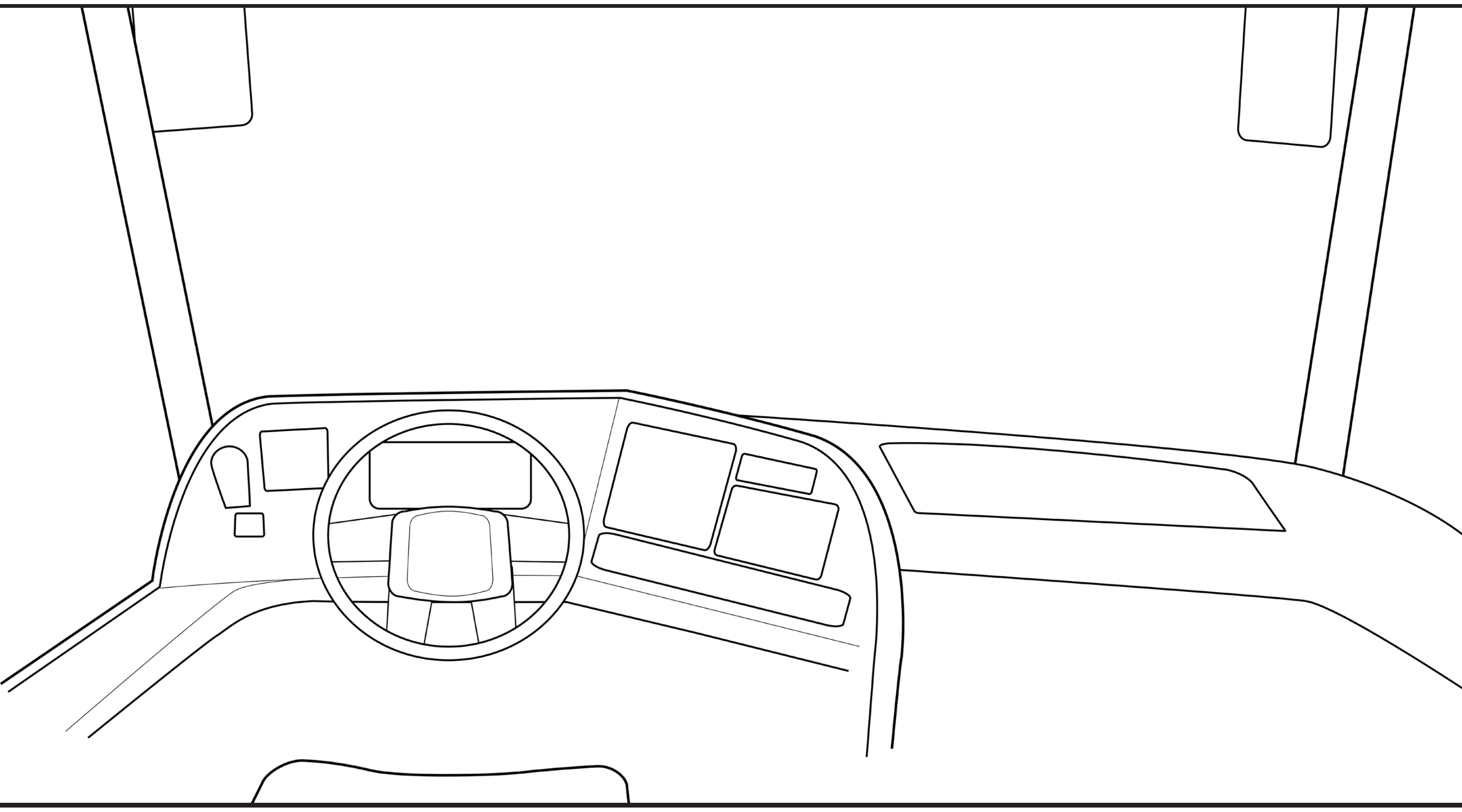
CHALMERS



Design Coach for Coach Warning Design

A Strategic Approach to Active Safety Warning Interaction in Coaches

M.Sc. Thesis in Industrial Design Engineering

MAKSIM HANSÉN GOOBAR

JONAS ISAKSSON

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017

Department of Product- and Production Development
Division of Design & Human Factors

Master of Science Thesis

Design Coach for Coach Warning Design

Master Thesis

MAKSIM HANSÉN GOOBAR

JONAS ISAKSSON

SUPERVISOR: HELENA STRÖMBERG
EXAMINER: LARS-OLA BLIGRÅRD

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017

Department of Product- and Production Development
Division of Design & Human Factors

Master of Science Thesis PPUX05

Design Coach for Coach Warning Design
Kandidatarbete inom civilingenjörsprogrammet Teknisk Design

Chalmers University of Technology
SE-412 96 Göteborg, Sweden
Telefon +46(0) 31-772 1000

Cover photo: Maksim Hansén Goobar
Print: Repro Service Chalmers

Preface

This report presents a master thesis covering 30 ECTS credits conducted between September 2016 and February 2017. The thesis was conducted by two students attending the master of Industrial Design Engineering at the division of Design and Human Factors, department of Product and Production Development at Chalmers University of Technology.

During this thesis project we have received a lot of help and support from different instances which have been crucial and have had a positive impact of both our individual experience conducting this project as well as on the results. Firstly, we would like to extend our gratitude towards our supervisor at Volvo Bus Corporation, Maria Gink Lövgren, for a great cooperation and all of the support we have received during the project. The accommodation and willingness to give input and help answer questions have aided us greatly in achieving our results.

We would also like to extend a special thanks to Erik Aremyr and Martin Jönsson for our close collaboration during our thesis projects and for their constant willingness to lend a helping hand. Together with Filip Oscadal and Kamil Dolezal, they have also brought positive energy and inspiration to the every day life during the thesis work.

Lastly, we would like to extend our gratitude and thanks to the support we have received from our supervisor, Helena Strömberg, and examiner, Lars-Ola Bligård at the department of Product and Production Development at Chalmers. They have been a great source of feedback during the project and have helped steer us in the right direction.

Gothenburg, March 1st 2017,
Maksim Hansén Goobar and Jonas Isaksson

Abstract

The goal of this project has been to develop a strategy for designing the human-machine interaction of active safety warnings when implementing new Active Safety Systems at Volvo Bus Corporation. Factors to consider was differences from application in other vehicles and how to facilitate user and context centered approach. A conceptual human-machine interaction for a “Lane change support” was also to be developed to communicate and refine the strategy.

To reach insights in context specific problems and aspects, user studies of coach drivers were performed through interviews, questionnaires, observations and a workshop. This was complemented with reviews of literature regarding Human Factors research in different areas related to advanced driver assistance systems. In order to formulate a relevant strategy with emphasis on user centered design and human-machine interaction, literature reviews and workshops on the topics also was conducted.

From analyses of the research key functions for the strategy was defined as Encourage focus on user and interaction, Facilitate a systematic development process, Include different level of abstraction, Encourage exploration and documentation, Provide easily obtainable information relevant to active safety warning design in coaches.

To accommodate these functions the strategy, called Strategy for active safety warning Interaction in coaches (SASWIC), was developed into three components. A design process to facilitate a structured user centered design approach as well as make sure that important aspects are considered. An interaction model illustrating the core interplay and division of user and machine tasks, and an information framework presenting findings and discussions regarding a range of aspects relevant to the human-machine interaction between coach driver and an active safety warning user interface

With the help of the strategy and complementing research a conceptual interaction and user interface for a Lane change support system for coaches was finally developed. The interaction is divided into four warning stages and uses multimodality.

As a whole the strategy with its components act a comprehensive resource, summarizing relevant information as well as offering tailored design tools. This contributes to the overall understanding of active safety warning application in coaches and specifically to Volvo Bus Corporation development work in the very same area.

Glossary

In order to facilitate reading, some abbreviations are used throughout the report are presented below.

HMI - Human-Machine-Interaction

HM - Human-Machine

UI - User interface

ASS - Active Safety System

ASW - Active Safety Warning

ADAS - Advanced Driver Assistance Systems

SA - Situation Awareness

VBC - Volvo Bus Corporation

FCW - Forward Collision Warnings

LDW - Lane Departure Warnings

LKS - Lane Keeping support

LCS - Lane Changing support

BLIS - Blind Spot Information System

ACC - Active Cruise Control

Table of Content

1. Introduction

The following chapter introduces the master thesis by presenting the background of the project, the project purpose and goals established, and the delimitations made to create the scope of the project.

1.1 Background

Traffic safety is a major issue in today's society. Traffic-related accidents claim more than 1,2 million lives each year, making road traffic the 9th most common cause of death worldwide and the number one cause among people aged 15 to 29. It is estimated to generate governmental costs of around 3% of GDP (World Health Organisation, 2015). With increasing mobility and motorization the number is only expected to increase further, creating an impending need for safety improvement.

The sector of road traffic that is buses and coaches is not overrepresented in road accidents, but due to the fact that these vehicles carry a large amount of passengers as well as it being big and heavy vehicles, an accident involving a bus or coach can produce great damage and high number of injuries and fatalities. When examining the total travelled passengers miles in U.S, statistics show that the risk of an bus or coach accident is close to that of cars (Kaplan and Prato, 2012).

Just like mobility overall, the coach industry is growing and with it the number of trips and travelled passenger kilometers. Thus, it also requires safety improvements. Improving traffic safety is a multifaceted work concerning issues such as road user behaviour as well as road and vehicle design, issues that are approached through legislation, road safety education, infrastructure remodeling and the advances in the vehicle development (World Health Organisation, 2015).

With safety as a core value and branding point, The Volvo Group, consisting of a number of different brands including Volvo Trucks, Volvo Penta and Volvo Buses, aims to be in frontline of vehicle safety. During the almost 90 years of creating buses, Volvo has continuously implemented safety features in pursuit of their zero accident vision, as stated by Volvo buses Safety Director, Peter Danielsson (Volvobuses.se, 2016). Through the years the industry together with academia have generated solutions in vehicles that increase safety both for the vehicle's user, passengers and other road users. Much effort has been put into measures minimizing damage when accidents occur, later called passive safety, with car body design, safety belts and airbags being some examples. Through the development in design of mirrors, lights, windshields, among many things, the chance of detecting risks and the possibilities of avoiding accidents have also improved through the years.

With the rapid advances in technology and the move towards autonomy in driving during the last decade, possibilities for further ways of preventing accidents through the help of sensors and information are appearing. This has resulted in the creation of a range of new systems to support the driver, called Advanced Driving Assistance Systems (ADAS) and Active Safety Systems (ASS), aimed to facilitate safe driving by either alerting drivers and/or intervening on their own, when dangerous situations are detected. These systems use sensor technology to detect and understand the state of the vehicle and its surrounding. Some examples of ASS include braking systems such as ABS and traction control, as well as sensor based systems such as adaptive cruise control (ACC) and forward collision warning (FCW) systems. As these systems need to convey the information gained from the surroundings to the driver, most Active Safety System have its associated Active Safety Warnings (ASW) presented at possible risk situations.

A key factor for the success of Active Safety Warning is a suitable human-machine interaction, which is the entire communication and interaction between the system and the driver. This means that the warning interface needs to convey the correct interaction with the system to the driver in order to avoid risk situations. The way in which to do so may vary depending on the context of use. Therefore, different physical designs of vehicles as well as different driver conditions create variations that needs to be considered when designing the human-machine interactions and user interfaces.

Many of the Active Safety Systems implemented into Volvo's coaches today are initially developed for trucks and truck drivers, and later implemented in coaches. As a result, the differentiating aspects mentioned risk making the active safety systems less effective than intended, or even obstructing for the bus drivers. Therefore, Volvo Buses seek a deeper understanding of the specific characteristics of the intended user and use context of their Active Safety Systems, in order to be able to optimize future human-machine interaction for their coaches.

1.2 Project purpose

The purpose for this project based on the background was defined as follows.

The purpose of this thesis is to investigate and define a strategy for designing the human-machine interaction and user interface of Active Safety Warnings when implementing new Active Safety Systems at Volvo Buses. The strategy should highlight important aspects to consider for developing human-machine interaction and user interfaces for active safety systems in coaches, underlining their difference in comparison with aspects from other types of vehicles. The strategy is meant to facilitate a user centered design, optimizing it for coach drivers and the context of a coach. To test and refine the strategy, as well as to act as a communicative example, a conceptual human-machine interaction and user interface for a specific ASW will be developed.

1.3 Project deliverables

In order to complete the project purpose with more measurable goals, the following deliverables were formulated.

The main deliverable of the project is a document containing a strategy for design of human-machine interaction for Active Safety Warnings in coaches, made out of guidelines and design policies in the form of text and graphics. The format for the strategy will be developed depending on the findings in the research.

The second deliverable is a conceptual human-machine interaction and user interface for a specific Active safety warning designed according to the strategy. The design of the concept will be basic and represented through text, sketches and conceptual pictures but with a clear relation to the strategy.

1.4 Report structure

This report is structured in a non-traditional way in order to facilitate reading and emphasize on the result heavy nature of this project. The report can be divided in two parts: an introductory part and a results based part. The first part of the report consists of three chapters and aims at establishing an understanding for the project and how it was conducted.

1. Introduction. This chapter introduces the thesis project and presents the reader with information regarding its purpose and deliverables.

2. Theoretical framework. This chapter contains a brief presentation of relevant theory needed in order to understand the project and this report.

3. Process and methodology. This chapter presents the process used to conduct this thesis and the methodology applied in the different parts of the process. The chapter is also presented in a chronological order to facilitate reading.

The second part of the report contains the results produced during the project as well as a discussion regarding their, and the project's, credibility goal fulfillment.

4. SASWIC - Strategy for Active Safety Warning Interaction in Coaches. This chapter introduces the reader to the main deliverable of this project which is the strategy for the design of human machine interaction for Active safety warnings in coaches. This is done by briefly presenting the strategy's three components: the design process, the interaction model and the information framework.

*5. Strategy - Design Process and Interaction Mode*l. In this chapter, the design process and interaction model are presented in full together with their intended use and internal relationship.

6. Strategy - Framework. This is where the information framework is introduced by explaining its design and indented use. The framework itself, being an information bank of research made, is presented as an independent part before the appendices.

7. Lane Change Support concept development. This chapter contains the presentation of the second deliverable: the Lane change support system concept created by applying the strategy to a real case. This chapter is meant to illustrate the use of the whole strategy.

8. Discussion. The project as a whole, the results as well as the methodology used are all discussed in this chapter. The chapter also aim to establish key findings of the project and how they relate to common practice and today's research within the field of Active safety warnings in coaches.

References. The sources referenced and used in the report are listed here. The sources from the research used to create the Information framework are listed within the framework itself.

Information Framework. Here, the project deliverable that is the Information framework, createad as a part of SASWIC, is presented in full as an independent piece.

Apendices. Relevant appencides such as interview and workshop templates used to concuct this project are presented here.

2. Theoretical framework

This chapter presents definitions relevant to the understanding of this report as well as a presentation of existing research in the scientific fields touched upon in this project.

2.1 Human-machine system and User centered design

This section presents definitions and research regarding human-machine systems and user centered design as well as explains how they relate to each other.

2.1.1 Human-machine system, interface and interaction

A human-machine system (or man-machine system) refers to a system where a human (an operator or user) with the help of a machine tries to achieve specific goal. This is done by completing tasks using the functionality of the machine (Bohgard et al., 2008). The parts of the machine that the operator uses to interact with the machine within a Human-Machine system is called the user interface (UI) or Human-machine interface (HMI) and can consist of both input and output devices. The interaction between the operator and the machine in itself can be called Human-Machine interaction, sharing the same abbreviation (HMI) (Bohgard et al., 2008). In order to emphasize the importance of not mainly directing focus to the interface, but rather the user and her interplay with the machine, the terms human-machine interaction and user interface will be used in this report.

2.1.2 Human-machine interaction model

In the field of human factors, many different models have been created to describe the interaction in a human-machine system. For example, Janhager (2003) proposes a model where the interaction has been separated into a user and a technical process. These processes occur concurrently over a timeline during a described use case. This to ensure that both user and technical aspects are taken into consideration when assessing a human-machine system. In addition, Janhager has divided the user-process into user action and mental activities, describing the actual goal oriented use and the experienced emotions and attitudes respectively in separate streams. In Janhager's model, the technical process describes the technical functions a machine performs during the use procedure.

Investigating the relationship between user and machine tasks in a similar way to Janhager was determined to be useful as it could provide a concentrated fundament from which to design a human-machine interaction. It was also considered potentially helpful as a mediating object when trying to communicate a user and interaction focus by relating it to concurrent machine tasks.

2.1.3 User centered design in a human-machine system

The implementation of new machine systems or functions into a human-machine system with the purpose of helping users, for example by increasing safety, also comes with the risk of generating new problems and risks. This can for example be due to lack of understanding of how the new human-machine interaction affects user workload or unconsidered situations in the interaction that neither the machine nor the user will be capable of interpreting. User centered design, with the core being investigations of human factors issues through studies of an appropriate community of users, is suggested to offer an approach where such potential consequences can be identified and mitigated in advance (Boy, 2012).

2.1.4 ACD³ Design process

The ACD³ process is a cohesive framework aimed at structuring and concretising the different parts and aspects of a design process during product development (Bligård, 2015). The process was developed by Lars-Ola Bligård at Chalmers University of Technology in Gothenburg, Sweden. ACD³ provides a holistic view of the design process by providing systematic structure in different levels of abstraction. The different levels of abstraction and design work are illustrated in Figure 2.1. This is meant to facilitate the overview of the process and allow for interchanging work with design and requirement setting in each step. Due to it being a generic framework, the ACD³-process can be applied on most types of product development, in parts or in full.

The process ranges from need identification aimed at asserting effect goals on the socio-technical system, to production and launch of a finished product. It thoroughly investigate both user and machine separately as well as in their planned interactions. The ACD³ process is meant to be particularly useful during the planning stage of a product development by highlighting how and where the different design activities exist in the different phases. During this project, the detailed structure, inclusion of different levels of abstraction and emphasis of user, machine and interaction provided a resourceful tool to use for exploring and deconstructing human-machine interaction with ASW in coaches.

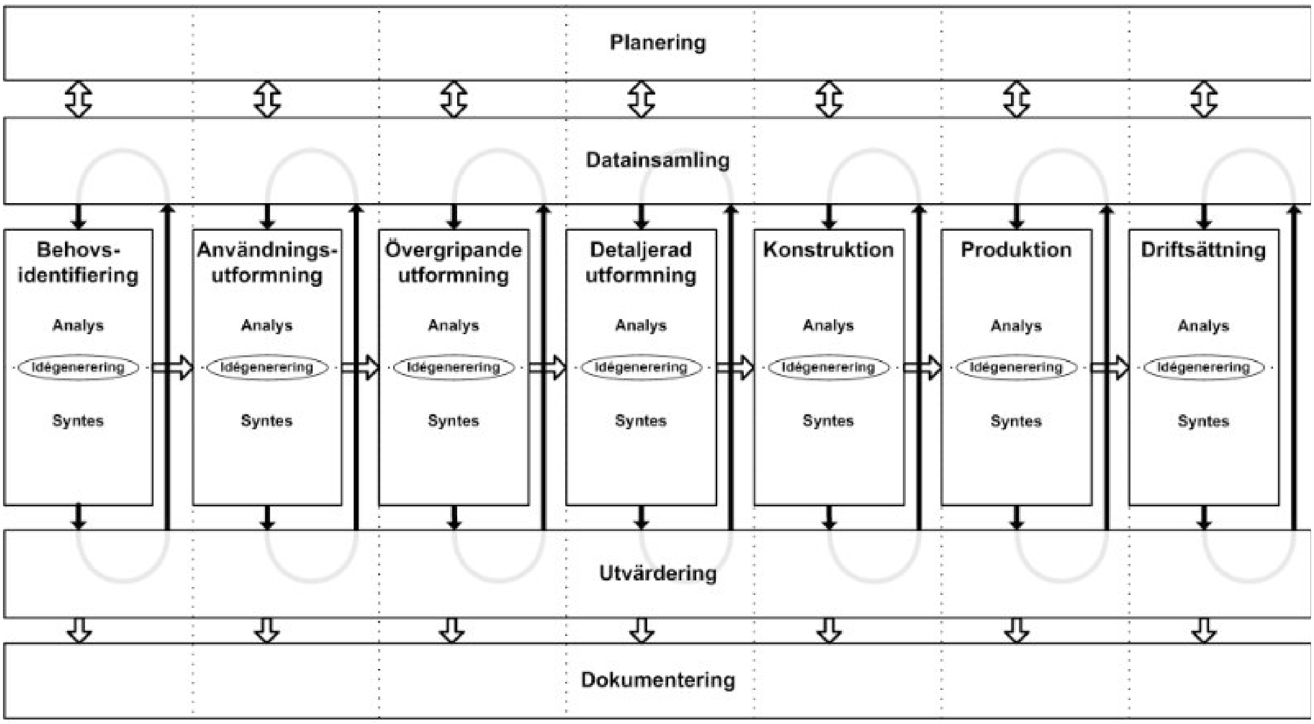


Figure 2.1 Overview of ACD³ design levels (text in swedish) (Bligård, 2015)

2.2 Coach, ADAS and active safety

In this section the definition of coach and different technical in-vehicle assistance systems are presented as well as research within the area.

