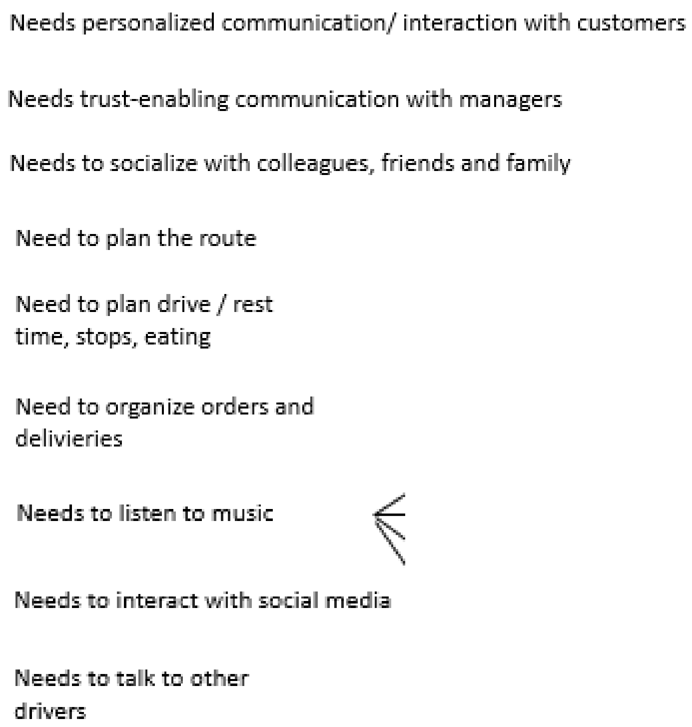
Touch vs. mid-air gestures

Authors in [41] presented a study aimed at comparing the degradation of the driver's performance during touch gesture vs mid-air gesture use for infotainment system control. The decrease in performance is measured as the deviation from an optimal baseline. This study concludes comparable deviations from the baseline for the secondary task of infotainment interaction for both interaction variants. This is significant as all participants are experienced in touch interaction, however have had no experience at all with mid-air gesture interaction, favoring mid-air gestures for the long-term scenario.

Use cases

Business impact maps were used for defining the users and the use cases. It describes the project goals in relation to the actors, impacts and deliveries [45]. For the SEER project the goal is to develop Seamless, Efficient, Enjoyable and Safe interfaces. A new impact map was created to show the truck drivers’ needs. It was based on interviews and observations with 13 long haul drivers. The actors/ personas were defined as the Organizer, the Communicator, the Time killer and the Avid truck driver.

Three main impacts were connected to each actor, to define their major needs. These impacts were the ones that the project was aiming to create in the development phase to solve the user needs. The concept development was focused on the Organizer, the Communicator and the Time killer, which resulted in the following examples of impacts or user needs:



For car concepts an existing impact map was used, which is confidential, but including some similar user needs as for the truck drivers.

Examples of user tasks that were in focus in the text input method study [46] were:

- Read a text message.
- Type and Send a text message.
- Read an email.
- Type and Send an email.
- Read a social media message.
- Comment on a social media post.

Finally the deliverables in the impact map answer the question what? They are the features and the project scope designed and delivered during the concept development.

6.2 WP2 Concept development

Concepts

In iterative processes with different focus areas, concepts have been developed in the project. The processes have included exploring ideas, prototyping and testing with users, followed by further ideating and refining of concepts.

Below follows an overview of the concepts developed in the project:

- 2 master theses – text input (Interaction design Chalmers) [50, 51]
- Simulator study – text input (Scribble, Qwerty, Swipe) [46]

- Iterative concept development (including 1 thesis [49]) – HUD interface for non-driving related tasks (texting, social media. Interaction, amount of information, suppression)
- Thesis: HUD concept for non-driving related tasks (HUD angle, suppression, interaction, UI) [49]
- Thesis: Communicating ADAS status with sound [48]
- Thesis: Evaluation of Voice assistants [47]

Text input

The first part of the project focused on text input in a driving context where concepts were developed in two Master Theses (Kjellquist, J. and Lidin H. (2018)). Designing for Semi-Autonomous vehicles. In-Vehicle Digital Communication During Low-level Automation In Congested Traffic Environments and Arvidsson, J. and Granström, J. (2018). Interaction With In-Vehicle Infotainment System [50, 51]) and further evaluated in a simulator study. Concepts evaluated for text input were;

- T9
- Qwerty
- Qwerty with swipe
- Scribble

Different placements of the interaction area were also explored in the theses;

- Touchpad on steering wheel
- Touchpad on center stack (hand-down)

In a following simulator study [46] different text input concepts were tested against each other with text output in a Center Stack Display (CSD)/SID and a HUD. The input concepts tested were; Qwerty, Qwerty-swipe and Scribble. The results from the simulator study shows that Scribble was the most preferred input method while driving and HUD the safest output device for the task.

HUD interface

With findings from WP1 and the text input study, concepts for an interactive HUD interface were developed [46]. The iterations focused on different aspects such as placement and transitions, including exploration and evaluation of concepts. This was carried out at Semcon and in a master thesis supervised by Semcon. The first concepts developed and tested were;

- Safe – as little information as possible when not interacting
- Efficient – information separated into categories defined by system or user
- Enjoyable – timeline with information in real time

The concepts were tested with vehicle interface experts in a static setup with touch interaction. A combination of Safe and Enjoyable was desired to develop for the next iteration. Different ways of interacting with non-driving related notifications were then developed and tested in the following iteration. It was tested with car drivers in a static setup with interaction through a representation of buttons on a steering wheel (Figure 1). The main findings are to avoid multiple direction navigation and to only highlight the selected object to support navigation in the interface.
In the third iteration the way of presenting interaction options in the UI was in focus. Two concepts were tested;

- Fixed position of selection – items moving
- Fixed position of items – selection moving

This was tested in a desktop simulator setup (Figure 2). The main finding is that that it is easier to navigate in an interface were objects are static and highlight moves while driving. This since it facilitates navigation while having visual focus on the road and switching focus between road and interface.

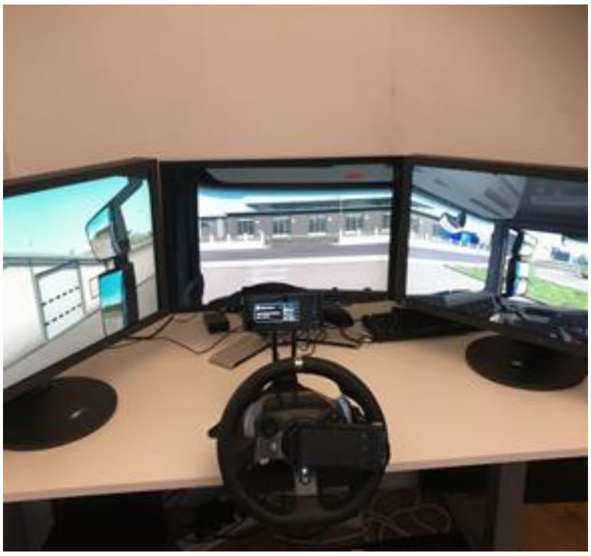


Figure 1. Static simulator setup.

Figure 2. Desktop simulator setup.

In a master thesis (Industrial Design Engineering), HUD concepts were further developed looking at reading text, navigating in the interface, interaction transitions and look down angle. There is a strong connection between the look-down angle and both UI performance and driving performance when doing interactive and visually demanding secondary tasks. The first behavioural approach appears mostly in the 2.5º-5º angles. In these positions, users are able to see both the HUD and the road. The HUD interaction where shown to benefit from enhancing visual elements through animations and micro interactions.

Information suppression

In desktop simulator setups at Semcon the effect of suppressing notifications in different situations as well as different ways of suppressing information, were explored and tested. The studies shows that drivers are negatively affected by receiving notifications in stressed situations (e.g. while turning or braking) but also by receiving several notifications in a row. It is therefore recommended to suppress non-driving related notifications in driving situations where the workload is already high and to group notifications if more than one have been received. It is also found that drivers could get annoyed or confused if information they are currently interacting with disappears. This is the purpose for developing a concept for temporary information suppression in the HUD interface.

Sound and voice interaction

Two master theses [47, 48], supervised by Volvo Cars, explored sound communication respectively voice interaction for the driving context. An identified opportunity was to communicate status of ADAS with sound, since the visual information often was missed. Since there are many different auditory alerts in the vehicles today the concepts focused on more subtle sounds. From several iterations, testing sounds in a simulator setup, it was found to be useful with a short off-sound for when Pilot Assist (Lane Keeping Assist) failed to follow any lines and an on-sound for when it functioned again. An increasing white-noise sound was found to function well for communicating that the driver should resume control. For more results from the thesis see 6.4 WP4 HMI recommendations.

“Make-no-sound"-sounds thesis

Below follows a summary of Broo V. and Tengroth A. (2019) [48]. Enhancing the drivers’ user experience by broadening the sonic environment, two visual designers take on sound design.

What “Make-no-sound"-sounds can communicate

With the use of “Make-no-sound"-sounds the driver will stay informed of the mode status without having to take focus from the forwards driving condition. The sounds are designed not to be intrusive, in the way that warning signals are, and could therefore be missed if the driver does not know that they will arrive. Therefore, they should not be used for warnings such as safety warnings that require immediate action. The assistive functions demand that the user has their full focus on their driving environment and therefore the “Make-no-sound"-sounds should not create an over-trust in the system. Rather the sounds should inform the driver that the function is no longer supporting their driving, without having the driver to look away from the road ahead, thus creating the need to be non-intrusive.

Tests from the thesis work has shown that "Make-no-sound"-sounds have a high learnability, after a few times of exposure the driver will recognize the sounds and when informed of their meaning will understand the information they are conveying and recognize them more easily. However, the tests have shown that the “Make-no-sound"-sounds need to work alongside additional subtle feedback to be able to convey all of the information that the driver requires. Test 2 and 3 showed that repeated exposure to the “Make-no-sound"-sounds did not annoy the users, nor felt intrusive.

Using lowering of volume as a “Make-no-sound" -sound

A lowering of volume is already implemented in cars today and fits well into the mental model of communication in cars and feedback in cars. It was shown in Test 2 that when natural pauses occur in the media it was more difficult to hear and to react upon, mainly during the secondary task of making a phone call where the phone signals already have natural pauses. It was a preferred way of receiving auditory feedback as it was the opposite of adding another sound, thus feeling less intrusive. This could also come from the fact that, as mentioned before, this type of auditory feedback is already used in the current system and therefore people are more acceptant of it.

Using short muffled feedback as a “Make-no-sound"-sound

During Test 2 the muffled sound was the only “Make-no-sound"-sounds that every user could identify. The users understood its meaning, reacted accordingly and did not feel annoyed or find it intrusive. It was noticed when played at different volumes both with additional media sound and only with the ambient sound of the road. It was the favourite “off” sound from test 1 as the users felt it conveyed that function the best. In test 2, the users found it to be the most informative sound out of the three. The users also felt that it was less annoying and more kind than the way a warning sound is designed today. If a warning signal can be likened to someone screaming at you to do something, this sound was considered to be someone offering their help and guidance.

Using white and ambient noise as “Make-no-sound"-sounds

During Test 3 it was made clear that an ambient noise of a character that is not associated with something being wrong with car was appreciated and an idea that many users enjoyed and felt had a lot of potential. It is however important that the sound matches the ambient noise that is experienced in the car so as not to associate it with something else. The biggest issue with this sound was that many test participants felt confused when the sound was applied as an indication of whether the function was active or not. The users did not understand why they were pushed into having PA activated by the sound. It was also made clear that the ambient noise did not need to be active all the time and that a shorter version of the sound that matches the time it took for the user to block it out would be favourable when it comes to using this type of auditory feedback as this would be considered more of a nudge.

Categorizing “Make-no-sound"-sounds

It was retrieved from Test 1 that the sounds should belong together to be more understandable as well as to be less intrusive. The adjective used in the first test as well as the information retrieved from the literature review show that an “off” sound is characterized as short, chopped off, muffled, pitchy and dark. An “on” sound is characterized as happy or light and indicated that something was finished or mediating a function that “keeps on going”.

When to use which “Make-no-sound" -sound

A great way of using “Make-no-sound" -sounds should be to use short muffled sounds when a function activates or deactivates and use a longer ambient noise when the driver should be nudged to for example apply steering which is an issue when using PA. This was retrieved from the tests and was summarized and tested in the last test.

In-vehicle voice assistants

Below follows a summary of (Khanh) Nguyen C. and Falkengren W. (2019) [47]. Master thesis at the Department of Computer Science and Engineering, Chalmers University of Technology.

Results and Guidelines

A review of existing design guidelines was done to gain an understanding of what each set of guidelines covered with respect to voice assistant interaction in vehicles. These were:

- Android Auto Design Guidelines URL: https://designguidelines.withgoogle.com/android-auto/ (visited on 02/12/2019).
- Apple Car Play Human Interface Guidelines URL:https://developer.apple.com/design/human-interface- guidelines/carplay/overview/introduction/ (visited on 02/12/2019).
- Google Conversation Design URL: https:// designguidelines.withgoogle.com/conversation/conversation-design/welcome.html (visited on 02/12/2019).
- Amazon Alexa Design Guide URL: https://developer.amazon.com/docs/alexa-design/get-started.html (visited on 05/03/2019).

These guidelines were selected for review since they are directly tied to the two commercially available integration interfaces. A review of existing NHTSA guidelines was also done, as those guidelines specifically deal with traffic safety:

- NHTSA. Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices. Technical report 81, NHTSA, 2013, pages 1–54.
- NHTSA. Visual-Manual NHTSA Driver Distraction Guidelines for Portable and Aftermarket Devices. Technical report 233, NHTSA, 2016, pages 87656–87683

The results of the literature review would be used to identify established guidelines which work well to decrease visual distraction and cognitive load. The review was also used to identify areas where the guidelines were not followed by existing voice assistants and to identify gaps in the guidelines with respect to distracted driving and voice assistant interaction (explored using summative on-road and prototype simulated driving evaluations).

A set of new and improved guidelines have been developed specifically for designing in-vehicle voice assistant interaction. These new guidelines are based on the problems and insights identified from the summative and prototype evaluations. The new guidelines were described in terms of the same themes as the existing guidelines: voice and manual input, general voice responses, situation awareness, presenting choice, error handling, discoverability, display, and notifications. The guidelines are presented in more detail in section 6.4 WP4 HMI recommendations.

6.3 WP3 Methods catalogue

Methods catalogue

The methods catalogue is a SWOT ("Strengths", "Weaknesses", "Opportunities", and "Threats") [54] analysis performed on methods used or considered to be used to evaluate different problems derived from WP1. A column defining if the method is considered suitable to evaluate automation level 1-2 has also been added.

Scenarios 1-4

Below follows a description of the scenarios evaluated in the project:

1. Eye-tracking, Questionnaires and vehicle data was used for evaluating Scribble, QWERTY and QWERTY-Swipe as input method for messaging in a car and truck simulator. Output varied between HUD and SID [46].

2. Lane change test, eye-tracking and UMUX lite was used to evaluate task difficulty and preferred information output (i.e. HUD vs. SID) with regards to safety, efficiency and satisfaction. The aim was also to see what effects adding the variable of automation (i.e. Adaptive Cruise Control and Lane keep assist) would have on the results. Tests performed in an LCT environment setup in a simulator representing a FH truck. Other methods considered were Detect-Response Task and Occlusion. Due to already high number of variables in this study the mentioned methods were not used but suggestion is to explore these further to avoid confounding factors when comparing concepts using different modalities for input/output.

3. Quick and cost-effective methods needed to evaluate HUD concepts. Development of occlusion used for HUD evaluation, novel method approach called "BLUR".

4. Cognitive workload measurement based on CAN data.

Table 1. Methods catalogue: SWOT analysis of the selected methods and discussion on optional or excluded methods

	Strengths	**Weaknesses**	**Opportunities**	**Threats**	**Suitable for evaluating automation level 1-2 [1]**
Lane Change Test ISO no: 26022:2010 [52] Was used to evaluate scenario 2	Takes task complicity into consideration Can differentiate well between different in/output media independent of modality	Due to that the method is based on quick lane changes it is not suitable to use for measuring effects of automation Repetitive for test persons if you have many variables Difficult to calculate personal baseline Can only be used to compare concepts not to evaluate safety parameters for stand-alone concepts	Expanded to fit for driving truck instead of car Possible to use simplified method to calculate baseline for each driver	Learning effects for test tasks, although can be mitigated through the use of extra baselines	No, method setup work against the purpose of lane keeping assist.