2.2.1 Coach

Coaches (or motor coaches in the US) are heavy vehicles within the category buses. They are designed for tourism and longer trips compared to city/transit buses, which puts demands on things such as better comfort, more luggage space and bigger windows. Coaches can either be single floor or double-deckers.

In a single floor coach the driver seat is usually elevated a bit to increase viewing distance. Passenger seats are situated on an even more elevated floor, above luggage compartments. The windshield covers almost the full front of the vehicle to allow passengers a forward view. Mirrors are generally placed in front of the wind shield. An example of a Volvo coach is shown in Figure 2.2.

2.2.2 ADAS, Active safety and autonomy

The term Advanced Driver Assistance System or ADAS is a subset of Driver Assistance Systems (DAS) and regards systems focused on driver aid and accident prevention. (Schwarz, J. et al. 2009) Technologies for detecting and processing risky situations (such a radars and cameras) and determining and presenting appropriate feedback can be called active safety technologies (Arthur D. Little, 2014). ADAS for accident prevention that include these types of technology are commonly called Active Safety or Active Safety Systems, but widespread definitions are lacking and vehicle manufacturers use the terms in individual ways. An important distinction should be made from the use of the term Active safety as referring to safe driving and good driving environments. The functionalities in active safety systems, aside from the detection tasks, can include both communicative tasks, such as warnings, and automated driving tasks such as emergency braking.

The warnings communicated through the user interface of active safety systems to users (first and foremost the driver) are sometimes called Active Safety Warnings (ASW) and often represent the central human-machine interaction.

Figure 2.2 Example of a Volvo Coach (Volobuses.com)

Common active safety systems that include warnings are those with the purpose of preventing unintentional lane departures (Lane Departure Warnings, Lane Keeping System, etc), forward collisions (Forward Collision Warning, etc), accidents related to vehicle blind spots (Lane Change Systems, Blind Spot Information System, etc), problems due to wrong tire pressure (tire monitoring system) and drowsy or inattentive driving (Driver attention alert). In today's vehicles, the warnings of these systems are often either presented visually, (e.g. interfaces, head up displays, lights), auditory (e.g. buzzers, alarms) or haptically (e.g. vibrations, pulsation). An example of a visual warning is shown in Figure 2.3.

Active safety systems are mainly integrated in the vehicle by the producer but there are also options available through the aftermarket, mostly with communicate functionalities. Regulations are pushing development by demanding integration of certain functionalities and systems in new vehicles. New heavy vehicles such as coaches are obligated to include system for emergency braking and lane departure prevention as of 2015 (Arthur D. Little, 2014), and further requirements are coming.

Figure 2.3 Head up display warning (Volobuses.com)

The continuous development of active safety can be seen as part of the automotive sectors journey towards autonomous driving. The technologies that are prerequisites for ADAS such as radars and cameras, are also a part of what makes completely autonomous driving a possibility (Arthur D. Little, 2014). Looking at the interaction there are still important differences to consider as active safety systems, especially those related to collisions, generally should not substitute driver tasks but only compliment them (Schwarz, J. et al. 2009).

2.2.3 Research on ADAS development

Research regarding ADAS development can be divided into research on sensor technology, user interface development and development of automated driving actions, the two later strongly connected to the Human-Machine interaction and human factors.

There are extensive investigations in the effect and efficiency of different aspects of warning interfaces, such as different modalities (haptic, visual, auditory) and their respective types of warning devices, one example being the extensive compilation by Haas and van Erp (2014). There are also a considerable amount of research on test design of said devices and their safety systems. Available research is generally based on studies on cars, with heavy vehicles only specifically considered in a minority with most cases concerning either trucks or transit buses. This indicates the lack of knowledge about the specific context of coaches and how application of active safety systems in coaches actually affects warnings interface design.

There are attempts at providing guiding documents for the design of ADAS and collision warning systems, including both sensor technology as well as warning interfaces. The National Highway Traffic Safety Administration (NHTSA), a part of the U.S Department of Transportation have produced and gathered much research in the field. Their report "Crash Warning System Interface: Human Factors Insights and Lessons Learned" (Campbell et. al, 2007) presents a comprehensive and didactic overview derived from a great number of research papers. It gives clear categorization of aspects such as warning stages, warning types and their relation to modalities essential to construct an effective user interface.

The report also addresses application in heavy vehicles suggesting suitable considerations for trucks and transit buses regarding some of the presented aspects. Another, more recent, NHTSA report (Tidwell et. al, 2015) investigates the effect of a couple of different forward collision warning configurations in heavy vehicles. It is one of very few with tests performed in coaches. It was found that the results and considerations presented in these reports was supported by findings from the user studies.

Additionally, there are finished as well as ongoing international research projects concerning the complete development of ADAS, one such example being the EU-funded Prevent project. In the report Response 3 - Code of Practice for the Design and Evaluation of ADAS (Schwarz, J. et al. 2009), a part of the Prevent project, a code of practise for a general ADAS design and evaluation process is presented. The report gives brief descriptions of the activities related to the design of the ADAS and extensive aspects to consider in terms of concept evaluation.

The overall field of research on ADAS development can be described as mostly consisting of a multitude of smaller but very specific studies into specific factors. The larger ADAS research reports from the NHTSA and the Response 3 can be said to have a more practical approach with focus on the development of new system. These reports try to bring different research together in order to provide a holistic view of a very complex area, a difficult feat to accomplish. Therefore, whilst having these larger reports in consideration during the project, it was also deemed important to explore the smaller more specific research papers and build a new opinion of the subject.

2.3 Strategy

The word strategy is a broad term with many different definitions. According to the Oxford dictionaries a strategy is "A plan of action designed to achieve a long-term or overall aim" (Oxford Dictionaries | English, 2017). The term strategy is frequently applied in many different areas (military, business, management, marketing, etc) and within in each area experts tend to emphasize different variations of this definition. According to Richard Rumelt, doctor in business at Harvard Business School and former President of the Strategic Management Society, the kernel of any strategy are three elements; a diagnosis, a guiding policy and a set of coherent actions (Rumelt, 2011). He describes the elements in the following way

The diagnosis:
".. defines or explains the nature of the challenge. A good diagnosis simplifies the often overwhelming complexity of reality by identifying certain aspects of the situation as critical."
The guiding policy

".. is an overall approach chosen to cope with or overcome the obstacles identified in the diagnosis."
The coherent actions

".. are steps that are coordinated with one another to work together in accomplishing the guiding policy.""

On a similar note he mentions three important aspects a strategy should consider (Rumelt, 2011.). Premeditation, in the sense that there always is a need for some type of guidance that is formed in advance, even if changes and adaptations to some extent can be done throughout the work. Anticipation, as reflection in how others concerned will think and act. And finally coordinated actions that can be performed independently but together create a powerful whole.

This suggests that a strategy should not focus on giving a few static answers or goals but rather act as a comprehensive resource that can give proactive support for future work. This can be done by providing an overview together with well-founded directives, identified obstacles and tools for addressing them.

3. Process and methodology

The purpose of this chapter is to present the process used in this project as well as the methodology applied during the different project parts. Firstly, the process for the whole project will be presented holistically together with a Gantt schedule describing the time management (Appendix 1). Later the different project parts will be presented chronologically together with the methodology used in each part.

3.1 Project process

Due to the project's main deliverable being a strategy for the creation of new human-machine interactions, rather than an human-machine interaction itself, the process used for this project differed from a more traditional design process. The overall process model used is loosely based on the Double-Diamond design process created by the Design Council (UK) in 2005 (Dstudio.ubc.ca, 2016). The double diamond model consists of two divergent and convergent phases, the first of which focuses on research and analysis, and the latter on concept development and implementation. However, the process used for this project consisted of three divergent and convergent phases, namely a research and analysis phase, a strategy development phase, and a Lane Change Support development phase. All three phases were somewhat concurrent and developed iteratively.

The activities performed and methods used in the three phases are presented individually below in chapter 3.2-3.4. In order to achieve a better overview and to understand how the activities relate to each other, they are also illustrated in Figure 3.1.

3.2. Research and analysis

During the first part of the project, research and analysis, an extensive literature study was conducted of current relevant theory and research covering information in multiple areas of interest at different levels of abstraction. In addition, several user studies were performed which all will be presented below. These studies were performed in order to fulfill the purpose of providing Volvo with information, as well as to create a basis for the decision of strategy format. Once the format was set, the research was used for further development of the strategy.

3.2.1 Pilot study - active safety systems

In order to gain a basic understanding of the project scope and the area around which the project revolves, an initial pilot study was performed. One of the main goals of the pilot study was to acquire knowledge regarding active safety systems and active safety warnings. This was partly done by a small benchmarking study where different coach manufacturers were studied and their active safety systems analysed. The general idea of active safety systems was also researched into in order to further define the scope of the project.

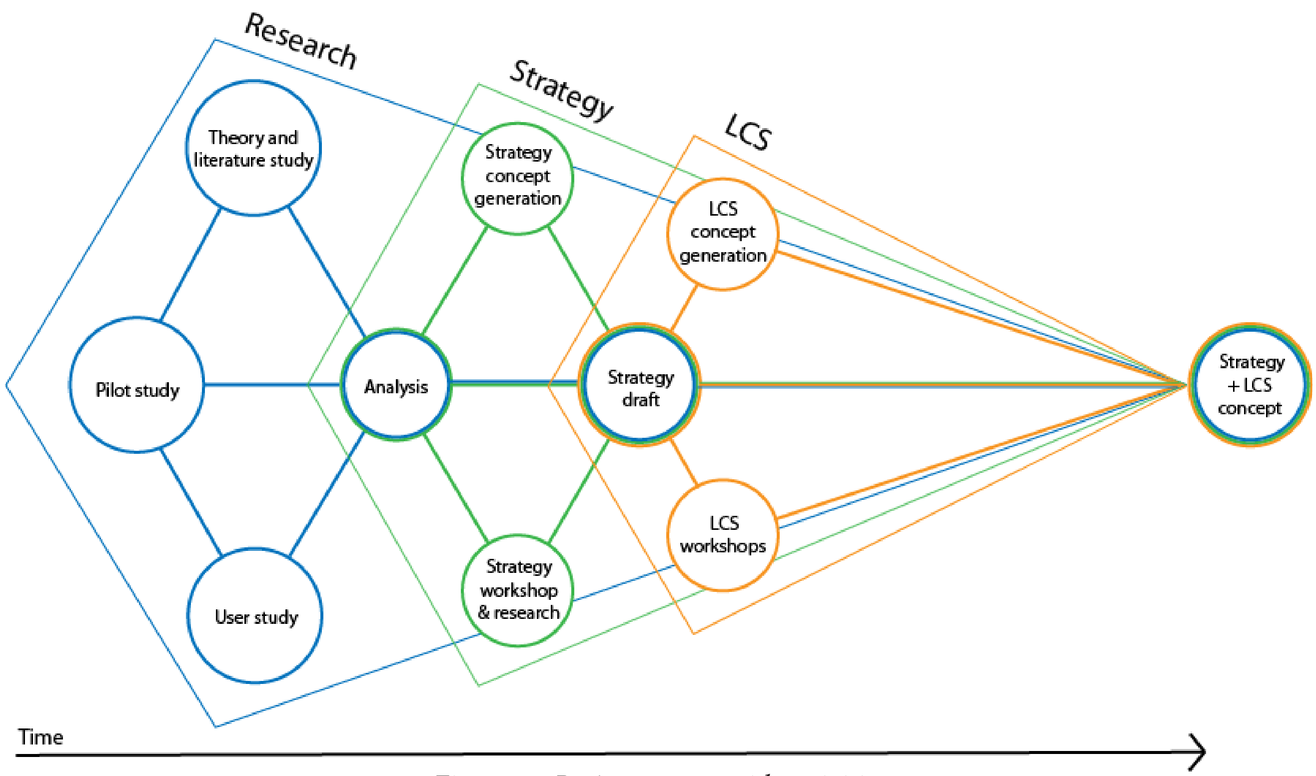


Figure 3.1 Project process with activities

As a part of the benchmarking study, a visit to the automotive exhibition "Persontrafik" was conducted. The idea was to gain firsthand information from several coach manufacturers about the future of active safety systems.

Several meetings with, and research into Volvo Bus Corporation was also performed at the start of the project. During this research, the aim was to map their approach to safety and active safety systems as well as to gain an understanding of their expectations for this project. Furthermore, the general working process and design process when implementing new active safety systems was thoroughly investigated.

3.2.2 Theory and literature study

One of the project deliverables was to deliver a research based strategy where guidelines and design related aspects for active safety warnings was presented. As the strategy was to be generic and applicable for all future active safety systems, there was a need for a broad approach to the theory and literature study. Therefore, in order to encompass all of the relevant aspects, the research was divided into specific design aspects for active safety systems as well as general design aspects.

The general design theory researched aimed at providing Volvo with a solid foundation of knowledge concerning human cognition and alarm theory. This was deemed necessary as more specific design guidelines can both be extrapolated from and explained with general theory. The more specific theory research was related to a number of relevant areas such as active safety systems and active safety warnings in different types of vehicles, workload and cognition whilst driving, and how different modalities affect the user in alarm systems.

Several different sources were used to acquire the literature studied during this phase. Most scientific publications reviewed were found through the Sumon database holding all information accessible at Chalmers library as well as through Google scholar. The keywords used consisted of system related keywords (e.g. active safety systems, ADAS), context related keywords (e.g. coaches, buses, bus accidents), and user related keywords (e.g. driver workload, driver distraction). Additional relevant theory was found through course literature and recommendations from supervisors at Chalmers.

The first approach of the literature study was to find as many articles as possible which could have implications relevant to the project. The next step was to skim the abstracts and do a primary selection of literature, whilst also dividing them into different categories. The remaining literature was then read and later analysed according to the process described in 3.2.4.

3.2.3 User studies

The user studies were conducted to obtain coach specific information relevant to the active safety warning-system development. This was particularly important since most published research only concern cars and trucks. Three different methods were used to gather information from users in this project, namely questionnaires, interviews and observations. The reason for having three different methods was to obtain both quantitative and qualitative data which could support or contradict each other, raising the validity of the study.

The target group of the user studies were coach drivers, who often work for small bus chartering companies and are on the road for long periods of time during the day. Therefore, the idea of finding a perfect representation of the target group for the user studies was discarded quickly. However, by sampling users from different bus chartering companies and different geographical locations a good representation was deemed to have been achieved.

The decision was also made to not exclude users from other countries as it could be beneficial considering Volvo buses being active in several countries around the world. Furthermore, the study chose to include users of other coach brands than Volvo in order to achieve a wider and more general knowledge base regarding the user's needs and opinions of active safety systems.

Questionnaires

Two questionnaires were sent out as a part of the user study phase of this project. Both questionnaires were sent out in the Facebook group "Coach Drivers International", whose members consist of over 3000 coach drivers based mainly in Great Britain, but also from other parts of Europe.

As the demographic of the coach drivers in the Facebook group couldn't be controlled or chosen, age and experience of driving coach were asked in both questionnaires. One of the only certainties concerning the demographic was that all participants were, to some extent, active Facebook users.

The first questionnaire was sent out early on in the project and aimed to ascertain several aspects concerning the driver's' overall workload and experience when operating a coach. The questionnaire included questions regarding the experienced workload and emotions when driving in different context. For example, the participants were asked how they felt when driving in different environments, and were given semantic scales with different emotions to rate their experience. They were also asked how often they experienced high mental workload or mental fatigue, as well as how it affected them and what induced it.

The questionnaire also contained questions regarding their previous experience with active safety systems the perceived user experience concerning them. The participants were asked which active safety systems they had used, how they felt in general when using such systems, what type of warning devices they had experienced (e.g. seat vibration, head-up-display), what they thought about the warning devices and why they disliked them if they said they did. The questionnaire in full can be found as Appendix 2.

The second questionnaire was sent out at the beginning of the Lane change support development and had two purposes. Firstly the questionnaire aimed at gather some more knowledge for the framework regarding the user experience of active safety systems and to map the users' attitude towards different aspects of warning systems. For example, the questionnaire asked about their attitude towards active safety systems, if they ever had turned off such systems and why. Secondly, the questionnaire also contained specific questions regarding Lane change support in order to obtain a solid foundation for the human-machine interaction concept development (see Appendix 3). Among the Lane change support-specific questions were questions regarding if they wanted a blind spot warning system, in what situations they wanted it and how critical they rated those situations.

Interviews

In total, six interviews were conducted for the purpose of this thesis. The interviews were of a semi-structured nature where follow up questions were allowed in order to obtain more comprehensive answers and thus a deeper understanding. Four of the interviews were conducted over the phone, with coach drivers from different companies found in the benchmarking study. The remaining two interviews were performed on site and combined with ride along observations in the participants respective coaches.

The participants consisted of coach drivers of all ages, 5 male 1 female, with varying amount of experience driving coaches. The selection of participants were made solely on the availability of the individuals but were considered to be representative for the profession as experienced by the authors of this paper. The participants were found by contacting local coach chartering companies as well as from contacting the Swedish Facebook group "Busschaufförer i Sverige", consisting of 870 bus drivers from all over Sweden. The number of interviews was decided as they were conducted and a perceived level of saturation in answer diversity was attained.

The interviews aimed at obtaining general knowledge regarding the physical and cognitive demands when driving, as well as general driver behaviour and attitudes. As many of the interviewees had additional experience of driving cars and trucks, the interviews also aimed at exploring the difference in workload and user needs between driving a coach and other types of vehicle. As focus for this project was active safety systems, the user interfaces in the cab interior with the different systems were of particular interest during the interviews. The template used for the interviews can be found as Appendix 4.

Observation

In order to obtain a better understanding of the issues mentioned in the interviews, and the context for our project, two observations were conducted simultaneously with two of the interviews. The two coaches used for this purpose were both Volvo coaches. The first coach was a test driving bus at the Volvo Bus garage and only had Forward collision warning installed. The interviewee operating the bus for this observation was a Volvo employee working there. The other interviewee was an employee at Majorna buss, driving his own coach with Lane departure warning, Forward collision warning and Adaptive cruise control installed.

During the observations, the coach cab and interfaces were documented and interviews were conducted whilst the drivers were operating the vehicle during a shorter drive. The observations were also meant to facilitate for the interviewees to discover different issues by discussing the tasks being performed. An example of this is discussing active saftey systems and lane departure warnings whilst trying to trigger that particular system.

3.2.4 Analysis

In order to structure and categorise all of the collected research, an analysis was conducted. Since the research consisted of many different formats, from literature and scientific publications to questionnaires, recorded interviews and recorded observations, the different sources were analysed separately at first in order to obtain similar formats for later comparison.

The research papers and theory from the literature study described in 3.2.2 were analysed thought conducting an affinity diagram (Martin and Cannington, 2012). The papers and literature were read and paragraphs deemed relevant were highlighted. The highlighted passages from all of the sources were printed and cut into small text pieces and quotes. These were then sorted into similar piles whereupon several distinct categories could be discerned.

In order to analyse the interviews, they were first transcribed whereupon the quotes from the interviewees were used to perform an affinity diagram in the same manner as with the literature. The answers from the questionnaires had been compiled through converting the answer sheet data to written text. Thereafter, the questionnaire findings were compared with the sorted information gained from the interviews in order to establish if there were any contradictory results. This was not found to be the case. How the analysed material from the different studies were used is presented in chapter 3.3 Strategy development.

3.3 Strategy development

Creating the strategy proved a challenging task as there were no clear definitions to turn to and no specifications from Volvo. The goal of the strategy stated in the project purpose was to present the research done to provide guidelines when developing new active safety warnings. However, this broad purpose meant that it could take many different forms to aid ASW development in different ways. From the theory regarding strategies summarized in chapter 2.3 it was determined that the strategy should provide a wide and versatile long term approach rather than static goals. It was also determined that the strategy should work to both help Volvo diagnose problems regarding ASW-development as well as offer an overall and coordinated approach to overcome these.

In order to explore different formats for the strategy, a workshop was held where strategies were discussed in broad terms. A key insight gained from the workshop was the need for understanding the company's own design process where the strategy is to be implemented. In order for a working strategy, knowledge gaps and process limitations need to be considered and compensated for in a strategy. This opened up for possible solutions both being adapted to fit Volvo's current design process, as well as allowing a solution to influence and change their current design process. The research and analysis performed previously during the project also provided grounds for narrowing down the options for the format.

With basis in the aspects mentioned above, an ideation phase was started where brainstorming and benchmarking of other types of strategies were used to generate ideas for the format. This resulted in several different conceptual ideas for strategy formats which were then discussed with both supervisors at Chalmers as well as with Volvo in order to move on with the most promising ideas.

Instead of solely presenting information and guidelines, the main focus of the final solution was chosen to be a generic design process for the development of new concepts for active safety warnings. This solution were to be complemented with an information framework of research findings, as well as with an interaction model to further tie the active safety warning development to the user. The reasoning behind these decisions were to help Volvo adapt to a more user centered design process. This was considered very important as findings in the user studies suggested that many use issues stemmed from problems with the use and systems rather than the interfaces of the warnings.

Further literature studies was made into design processes, interaction models in human machine-systems and active safety systems in order to further refine the strategy. A more concrete concept was presented to Volvo at a halftime presentation where the idea was approved. The strategy was later tested and validated when creating concept for a Lane change support system which led to minor refinements (see 3.4).

Strategy workshop

The strategy workshop conducted was in the format of a focus group where questions and ideas were discussed in a group with a moderator mediating the discussions. Three participants were present at the workshop, two students from the master program Industrial Design Engineering at Chalmers and one student from the master program Industrial Ecology. The participants were of both sexes and between 25-26 years of age. The participants were chosen as they all have experience working in product development projects and using different design processes and strategies.

The workshop consisted of two parts, with the first aiming at exploring the idea of a strategy, discussing possible uses and what is desired from a strategy in a product development project. In order to facilitate for the participants' thought process, pictures of visualized strategies were used as mediating objects. In the second part of the workshop, some findings from the research and analysis were presented together with the project scope in order to discuss how different strategies could be used in this project. The full discussion template for the workshop can be found in Appendix 5.

3.3.1 Framework development

The information framework created as a part of the strategy is supposed to support the development of new active safety warning-systems by acting as a holistic database contributing with information in a wide range of aspects relevant to the development work. This demanded compilation of all of the research conducted into one format that should be easy to access, despite its wide range. This also meant continuous analysis in order to relate different findings and produce discussions.

Due to the lack of research found regarding coaches compared to cars, trucks and even city and transit buses, the framework was decided to gather and connect relevant findings from the different fields together with the result from the performed user studies.

Analysed research findings from literature and the results from the user studies (described in 3.2.4) touched on related topics in many cases. Above mentioned difference regarding the type of vehicles in which Advanced driver assistance system research has been performed suggested that its validity for application in coaches could be seen as uncertain. The user studies was not of such character that they strictly could confirm or disprove many of the implications found in literature, for example quantified efficiency of different types warnings devices. They were therefore decided to be kept separated, for readers to easily determine the source and character of the information.

Two options for structuring the information within the framework were contemplated; by subject or by source of information. Structuring it by source would facilitate use in cases where only one type of research would be of interest, most evidently if only an overview of strict coach/user-related information is desired. The possibility for relating and comparing findings from different sources, in order to draw richer conclusion, would in this case become tedious and potentially not performed. By instead structuring the framework around subjects such comparisons would be encouraged. The later was found to be favourable in order to efficiently be able to integrate use of the framework with the overall strategy and its components. To present the subjects in an orderly fashion, in a way that made each subject approachable on it own, an article format was developed.

The work with structuring the framework and making it easier to navigate also included categorizing and sorting the subjects. Early on it was said to be favourable to avoid a structure with too many hierarchical levels, to allow easier access to individual articles and better overview of the whole. The structure evolved throughout the work with the framework, adding and taking away hierarchies until a balance was reached. The final structure places subjects in groups under three main areas. User, with focus on human conditions that influence the interaction, Context, with focus on important aspects of the context in which the interaction takes place, and active safety warnings, focusing on the machine part of the interaction. To illustrate the connections between aspects and to facilitate navigation between articles as well as specific parts of the design process, cross references were added. These would help the user continue the exploration of information without having to return to an outline.

When the structure was created work on supplying the framework with content meant continuous exploration and comparisons of different subjects, looking further at how the subjects related to each other and which findings were most relevant to present. This also helped produce discussions summarizing what the different findings in each subjects together could implicate.

3.3.2 Design process development

When the decision had been made to create some sort of design process to support and give structure to the development new concepts for ASW, work began with creating a format in which the process would be presented. In order to structure a user centered design process, inspiration was taken from the ACD³ design process from Lars-Ola Bligård, researcher at Chalmers University of Technology (Bligård, 2015). The ACD³ method divides the process into phases where subjects of different abstraction levels are treated. By starting the design process at a higher level of abstraction, the underlying problematics behind the wanted active safety warning solutions can be investigated, providing a better foundation for making better detailed design decisions later on.

Since the strategy is meant to be generic and used for all future active safety systems, specific methods were excluded from the design process. Instead, after discussions and in consensus with Volvo, the main features of the design process was chosen to be a set of exploratory questions and deliverables. These questions and deliverables were specified and sorted into the different levels of abstraction in the process template.

The questions used for each part of the design process were partly derived from adapting general questions found in ACD³ to more the more specific use of active safety warning-development. The questions were also partly derived from other ADAS development research as well as from the conducted user studies. In order to avoid static answers and to encourage reflections, the questions were made to vary in level of detail and openness. A rough selection of the most important questions were also made in order to avoid overloading the user of the process with questions.

3.3.3 Interaction model development

The interaction model complementing the design process was one of the original concepts for presenting the entire strategy. The idea was to emphasise the interaction between human and machine in a warning system in order to convey a wider and more user centered approach to active safety warning development. This was deemed necessary as many of the active safety warning-system related problems found in the user studies stemmed from problems beyond the warning interface. An example of this would be the user's mental model of a risk situation and when a warning is needed mismatching with the active safety warning-system boundaries. Emphasising the interaction also meant to facilitate thinking of HMI as human-machine interaction rather than only a human-machine interface, thus using a more user centered approach.

The original model consisted of four steps, representing the interaction between user and warning systems. The steps were: grab attention, communicate message, interpret message and perform action. The first two steps of the model were attributed to machine tasks and the last two to user tasks, reflecting which part performed the action. The model was meant to not only illustrate interaction, but also to be used as a tool for discerning where in the interaction different problems can occur with different systems.

In order to evaluate if the interaction model was a good method of representation of the generic interaction with warning systems, the user and machine tasks of current active safety warnings were mapped into the model. This resulted in the model being altered, placing user and machine tasks into concurrent steps instead of following each other in the interaction sequence. The model was also completed with further steps. The rearrangement was deemed necessary as the model needed to be generic for all future active safety systems of different technological principles. The separation allowed for possible changes in the machine tasks on behalf of Volvo, without changing any fundamental user tasks.

After the halftime presentation, a brief literature study into research papers concerning a similar interaction model by Janhager (2003) was in order to assess the validity of the interaction model. Minor changes were made after this, including further specifying and describing the interaction taking part in the different steps. This to make the model easier to comprehend.

3.4 Lane Change Support development

The Lane change support concept development phase consisted of the ideation and conceptualization of a human-machine interaction and user interface for the specific active safety warning, using the strategy draft as a basis. The Lane change support development served two purposes: to further evaluate and improve the strategy in an iterative manner as well as to create an human-machine interaction and user interface concept for exemplifying the strategy. Since the proposed strategy served as basis for the Lane change support development, work circulated around the design process which was worked through step by step. Collection of relevant data was done from the research performed previously (included in the framework) as well as by complementing research in form of two workshops described in 3.4.1.

With the help of the workshop findings and framework information, the explorative questions from the design process could be answered, and the deliverables for each step could be specified. To be able to visualize, comprehend and try out suggested embodiments/interfaces simple sketches, projections and 3D-models were used.

During the Lane change support concept development, changes were made to the formulations of questions and deliverables in the design process, and evaluative questions were added. These changes were made to make the design process more generic to function for all types of future systems as well as to cover the important aspects found during the research studies compiled in the framework.

3.4.1 Lane change support development workshops with Volvo and coach drivers

Two workshops were performed as part of the Lane change support development, one with coach drivers with the intention of generating Lane change support human-machine interaction and user interface concepts, and one with HMI developers at Volvo Bus Corporation in order to evaluate the how easy the strategy was to use. Both workshops helped data collection for the Lane change support development as well as to generate ideas and evaluate the process.

Two coach drivers participated in the first workshop, a female aged around 30 and a man aged around fifty. The second workshop was held with two developers at Volvo Buses. Both workshops were conducted in a similar fashion, with basis in using the created strategy. The workshops touched upon the different steps in the created design process, with the help of the developed interaction model as well as mediating objects such as paper roads and cars, line sketches of a coach interior and pictures of different warning devices. During the coach driver workshop, a moderator asked the participants questions inspired by and relevant to the different process steps. In contrast, during the Volvo Bus Corporation workshop the participants were encouraged to use a draft of the strategy to answer the questions by themselves as far as they could. The workshop templates for the two workshops can be found as Appendix 6 and 7.

From the Volvo Bus Corporation workshop outcome it was concluded that the strategy format worked well and was understandable by the Volvo developers. However, it was also concluded that further introduction and explanations were needed to the different process steps and questions in order to increase the intuitiveness and learnability when using it.

4. SASWIC - Strategy for Active Safety Warning Interaction in Coaches

This chapter will introduce and give an overview of the main deliverable of this project, the active safety warning development strategy called SASWIC. Relevant background will be given using research findings in order to create an understanding for the character and design of the strategy. Key factors extrapolated from the findings will then be presented, together with the strategy's three main components: a concept development process, a framework and an interaction model. An overview of SASWIC is seen in figure 4.1.

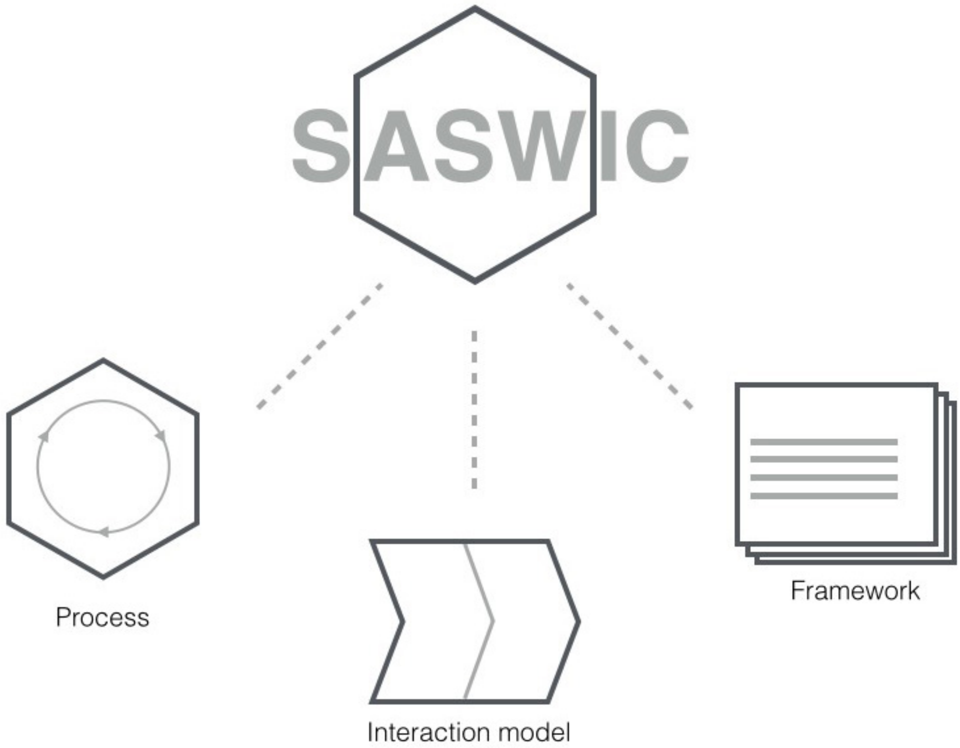


Figure 4.1. SASWIC with its three components

4.1 Key research findings and key functions

During the pilot and research studies performed in the first half of the project, a number of key findings were made that later served as inspiration for the design of the strategy. These key findings are presented below.

One of the major influencing factors is Volvo's preconditions. As Volvo is the client of this project and the future user of the strategy, it is important to adapt it and make it as useful as possible for them. One of the key findings is therefore the technology driven process the HMI-department at Volvo often adapt to, especially when presented with a finished technical system only in need of a warning interface. This is in contrast with the human-centered design approach which is considered useful when designing human-machine interaction (Boy, 2012). User studies also found a tendency by drivers to turn off certain active safety systems as they were considered irritating and not seen as useful, indicating that user perspective needed further attention. The strategy is therefore aimed to *Encourage focus on user and interaction* in order to provide means for highlighting important human factors and user related aspects often missed when using a technology driven process. As Volvo possess a lot of existing knowledge regarding technical aspects, the emphasis on the user and interaction is meant to balance out the product development process, creating equilibrium.

No articulated development process or methodology was described by Volvo and neither the availability of extensive documentation from earlier developments. To work with design in a systematic way, with structured process that includes performing studies and documenting findings and decisions, is a mean to efficiently address the most relevant aspects, easily iterate work and to achieve continuity. As the strategy is meant to provide a general design approach applicable to continuous development of active safety warning systems of different purposes, it is decided that it should encourage such activities. Two key functions is therefore said to be *Facilitate a systematic development process* and *Encourage exploration and documentation.*

Apart from gaining insights for strategy functions from Volvo, the literature and user research performed also provided inspiration through the findings. The user studies resulted in number of important coach specific findings with potential influences on active safety warning design. These aspects concerned the role as coach driver, the vehicle itself, the environments in which it operates, the design of current active safety warning interface, and much more. A few examples of important key findings from the user studies are presented below. These examples act as a representation of generic findings where underlying factors can be discerned, differentiating the needs of the coach driver with those of the operators of other vehicles regarding the design of new active safety warning-systems. Complete and more specific user findings will be presented in the information framework.

Examples of key findings from user studies

Coach drivers are generally service minded and very concerned about passenger safety and comfort. Their responsibilities aside from driving concern staying on schedule and planning and arranging other trip-related elements included in the service they are a part of providing. They often adjust their driving behaviour in order to maximise passenger comfort.

Coach drivers generally experience a sense of responsibility for their passengers safety, making them take extra caution and be extra attentive when driving with customers. In situations where active safety warnings are triggered the driver can therefore often already be aware of the cause/risk but has an intention that the system does not take in consideration, generating many nuisance warnings.

Active safety warnings are frequently turned off due to being found annoying, incorrect and not useful. Warning messages in general are thought to be a source of distraction and disturbance, especially if auditory. Passengers hearing or perceiving warnings can also be a cause of complaints as they can see the driver as less skillful.

A coach is a big vehicle with problems such as big blind spots and overhang both in front and back, making them ungainly to operate in many situations. Unlike city buses coaches operate on many kinds of roads in vastly different environments. It can be in city centers, highways, small country lanes, mountain roads and so on. The different roads and environments come with different types of driving scenarios concerning and different risks. Current active safety warnings are reported to only be useful in limited cases.
The sometimes complicated driving and side tasks together with the presence of passengers, guides, their devices as well as entertainment systems can result in high stress levels and fatigue.

When also considering findings from literature, mainly focused on other vehicles types, an even wider spectrum of relevant aspects surfaced, including Information on advanced driver assistance systems and warning design and its relation with human factors. An overview illustrating some of the factors are presented in figure 4.2. These factors and their connections form a complex and intricate network making it difficult to discern specific factors as a cause or solution to a problem, thus a understanding of the whole system is favourable. The factors are also present in different levels of abstraction, making it difficult to relate them to each other without a systematic categorisation. One example would be that auditory warnings on a low level of abstraction have different discernibility depending

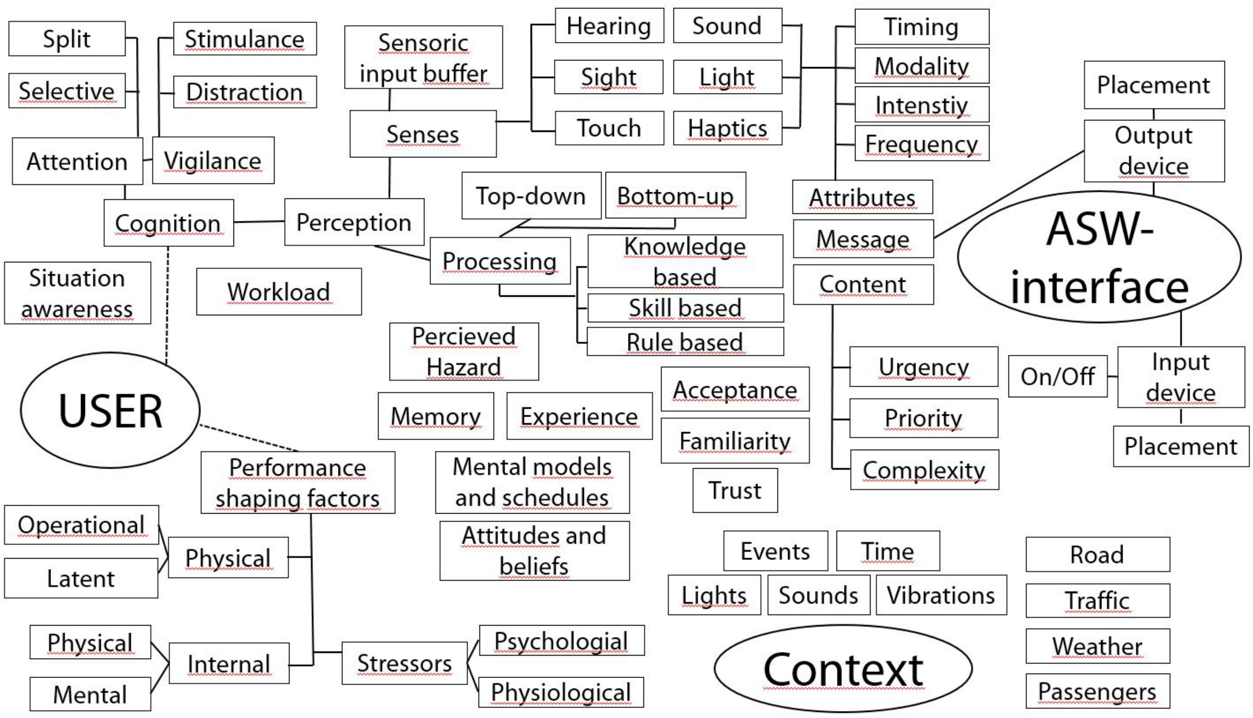


Figure 4.2 Mapping of factors affecting active safety warning design in coaches

on frequency and tone, whereas on a higher level of abstraction all types of auditory warnings are often disliked by coach drivers as they can disturb passengers.

Understanding different levels of abstraction allows for a more holistic view where problems can be identified and solved at different levels, creating a better basis for the final solution. The strategy should therefore *Include different levels of abstraction*. This is also aimed at countering the complexity and quantity of factors found in the different studies, affecting the active safety warning development. Additionally, in order to fulfill the project purpose, the strategy *Provide easily obtainable information relevant to active safety warning design in coaches*. This is to be done with emphasis on easily obtainable since the strategy should be supportive rather than an increase in workload. All of the key functions for the strategy are summarized below.