Eye-tracking measures ISO 15007 [53] Was used to evaluate scenario 1 and 2	Independent of modality Advanced systems can measure many different parameters	Very time consuming to evaluate and analyse in the post-study phase High expertise in handling the eye-tracker and in analysing data is needed. Overlapping Area of Interests (AoI) is hard to measure, i.e. Head-up Displays Need to secure AoI with every test person, time-consuming Cumbersome to re-calibrate the eye tracker after each break	Non-invasive method Reliable methods with high validity No active participating of the participant is needed (the participant does not need to follow special instructions) Gives deeper insight into user attention patterns and thereby influence how to design ADAS.	Definition of area of interest effects the results Measuring fixations can not 100% be interpreted as “cognitive awareness” – see also “look but failed to see effect” Also in the peripheral field of view drivers are aware of objects, however that is not measured by eye-tracking Missing or poor data quality if technical failures are realized too late The time-sync between vehicle measures and eye tracking measures needs to be exact as per millisecond, otherwise data becomes invalid. The behaviour of the test person could be influenced and their eye movements could become unnatural (see experimental effect)	Yes

Occlusion ISO 16673:2017 [56] Was used to evaluate scenario 3	Cheap, quick	Cannot be used for evaluation of voice interaction concepts for HUD	Test occlusion concept for HUD, see section 6.3.1.2 about “BLUR” method		Yes
Vehicle data Was used to evaluate scenario 1	Fully objective Data, no manipulation by the participant is possible Various measures possible to measure at the same time All time-syncs between different vehicle measures are automatically handled by the system Easy to replicate	Expensive to obtain and Needs high expertise in programmin g for data collection Data post-processing is time consuming and requires high expertise Thresholds of ADAS (e.g. activation only above 50 km/h) needs to be known and taken into account because they can influence data collection	Opportunity to measure in Driving simulators with the possibility to manipulate the handling of the vehicle (e.g. various automation levels) No special instructions for participants are needed and data collection works in the background Accumulated data can be stored in bigger scale national or international, anonym databases (e.g. to generate algorithms or machine learning)	Data recording needs to be Automatic, otherwise the chance for missing data is very high	Yes
CAN Data as workload measuremen t Was used to evaluate scenario 4	Low-cost, non-intrusive and easily implementab le in the vehicles which already	Still requires developmen t and analysis to build a model which can reliably	It has a potential to raise the level of safety (e.g. monitor driver’s level of alertness), lower the stress level	Might only indicate the high workload level and not be sensitive to low levels.	If successful analysis, yes

	collect these data	predict mental workload	(avoid presenting not important information while a driver is in a high cognitive workload state e.g. difficult crossroad) and improve user experience in general (adapt the user interface according to the cognitive workload for more serene experience). Could be further explored to investigate if the method is suitable to evaluate how automation affects cognitive load when doing ST interaction.		

Question-naire, TLR-X Was used to evaluate scenario 1	Questionnaire is standardized Subjective data on perception is a powerful addition to objective data like eye-tracking and vehicle data. Data is easy to analyse in the post-study phase Data provides possibility for post-questionnaire interview if necessary	Time consuming to fill in, especially when there are numerous experimental stages Instructions could be misunderstood/misread by participants	Questionnaires invite the participants to reflect more than usual Awareness and reflections are triggered in directions that would not occur with interviews	“Experimental effect” can cause participants to answer with biases (e.g. social biases) Difficult with interpersonal validity, easy with intra-personal validity Risk that participants answer randomly if they are unmotivated or tired	Yes
Survey data from social media Was used to provide requirements for	Data collection from a big poll or participants is possible in a short amount of time (e.g. Survey via	“Bubble effect” can occur which is that only participants with similar demographics and backgrounds	Big polls Comments and reactions from a wide variety of participants Survey software can	Data could be manipulated – no way to prevent that Requires intrinsic motivation from	Yes

experiment-tal designs	Facebook can reach > 100 participants easily) Versatility of survey: versile answering methods are possible (in written, multiple choice etc.) Low cost Easy to distribute survey among different channels and target groups Easy to analyse data post-study Easy to set-up and easy to administer	will be reached (this minimizes the data being truly representativ e) Not possible to control when and where data was entered Risk that questions get answered by non-target group (that can almost not be prevented) Lack of depth Respondents may not feel encouraged to provide accurate, honest answers	analyse advanced statistics automatically by just one-click A broad range of data can be collected (e.g. attitudes, opinions, beliefs, values, behaviour, factual)	participants because there is no to little incentives for participation Unclear who is the owner of the data	
UMUX lite Was used to evaluate scenario 2	Shorter version of UMUX and can be converted into a SUS score Can differentiate between different output/input concepts Quick and fast	Might need complement ing questions		When translating questions you might lose content or purpose	Yes

Impact Map [55] Was used to provide requirements for experimental designs	Condensed knowledge about user needs. Helps to avoid thinking about the solutions too early in the design process. Highlights that our users might behave in several different ways depending e.g. on the purpose of using the car (work or meeting friends)	Validity depends on quality of in-data Is a development method. Does not result in any measurements	Serves as input to designing concepts. Small incremental fulfilled needs contribute to completion of fuller user scope	Can be used for checking if user needs are fulfilled on a high level, but does not measure distraction, effectiveness or usability of the concepts, nor how enjoyable they are.	Yes

Evaluation of existing methods

For collecting user needs and requirements in the beginning of the project both impact map [55] and social media surveys were used. Three studies were performed to evaluate if the methods were suitable to evaluate multimodal concepts. The methods usefulness for evaluating the support of automation level 2 was also explored.

Social media investigation

Jesper Kjellquist and Hampus Lidin (2018) [50] worked on their master thesis titled “Designing for Semi-Autonomous vehicles. In-Vehicle Digital Communication During Low-level Automation In Congested Traffic Environments” which shows different prototypes of text input with QWERTY and T9 during low level automation. The master thesis students have not only conducted an extensive literature study but also a survey on social media. “[…] we prepared a survey to send out to car and truck drivers with different driving skills. The purpose of the survey was to get close feedback from the core target group, and to gain insights about what their goals might be with a new form of HMI for semi-autonomous motor vehicles. The survey was prepared using Google Forms, which supports the functionality to conditionally show questions depending on previous answers. This was appropriate for us, since we had two different areas of interests (highway and city driving, respectively) between us and our peer group of the SEER project.” (Kjellquist & Lidin, 2018, p. 24). “The survey was distributed through several forums on the Internet, mainly on Facebook groups administered by truckers and semi-autonomous car enthusiast. This way, we were able to get responses from several different parts of the world. An overview of the 153 responses we got can be found in Appendix B in the thesis.” (Kjellquist & Lidin, 2018, p. 25) The results show how often participants use voice calls vs text messages and how experienced they are with different ADAS in city and in highway scenarios (see p. 52+ of Kjellquist & Lidin, 2018).

Study: Texting while driving with Level 2 automation: A distraction or an opportunity?
Wege, C., Maculewicz, J., Nilsson, J., Theodorsson, N., Andersson, J., & Habibovic, A. (2018). *Texting while driving with Level 2 automation: A distraction or an opportunity?.* Proceedings of the 6th Driver Distraction and Inattention conference, Gothenburg, Sweden, October 15-17, 2018 (online). https://www.researchgate.net/publication/328413328_Texting_while_driving_with_Level_2_automation_A_distraction_or_an_opportunity [46]

Wege C., Maculewicz J., Nilsson J., Andersson J., Habibovic A., (Pending submission), Safer texting for connected truck and car drivers - Using various keyboard types while driving with level 2 automation.

Maculewicz J., Wege C., Nilsson J., Andersson J., Habibovic A., (Pending submission), Texting while driving with Level 2 automation: A comparison of three text input methods – Qualitative approach.

Summary

This study explores how driver behaviour and experience of secondary task interaction changes when systems that simultaneously support both longitudinal and lateral control of the vehicle (Level 2) are active in passenger cars and trucks, as compared to manual driving without any additional support. In particular, it investigates how drivers' self-assessed experience of the ease and enjoyment of typing while driving are affected by characteristics of typing interfaces. For truck drivers, the effect of system feedback placement is also explored. The main hypothesis is that Level 2 automation will enable drivers to type while driving without inhibiting safety. As such, the study provides knowledge on how texting as secondary task should be designed to allow for a simple, seamless and safe interaction while using support systems of automation Level 2 in passenger cars and trucks.