Key functions:

- Encourage focus on user and interaction
- Facilitate a systematic development process
- Include different levels of abstraction
- Encourage exploration and documentation
- Provide easily obtainable information relevant to ASW design in coaches

4.2 Overview of components

In order to provide the defined key functions, the strategy is developed into a three piece solution where the different components have different functionality. The components of SASWIC are meant to work together to contribute to the development of human-machine interaction concepts for new active safety warnings. The three pieces of SASWIC are a design process, an information framework and an interaction model (Figure 4.3). On the next page follows a brief description of the purpose of each component and its relation to the key functions.

The design process aims at giving guidance and structure to the development by dividing it into steps and allocating important design aspects to each part. It is also meant to promote a user centered design approach, where different levels of abstraction are made clear as well as to encourage exploration when developing new active safety warnings. The design process should contribute with the following key functions.

- Facilitate a systematic development process
- Include different level of abstraction
- Encourage exploration and documentation

The framework aims at giving support and resources by gathering and structuring information about central aspects influencing human-machine interaction with active safety warnings. It is also meant to help promote

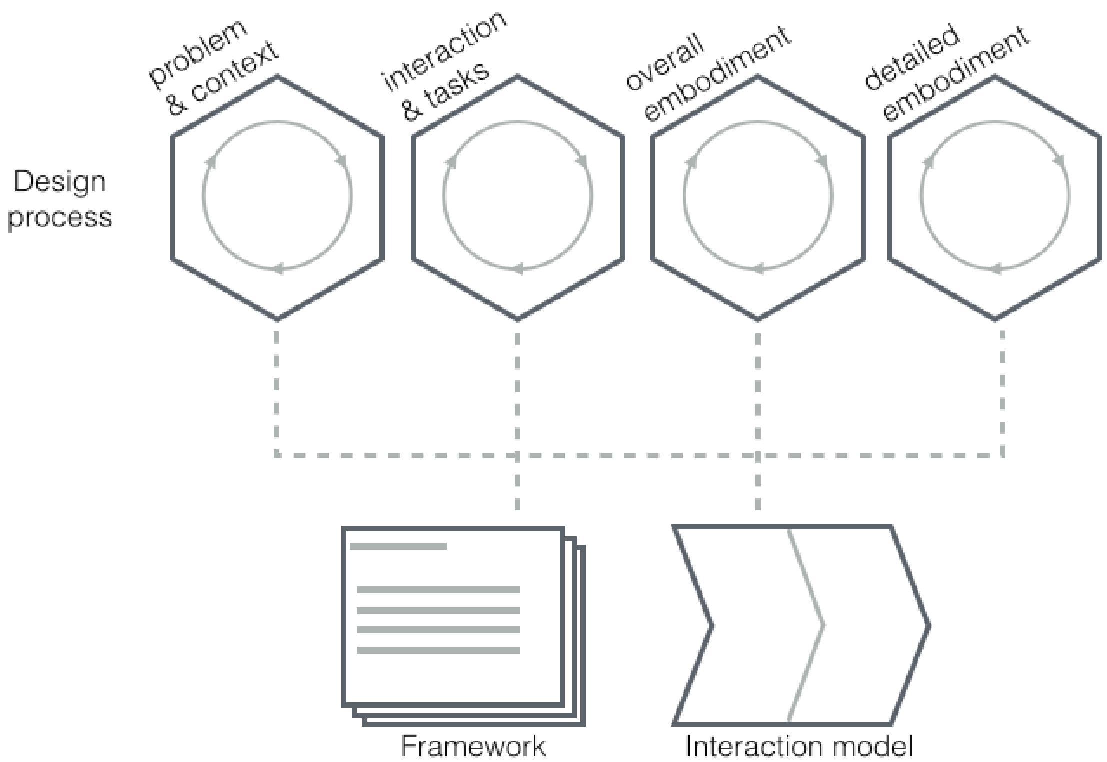


Figure 4.3. Strategy components and their relation

documentation of new findings to create a knowledge bank where previous active safety warnings development can be used as guidance in future projects. The framework should contribute with the following key functions.

- Include different level of abstraction
- Encourage exploration and documentation
- Provide easily obtainable information relevant to ASW design in coaches

The interaction model aims at giving support by illustrating and summarizing the core interaction between user and active safety warning interface by linking system functionality to user tasks. The model is also meant to provide support for exploring areas outside of machine functionality. The interaction model should contribute with the following key functions.

- Encourage focus on user and interaction
- Encourage exploration and documentation
- Provide easily obtainable information relevant to ASW design in coaches

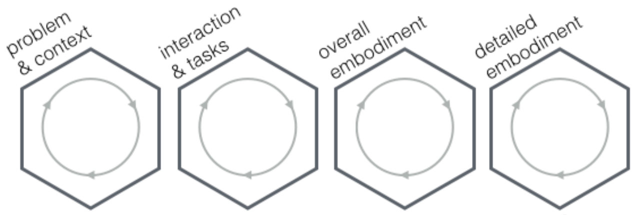
In conclusion, the three components of the SASWIC strategy aim at completing each other by together fulfilling the different key functions. The strategy components, their internal relationships and their intended use are presented in full in the chapters 5 and 6.

5. Strategy -
Design Process & Interaction Model

This chapter presents the Design Process and the Interaction Model part of the SASWIC strategy, explaining their functionality and how they are supposed to be used.

5.1 Design process overview

The design process covers central design work related to human-machine interaction that should be considered during the user centered development of human-machine interaction concepts for active safety warnings. It is divided in four steps, each with three parts, and is designed to be an efficient design tool (Figure 5.1). The following parts will explain the structure and purpose of the design process.



Figur 5.1: The four steps of the SASWIC design process

5.1.1 The steps

The design process is divided into four consecutive steps that represent different abstraction levels from problem identification to detailed design solutions. One step should be worked through before the next is initiated, but the process is meant to be iterative and it can be necessary to go back to an earlier step to continue exploration in that design level. By working through all the steps a good understanding of the whole human-machine interaction can be reached and design decisions can be clearly motivated.

The four steps in the design process are inspired by the first four design levels in the seven leveled ACD³ process (Bligård, 2015). These levels describe needs finding, usage design, overall design and detailed design. In accordance with ACD³ and to achieve a holistic view, the process starts off with subjects at a more abstract level and works its way towards more detailed design. The focus of the design process is the man-machine-interaction and development of concepts with emphasis on user centered design. Technical aspects regarding construction and production focused on in later stages of ACD³ are not taken into account in the four steps. This delimitation was made in consultation with Volvo as they already possess a lot of knowledge in those areas. These technical aspects should ideally instead be considered by Volvo continuously through the design process to prevent the development of concept that cannot be realized, but should not govern the design process.

Step 1, Problem and Context, and step 2, Interaction and Tasks, in the design process are completely free of warning embodiment and interface specification. Instead, step 1 and 2 revolves around mapping the problem to be solved with an active safety warning and specifying what interaction with an active safety warning-system is needed to solve it. This separation creates a divergence from the structure of ACD³ where physical layout is considered, although not fully explored, in the first steps. The reason for avoiding embodiment early in the process is to prevent possible design choices from being coloured too early by existing active safety warning interface solutions as well as by the habit of using a more technically driven process. This corresponds to the key function of encouraging focus on the user and interaction.

Step 3, Overall Embodiment, and step 4, Detailed Embodiment, the physical layout of the active safety warning interface is defined. In these steps, the interaction and tasks defined in step 2 are meant to be embodied with a physical warning interface. In addition to only embodying the defined interaction, this step is also intended to assess the integration of the active safety warning-system with other systems in the coach. This is mentioned as important by Response 3 (Schwarz, 2009).

Figure 5.2 visualises the four steps in the SASWIC design process through the deliverables from each step. The figure illustrates how the deliverables relate to those of earlier steps and how the design gets more detailed with each step. The number of branches varies depending on which deliverables are defined in each step of the design process. As can be seen, the process starts out at a more abstract level of defining a problem scenario and end by defining attributes of different warning devices.

Since this design process only concerns the development of concepts and is delimited from the later stages of product development, these concepts are required to go through rigorous tests to confirm functionality and efficiency before detailed technical design and implementation can be considered. The process should thus be followed by a systematic test phase, suggestively comprising simulations and live test.

5.1.2 Exploration, Deliverables and Evaluation

Each step contain three parts called Exploration, Deliverables and Evaluation. The division into parts is meant to ensure that data collection, analysis and synthesis is performed in every step of the process.

The exploration part of each step have the purpose to promote extensive design exploration in order to reach important insight before defining design aspects. This

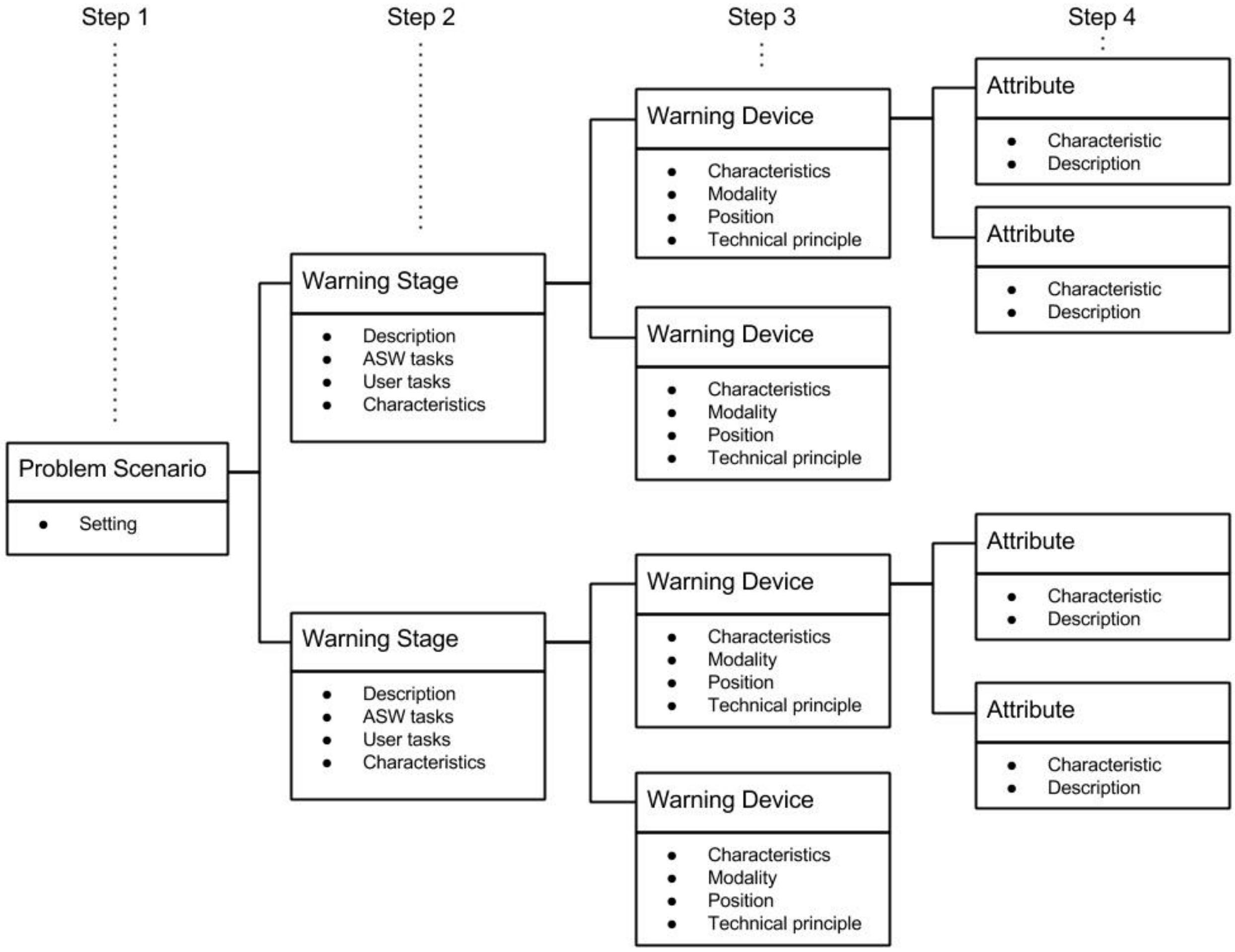


Figure 5.2. Visualization of the design variables defined in the deliverables of each step.

is done by a set of suggested questions to be asked and sought answers to. The questions represents central matters in a general man-machine design process (ACD³) but specified to the specific man-machine-system that is active safety in coaches. The questions are meant to address important issues to help and guide the systematic exploration and the definition of the deliverables. They generally do not have one "correct" answer but should rather generate a multitude of answer (and more questions) that creates understanding of the interaction and helps decision making.

The deliverables in each step comprise core design variables and related aspects that should be defined and decided upon to be able progress in the design process with the correct focus. Without clearly defined deliverables from earlier steps coming design decisions will be harder to motivate and the design features will be chosen more randomly. By working with the exploration part, a good basis for defining the deliverables should have been reached. In all steps, the deliverable part requires the SASWIC user to list conflicting design aspects which haven't been resolved and need to be considered in following steps.

The evaluation part has the purpose to ensure that the decisions made in the step cohere to those from earlier steps as well as to general critical interaction aspects. Evaluation is ideally performed throughout exploration, but is also necessary to look over as a last activity before continuing to the next step. ACD³ describes two types of evaluation, formative and summative, where the aforementioned is used in the SASWIC design process steps and evaluates aspects such as utility, usefulness and function. The summative evaluation contains aspects such as testing, verification and validation outside the process scope but meant to be performed when a concept has been created.

The questions presented in the evaluative parts of the SASWIC design process are inspired by the suggested evaluative process in Response 3. Response 3 uses a large framework of questions to ask during the evaluation of concept for advanced driver assistance systems user interfaces. As many of the questions in Response 3 overlap and some are outside of the process scope (e.g. cost of production), the evaluative step only contains a selection of the Response 3 questions. This selection is divided over the different phases in the SASWIC design process. As many evaluative factors affect several parts of the design process, some questions are asked in more than one step.

5.1.3 How to use the design process

The design process of SASWIC should be applicable when working with human-machine interaction and interfaces for ASWs both if there is a pre-existing ASS and when there is none. Potential predefined aspects due to a pre-existing system should not alter the process, and shouldn't contribute to steps being skipped. SASWIC users are encouraged to explore each step even if the deliverables are predefined since it could help highlight potential problems and contradictory design aspects with the predefined technical functions.

When using the design process in a human-machine interaction-development project, information from user studies, research, etc, should be collected and analysed continuously to be able to answer the questions and understand problems and possibilities. The SASWIC framework presented in chapter six can act as an information source to turn to, but should not substitute studies regarding more specific aspects of a project. The framework can also act as tool for documentation of findings from projects to make them easily accessible later on.

When all steps are covered and one or, ideally, more concepts have been created they should be be tested and compared against the goals and demands from the different steps. If changes are found to be necessary the different steps and documentation from the work can help identify design variables or design levels that require further attention in order to address the problem effectively.

5.2 Process steps

The four steps of the SASWIC design process are presented separately and in detail below.

5.2.1 Step 1 - Problem and Context

Step 1 represents the highest level of abstraction in the concept development and explores the environment where the solution is meant to be active in. The fundamental questions raised here concerns the purpose, abilities and the desired effect of an active safety warning system as well as the designated context. These subjects are essential as they will determine if a concept can be deemed to be successful or not. If the warning system cannot create the desired effect, within the defined boundaries, the purpose will probably not be fulfilled and the system can become redundant.

Aspects considered in Step 1 might be pre-defined due to the existence of an Active Safety System that the interaction should be built around. The step should still be thoroughly worked through to ensure that good understanding of context and user aspects related to the human-machine interaction is formed.

Exploration

The exploration in this step is divided into "Problem" and "Abilities and effect". The first set of questions focuses on exploring the problem, its cause and context. The second set focuses on what the warning system can do to address the problem, what actual effects that it is meant to create and in which context it supposed to work. In order to assist with answering, or provide background information to, the explorative questions it is recommended to turn to the User and Context chapters in the SASWIC framework.

These questions are meant to support design work by provoking fundamental understanding and should be explored thoroughly. It is important that the answers are sought from relevant and representative sources such as research and concerned users. Answers should be descriptive and exhaustive to be give a good picture that can be used as support for design decisions and evaluation. The questions do not necessarily have to be answered chronologically.

Problem

- What is the problem that the warning system is supposed to address?
- When does the problem occur?
    - E.g. physical events, driving scenarios
- Where does the problem occur?
    - E.g. traffic context, types of roads, specific locations
- Why does the problem occur?
    - E.g. problem cause, environmental and user factors
- Does the problem type or problem cause differ between physical or environmental contexts?
- Does the problem type or problem cause differ between drivers?
- Which parties are involved in the problem, both directly and indirectly?
- Are there situations and contexts that are more critical and/or common?

Abilities and effects

- What is the main effect that the warning system should generate?
- Are there any more effects the warning system can and/or should generate?
- During what preconditions and in what contexts is it required to generate the effects?
- How can you determine if the effects are generated? (this should be based in the findings from problem and context)
- What abilities can the warning system have to generate the effects?
- Could other solutions than a warning system provide the effects?

Deliverables

After working through the explorative questions, these deliverables should be defined before moving on to the evaluation and to the next step. The deliverables are meant to act as a set of parameters within which the solution should function and later be evaluated by. These parameters concern both contextual aspects such as specific traffic environments or weather conditions as well as specifying user conditions and intended user. The goals should describe the intended effect on the whole socio-technical system, desired aspects regarding the human-machine interaction and use of the warning system and desired influences on other identified stakeholders (such as passengers and other road users). Finally the conflicting design aspects should describe aspects that already have been identified as conflicting or contradictory so that they can be studied closely in the following steps.

Main problem and solution

- Describe the main problem to be solved
- Describe the settings in which the system is should be functional
  - Traffic environments
  - Traffic situation
  - Environmental conditions
  - User conditions
- Describe the scenario(s) from which to develop and evaluate the problem
- Describe the intended user and important characteristics

Goals and conflicting aspects

- Describe the goals the solution aims at achieving
  - Effect goals of warning system
  - Use goals
  - Stakeholder goals
- Describe potential conflicting design aspects

Evaluation

The evaluation in Step 1 concerns establishing whether the specified problem, context, user and goals are correct and reasonable enough to move on to step 2. In order to do so, it is recommended to consult and evaluate together with different stakeholders. The following questions are presented as guidance and are suggested for evaluating this step.

- Are the defined problem, context and scenarios relevant and correct?
  - Have traffic situations where driver workload is very high/low been considered?
  - Have traffic situations where a warning system might have negative effects on driver workload (very high/low) been considered?
- Are the defined users attributes relevant and correct?
  - Have relevant attributes (such as physical abilities, experience and skill) of the intended user group been defined?
- Are the defined goals relevant and correct?

5.2.2 Step 2 - Interaction and Tasks

In step 2 the use of, and interaction with, the warning system is explored together with its functionality. Central areas to define are when the warning system should communicate something and what the warning message should be in that situation. By having a clear idea of the situations where a warning is useful and the corresponding warning message, the core of the human-machine interaction can be understood. This since the designer will know what qualities the interface should embody in which situation.

In this step, it is recommended to start using the created SASWIC interaction model presented later in chapter 5.3. The interaction model illustrates the most basic and generic functionality of and machine tasks of an active safety warnings. This is meant to help relating the user tasks and overall human-machine interaction to machine functionality, whilst also acting as a mediating object when discussing this step.

Whilst the exploration of this step focuses on exploring the interaction with the system originating in user needs, the deliverables are set to define the warning functionality and characteristics later used to set the embodiment. This is meant to bring the deliverables closer to the embodiment, facilitating the work when starting step 3.

Exploration

The exploration in this step is divided into the three groups Function and stages and Interaction and tasks and Misc. The first group focuses on the main function and supportive functions and breaking down the scenario into situations that can generate warning stages. A general description of the main function of an ASW can be said to be "communicate risk to driver". Depending on what problem the warning system is meant to address this description should be completed with specification of the situation and risk.

Aside from the main function there can be supportive functions such as "communicate status of warning system", "communicate presence of warning system", "communicate functionality", "enable user control over warning system". These functions can make the warning interaction more effective as well as enhance use and use experience. In this version of the process "enable user control over system" is the only supportive task included as it was determined to potentially have very strong influence on warning interaction.