Results

Statistical analysis of the results on driving performance showed for longitudinal control there was no significant effect of the display position nor keyboard type on the standard deviation of speed. Automation as a factor was not taken into account for driving performance measures, as speed was not controlled by the driver in automated driving. For the lateral control of the vehicle such as several lane deviation measures the safest keyboard type is QWERTY and the least safe is QWERTY-Swipe. Automation had a direct effect on an increase in the number of messages written in the same time period. Independent of output display or automation, the keyboard type has a significant effect on the number of messages written in a given time period. With QWERTY a significant higher number of text messages can be written.

On glance behaviour it was found that there are more glances off road when driving manual compared to when driving in automation, which is an unexpected effect. The least safe glance behaviour is found when using QWERTY-Swipe compared to the other two tested keyboards. The safest glance behaviour is found for Scribble. The same effects are found for car and truck drivers. When using a HUD, truck drivers look more off road compared to when truck drivers use a secondary display.

Conclusion

As Scribble and QWERTY but not QWERTY-Swipe were found to be a successful text input method, it is concluded that in the future texting can be made safer for both connected truck and connected car drivers.

Lane change test study/eye-tracking study
A Lane Change Test (LCT) was initially tested by project participants in a desktop simulator before a more comprehensive test in a truck simulator at Volvo Trucks. The purpose was to evaluate the

method to find if it would be suitable for evaluating HUDs compared to SID displays and level 2 automated driving.

The study shows that the driving performance is very similar with HUD and SID in LCT measures (Mean Deviation from optimal path), but task completion time is shorter with HUD output. Task Completion Time correlates with eye glance analysis, where there were more long glances on the SID, and with subjective assessments.

CAN data (On-road study Volvo cars)

Test was performed to analyse the potential correlation between the established workload measurement (ECG, RSP and pupil size) and CAN data. We invited 9 participants to drive the car in real environment with or without Pilot Assist. While driving we measured the heart rate, respiratory rate as well as pupil size (eye-tracking) and recorded CAN data. Driving session lasted app. 45 min.

This was the very first step towards non-invasive and low-cost workload measurement method which could be used in real-time to establish drivers' mental workload and adjust the HMI accordingly. Although the analysis of the collected data was too complex to finish before the end of the project, preliminary results are shared in 6.3 WP3 Methods catalogue, SWOT analysis.

Exploration of novel methods

Blur

The Blur method is a suggested method, developed in the project, for measuring the visual demand of interfaces on vehicle HUDs. It is meant to follow the same protocol as the aforementioned Occlusion method, but instead of completely occluding the interface it blurs it instead. The idea is that a blurred interface can simulate HUD interaction more accurately since a driver is typically able to see both the HUD and the road view at the same time.

The suggested Blur method was tested against Occlusion and simulator test for validation. The study supports the initial suggestion, that the Blur method is more suitable than the Occlusion method for testing interaction in HUD interfaces on an experiential level and should be especially suitable as a tool for comparison tests.

Desktop simulator

Desktop simulator is a very efficient method to quickly try the concepts at early stages of the development. It is necessary to implement concepts within the context when e.g. testing sound interaction. In the master thesis 'Make-no-sound Sounds' [48] it was shown that participants who tested sound only through a listening test judged them differently than when testing in the car context. The difference is seen especially when sounds are connected with a specific function. It helps the participants to relate to the environment much easier. With desktop simulator only early concepts should be tested. The final once should be tested in real environment to achieve not only high level of functional but aesthetical synergy with the rest of the product (in this case a car).

LCT adaption for truck

An LCT scenario according to the ISO standard [52] was built in the development environment used at Volvo trucks driving simulator. Results indicate it is possible to use LCT in a truck simulator since the baseline performance requirement was fulfilled for all participants.

6.4 WP4 HMI recommendations

Below follows a summary of the HMI recommendations derived from master theses and research findings in the project based on WP (1-3).

The primary objective of this section is to provide guidelines and recommendations for the design of in-vehicle systems that allow drivers to drive their vehicles safely in a complex and dynamic traffic environment. It is intended to assist in-vehicle and mobile application developers to develop safe and user-friendly interaction.

Display design

The key words “must”, “must not”, “should”, “should not”, “recommended”, and “may” in this document are to be interpreted as described in RFC 2119 (Bradner, 1997). Whenever ‘navigating’ is used, this means navigation within the UI, unless GPS navigation is specified. A summary of HUD recommendations can be found below.

For full content see Astorsson B. and van Sommeren P. (2019). *Creating a foundation for interactive heads-up displays* [49].

HUD Content

This set of recommendations provides guidance on the content of the HUD, i.e. what information should be available, what functions should be accessible, and what should not be shown.

- The information and interaction available on an interactive HUD should be situationally dependent.
- HUD content should change or disappear based on situational needs.
- Content restrictions may be done through function limitation, suppression or active warnings.
- HUD content availability should be dependent on active automation functions.
- Incoming notifications may selectively be displayed.
- Notifications may be delayed depending on the situation.
- Drive information should be displayed in addition to the interactive HUD.
- The driver should be able to choose from which apps to allow content or interaction within the HUD.
- Traffic situations may be used to predict or assist use.

HUD Interface

This set of recommendations tells how the user interface can be designed for, how the content can best be presented, and additional visual guides.

- HUD interfaces should enable navigation within the driver’s peripheral view.
- HUD interfaces should only present the most relevant information.
- Colours should be used solely to show hierarchy in the UI.
- Icons should be used where possible.
- Animations and micro interactions should be used to enhance understanding.
- Haptic input modes should match navigation through the UI.
- UI navigation should be unidirectional.
- Additional audible or haptic feedback should be used for HUD interaction.
- The current location in the UI may be indicated in the UI.
- Items such as notifications may be grouped to avoid clutter.
- Interactive HUDs should match expected phone behaviour where applicable.
- An enlarged capital letter may be placed in alphabetic lists to aid quick navigation.
- Voice control should be considered for short command.
- Voice should be available as an input method for messaging

HUD Physical

This set of recommendations indicates how HUDs should be physically placed to allow for the best interaction.

- Interactive HUDs should be placed 2.5 - 5 degrees below the driver's line of sight
- HUD interfaces should be positioned to not visually interfere with road events

Phone in relation to HUD

This set of recommendation indicates behaviour directly related to the phone, and its relation to the HUD.

- The HUD should be seen as a temporary extension of the phone.
- The HUD should be the only input and output when connected to the phone.
- Notifications on the phone itself should be disabled when connected to the HUD.
- The phone may be blocked from usage when connected to the HUD and the driver is alone.
- The driver should be able to choose whether the phone is paired with the system.
- The phone should be able to connect automatically.
- The car may send unhandled notifications to the phone after driving.

Messaging and notifications in relation to HUD

- Non-driving related notifications in driving situations where the workload is already high should be suppressed.
- If more than one message have been received notifications should be grouped.

I/O devices

Recommendations for manual input for messaging

- The results from the study performed by Wege C. et al. [46] suggests that Scribble and QWERTY but not QWERTY-Swipe can be a successful text input method. Future texting can be made safer for both connected truck and connected car drivers.

Recommendations for interaction with Voice assistants (VAs)

Below recommendations describe how drivers are able to provide input to the Voice assistant while driving, either by voice or manual touch. These guidelines are recommended to be followed when developing systems using voice assistants.

For full content see (Khanh) Nguyen C. and Falkengren W. (2019). *Designing in-vehicle voice assistants* [47].

Voice and Manual Input

These guidelines deal with how drivers are able to provide inputs to the Voice Assistant (VA) while driving, either by voice or manual touch.

- Build multi-turn dialogs for beginners and one-shot commands for experts. Empower drivers to directly access what they want and reduce the amount of time to complete a task.
- Supplement spoken prompts with visual components such as suggestions, alternative actions, or non-critical information that may aid drivers in content selection.
- Enable drivers to interrupt an interaction sequence by both voice and manual input. Allow drivers to later resume the interaction as a later, logical point in time or return to a previous state of interaction if little effort is required to start the sequence again.
- Assume drivers will reference anything presented on the screen by voice. Allow drivers to reference on-screen items by both title, superlative or generic reference.
- Allow drivers to trigger an action or intent by both manual touch and voice commands. This includes designing for multiple utterances for the same action or intent. Drivers can say "Start navigation" and "Take me to McDonald's", both of which start the intent for getting driving directions, the former which will require an additional turn in the dialog.

General Voice Responses

Existing guidelines for general voice responses were found to be overall sufficient when applied to the driving context, so only one new guideline is presented here.

- Provide responses quickly to minimize interaction between the driver and voice assistant. If the response time exceeds 2.00 seconds, the voice assistant to provide a clearly perceptible indication that the voice assistant is in the process of responding. The threshold of 2.00 seconds is based on NHTSA guidelines for traditional HMI input.

Error Handling

These guidelines deal with handling errors and reiterate existing guidelines for voice assistants and how important these particular guidelines are with respect to driving.

- Prevent errors whenever possible to avoid increased driver attention to the screen. Provide suggestions to alternatives or use partial matches to driver utterances provide contextually relevant prompts.
- Re-prompt drivers with a slight variation on the original prompt to provide additional clues for what kinds of inputs are appropriate to trigger the correct action or intent. When drivers don't understand what went wrong, they may repeat the same utterance slower and more clearly only to get stuck in the same error loop.
- Respond gracefully when data is unavailable and make the data connection status clear so drivers can know when they can attempt the action or intent again.

Situation Awareness

Guidelines for situation awareness deal with how the VA can build a context for the driver's current situation, as to prevent the driver from reaching their cognitive capacity.

- Keep track of the context of the dialog between the voice assistant and the driver to understand the use of pronouns and generic references and avoid repeating prompts or responses that may frustrate and distract the driver.
- Adapt to a driver's vocabulary for utterances and inputs. For example, a driver may have a preference for using the phrase "latest messages" to refer to "unread messages."
- Use the car's current context to avoid adding stress to a driver's situation. For example, if the driver encounters a car malfunction mid-interaction, do not create added stress to the situation by prompting or re-prompting the driver to complete the interaction sequence.

Presenting Choice

These guidelines concern how VAs respond to drivers and present choice architectures.

- Present a clear, simple set of options for the driver to choose from. Avoid using open-ended questions for prompts which can confuse drivers or cause them to answer in unexpected ways.
- Give drivers a brief overview when presenting a list, such as by noting how many items are in the list.
- Provide drivers with contextually relevant and differentiating information about items in a list to aid drivers in content selection without relying on a screen.
- Avoid auto-selecting an option for the driver, unless done through a setting previous set by the driver. For example, drivers may have set a preference to always start navigation using the most convenient route, instead of having to choose from multiple options.

Display

These guidelines deal specifically with the IVI display and how it can support VA interaction and addresses issues uncovered in the summative evaluation.

- Allow any selectable content on the screen to be visible to the driver even when the voice assistant is activated, so the driver can reference any onscreen content while giving voice input.
- Use contextually relevant suggestion chips to guide drivers to different task paths and provide a visual fall-back in case the driver missed the accompanying voice output. Allow drivers to hide suggestion chips either as an intent or as a personal setting.

- Avoid using full screen alerts to display information to the driver, unless as part of an interrupted sequence initiated by the driver. Full screen alerts often obscure contextual visual information related to the alert.

Discoverability

A challenge with voice assistants is conveying useful features to the user by voice. These guidelines deal with improving discoverability of VA features by the driver.

- Provide hints or suggestions for difficult to discover or open-ended tasks. For example, playing music is a more discrete task as most drivers have previous experience with music plays where music selection is usually done by song title, artist, playlist, or music genre. In contrast, getting directions is more open-ended and varied.

Notifications

Guidelines for using push notifications.

- Reserve notifications with sound for information or tasks that require the driver's immediate attention. Notifications accompanied with sound draws the driver's visual attention to the screen.

Recommendations for "Make-no-sound sounds"

The following section provides sound feedback to enhance function awareness.

For full content see Broo V. and Tengroth A. (2019). *Enhancing the drivers' user experience by broadening the sonic environment, two visual designers take on sound design* [48].

What "Make-no-sound"-sounds can communicate

- "Make-no-sound" -sounds should not be used for warning signals of high importance as they can be missed.
- Are suitable for nudging the user towards a reaction multiple times without being disrupting or intrusive.
- Is noticed but not intrusive and annoying when played multiple times during a short time period.
- Can communicate that the driver's attention is needed but without experience it won't be understood on its own.
- Has a high learnability.
- Cannot communicate the reaction needed or the reason for the feedback in and of itself and should therefore be used as a compliment to small visual or haptic feedback.

Using lowering of volume as a "Make-no-sound" -sound

- A lowering of volume as a feedback could only be used when media is played.
- The minimum length for the user to notice it needs to significantly be longer than a natural pause in media being played.
- A lowering of volume is more difficult to discern in media where natural pauses is more common such as podcasts, radio or audiobooks and are therefore not suitable for these types of media.
- Due to the fact that they are difficult to discern they should not be used when the driver is involved in secondary tasks separate from the dynamic driving tasks as they risk being overlooked.
- Is not considered as disturbing or intrusive and is therefore better to use if feedback signal activated multiple times.

Using short muffled feedback as a "Make-no-sound"-sound

- A short muffled sound has a high chance of being detected and reacted upon.
- It is less annoying and intrusive than today's warning signals and is considered informative and a kind nudge in the right direction.

- Can be used as an alternative to high pitch and intrusive warning sounds as a way to make feedback that occur often less annoying.
- Even though it doesn't share the same qualities as a warning signal it still matches the mental model of the driver that they need to react to the sound.
- Is discernible even when played in lower volumes or with a high media played.

Using white and ambient noise as "Make-no-sound"-sounds

- A white noise or an ambient noise can be used to nudge and guide the user into a certain behaviour or action.
- A driver will easily block an ambient noise if it matches the speed and road conditions that is driven on. When it is blocked, there is no need to keep the sound activated and it could then be slowly turned off to later be activated when nudging is needed.
- An ambient noise will not be as intrusive as a "beep" sound of today and can therefore be used more frequently without being annoying.
- An ambient noise is less annoying when it is not associated with something that is wrong with the car and the wind noise is perceived as the most pleasant within the car sound spectra.
- Using an ambient noise for a long time and then removing it creates a heightened user experience. Even if the ambient noise goes unnoticed the silence that ensues creates a much better experience for the driver.
- The user feels a satisfaction and thrives for a behaviour that is rewarded with silence.
- When the car is silent the user understands that he or she is using the car the way the car wants to be used and when used that way the user is in big need of understanding why the user should behave that way or else it will be perceived as confusing and annoying.

Categorizing "Make-no-sound"-sounds

- Sounds that belong to the same function and demands the same response should also share the same characteristics.
- The "on" sounds should have a lighter character and mediate a feeling of "keep on going" to the user.
- The "off" sound should have a darker character and be short in length.

When to use which "Make-no-sound" -sound

- Muffled "Make-no-sound" -sounds are more noticeable than the longer ambient noise and possesses a higher risk of being perceived as annoying if used several times during a drive.
- The reason for being nudged by an ambient noise needs to be clear for the user to not get annoyed with the sound.

7 Dissemination

7.1 Dissemination

The key target users for the products are car customers and customers at commercial truck and bus fleets. The knowledge generated will also come into the public domain through public dissemination. Scientific contributions have been made in discussions of HMI Guidelines and standards (eg. ISO), and to scientific journals/conferences regarding human factors in driver assistance and automation and safe implementation of automotive HMI.

The project provides input to on-going Advanced Engineering projects at Volvo Group Trucks Technology. Likewise the project is tied to Advanced Engineering projects at Volvo Cars. The industry partner Semcon will apply the results to support the aim to be among the best engineering service provider within HMI and multi-modal systems methodology and development. Besides the results benefiting the car industry, the competence and results gained throughout the project may become useful in other areas and contexts outside the automotive industry. The project will lead to a general increase in the capacity of innovation thanks to the experience gained in this project. Five M Sc theses have been conducted in the project which means contribution to knowledge sharing between industries and universities.

The project results are expected to have measurable benefits in terms of improved UX that increases customer attraction of the products that are produced by Volvo GTT and VCC. As safety is one of the concerns of the project, one can also expect reduced fatalities and serious injuries as well as reduced costs thanks to savings in material damage on vehicles and goods as a result of the project.

Increase knowledge in the area	X
Carry over to other advanced engineering projects	X
Carry over to product development projects	X
Introduced in the market	(X)
Utilized in investigations, regulations, political decisions.	(X)

7.2 Publications

A decision was taken in the project to focus on quality and more variables in fewer amount of studies than originally planned for. This resulted in one conference proceeding presentation, one conference proceeding submission and three papers pending submission.