The second group of questions puts attention on the interaction between the driver and the ASW by exploring the tasks they have to perform. To achieve the main function there are a number of general machine tasks such as "grab attention/alert driver", "communicate warning message to driver" and "communicate feedback to driver". These are illustrated in the interaction model, which can be used as support in exploration of these questions.

The explorative questions are meant to support design work by provoking fundamental understanding and should be explored thoroughly. It is important that the answers are sought from relevant and representative sources such as research and concerned users. Answers should be descriptive and exhaustive to be give a good picture that can be used as support for design decisions and evaluation. The questions do not necessarily have to be answered chronologically.

Function and stages

- How can the main function of the active safety warning be described?
- Can the risk scenario be divided into different stages where warnings (or information) can be of help?
- Does the criticality and risk differ in the different stages?
- Is there a need for potential supportive functions?

Interaction and tasks (Explore with support of interaction model)

- What actions should the user perform in order to solve the situation in the different stages?
  - Does the driver need to direct attention anywhere to solve the problem?
  - Does the driver need to perform any driving action to solve the problem?
  - Are any of these more important?
- What should the machine communicate in order for the user to respond with the correct actions in the different stages?

- What tasks should the machine perform in order to help the user solve the situation in the different stages?
- What tasks should the user perform in order to solve the situation in the different stages?
- What does the intended interaction procedure look like?
- What problems can arise in the interaction procedure?

Misc

- What are possible consequences if a warning stage is missed?
- Do the identified stages coincide with situations where warnings are unwanted?
- What are possible consequences of false warning or nuance warnings?
- Are there any similar warning systems in the coach?
- Do the identified stages coincide with situations where other warnings are activated?
- Which warnings are most important?
- Should the user be able to control the system in any way?
- What effect can a warning have on other stakeholders (passengers and other road users) in the different stages/situations?

Deliverables

The deliverables in Step 2 concerns the functionality and tasks of the warning system by defining design variables regarding warning stages and the warning messages of each stage. The warning stage characteristics to be defined in the deliverables are directly related to what the is desired to convey to the driver in the warning situation. The suggested characteristics are factors that have an effect on how the driver perceives and interprets the warning and can thus help to convey the right message.

Active Safety Warning overview

- Describe the
  - Main function
  - Included supportive tasks
- Number of stages

Warning stages

- Give a general description of the warning stage (and the warning type)
- Describe defined characteristics related to the tasks **Grab attention/Alert** and **Perceive**
  - Intended importance of grabbing attention/ perception
  - Intended timing
  - Intended prioritisation (to other warnings and driving tasks)
- Describe defined characteristics related to the tasks **Communicate** and **Recognition/Interpretation/Intention/Response**
  - Intended warning message
  - Intended criticality
  - Intended driver response
    - Desired direction of attention
    - Desired driving action
- Describe defined characteristics related to **Update warning status/feedback**

Supportive functions and user control

- Describe defined characteristics related to **User control**
  - User control functionality
  - Availability of user control

Goals and conflicting aspects

- Updated use goals with warning stage specific goals
- Update conflicting design aspects to consider and evaluate

Evaluation

The questions in this step are set to evaluate if the defined warning system functions and characteristics have an effect on the user and the use of the warning system. Some of the answers asked could be difficult to specify as they could vary depending on the embodiment in step 3. However, it is important to assess whether potential problems could be avoided by tweaking the deliverables in this step as it's beneficial to correct the problem early in the development process.

- Have driver behaviour concerning system operation from similar systems been considered?
- Are system reactions (warning stages? functions?) predictable?
- Do system reactions (warning stages? functions?) correspond to previous experience and driver expectations?
- Have you considered whether the system has any effect on how driving tasks are performed and if the driver risk losing relevant driving skills?
- Have potential cases of misuse been considered and if the driver risk overestimating their ability and adapting to a more risky driving behaviour?
- Have considerations been made to decrease the occurrence and negative effects from false and nuance warnings?
- Have dangerous situations due to false warnings (or misinterpretation) been considered?
- Have dangerous situations due to system configuration or activation/deactivation been considered?
- Are system messages appropriate with respect to the situation and are they displayed in time with respect of the messages purpose and criticality of the situation?
- Do the system messages consider different contextual settings, traffic situations and concurrent driver operations?
- Are adjustments to the system available for the driver and if so, are the effects of the changes understandable and performable when driving without causing unexpected behaviour?
- Is it possible for the driver to deactivate or overrule a system at any time, which assists a driving task?
- Will the system have a negative effects on driver attention due to decreasing need for activity and attentiveness or monotonic monitoring tasks?
- Will the driver's mental model of how the warning system works correspond to the functionality of the system, independent of previous experience with similar systems?
- Will the intended interaction with the system correspond to the driver's mental model of how to solve a warning situation?
- Are the system limits, system functionality, system status and modes of operation clearly understandable to the driver?
- Have you considered whether the system is intuitively understandable for a first time user of such systems?
- Have driver annoyance caused by the system been considered?
- Have effects on external persons such as other road user been considered?

- Can the driver perceive and understand that the system is not working if a malfunction occurs?
- Does the driver understand the system feedback and response to the driver action in warning situations?
- Does the system allow driver to maintain situation awareness and predict system responses in warning situations?
- Have you considered the possibility that specific skills may be required for safe operation of the system that some drivers, for example less experienced or with certain disabilities, may not have?

5.2.3 Step 3 - Overall Embodiment

In step 3 the overall physical design of the active safety warning user interface is considered and design work shifts towards technology. The functionality and warning messages defined in step 2 are mapped to physical warning devices with suitable attributes depending on their character.

Explorative work should focus on how the function, tasks and interaction can be made possible through different technical principles. For example, if the main function has been defined as "communicate risk" together with the warning task "communicate criticality", this should be communicated through embodiment of one or more warning devices. Additionally, the integration of the active safety warning concept with existing systems in the vehicle should be considered in this step. This is necessary as warnings from active safety warning-systems shouldn't be mistakable for those of other types of systems. The consideration of other systems is also essential in order reduce the risk of overloading drivers with information if multiple systems are active at the same time.

Exploration

The exploration in this step focus on creating a design space of how the warning tasks and warning message characteristics set in step 2 can be embodied with a physical layout. It also aims at exploring how the warning system can be integrated into the coach environment. If system control has been included as a supportive task, the exploration should also cover how this can be embodied. In order to assist with answering, or provide background information to, the explorative questions it is recommended to turn to the system chapter in the SASWIC framework.

The explorative questions are meant to support design work by provoking fundamental understanding and should be explored thoroughly. It is important that the answers are sought from relevant and representative sources such as research and concerned users. Answers should be descriptive and exhaustive to be give a good picture that can be used as support for design decisions and evaluation. The questions do not necessarily have to be answered chronologically.

Similar systems and integration

- In what ways will the system be integrated with current systems?
  - Can warning devices be combined?
- Are there embodiments of similar systems in other applications that should be considered?

Warning stage

- How can the appropriate level of driver attention be achieved?
- How can the the warning message and feedback be communicated?
- How can disturbance of other stakeholders be avoided?
- Which senses can be and are suitable to use?
- Should multiple senses be used?
- Which positions can and are suitable to use?
- What technical principle can and are suitable to use?
- Can multiple tasks be combined in the same warning device

User control and user control devices

- Should specific warning devices be possible to control?
- What positions can and are suitable to use?
- What technical principle can and are suitable to use?
- Should more variables be controlled in same location?
- How will the control be made understandable?

Deliverables

The deliverables in this step are meant to allocate the functionality and characteristics determined in step 2 onto warning devices. The warning devices are defined by their task (what the specific device should convey) and their physical embodiment in form of modality, position and type of device. This could for example be a visual lamp in the right corner with the task of communicating criticality and directing attention to the right mirror. The modality-specific properties needed in order to fulfill the device task are set in step 4.

Warning stage
- Number of warning devices
- Number of modalities
- Task and message allocation to warning devices

Warning devices
- General description of warning device purpose
- Intended tasks
- Intended communication characteristics
- Describe the overall embodiment
    - Modality
    - Type of warning device
    - Position

Supportive functions
- User control
    - Number of user control devices
    - Describe the user control device
    - User control functionality
    - Possible modes
    - Type of user control device
    - Position

Goals and conflicting aspects
- Updated use goals with warning device specific goals
- Update conflicting design aspects to consider and evaluate

Evaluation

The evaluation in step 3 aims at ascertaining whether the embodiment will fulfill the use needs and system requirements. The questions include evaluating how the chosen embodiment affects the user and use in a warning situation as well as how it will affect other stakeholders. It is recommended to perform some evaluation together with users once an initial physical embodiment has been defined.

- Does the overall embodiment reflect the intended message?
- Is the message comprehensible and unambiguous?
- Has considerations been made so that the overall embodiment of the human-machine interface minimizes risk of overload of sensory abilities and workload?
- Has considerations been made so that the overall embodiment of the human-machine interface does not confuse or distract the driver, even if inexperienced with the warning system?
- Have effects on passengers (actual and perceived by the driver) been considered?
- Have effects on external persons such as other road user been considered?
- Have considerations been made to decrease the negative effects from false and nuance warnings?
- Have driver annoyance caused by the system been considered?
- Will the driver's mental model of how the warning system works correspond to the embodiment of the system functionality, independent of previous experience with similar systems?
- Will the intended interaction with the system correspond to the driver's mental model of how to solve a warning situation?
- Are the system limits, system functionality, system status and modes of operation clearly understandable to the driver?
- Have you considered whether the system is intuitively understandable for a first time user?
- Will the system draw too much attention away from relevant driving tasks, potentially distracting the driver?
- Does the driver understand the system feedback and response to the driver action in warning situations?
- Have you considered the possibility that specific skills may be required for safe operation of the system that some drivers, for example less experienced or with certain disabilities, may not have?
- Can the driver perceive and understand that the system is not working if a malfunction occurs?

5.2.4 Step 4 - Detailed Embodiment

In Step 4 details regarding the physical design of the active safety warning user interface, consisting of warning devices, is considered. Each warning device has a number of design variables or attributes that should be set so that defined tasks can be fulfilled and warning message conveyed successfully. The possible attributes depend on the modality and type of warning device. For example auditory tonal warnings have attributes such as volume and frequency, whereas visual display warnings have attributes such as symbols and size. There are also general variables such as the duration of the outputted signal. Focus should be on the output from the device but can also concern its physical shape if it can influence the interaction.

Exploration

The exploration in this step focus on creating a design space of how a warning device can communicate the warning characteristics allocated to it in step 3, through different it's different attributes and variations of them. Usability guidelines and gestalt laws should be taken in careful consideration in this step.

Explorative work is focused on how the warning devices can act to make the communication as comprehensible and efficient as possible and thus support the interaction in the best possible way. It is important to consider every warning device that has been included in every warning stage, and how they on their own as well as all together interact with the driver.

The recognition and interpretation by the driver is essential to consider. The attributes should be able to communicate the intended message during different relevant settings and circumstances, defined in Step 1. Examples are high workload, bad lighting conditions, etc. Design should also consider how the negative effects in the case of false and nuisance warnings can be minimized.

The explorative questions are meant to support design work by provoking fundamental understanding and should be explored thoroughly. It is important that the answers are sought from relevant and representative sources such as research and concerned users. Answers should be descriptive and exhaustive to be give a good picture that can be used as support for design decisions and evaluation. The questions do not necessarily have to be answered chronologically.

Similar systems

- What attributes are used in similar warning devices and/or similar systems?
- What can effects of resembling or differentiating from these be?

Warning

- What attributes and variations have the chosen warning devices got?
- How can attributes from different warning devices be combined?
- How can the appropriate level of driver attention be achieved through the attributes?
- How can the intended communication characteristics be be achieved by these attributes?
- How can the intended message be differentiated from other messages from the same or similar devices?
- How can variations of these attributes make the communication as clear and efficient as possible?

User control

- What attributes have the chosen user control devices got?
- How can the user controls be operated into different modes?
- How can different modes be made understandable?
- Should specific variables and attributes be controllable?

Deliverables

The deliverables in Step 4 are specific attributes and characteristics of the warning devices defined in step 3.

Warning device attributes

- List the attributes and their purposes for each warning device
  - Attributes
  - Duration
  - Description

Complete active safety warning concept

- Describe the whole active safety warning interaction and interface
  - Warning stages
  - Warning devices
  - Warning device attributes
  - Supportive functions

Goals and conflicting aspects

- Updated use goals with warning device specific goals
- Update conflicting design aspects to consider and evaluate

Evaluation

The evaluation in step 4 is similar to the one in step 3 but considers the detailed embodiment fulfill the use needs and system requirements. The questions include evaluating how the chosen detailed embodiment affects the user and use in a warning situation as well as how it will affect other stakeholders. It is recommended that the evaluation is partly performed together with users in order to obtain a first validity check of the concept. After step 4 is finished, a complete evaluation and validation against effect goals should be conducted.

- Does the detailed embodiment reflect the intended message?
- Is the message comprehensible and unambiguous?
- Has considerations been made so that the detailed embodiment of the human-machine interface minimizes risk of overload of sensory abilities and workload?
- Has considerations been made so that the detailed embodiment of the human-machine interface does not confuse or distract the driver, even if inexperienced with the warning system?

- Have effects on passengers (actual and perceived by the driver) been considered?
- Have effects on external persons such as other road user been considered?
- Have considerations been made to decrease the negative effects from false and nuance warnings?
- Have driver annoyance caused by the system been considered?
- Will the driver's mental model of how the warning system works correspond to the embodiment of the system functionality, independent of previous experience with similar systems?
- Will the intended interaction with the system correspond to the driver's mental model of how to solve a warning situation?
- Are the system limits, system functionality, system status and modes of operation clearly understandable to the driver?
- Have you considered whether the system is intuitively understandable for a first time user?
- Can the driver perceive and understand that the system is not working if a malfunction occurs?
- Will the system draw too much attention away from relevant driving tasks, potentially distracting the driver?
- Does the driver understand the system feedback and response to the driver action in warning situations?
- Have you considered the possibility that specific skills may be required for safe operation of the system that some drivers, for example less experienced or with certain disabilities, may not have?

5.3 Interaction Model

In this chapter, the SASWIC interaction model will be introduced and presented.

5.3.1 Introduction

The SASWIC interaction model gives a chronological description of a general interaction between a coach driver (user) and an active safety warning interface (machine) during a warning event. The model breaks interaction into identified basic tasks that the two should perform in order for the interaction to proceed in the desired way. By doing so functions, problems and needs as well as related factors connected to user, machine and context can be identified more easily. Both physical and mental tasks are mapped in the model, some of them more evident and other more abstract (see Figure 5.3).

The upper row in the interaction model describes the tasks that the warning system should perform and the lower the tasks that the user should perform. The position of the tasks shows in what order they should be performed and what task they are closest related to in the other row. Each column can be said to represent a micro interaction.

The tasks described in the interaction model are based on what was found when breaking down warning scenarios of general warning systems. In a warning situation, the warning system needs to grab the attention of the operator which at the same time has to perceive the warning stimuli. The operator then needs to interpret that it is a warning and what it means, this corresponds to the warning system communicating a warning message. Consequently, the driver needs to make a decision and form an intention of how to respond, and then perform a response action. This action could be anything from a physical maneuver, a mental task or not responding at all. In order to encourage the user to form the right intention and choose a suitable response action, the warning system can try to communicate these aspects through the warning or other means. Depending on the user response performed, the warning system status is updated differently. For example, if the action has led to the warning situation being avoided, the warning system can be turned off, otherwise the warning can remain or intensify. The last step is for the driver to evaluate the updated warning status and the result of his/her action.

The interaction model can be used as a support both when exploring and shaping the interaction and interface, as well as when evaluating chosen design variables. It is important to understand that both user and machine have their part to play in the interaction. With every added functionality there are effects on the user tasks, adding new tasks or changing current ones. The responsibility over driving is with the driver, and it is important to consider that these new or changed tasks do not impair the driver's capability to perform the tasks that come with the driving responsibility.

During the course of a warning event things often happen quickly and many of the tasks presented in the model can take place almost simultaneously. The machine tasks "Grab attention" and "Communicate warning message" as well as the user tasks "Perceive", "Interpret" can all happen more or less together depending on how the system is designed and the abilities and experience the user has. The mental user tasks "Interpret" and "Form intention" can also be assumed to become more and more subconscious with extended use and experience.

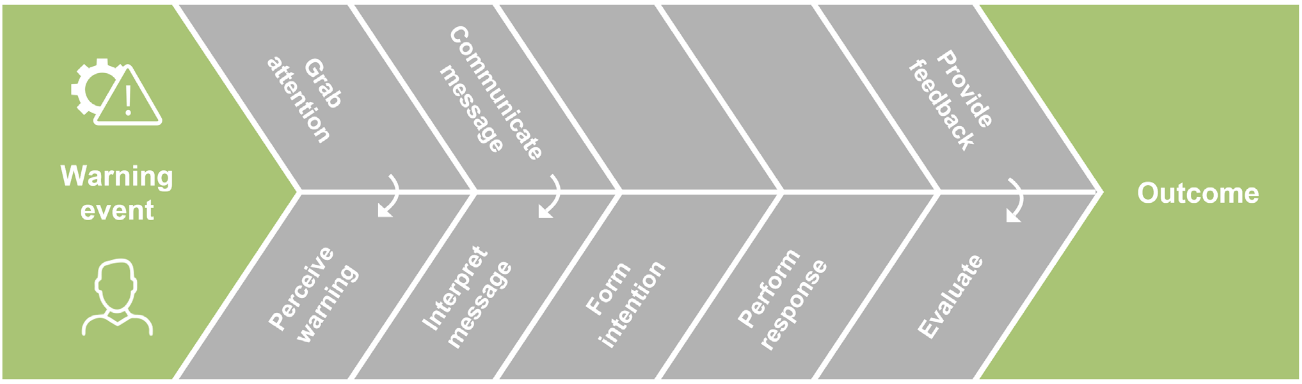


Figure 5.3 - The interaction model

Each of the tasks in interaction should still be considered separately as they all have a part to play, even if small during some circumstances. If problems occur in any of them it might lead to consequences and an unwanted outcome.

5.3.2 How it's used

The interaction model's purpose is to help break down a warning interaction with an active safety warning system into smaller components in a product development scenario. It is meant to be used as an illustrative example helping to both raise and answer questions, rather than an interactive tool. In Step 2 of the design process the model can be used to support exploration and definition of the tasks/warning characteristics that are part of human-machine interaction, based in each potential warning situation / warning stage that has been identified. In order to facilitate for first time use of the interaction model and concretize what type of questions that can be explored with the model, some exemplifying questions were created. For step 2:

Questions to explore in Step 2:

- When does the driver need to be notified?
- What information does the driver need to know about the risk?
- Based on what will the driver form his/hers intention?
- What action(s) are the driver likely to perform?
- What action(s) should the driver perform? (monitoring, driving)
- How will the driver understand that he/she performed the correct task?
- How will the driver understand that the warning event is over?
- When should the warning system alert? (timing)
- What should the warning system communicate? (message)
    - What criticality should the warning system communicate?
    - What required action should the warning system communicate?
- What should the warning system communicate to describe changes in the warning event?

In Step 3 and 4 the model can be used to support exploration and definition of the human-machine interface and its warning devices, based in the interaction and tasks defined in Step 2. Each warning stage should be looked at here as well. Example questions for Step 3 and 4 follow below.

- How can the driver's attention be grabbed?
- How can the warning system communicate its message? (message)
    - How can the criticality be communicated?
    - How can the correct action(s) be communicated? (monitoring, driving)
- How will the driver receive notice that he/she performed the correct task?
- How will the driver receive notice that the warning event is over?
- How can the warning system communicate changes in the warning event?

To conclude, the design process is the backbone of SASWIC, providing a user centered process for the development of active safety warnings. In order to facilitate the use of the process, the interaction model and information framework are provided as tools to utilize during the development work. The information framework is presented in the following chapter.

6. Strategy - Framework

The purpose of this chapter is to present the SASWIC framework that constitutes one of the components of the strategy. The framework is presented in its entirety as an independent part before the appendices, and contains an introduction where similar information is presented.

6.1. Framework overview

The information framework is one of the components of the SASWIC strategy. The key functions of the strategy that the framework should satisfy are to include different levels of abstraction, encourage exploration and documentation as well as to provide easily obtainable information relevant to active safety warning design in coaches. It also acts as summary for the research performed in this project and replaces specific chapters regarding literature reviews, user studies and analysis in this report. The framework is presented as an independent document in a format different from that of the rest of the report. This is done to make the information easier to approach and use outside of the context of this project.