Oral conference presentations

Wege, C., Maculewicz, J., Nilsson, J., Theodorsson, N., Andersson, J., & Habibovic, A. (2018). *Texting while driving with Level 2 automation: A distraction or an opportu*nity?. Proceedings of the 6th Driver Distraction and Inattention conference, Gothenburg, Sweden, October 15-17, 2018 (online).

https://www.researchgate.net/publication/328413328_Texting_while_driving_with_Level_2_automation_A_distraction_or_an_opportunity [46].

Make No Sound' Sounds – A Journey into the Realms of Sound Interaction (2020) Justyna Maculewicz, Fjollë Novakazi, Anna Tengroth, Viktor Broo. Submitted to CHI2020 conference, Honolulu, Hawai'i

Papers (pending submission):
Maculewicz J., Wege C., Nilsson J., Andersson J., Habibovic A., (Pending submission), *Texting while driving with Level 2 automation: A comparison of three text input methods – Qualitative approach.*

Wege C., Maculewicz J., Nilsson J., Andersson J., Habibovic A., (Pending submission), *Safer texting for connected truck and car drivers - Using various keyboard types while driving with level 2 automation.*

Bång O., Hillding J., Andersson J., Bjursten J., Heimler T., Lindström D. (Pending submission). *Method assessment of Lane-Change Test in the context of Head-Up Displays and Semi-Autonomous Driving*. (2019).

Master theses
Five master theses, for abstracts see appendix B.

(Khanh) Nguyen C. and Falkengren W. (2019). Master thesis at the Department of Computer Science and Engineering, Chalmers University of Technology. *Designing in-vehicle voice assistants* [47].

Broo V. and Tengroth A. (2019). *Enhancing the drivers' user experience by broadening the sonic environment, two visual designers take on sound design.* (2019). Master thesis at the Department of Industrial and Materials Science, Division Design & Human Factors, Chalmers University of Technology, Gothenburg, Sweden & User Experience Centre at Volvo, Gothenburg, Sweden [48]. https://odr.chalmers.se/handle/20.500.12380/256773

Astorsson B. and van Sommeren P. (2019). *Creating a foundation for interactive heads-up displays.* Master thesis at the department of Industry and material Science, Chalmers University, Gothenburg [49]. https://odr.chalmers.se/handle/20.500.12380/300006

Kjellquist, J. and Lidin H. (2018). *Designing for Semi-Autonomous vehicles. In-Vehicle Digital Communication During Low-level Automation In Congested Traffic Environments.* Master thesis at the Department of Computer Science and Engineering. Chalmers University, Gothenburg [50]. http://publications.lib.chalmers.se/records/fulltext/255506/255506.pdf

Arvidsson, J. and Granström, J. (2018). *Interaction With In-Vehicle Infotainment Systems. Development of Interaction Tools For In-Vehicle Infotainment Systems.* Master thesis at the Department of Computer Science and Engineering. Chalmers University, Gothenburg [51].

8 Conclusions and future research

The project has gathered knowledge about user behaviour, and how the secondary task interaction changes, when driver assistance systems are active. The impact map showed that the drivers had a need to focus on organizing, planning, communicating and interacting with entertainment and social media. This emphasizes the need for the SEER project and further research in this area. These activities are all secondary tasks and candidates for applying the validation methods and guidelines developed in the project.

A set of methods for evaluating different aspects of interaction with secondary tasks during assisted driving scenarios, have been tested and evaluated. Some methods (e.g. eye-tracking, vehicle data, occlusion and subjective measurements) have been found valuable and recommended to apply in future studies of secondary tasks during partial automation. The difficulty to evaluate the distraction from a HUD, using eye-tracking, still remains, due to the overlap of areas of interest. The Lane change test study indicate that the method can be used to differentiate between placements of displays. The mean lateral deviation, measurement from the Lane Change Test study, differs significantly for different displays, tasks and driving mode indicating that HUDs may be a good option for displaying secondary task output.

Head-Up display messaging concepts have been developed and validated. A HUD display was used for concept exploration in the project, since it enables the drivers to keep their eyes on the road. The results from this project shows a lot of promise and user satisfaction when interacting with HUDs, but the results show the interaction needs to be implemented with care in order to not overload the driver in cognitively demanding situations. There are also indications that the driver gets overconfident when interacting with the HUD display since the road is peripherally visible when performing secondary tasks. The SAFE concept from the idea generation in section 6.2 Concept generation, suppressing information handling in cognitively demanding situations, was the concept fulfilling the SEER requirements best.

One step in the project was to look into manual text input methods in order to conclude on the most safe and efficient input method. Further explorations of using scribble as text input method are recommended when designing concepts since it showed promising results to make future texting safer and more satisfactory for both connected truck and car drivers.

More and more Voice Assistants are introduced to support the driver with secondary task interaction. An evaluation and comparison of existing VAs were performed in the project. The results in this project has shown that in order to reach the intended effect of a VA, structure and feedback needs to be carefully considered.

With the help of literature research, user interviews and simulator studies, HMI recommendations have been developed, to support the development of seamless, efficient, enjoyable and foremost safe interaction. Some of the promising results and tendencies of the concepts developed in the Master's Theses, need to be tested on a larger scale to check if the tendencies could be proven statistically significant.

More research is needed to conclude on if using CAN data can be a quick and non-intrusive method to evaluate cognitive load. Evaluating HUD using eye-tracking can also be further explored to conclude on how to differentiate between overlapping Areas of Interest and placement of and content of HUD. Adding automation in the studies performed in this project has not shown significant results on driver's performance or task preferences. This topic is therefore recommended to be further explored in new research projects.

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Appendix A

Presentation at DDI 2018

Texting while driving with Level 2 automation: A distraction or an opportunity? [46]

Authors: Claudia Wege*, Justina Maculewicz, Jan Nilsson, Nina Theodorsson, Jonas Andersson and Azra Habibovic,

Keywords: Distraction; Driver support; Secondary task; Simulator; Texting while driving

This study explores how driver behavior and experience of secondary task interaction changes when systems that simultaneously support both longitudinal and lateral control of the vehicle (Level 2) are active in passenger cars and trucks, as compared to manual driving without any additional support. In particular, it investigates how drivers' self-assessed experience of the ease and enjoyment of typing while driving are affected by characteristics of typing interfaces. For truck drivers, the effect of system feedback placement is also explored. The main hypothesis is that Level 2 automation will enable drivers to type while driving without inhibiting safety. As such, the study provides knowledge on how texting as secondary task should be designed to allow for a simple, seamless and safe interaction while using support systems of automation Level 2 in passenger cars and in trucks.

Aim and research questions

This study explores how driver behavior and experience of secondary task interaction changes when systems that simultaneously support both longitudinal and lateral control of the vehicle (Level 2) are active in passenger cars and trucks, as compared to manual driving without any additional support. In particular, it investigates how drivers' self-assessed experience of the ease and enjoyment of typing while driving are affected by characteristics of typing interfaces. For truck drivers, the effect of system feedback placement is also explored, see Figure 1. The main hypothesis is that Level 2 automation will enable drivers to type while driving without inhibiting safety. As such, the study provides knowledge on how texting as secondary task should be designed to allow for a simple, seamless and safe interaction while using support systems of automation Level 2 in passenger cars and trucks.

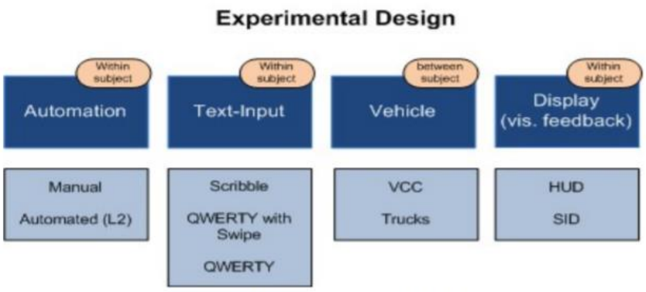


Figure 1. Experimental design

2 Figure 1.

Experimental design

Methodology Driver behavior and experience was compared in a texting-while-driving task with and without Level 2 automation active. The study was carried out in a fixed-base truck-cab driving simulator and involved 31 car drivers (8 females, 23 males; average age: 40 years) and 20 truck drivers (5 females, 15 males; average age: 42 years). The experimental design is illustrated in Figure 1. Each driver completed three driving conditions: a) driving without any automation and without any secondary task, b) driving without any automation while texting, and c) driving with Level 2 automation active while texting. The conditions b) and c) were randomized. These two conditions consisted of three texting sessions each where the drivers completed the texting task by using the following interfaces in a randomized order: Scribble (a smartphone application that enables texting by tracing a finger over the screen), QWERTY (a regular smartphone keyboard), and QWERTY with swipe (a regular smartphone keyboard with extended functionality that require just a swipe of the finger to enter letters), see Figure 2. All these interfaces were placed on the mid-right side of the steering wheel, accessible by the drivers' right hands. The car drivers experienced only one location of the system output, head-up display (HUD), and their experiment took about 100 minutes to complete. The truck drivers, on the other hand, experienced feedback in a HUD as well as in a side display (SID) in a random order, which resulted in an experiment of ca 150 minutes. A combination of qualitative (drivers' self-assessed a priori and posteriori experience) and quantitative (eye-tracking, vehicle speed, deceleration, etc.) data were collected.

In this paper, we have however chosen to mainly focus on the subjective experiences. In the a priori questionnaire, the drivers were asked about their background and experience regarding texting and driver support systems. During each typing session, the drivers' situation awareness was explored using a real-time probe technique based on the Daze method [13]. However, the probing questions were asked by one of the test leaders present in the truck cabin. The drivers were asked if they had noticed traffic safety relevant objects (e.g. signs, vehicles, and animals) present on the shoulder of the highway along the way. The a posteriori questionnaires were issued after each typing session and contained questions on how the drivers perceived their driving, the texting task, the texting interface, and the vehicle automation. Each questionnaire took about 1-2 min each to complete. At the end, the drivers completed a summarizing questionnaire. 3 SESSION 2 Effects on driving behaviour and performance SESSION 2 Effects on driving behaviour and performance 31 Figure 2. Timeline describing secondary tasks. The three typing tasks are repeated for each driving condition.

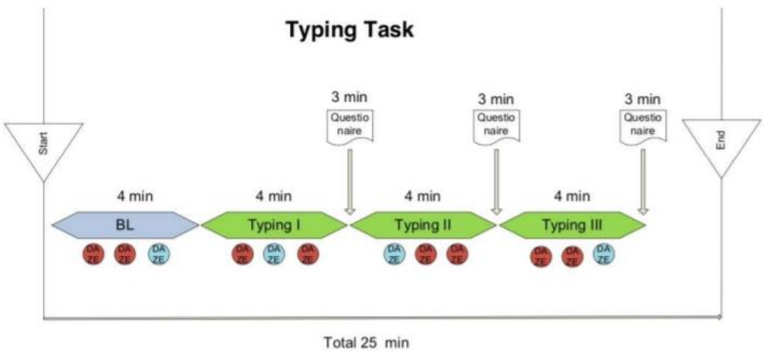
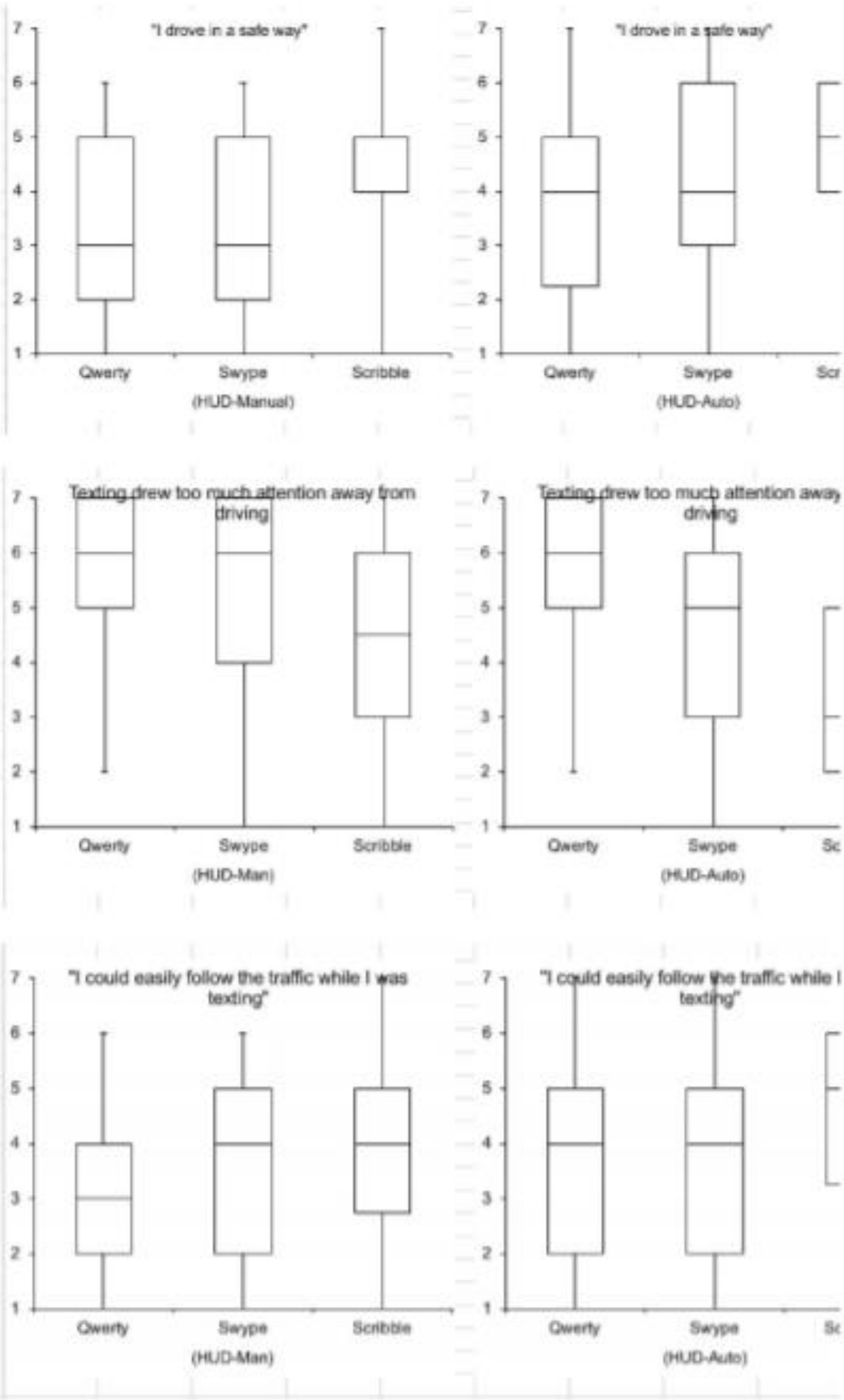


Figure 2. Timeline describing secondary tasks. The three typing tasks are repeated for each driving condition.

Preliminary results

The data collection has been completed very recently and the data analysis has just started. The results that are presented here are thus preliminary and based only on a fraction of the data collected. Overall, a great majority of the car drivers (N=20) and truck drivers (N=11) stated that their favorite typing interface was Scribble. Eight car drivers and six truck drivers stated that Swipe was their favorite, while only 3 car drivers and 4 truck drivers preferred Qwerty over the two other input interfaces. This is manifested also in drivers' self-assessed safety, where they frequently stated that they drove safest when using Scribble. It also outperformed the other interfaces in self-assessment of attention allocation (the drivers stated that the texting with Scribble took at least attention from the primary driving task), at the same time as the drivers stated that it was easiest to follow the traffic in front of them when using Scribble. These trends seem to be even more emphasized when driving with the Level 2 automation active. That is, the automation seems to have a (slightly) positive effect on the drivers’ experience, and it is again Scribble that outperforms the competing interfaces. These overall trends will be further explored using statistical analyses and added to the final paper. We aim also to further explore difference between HUD and SID feedback, something that is left out here. 4 SESSION 2 Effects on driving behaviour and performance 32 Figure 2. Timeline describing secondary tasks. The three typing tasks are repeated for each driving condition. Preliminary results The data collection has been completed very recently and the data analysis has just started. The results that are presented here are thus preliminary and based only on a fraction of the data collected. Overall, a great majority of the car drivers (N=20) and truck drivers (N=11) stated that their favorite typing interface was Scribble. Eight car drivers and six truck drivers stated that Swipe was their favorite, while only 3 car drivers and 4 truck drivers preferred Qwerty over the two other input interfaces. This is manifested also in drivers’ self-assessed safety, where they frequently stated that they drove safest when using Scribble. It also outperformed the other interfaces in self-assessment of attention allocation (the drivers stated that the texting with Scribble took at least attention from the primary driving task), at the same time as the drivers stated that it was easiest to follow the traffic in front of them when using Scribble. These trends seem to be even more emphasized when driving with the Level 2 automation active. That is, the automation seems to have a (slightly) positive effect on the drivers’ experience, and it is again Scribble that outperforms the competing interfaces. These overall trends will be further explored using statistical analyses and added to the final paper. We aim also to further explore difference between HUD and SID feedback, something that is left out here. 4 5 SESSION 2 Effects on driving behaviour and performance SESSION 2 Effects on driving behaviour and performance 33 Acknowledgment: The study is carried out in cooperation between AB Volvo, Volvo Car Corporation, Semcon Sweden AB, and RISE Viktoria as a part of the project SEER that is supported by the Strategic Vehicle Research and Innovation (FFI). Thanks to all participants in the experiment.