6.1.2 Structure

The framework is structured around subjects and uses a format without deep hierarchies to make it easier to integrate with the use of the overall strategy and its components. There are three main chapters: User, with focus on human conditions that influence the interaction, Context, with focus on important aspects of the context in which the interaction takes place, and active safety warnings, focusing on the machine part of the interaction. These chapters each contain a few larger research groups which are introduced with relevant theory (Figure 6.1). Within each group the research gathered during the project is divided into factors related to the development of Active safety warnings and presented in an article format.

User	1. Ergonomic factors 2. Acceptance factors
Context	3. External and internal context 4. Tasks and accidents
Active Safety Warnings	5. Active safety warning characteristics 6. Other

Figure 6.1 - Framework research groups

6.1.1 Content

The content of the framework consist of concentrated research findings from theory, literature, articles, user studies, product descriptions, etc, as well as analyses on influences on Active safety warnings design in coaches. The nature of the information is both empirical and theoretical. Much of the reviewed research concerns cars, trucks and city buses rather than coaches as it is a relatively small sector wherein not many specific studies have been performed. It was found to be relevant to include information from other sectors to provide a comprehensive picture, though the reader should be aware of differences.

An example of the framework structure, from the main chapters to the individual articles, is shown in figure 6.2. The framework articles each concern one or a couple of closely related aspects. Each article contains brief information and analysis regarding the specific aspect, gathered from sources of different character. The articles are divided into six parts: Introduction & theory, implications from literature, implications from user studies, discussion, cross-references and list of sources. These first first three parts deal with the research findings on the aspect. The different types of sources are kept apart to make them easy to distinguish for the reader. The discussion presents reasoning about how the findings can influence ASW design in coaches.

Chapter	Group	Article
Context	Group 3 External and internal context	Article 3.1 Road and road environment

Figure 6.2 - Example of framework structure

The cross references points the reader in the direction of articles that have strong relations to help the reader reach a greater understanding. Finally the source list accounts from where the findings were gathered. Some information can, due to its nature, be found in multiple articles, but in most cases related information is referred to through the cross-references. An example of how an article can look is given below in figure 6.3.

The framework is meant to be used in conduction with the design process and the interaction model to provide information about the factors that constitutes the human machine-interactions. The tailored framework format makes the information easier to approach when working with the other strategy components. Another aspect is the possibility to add information both in existing articles as well as by creating new ones. It thus works as a tool both for exploration and documentation which supports the designated key functions.

Group 3
External and internal context | **Context**

Article 3.1

Road and Road environment

Introduction and theory

Due to the nature of the coach industry the environments and roads which a coach travels by varies a lot. Compared to city and transit buses that travels the same route over and over again the types of roads and environments are much more unpredictable.

Roads of main interest are are city, urban, highway and country roads. The road itself affects by the size and number of lanes, the traction, etc. The surrounding environment impacts driving through the effect on vision, with changes in the field of view and potential distractions.

Implications from literature

Campbell et al. (2007) describes how truck drivers rate the impact of different driving conditions, placing Road traction(51%) and Visibility(26%) at the top.

Implications from user studies

Some drivers drive mainly in city environment whereas others drive mainly on highways and country roads. The coach drivers generally feel a bit stressed when driving in a city environment. However, none marked that they're at the highest stress level, and some even marked that they were really relaxed. This might be due to the difference between cities and other driving conditions. They also feel attentive, stimulated and very alert, suggesting that city environment is a demanding context to drive in, requiring a high level of cognitive processing.

The coach drivers feel more relaxed when operating outside of the city environment. However, they are still very attentive and feel stimulated during their driving. The reason for drivers feeling very attentive yet relaxed during highway/country road driving can be discerned from the answers about if there's any kind of road that's more demanding to drive. 19 out of 43 drivers mentioned country lanes to be more demanding to drive. The most common reason mentioned was the narrowness of the road in relation to the buses size, but night time was also attributed as a contributing factor. 8 people also mentioned motorways as the most demanding. 12 people didn't find any road to be more demanding.

Discussion

Coaches operate in many different environments which can complicate the use of ADAS and active safety warnings as their efficiency differs depending on the environment. This is amplified further by the fact that the size of coaches makes them come very close to objects in tight environments or small lanes, setting of warnings. A potential solution could be systems with different modes for different environments. When developing an active safety warning-system it is thus important to consider in what environments it should function and how the system and user should behave in other environments.

Cross references

1.2 Attention, inattention, distraction
1.4 Workload and fatigue
3.2 Weather and time-of-day

Sources

Campbell, J. L., Richard, C. M., Brown, J. L., McCallum, M. (2007). Crash Warning System Interfaces: Human Factors Insights and Lessons Learned. (Report No. HS 810 697) Washington, DC: National Highway Traffic Safety Administration.

Context - Group 3: External and internal context - Article 3.1: Road and road environment 29

Figure 6.3 - Example of a framework article

7. Lane Change Support concept development

In this chapter, the evaluation of SASWIC through the development of a human machine interaction concept for a Lane Change Support system will be presented. The different steps of the SASWIC will be presented individually, highlighting the use of the strategy and how its components contributed to the concept development. Insights gained regarding the strategy when applying it on the LCS development will also be presented.

7.1 Lane change support development overview

The Lane change support concept development presented below focuses on work and results achieved by consulting step one through three of the design process. Step four (detailed embodiment) was not completed due to time limits. The descriptions of each step is divided into what activities that were performed, how reasoning was made and what the results were.

No special directives or requirements were given from Volvo regarding the Lane change support. Predefined functions and limitations that might determine parts of the human-machine interaction between driver and warning system were thus not taken into account and focus has been on how to shape the human-machine interaction and interface.

7.2 Step 1 - Problem and Context

To gather information about problems and needs related to the blind spots of coaches, drivers were questioned through interviews, surveys and a workshop. Research in the form of literature on the subject was also addressed.

There was a big consensus among coach drivers that blind spots caused many problems. This was supported by accident research that stated that blind spot accidents account for about 5% of all accidents with heavy vehicles (Volvo Trucks, 2013).

It was also found that there are a three types of blind spots around the coach: the ones on each side of the coach that the mirrors are unable to show, the ones in front of the bus obstructed by the A-pillars and mirrors (in some vehicles) and finally the area right behind the bus as there is no mirror showing that area. The two blind spots on the vehicle's sides differ a lot as the distance to each mirrors is different.

The three different types all came with problems but they could differ in occurrence and character. Most of the blind spots problems were said to occur during driving in city environment where there are many object to consider and the not much room for the big coach to move around in. Examples of these problems were rails or poles close to the road that the rear overhang of the bus could collide with during a turn, the presence of bikes or pedestrians close to the coach, etc. During driving on bigger road such as highways and country lanes, blind spot-related problems were not said to be that common but the potential consequences of an accident were said to be bigger due to the high speed.

Both responses from drivers and studies on glance behaviour suggested that a big part of the monitoring done by the driver is directed towards the mirrors and that the peripheral vision is very important. Drivers described it as a constant attention loop between mirrors and forward view, with occasional glances towards the dashboard. When preparing for a turn even more attention is directed towards the mirrors.

Despite this it was said that there can be situations where a vehicle somewhere in the blind spot remains undetected, though this is rare. Reasons could be that much of the attention has to be distributed towards something else than the mirror for a short while, due to the occurrence of something unexpected or critical. One scenario that was described as an example was when a vehicle in front of the coach deaccelerates. The coach driver might decide to change lane to avoid breaking as it could disturb or even hurt passengers. With much of the attention focused on the vehicle in front the risk of a vehicle in the blind spot goes undetected increases.

The wanted abilities for the warning system was described as "help avoid lateral accidents connected to agents in blind spot", with the additional ability "make the driver feel informed and in control".

It was determined that the problem to address was the blind spots on the sides of the coach and that the context to focus on was highways and country lanes. Earlier research had shown that coach driving differ a lot depending on the environment and within the scope of the project it was not possible take all these environments in consideration. It was said that the warning system should have effect during all weather conditions, both night and day and with high noise levels in the coach. It was also said that it should have minimal effect on other road users as well as passengers. The scenario described above was chosen to design the interaction around.

The final deliverables from step 1 are presented on the next page together with an illustration of the scenario (Figure 7.1).

Main problem

- Lateral accidents due to collisions with undetected agents in side blind spot

Setting

- Highway and larger road with speeds over 70km/h
- Regular traffic and heavy traffic
- Should work in all weather conditions and at all times of the day

Scenario

- Overtake of slower vehicle at highway, undetected vehicle in blind spot.

Goals and conflicting aspects

Effect goals

- 100% of accidents in test scenario avoided. Determined through simulation and live tests.
- Use goals
- Relieve driver. Measure perceived stress/workload with and without ASW concept.
- Achieve acceptance. Measure long term use of system. If optional (when integrated in coach) it should be used during 95% of potential use time.
- Induce sense of control

Stakeholder goals

- Warning system should not disturb passengers if possible to avoid.
- Warning system should not disturb other road users.

Describe potential conflicting design aspects

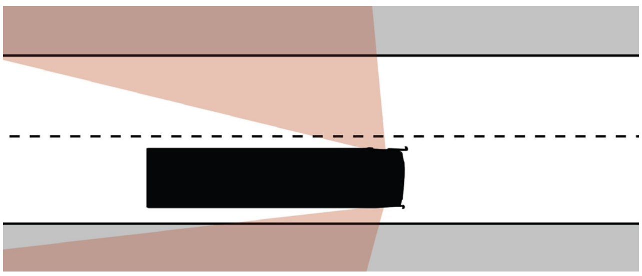


Figure 7.1. Coach blind spots that the LCS should mitigate consequences of.

7.3 Step 2 - Interaction and tasks

The user studies mentioned in step 1 were also used in step 2 to gather information about functionality, interaction and tasks important in warning system regarding blind spots. Similar systems in cars and trucks were also studied through videos and description.

During the workshop with coach drivers blind spot situations on highways, with focus on the chosen scenario, were explored further with the help of simple models. A couple of different situations where warnings (or information) potentially could help were identified.

These situations consisted of when a vehicle is approaching a blind spot, when a vehicle enters and resides in the blind spot, when the coach driver shows initiative to turn (with indicators) and a vehicle is present in blind spot, and when a turn is initiated with a vehicle present in the blind spot. The last one could both be when indicators are active and when they are not. The situations were explored one by one to get an understanding of how the driver could perceive the situation in terms of criticality and what the driver needs looked like in each of them.

Suggestions for what support and information the warning system could provide were explored. Examples were: the location of the vehicle in the blind spot, what side it concerned, what the driver should or shouldn't do, what type of vehicle it concerned and mechanical prevention from turning.

An important usage aspect that came up was that the identified situations likely would occur with the driver being well aware of the presence of a vehicle in the blind spot, causing a nuisance warning that will get problematic if obtrusive. As indicators at times are used to communicate the wish to turn, rather than the intent to turn, and done so quite a while before a turn is possible, a number of vehicles might pass through the blind spot without risk. Sometimes communication of this wish had to be enforced by small nudges towards adjacent lane. This was partly due to the fact that coaches are hard to move quickly through traffic and the lack of consideration from other road user forces the coach drivers to take these measures.

The situation wherein a turn is initiated without activated indicators was found to be the only one where a strong warning generally would be motivated as the action by itself is a violation. The situation was said to occur with reckless drivers or, like in the scenario, if a turn had to be initiated very suddenly. Many drivers have also stated that they would might rather risk a blind spot accident than breaking to avoid forward collision if passengers are moving around in the bus.

After exploring the situations further, four situations where warnings could be beneficial were specified. The framework was used as support in order to describe these.

1. Vehicle residing in blind spot. Very mixed opinions. Very frequent occurrence. Good to be informed about but not warned about. Risk of distraction if in anyway obtrusive. Information about which side and the location in blind spot could be favourable to show.
2. Driver shows initiative to turn (activating indicators) with undetected vehicle present in blind spot. Higher criticality than 1, but still sensitive as drivers generally have good situational awareness with mirrors being carefully monitored. A vehicle entering the blind spot at this point is likely to be noticed.
3. Driver initiates turn (with activated indicators) with undetected vehicle in blind spot. Higher criticality than 1 and 2, but sensitive for the same reasons. Drivers can nudge adjacent lanes deliberately.
4. Driver initiates turn with vehicle in blind spot and without indicators being activated. Very critical. Clear violation as indicator lights are to be used when switching lanes. Possibly due to driver risk assessment of danger in front of vehicle.

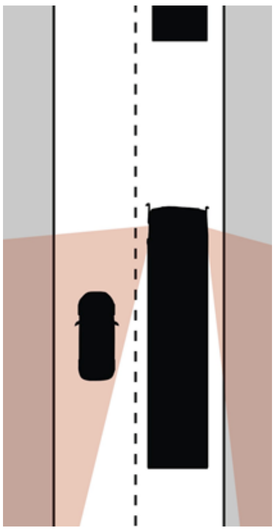
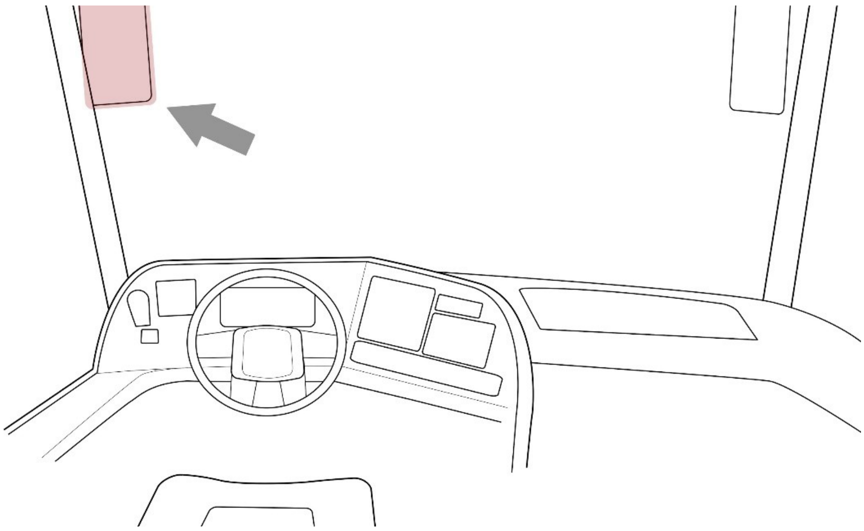
A system with similar functions common in today's coaches is the Lane departure warning or Lane departure warning (in Volvo). It signals when the coach is about to leave a lane without prior activation of indicators. It was said to be important to differentiate Lane departure warning from Lane change support as the latter is more critical and that the Lane departure warning often is ignored. As Lane change support is present in some cars drivers might have prior experience. It could therefore be favourable to design the Lane change support for coach in a similar way to match mental models. Through the scenario it was highlighted that presence of a forward collision warning also was important to take into consideration, as it might be triggered at the same time.

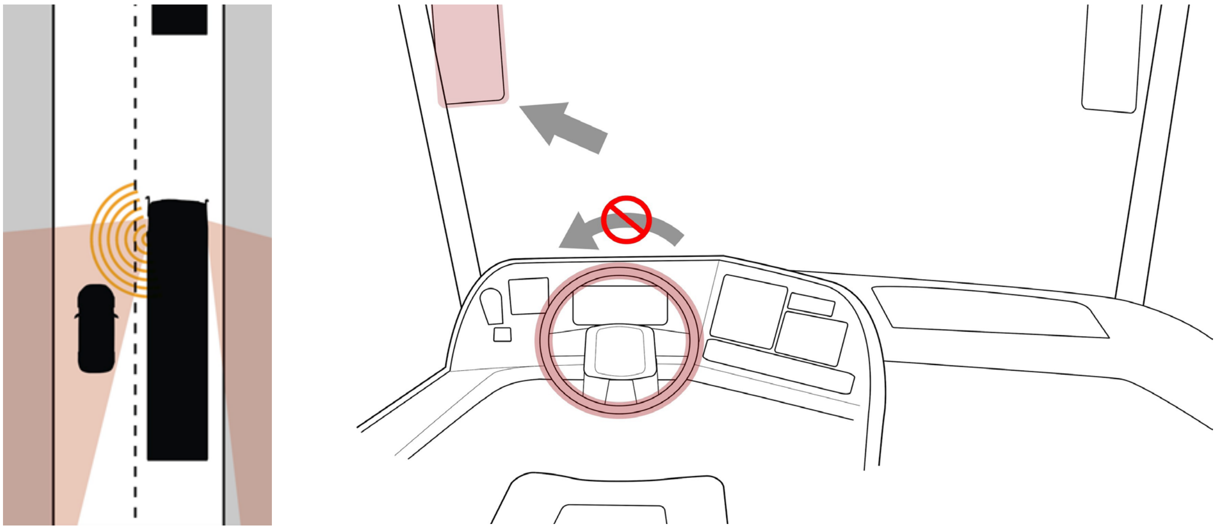
Regarding supportive functionality it was reasoned that the system should be controllable in the same way current systems are to support the same mental model. That meant including the possibility to deactivate and activate the system, and in some systems make adjustments regarding range. The later functions were disregarded in this concept development due to them being more indirectly tied to the interaction with the system during a risk scenario.

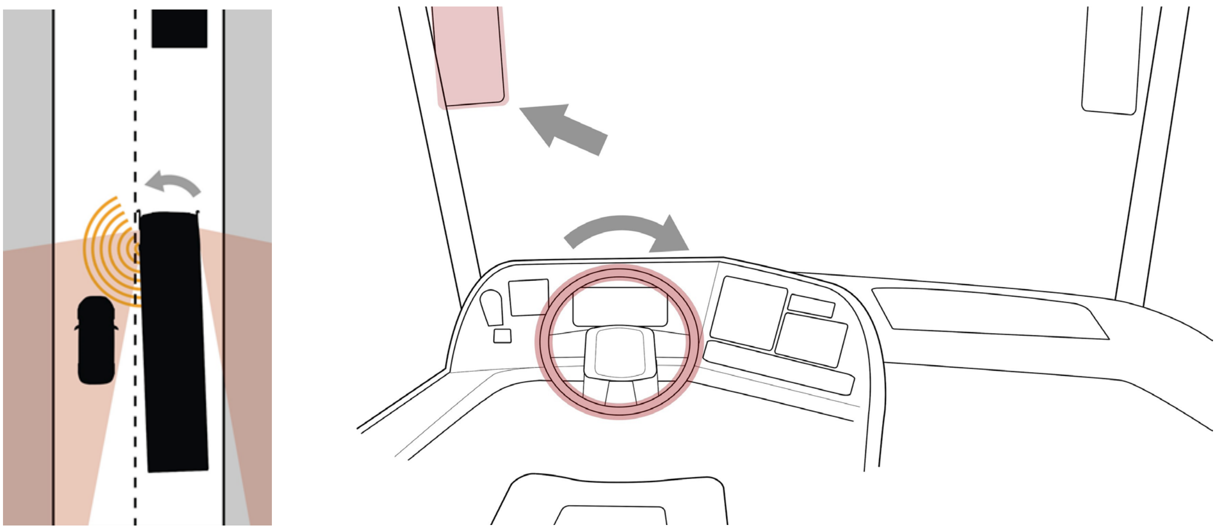
The final deliverables of the step are presented below.