"I drove in a safe way"
Qwerty
Swype
Scribble
(HUD-Manual)
"I drove in a safe way"
Qwerty
Swype
Scr
(HUD-Auto)
Texting drew too much attention away from driving
Qwerty
Swype
Scribble
(HUD-Man)
Texting drew too much attention away driving
Qwerty
Swype
Sc
(HUD-Auto)
"I could easily follow the traffic while I was texting"
Qwerty
Swype
Scribble
(HUD-Man)
"I could easily follow the traffic while I texting"
Qwerty
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(HUD-Auto)

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Appendix B

Abstracts from the theses conducted in the SEER project can be found below:

”Make-no-sound”-sounds by Viktor Broo & Anna Tengroth

Abstract

The automotive industry is moving towards automated driving, this transfers more of the dynamic driving tasks from the driver to the system. While full automation is not available as for now, today’s automated driving system such as Adaptive Cruise Control (ACC), which supports in longitudinal control, and Pilot Assist (PA), which supports in both longitudinal and lateral control of the car, is in the forefront of creating a more automated driving experience for drivers. A more automated driving situation creates a need to keep the driver aware and informed of how and when the system is aiding their driving.

This project aimed to improve the user experience of a driver using the two assistive function ACC and PA, through the enhancement of auditory feedback. In order to do so the main goal was first to understand the current user experience of drivers using these functions. The information was gathered through a use study consisting of survey answers, a use test and interviews with both experienced and inexperienced users as well as a benchmark of current vehicles equipped with the same or similar functions.

The result of the project was the introduction of the term “Make-no-sound”-sounds, a new type of auditory feedback to inform the users of their mode status. “Make-no-sound”-sounds are a collection of sounds that guides the user into a behaviour that is preferred and provides them with the opportunity to retrieve information without looking away from the road. These sounds were the result of three tests, with their basis in the use study, done to investigate whether the user experience could indeed be enhanced through providing a broader sonic environment for the two functions at focus.

A final concept using these sounds as the only auditory feedback for PA was tested. This resulted in a set of guidelines of how to use subtle auditory feedback to enhance the user experience of driving a second level automated vehicle. These types of sounds should not be used for warnings of high level. Secondly, they are non-intrusive, does not disrupt the driver and can be played multiple times without being considered annoying and as such will enhance the user experience of the driver using the assistive function.

Designing in-vehicle voice assistants by Connie (Khanh) Nguyen and William Falkengren

Abstract

Voice assistants are increasing in popularity with the rise of devices like smart speakers and screens. As people grow accustomed to using these assistants, it is likely they would want use the same voice assistant in their car. Many modern cars already support integration of voice assistants from both Apple and Google. In this project, voice assistants integrated into the vehicle and their effects on safety in terms of increased diverted attention and cognitive load are examined. Current voice assistants are also reviewed. Apple Siri and Google Assistants, two commercial voice assistants, are evaluated under the conditions of manual driver, as well as with longitudinal and lateral assistive drive features. New, improved design solutions and guidelines were evaluated through two prototypes with different approaches to solving found problems in existing voice assistants. The results indicate several similarities and differences in the existing design guidelines for the different voice assistants. Users provide input and thoughts about the existing solutions. New design solutions for decreasing distraction and cognitive load are presented. These new solutions can help continued research and further improvement of voice assistants within cars in the future to come.

Creating a Foundation for interactive Heads-Up displays by Billy Astorsson and Paul van Sommeren

Abstract

Level 2 automation has been shown to lower the cognitive workload needed to operate vehicles. As a result, drivers may experience a cognitive underload while driving. This may encourage the driver to use their phone, resulting in unsafe situations.This thesis lays a foundation for creating interactive heads-up displays (HUD) that may replace the need for using a phone. The focus is put on the user experience of the HUD specifically implemented in cars and trucks. In order to do so, several aspects within the scope of this research are investigated.

User research, through cultural probes and context mapping, explores current use of phones. The results show the need for staying connected, and the development potential of an interactive HUD. A previously untested method, called the Blur method, is shown to be a better representation of HUD use than the industry-standard Occlusion method. It is further shown to be a valuable method for qualitative evaluation of interface designs. The look-down angle from the driver's line of sight is shown to be essential in task performance, with an optimal angle being between 2.5° and 5° below the line of sight.

A human-machine interface concept with level 2 Wizard-of-Oz automation is created based on the research in this thesis. The concept shows significantly positive results ($p<0.05$, $n=12$) on the attractiveness, perspicuity, efficiency, and simulation scales of the User Experience Questionnaire. This thesis presents 32 guidelines in the categories of HUD content, HUD interface, physical implementation and relations to the phone. The guidelines serve as a basis for designing a HUD that combines a safe, efficient interaction with an enjoyable user experience.

The guidelines create a foundation for designing interactive HUDs, and the authors recommend a holistic approach into further research and development of the interactive HUD and potential guidelines.

Keywords: interactive heads-up display; level 2 automation; cognitive underload; blur method; look-down angle; user experience

Designing for Semi-Autonomous Vehicles: In-Vehicle Digital Communication during Low-Level Automation In Congested Traffic Environments by Jesper Kjellqvist and Hampus Linden

Abstract
The automotive industry is moving towards autonomous driving, and as more driving task responsibilities are transferred to the motor vehicle, the driver can engage in more non-driving tasks. In this project, we have investigated driver behaviour with so called secondary tasks (STs) in semi-autonomous motor vehicles, and how a human-machine interface (HMI) for digital communication, and other STs, can be designed for this level of autonomy. We have sent out a survey, created concepts, implemented low- and high-fidelity prototypes, and conducted user tests, in order to find a solution which is both comfortable, efficient, and safe to use while driving. Our solution consisted of a system with a head-up display (HUD) by the windshield, and two touch sensitive trackpads mounted at either side of the steering wheel. The trackpads control the content shown in the HUD, by using common touch gestures, such as pressing, swiping, and typing with our own interpretation of a T9 input method, which we call Circular T9. In the end, we had insufficient data to conclude whether our solution was safe enough in a real driving setting. The feedback from the user tests have been generally positive towards the concept, but critical towards the high-fidelity prototypes, specifically that there is insufficient feedback from the input interface. Our hope is that this project will inspire other projects in designing HMIs for future motor vehicles.

Keywords: Automotive, semi-autonomous driving, secondary tasks, human-machine interface, digital communication, interaction design, concept design, Circular T9, trackpads, head-up display.

Interaction with In-Vehicle Infotainment Systems: Development of Interaction Tools for In-Vehicle Infotainment Systems During Low-Levels of Automation In Rural Environments by Jonas Arvidsson and Jonathan Granström

Abstract

Increasingly more car manufacturers are implementing advanced driver-assistance systems in vehicles. Furthermore, the rise of smart devices has created an environment where people expect more of their devices to be connected to the internet.
As a result, the infotainment systems in vehicles are becoming more connected and provide more functionality, e.g., direct messaging. This thesis presents a concept which allows a driver to interact with the communicative tasks of an infotainment system in both non- and partially automated vehicles, driven in rural environments. The concept consists of a trackpad placed to the side of the driver, in an arm rest position, which acts as the input device. A head-up display placed in the front window of the vehicle is used as the output. We believe the concept shows promise, but requires more development in certain areas, such as text-input, and more thorough evaluation in real life environments, in order to properly confirm if the concept is safe enough to use in a vehicle when driving.

Keywords: automotive, interaction design, human-machine interface, autonomous, infotainment, user interface