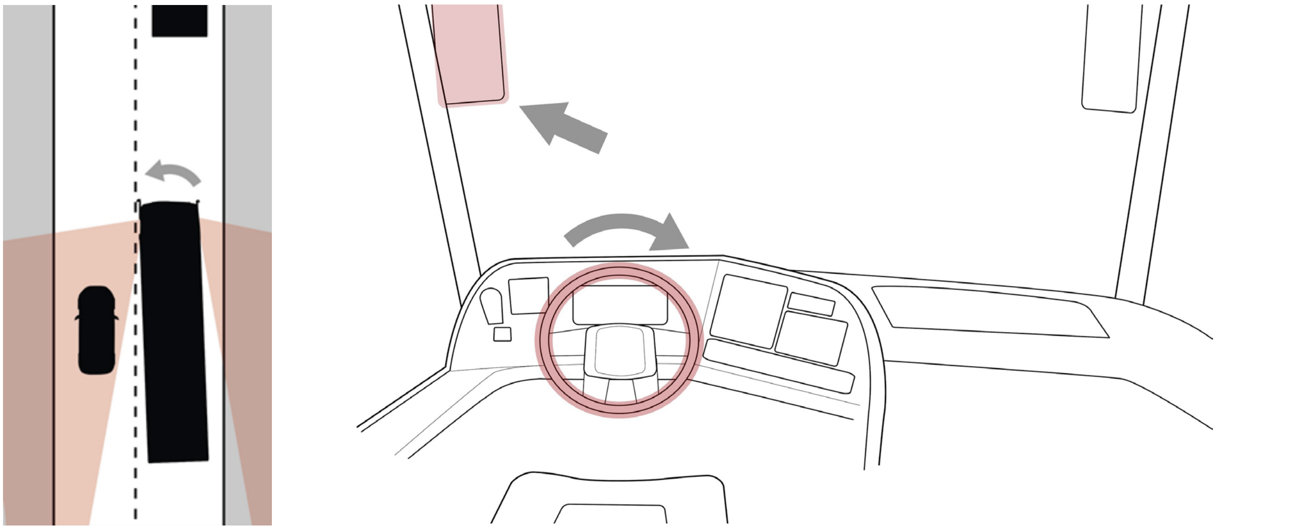
Active Safety Warning overview

Main function: Communicate risk due to vehicle in blind spot
Supportive functions: none
Number of stages: 4
User control:
Activation and deactivation should be possible.

Warning stage 1
Description: Vehicle enters/resides in blind spot. (Cautionary, lateral) **Alert characteristics:** non-important, only when evaluating risk of LC, timing immediate, not prioritised. **Communication characteristics:** vehicle in blind spot, specific side, very low criticality, attention to side mirror, no action
 
Updated waring status/feedback: indirect feedback, warning stops

Warning stage 2
Description: Vehicle enters/resides in blind spot, indicator activated. (Cautionary, lateral, collision) **Alert characteristics**: Possible high importance, most commonly low/medium importance, timing immediate, prioritised **Communication characteristics**: Vehicle in blind spot, specified side, attention towards mirror, postpone intended action

Updated waring status/feedback: indirect feedback, warning stops

Warning stage 3
Description: Vehicle resides in blind spot, indicator activated, turn initiated, line about to be crossed. (Imminent, lateral, collision) **Alert characteristics**: High importance, driver needs to perceive immediately, timing immediate, prioritised **Communication characteristics**: Collision imminent with vehicle in blind spot, specified side, high criticality, attention towards mirror, abort turn

Updated waring status/feedback: indirect feedback, warning stops

Warning stage 4
Description: Vehicle resides in blind spot, turn initiated, line about to be crossed, indicator not activated. (Imminent, lateral, collision) **Alert characteristics**: Very high importance, driver (and possible passengers) need to perceive immediately, immediate timing, highly prioritised **Warning stage characteristics**: Collision imminent with vehicle in blind spot, specified side, very high criticality, attention towards mirror, abort turn

Updated waring status/feedback: indirect feedback, warning stops

Contradictory design aspects to be considered

- Warning stage 2 can occur very frequent (due to use of indicator in situations where agents in BS are monitored) and should therefore not be intrusive, but should still be strong enough to grab attention in situations where blindspot is not monitored properly.
- High frequency of warning stage 1 and 2 might induce annoyance and disturb passengers.
- Prio of warnings in warning stage 3 and 4 in scenarios where a forward collision and lane change collision is possible outcomes.
- Warning stage 3 might be planned to signal intention to turn to other road users, in these events warning can cause annoyance and disturb passengers.
- Big difference in distance to right and left side mirrors from driver position.

7.4 Step 3 - Overall embodiment

To gather information in which to base the embodiment of the Lane change support, findings from research and opinions of coach drivers were addressed through the performed workshop, interviews and questionnaires. The interface of similar systems in cars and trucks were also studied through videos and descriptions. The development of the embodiment of different warning stages was done iteratively to better match the different warnings. Opinions from drivers as well as guidelines from research was balanced against each other.

The interface of similar systems identified in step 2 were looked at to give directions and inspiration to the embodiment. Some notable aspects were that the Lane departure warning in Volvo coaches is presented through spatial seat vibrations (haptic) or a sound (auditory) and the Forward collision warning with Head up display (HUD) light (visual) followed by sound. Lane change support in other vehicles commonly use lights in mirrors (visual) and in some cases in A-pillars. Sounds are used in some of them.

Visual warnings were identified as the best option for warnings of low criticality that could occur frequently. Driver concerns regarding auditory warnings motivates that they should not be used in situations where nuisance warnings can be frequent. Haptic warnings are seen as less problematic than auditory but are still disturbing when frequent as they are harder to get used to compared to visual.
For visual warnings devices, positions of interest that could help convey the message were found to be in mirrors, a-pillars and the windshield. They are all part of the regular monitoring and the mirrors closely related to the problem of blind spots.

Below follows brief summaries of the reasoning regarding the overall embodiments of each warning stage. The framework was used as support in order to make the decisions.

Stage 1
This stage only concerns information of very low criticality thus visual stimuli was seen as suitable. A missed warning does not generate big consequences so design should be discrete and non-intrusive. To avoid drawing much attention and instead facilitate detection during regular monitoring a location by the mirrors was said to be favourable. This would also help to communicate the type of problem and where attention was needed. As detailed information probably isn't necessary the type of visual warning device could be a lamp or maybe a visual icon.

Stage 2
In this stage increased criticality should be communicated but still in a non-intrusive way due to high risk of nuisance warnings. The addition of sound or vibration was therefore found to not be appropriate in this step either. Instead attributes of the visual warning device should change to communicate the change of criticality (Step 4). The position and type of warning device could also be the same, as mirrors are expected to be monitored when indicators are activated. The changes in attributes should help prevent missing the warning and should grab more attention than in stage 1.

Stage 3
The third stage is stated to be critical and potentially imminent to a lateral collision. The stage supposedly occurs if the drivers has missed the other stages, a vehicle car approaches fast from behind or when "nudging" to communicate a wish to turn. If the driver has missed earlier warnings chances are that warnings close to the mirrors aren't sufficient at this point. The addition of visual stimuli closer to the forward line of sight, to increase chance of detection, was found to be favourable. A HUD-light was suggested. To be able to distinguish it from the HUD-light used in the Forward collision warning as well as signal side the HUD-lights would be positioned on the sides of the Forward collision warning HUD-light. By attributes in the detailed embodiment further distinction should be added to avoid confusion. An important consideration is whether the HUD-light possibly could draw attention away from the mirror. Especially on the right side as monitoring of the right mirror requires the driver's head to be turned. The warning devices from Stage 1 and Stage 2 are still included and should through changes of attributes signal a higher criticality than earlier stages.

A warning device using a modality with better abilities to grab attention could be required. Auditory warnings is one option but due to the possibility of nuance warnings, drivers were very negative towards this when asked. Another option is a haptic stimuli. To be effective it must be positioned so that it cannot go undetected, i.e. in an object that the driver always is in contact with. Two potential positions were the driver seat and the steering wheel. To avoid confusion with the seat vibrations used in Lane departure warning the steering wheel was found to be best suited. This location can also support the communication of a turn-related risk.

Stage 4
Stage 4 is similar to step 3 in most ways but with the difference that it includes a clear violation due to indicators not be activated. Together with drivers it was said that this suggested that an auditory warning was appropriate. The sound would make sure that the driver immediately interprets the criticality of the situation, even if inattentive. The sound can also communicate the concerned side very efficiently, if positioned on the sides of the driver. To be consistent all the earlier warning devices should be included in this stage as well if not found to cause an overload.

The final deliverables for step 3 are presented in the following pages, sorted in their warning stages.

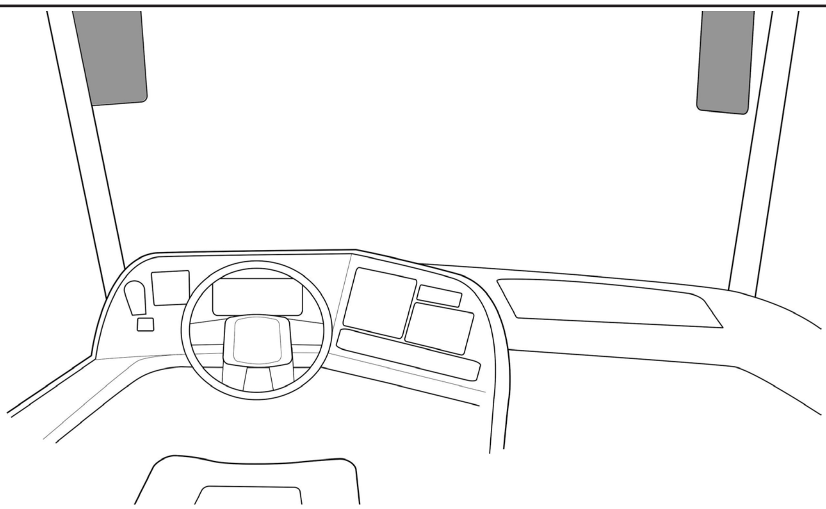
Supportive functions
User controls
- One use control device
  - Activation/deactivation of system

User control devices
- Activation/deactivation of system
- On/off
- Button
- Instrument cluster, along controls of other ASW.

Update use goals with warning device specific goals
- Warning device A should be discernible when driver glances towards mirrors
- Warning device B should be discernible when driver looks straight ahead as well as to sides.
- Warning device C should be discernible by hands placed anywhere on steering wheel.
- Warning device D should be discernible no matter of head position and in all audial environments.

Warning stage 1

Number of warning devices: 1
Number of modalities: 1
Task & Message: Grab attention when monitoring blind spot, communicate vehicle in blind spot, side, attention towards mirror, very low criticality

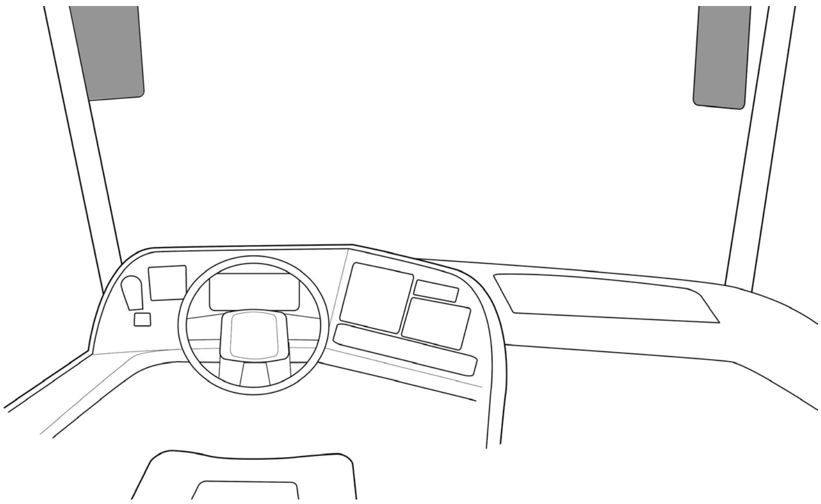


Warning device A

Task: Grab attention when monitoring mirror and communicating message
Communication: vehicle in blind spot, side, attention towards mirror, very low criticality
Modality: Visual
Type: Lamp
Position: Mirror

Warning stage 2

Number of warning devices: 1
Number of modalities: 1
Task & Message: Grab attention when forming intention to start LC, communicate vehicle in blind spot,side, low criticality, attention towards mirror, postpone intended turn

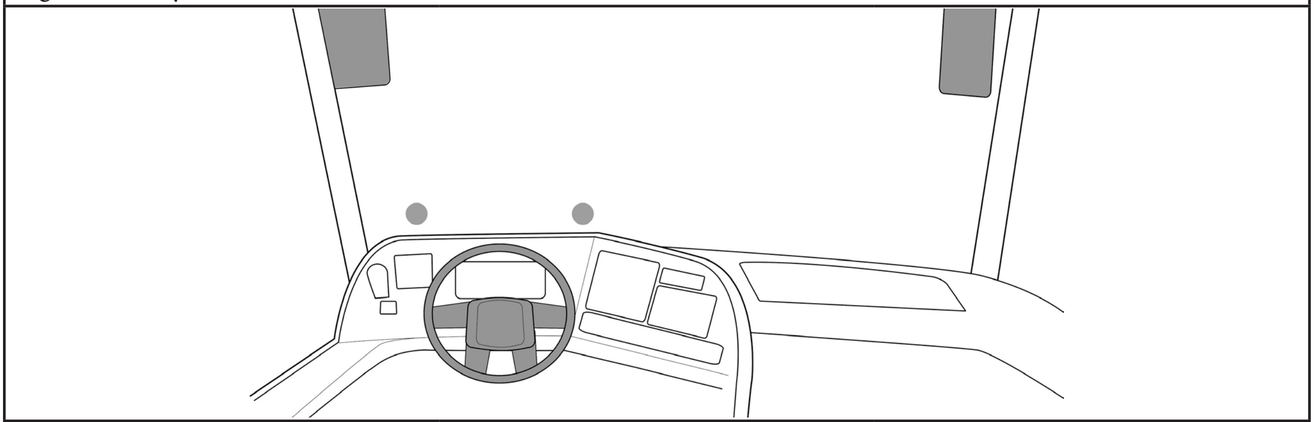


Warning device A

Task: Grab attention when forming intention to start LC, communicate message
Communicate: vehicle in blind spot, side, attention towards mirror, low criticality, postpone intended turn
Modality: Visual
Type: Lamp
Position: Mirror

Warning stage 3

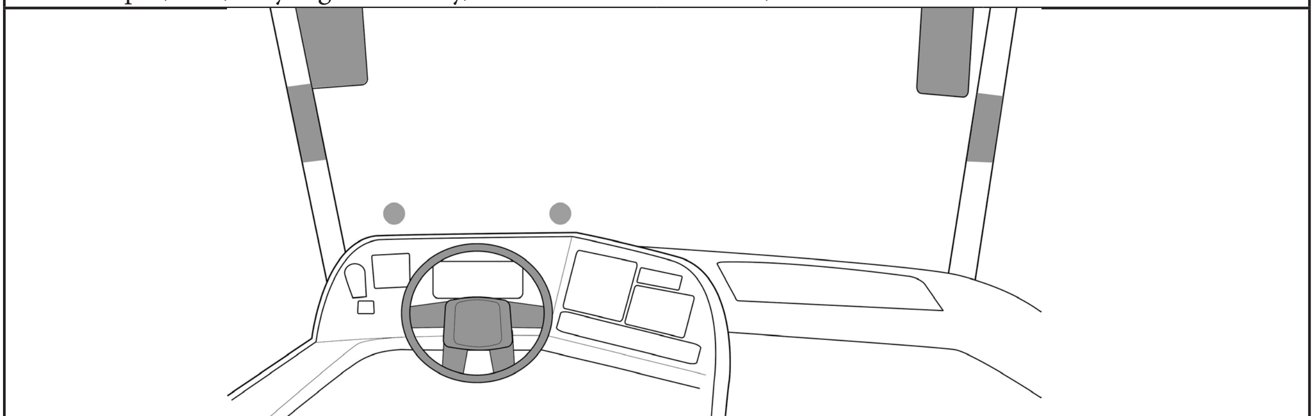
Number of warning devices: 3
Number of modalities: 2
Task & Message: Grab attention immediately, communicate collision imminent with vehicle in blind spot, side, high criticality, attention towards mirror, abort turn



Warning device A	Warning device B	Warning device C
Task: Grab primary attention, direct attention to mirror **Communicate**: vehicle in blind spot, side, attention towards mirror, high criticality **Modality**: Visual **Type**: Lamp **Position**: Mirror	**Task**: Grab attention in case WD A fails, direct to side **Communicate**: side, high criticality **Modality**: Visual **Type**: HUD **Position**: Windshield (sides of FCW HUD)	**Task**: Grab attention in case A+B fails, exhort action **Communicate**: abort turn **Modality**: Haptic **Type**: Vibration device **Position**: Steering wheel

Warning stage 4

Number of warning devices: 4
Number of modalities: 3
Task & Message: Grab attention immediately in all conditions, communicate collision imminent with vehicle in blind spot, side, very high criticality, attention towards mirror, abort turn



Warning device A	Warning device B	Warning device C	Warning device D
Task: Direct attention to mirror **Communicate**: vehicle in blind spot, side, attention towards mirror, very high criticality **Modality**: Visual **Type**: Lamp **Position**: Mirror	**Task**: Direct to side of A fails **Communicate**: side, high criticality **Modality**: Visual **Type**: HUD **Position**: Windshield (side of FCW/HUD)	**Task**: Grab attention in case A+B fails, exhort action **Communicate**: abort turn **Modality**: Haptic **Type**: Vibration device **Position**: Steering wheel	**Task**: Grab attention (Main device), alert and communicate urgency. **Communicate**: side, very high criticality **Modality**: Auditory **Type**: Speaker **Position**: A-pillar

Conflicting design aspects to consider

- Nuisance warnings are still a risk, especially in stage 1-2
- Prioritisation of the LCS system and other systems in multiple risk situations.
- Big difference in distance to right and left side mirrors from driver position.
- Two visual warnings devices to limit annoyance can be confusing, can overload visual sense.

7.5 Final concept - Lane Change Support

The final Lane change support concept is presented by a compiled description of the interaction and the user interface developed through Step 1 - 3.

The Lane change support concept is developed to primarily be an efficient mitigation of lateral collisions due to undetected vehicles in blind spots during driving in high speeds on highways and other big roads. The scenario around which the concept is developed concerns an overtake of a slower vehicle where an undetected car is located in the blind spot in the lane which the coach is about to change to.

The ASW system contains four warning stages of different character. The first stage is activated as soon as a vehicle enters the blind spot. A lamp by the mirror of the concerned side is lit in a discrete manner to make sure that driver understands that there is a vehicle present when routinely glancing towards the mirror. No specific action is desired from the driver apart from acknowledging the warning then monitoring the side mirrors.
The second stage is activated if the driver shows a first intention to make a lane change by turning on the indicators and a vehicle is present in, or enters, the concerned side's blind spot. The same discrete lamp is lit but with changed attributes to make it a bit more conspicuous and to communicates a slight increase in criticality. The lamp is meant to alert the driver of the danger by monitoring the mirror and thus not initiating the lane change.

The third stage is activated if the driver initiates a lane change, with blinkers activated and a vehicle present or entering the concerned blind spot. The lamp in the mirror changes attributes to become more conspicuous and to communicate a big increase in criticality. To decrease the risk of the warning being missed a HUD-light is lit in front of the driver. The HUD-light is meant to direct the driver's attention to the side mirrors, and thus realising the danger and abort lane change. The attributes of the HUD-light should signal side and not be confusable with the Forward collision warning HUD-light. To compensate for a potential lack of visual perception (e.g. in case of drowsy driving) the lights are accompanied by a vibration in the steering wheel that instantaneously alerts the driver and at the same time communicates that lateral driving action is needed.

The fourth stage is activated if the driver initiates a lane change without proper preparation, i.e. without indicators activated, and a vehicle is present in or enters the concerned side's blind spot. The lamp in the mirror, the HUD-light as well as the steering wheel vibration from previous steps are all activated. In this stage an auditory signal is also presented from the concerned sides A-pillar. These combined warning devices are meant to alert the driver of immediate danger and signal to the driver that a violation has occurred. The desired driver action is to abort turn, but it will not be forced mechanically. The final concept is illustrated in Figure 7.2.

Apart from evaluating the contradictory design aspects and potential problems, some further studies are needed regarding:

- Detailed embodiment of the warning devices, determining attributes such as color, intensity and duration.
- Exact location of warning devices
- Effects on other road users.
- The size of the area of the blind spot that activates the stage.
- If the risk of distraction and annoyance is considered greater than the intended support.

7.6 Evaluation and refinement of the Strategy

The Lane change support concept development was performed to both communicate an example on how the strategy can be used as well as to evaluate and refine the SASWIC strategy in general and the SASWIC design process in particular.

The overall format of the process was considered to offer an efficient approach. Both in workshops with developers and coach drivers it provided a good support to structured exploration of different abstraction levels of the design.

Throughout the progress of the concept development some adjustments were done. A main concern was to achieve a balance where the process could be applicable to many potential active safety warning systems with different purposes and effects, but still have a sufficient

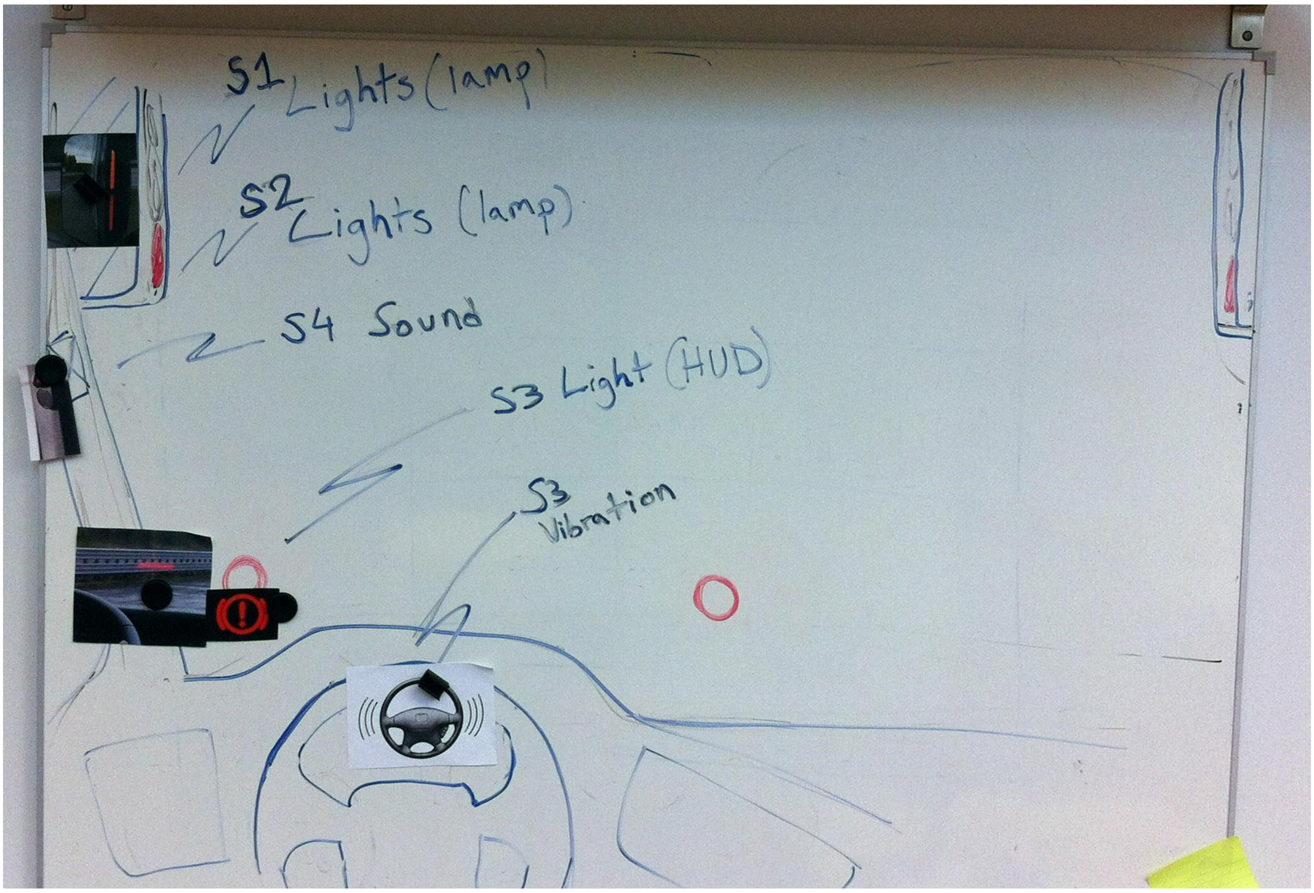


Figure 7.2. Sketch of LCS concept interface created during the development

explicitness in its topics to be accessible without extensive pre-knowledge of user centered design processes. Many minor adjustment concerned reformulating, adding or removing questions, to make the process easier to use.

Some of the more notable adjustments were expanding the evaluative questions, with the support of Response 3, to make sure that more intangible problems concerning user aspects weren't overlooked, or only considered after development.

Including user control as a specified supportive function to consider. This due to it being identified as potentially having strong influence on the embodiment of the main functions.

Moving the deliverable "technical principle" from Step 4 to Step 3 as it was found to be unavoidable to consider when exploring "modality" and "position".

Narrowing down Step 1 to solely focus on active safety warnings and not contemplating other solutions as it was considered to be outside the scope for developing active safety warnings.

To summarize chapter 7, it presented the results from using the three strategy components of SASWIC to create a concept for a Lane change support system for coaches. The chapter also illustrated how demands are set and design choices are made throughout the process steps as well as the level of simplicity and structure the deliverables can have. The Lane change support concept created is therefore to be seen as an example of the strategy use rather a detailed and finalized concept.

8. Discussion

In order to ascertain the validity of and contribution from this project, this chapter will hold a discussion regarding the subject. The chapter will discuss to what degree the purpose of the project has been fulfilled together with how the results differ from other research made into the area. This will allow for an assessment whether the study has made any new contributions to the field. The study's validity and process will also be discussed briefly followed by recommended further research.

8.1 Purpose fulfillment

The purpose of this thesis was to define a strategy for the design of new active safety warnings for Volvo Buses. In part of doing so, the strategy is meant to highlight relevant aspects for active safety warning development and their relevance for coaches as well as promote user centered design.

The outcome of this project is a three-component strategy that gives guidance in systematic user centered design and gathers and connects dots in relevant subjects. The wide approach and generic nature of the strategy enables it to be relevant not only for the development of one specific system but for many potential systems. These aspects corresponds well with the project purpose set out to fulfill.

Within the created strategy the three main components are a design process, an information framework and a interaction model. The design process structures design decisions essential to ASW interaction depending on level of abstraction and thus emphasizes the importance of creating designs that answers to identified needs and stated goals. The information framework acts as a resource that supports understanding of important subjects and a tool for accessing and organizing findings and theory. The Interaction model, illustrating the main interplay between user and machine, concretizes the core of the interaction, bridging a technology driven thinking to its user centered counterpart. All three addresses important aspects to consider when working with human-machine interaction and together they become a comprehensive resource for Volvo Buses to use in their work with development of active safety warning interaction and user interfaces.

The purpose of this project also states that an example use of the strategy should be illustrated by applying it on a system. The conceptual user interface and interaction for an Lane change support system illustrates how the different parts of the strategy can be used together to create conceptual ideas for further evaluation.

8.2 Contribution to practice

When discussing the contribution of this study, it is necessary to look at the strategy's individual parts.

The findings from coach related user studies performed in the project are presented in the information carrying component of the strategy, the framework. They are put it in relation to findings from related literature research and discusses what possible conclusion that can be drawn. The structure of the framework also contributes with the possibility to get a more holistic overview, including aspects regarding user, context and active safety warning system. The framework thus fills a gap in terms of the lack of research regarding coaches as well as creating better possibilities to complement the technology focus common in the industry. The framework component constitutes a big contribution in terms of allowing better understanding of context specific aspects regarding coaches and active safety.

The interaction model was created to further emphasise interaction and human-machine interplay and took inspiration from interaction theory and Janhager's interaction model (Janhager, 2003). The created model is meant to be specific for only active safety warning systems yet also generic to fit all types of future active safety warning-systems. This raises the question whether such a specification facilitates applying the model on different active safety warning systems or makes it too specific and restrictive. A more generic model could cover a wider range of systems but wouldn't offer as much support as the created model as it describes the base interaction in an active safety warning system. Thus, the model might not be applicable for all types of future systems, but it could still be considered as a contribution to practice as the pre-defined interaction is likely to save time in most product development scenarios.

In order to establish the contribution of the design process component of the strategy, it needs to be compared with the different fields it wishes to combine. One is the research field of design processes within the field of product development and one is the specific field of ADAS and active safety warnings development in terms of available reports and actual implementation in industry.

The created concept development process is modelled according to conventional design processes within the field of human factors in the sense that it's iterative and based on problem exploration and user needs. The main inspiration is the comprehensive ACD^3-process from which many central components were acquired (Bligård, 2015). It is important to understand that the SASWIC-process does not try to address all dimension and details of a complete development process to the same extent as the ACD^3-process. The fact that the SASWIC-process is tailored around the interaction with the active safety warnings means that the result is a process that is straightforward to apply when developing an ASW interaction and interface concept, which was considered essential to this project. The major consequence is potential gaps between the designed concept for interaction (and interface) and technical restraints in the other parts of the active safety system. Another can be that the more narrow approach risks preventing solutions that could span outside the field of active safety warnings.

The process described in Response 3 (Scwartz et al., 2009) shares many similarities with the SASWIC process but also covers later steps of ADAS development including descriptions of extensive evaluation procedures, concept selection and so on. The full process divides ADAS development into the two parts concept phase and series development. The concept phase in turn contains a definition phase where the developer is supposed to draft interaction and interface concepts. Response 3 divides drafting human-machine interaction concepts into three activities, namely drafting ADAS functionality, human-machine interaction and usage, which are similar to steps in the SASWIC-process. Two important differences are that the SASWIC-process starts with exploration of the problem and context, and continuously evaluates against common problems, allowing design decisions to be easier to motivate throughout the concept development. The proposed activities within the drafting of human-machine interaction concept are also very brief. The SASWIC-process contributes with a richer support to the creation of concepts by highlighting important design variables together with continuous concern for use critical aspects. The approach applied in the SASWIC-process could therefore be argued to facilitate development of relevant ADAS human-machine interaction concepts with a user and problem focus. Important to note is that the activities of validation, testing and concept selection still should be attended to.

8.3 Contribution to research

The existing research into relevant aspects and areas to consider when designing for advanced driver assistance systems (ADAS) and active safety systems is heavily focused on the car industry. That heavy vehicles should receive more in depth attention is implicated by the fact that this sector already has legislation enforcing that new vehicles should come with certain active safety systems installed.

The instances where heavy vehicles are addressed in reviewed literature are very limited in details and almost exclusively looks at trucks and transit buses. This is not to say that the findings and guidelines from earlier research not are applicable in the development of active safety warning design in coaches as well (in many cases they have been found to be). In order to evaluate this as well as to make the systems as useful and functional as possible in every application there is a big value of context specific research. The reviewed literature also tend to have a predominance of going in depth with machine aspects rather than creating a fundamental understanding of user needs.

The above mentioned importance of context specific research can be exemplified by some of the more prominent and unanticipated findings from the user studies. An example of this could be the drivers' inclination to turn off active safety warnings as a result of not only false and nuisance warnings, but also to avoid passengers from being irritated. In relation to this, one of the main findings was also how often the size of a coach together with the driving behaviour will trigger false or nuisance warnings. As the coach driving profession involves responsibility for passenger safety and comfort, the requirements for active safety warnings differ from those in other vehicles. An example of this would be the complications in building trust with new active safety warning-systems, especially if combined with semi-autonomous functions such as automatic brake or steering wheel torque.

Many coach drivers showed a positive attitude towards the idea of active safety warnings, but the user studies also gave strong indications that they were found to be problematic, with recurring examples of how they caused disturbance and potential distractions. Literature suggests that these kinds of systems can help decrease the number and severity of accidents, but actual avoided accidents are hard to measure and so is the long term effects of driving with more aids. Thus it is hard to determine whether the effects overall effect this far is positive or negative.

On a similar note a lot of research focuses on how to make the warnings detectable and salient in most conditions, whereas a big obstacle highlighted in the user studies are the frequent false alarms and nuisance warnings where the warnings instead become distracting or annoying. This contradicting problematic between developers' aim of warning systems being completely safe in every situation and the acceptance of the users is one of the most important findings of this project as it is very palpable for active safety warning-systems in coaches. With more advanced sensors some of these unwanted warnings can be avoided but as users pointed out there will probably always be situations where the systems are unable to understand the intention of the driver. However, even more effort should be put into warning design that consider and try to mitigate intrusion and distraction.

Another matter is the different environments that coaches travel in. The big differences between cities, country lanes and highways produce different stress levels for the drivers and are connected to different kinds of incidents. This can render an active safety warning that is appropriate in one environment to be dysfunctional in another. The approach suggested in the strategy is to choose critical context and environments to focus the design around. This is not without consequences as it potentially leads to systems that mainly are useful in specific environments. Creating systems that can change according to environment could be a solution but it will require research in effects on user understanding.

8.3 Validity of study

In order to establish the validity of the project and its result, the different strengths and weaknesses of the study will be discussed below.

8.3.1 Project scope and process

The project scope and delimitations set at the beginning of the project left a lot of uncertainties and could have helped to define the circumference of the project better. In order to set reasonable parameters for the project, the main deliverable "A strategy" could have been defined better as a strategy in itself leaves a lot of room for interpretation. The vague definition contributed to the original concept of only creating a research framework grew into the three component strategy presented in this report. This is likely to have affected each deliverable negatively as less time could be allocated to each component.

However, the addition of the process and interaction model helped in fulfilling the project purpose by providing tools that supports user centered design, which could be reasoned to make up for the loss of time.

Furthermore, the goal of creating a strategy for all types of future active safety warnings could have been limited more than just disregarding autonomous systems. This would have helped the project from feeling to general and could have made the project more impactful.

8.3.2 Results

The validity of the results could have been affected by several different things during the project course. During the research phase, the selection of participants for the user studies could have had an effect on the project outcome. As the questionnaires were sent out in online Facebook groups, it could be argued that mostly avid Facebook users were reached. This could have resulted in data only being gathered from people who also can be suspected to be more technology prone and positive to new systems. However, as there was no shortage of negative responses regarding active safety warnings, this could be concluded to have little effect. Furthermore, since the questionnaire results were complemented with research in form of interviews and workshops, their impact on the overall project was mitigated.

The user studies conducted involved around 60 unique individuals in total, most of which participated with questionnaires and all of them with experience of coach driving. The selections in reviewed literature amounts to much larger number, something that could be argued to not be represented in the presentation of findings in the framework. The fact that the user studies are context specific unlike the vast majority of literature, in combination with the solution of presenting both types of findings, this can be said not to influence validity.

The findings from the user studies concern the user's own descriptions of the use of the system and it is thus not certain that it is representative of the actual use. Earlier mentioned prominent findings, such as the user's inclination to deactivate systems and the report of frequent nuisance warnings, suggest that closer and quantitative studies should be done to get a better picture of how of the actual use and interaction.

By using the strategy as a basis for the development of a concept for a Lane change support a first evaluation with subsequent refinements was performed. This evaluation indicated that the strategy in general and the process in particular gave good support to ASW development work, raising awareness of important aspects and issues at an early stage and shaping the interface from the desired interaction instead of the other way around.

The balance between ease of understanding for the overall structure compared to details regarding exactly what should be specified within in each step was found to be hard to calibrate from this one example. How to better address supportive functions such as user control and system status should also be looked further into. These functions can have a strong influence on the interaction with the system but are partly outside of the warning interaction.

Users of the strategy might find it problematic that no pre-defined answer or strict guidelines in many important design question are presented. This was decided to be avoided early on as the substrate from the studies not permitted that level of detailed conclusions. If further studies and test are performed and documented more explicit guidelines can hopefully be defined.

8.4 Sustainability and ethics

Traffic safety and the reduction of accidents, as well as working conditions are all matters of social sustainability. Aside from the regular responsibilities of a driver, driving a coach also means responsibility over the lives of passengers. This makes avoiding accidents crucial and increases the importance of effective active safety warning-systems. Driving a coach also means long driving sessions, at times during nights, adding even more strain on drivers. If designed right human-machine interactions for active safety warnings can reduce the workload and relieve the driver of stress, both increasing well-being and general safety. This highlights the importance of a well-balanced and user centered design when adding human-machine interactions in critical working environments such as coaches to avoid increased cognitive workload and stress, which in the end can lead to an increased risk of accidents. This project can therefore be considered to have a positive effect on social sustainability if SASWIC is implemented to achieve more user adapted solutions for ASW in coaches.

8.5 Conclusion

Designing interactions concerning Active safety warnings is not just a matter of picking the right warning lamp, but a complex puzzle where different situations, experiences and technical aspects have to be managed. This project concludes that coaches have their own configuration of factors, a prominent one being the presence of passengers and their influence on the coach driver. Where much research have looked at specific technical solutions, mainly in cars and trucks this project has taken a comprehensive approach covering both design methodology and a wide range of factors with influence on the design and interaction. It has shown that holistic strategy is necessary to encompass the complexity of the interaction and support a systematic working procedure

The three components of the strategy combines established theory with new research and insights and presents tailored tools for understanding and developing interaction together with a bank of information that supports this work. The components individually share similarities with earlier studies but joined together they constitute a comprehensive and accessible whole, that efficiently can be used to produce concepts. These strategically developed concepts are crucial steps in the design of interactions that correlates with the preferences of the user, fulfill their purpose and create desired effects, something utterly important when it comes to road safety.

8.6 Next step & further research

Due to the wide scope of the project and the development of four different deliverables, the time limit left many interesting aspects still to investigate and further work that needs to be done. In order to develop the strategy further descriptions of how complete evaluation and tests of the developed concept should be added. The strategy should also be applied in other active safety warning system development projects in order to find possible gaps in information needed. Most importantly the strategy should also be tested further by Volvo in real cases in order to enhance usability aspects of the strategy.

Further research should also be made into active safety warning and coach related aspects in order to further complete the framework. However, this is also meant to be done by Volvo during their active safety warning development process as they discover what specific information they need during their product development. To promote long term use, the framework would benefit by being integrated into a documentation system at Volvo, making it available for all interested parties and departments involved in the creation of new active safety warnings. More extensive user studies, especially quantitative, are also encouraged in order to expand the research field of coach related ASW development. This could be done using means not available within the parameters of this project such as eye-tracking driver behaviour. Suggested questions for further research in the area are:

- Can implementation of more active safety warnings be determined to have a positive effect on accident mitigation and coach driver workload?
- How are negative side effects, such as annoyance and distraction, from active safety warnings most efficiently mitigated in order to reach higher acceptance?
- How can active safety warning design better address the requirements of different environments?
- Can other supportive functions (such as cameras) substitute active safety warning warnings?

References

Arthur D. Little, (2014). The Future of Active Safety - The next steps towards autonomous driving. Arthur D. Little, pp.1-3.

Bligård, L. (2015) ACD³ - Utvecklingsprocessen ur ett människa-maskinperspektiv. Göteborg : Chalmers University of Technology (Research series from Chalmers University of Technology, Department of Product and Production Development: report, nr: 96).

Bohgard, M., Karlsson, S., Lovén, E., Mikaelsson, L., Mårtensson, L., Osvalder, A., Rose, L. and Ulfvengren, P. (2008). Arbete och teknik på människans villkor. 1st ed. Stockholm: Prevent, pp.343-344.

Boy, G. A. P. (2012). Handbook of Human-Machine Interaction. : Ashgate Publishing Ltd. Retrieved from http://www.ebrary.com pp. 2-3

Campbell, J. L., Richard, C. M., Brown, J. L., McCallum, M. (2007). Crash Warning System Interfaces: Human Factors Insights and Lessons Learned. (Report No. HS 810 697) Washington, DC: National Highway Traffic Safety Administration.

Dstudio.ubc.ca. (2016). Design Processes | UBC d.studio. [online] Available at: http://dstudio.ubc.ca/research/toolkit/processes/ [Accessed 7 Dec. 2016].

Haas, E. and van Erp, J. (2014). Multimodal warnings to enhance risk communication and safety. Safety Science, 61, pp.29-35.

Janhager J. Utilization of Scenario building in the technical process. in Proceedings of the 14th International Conference on Engineering Design, Stockholm, 2003.

Kaplan, S. and Prato, C. (2012). Risk factors associated with bus accident severity in the United States: A generalized ordered logit model. Journal of Safety Research, 43(3), pp.171-180.

Martin, B. & Cannington, B. (2012) Universal Methods of Design. Beverly, MA: Rockport Publishers, pp. 12-13

Oxford Dictionaries | English. (2017). strategy - definition of strategy in English | Oxford Dictionaries. [online] Available at: https://en.oxforddictionaries.com/definition/strategy [Accessed 1 Feb. 2017].

Rumelt, R. (2011). Good strategy, bad strategy. 1st ed. New York: Crown Business.

Schwarz, J. et al. (2009). Code of Practice for the Design and Evaluation of ADAS. PReVENT Report 11300, v5.0, Response 3, a PReVENT Project. Preventive and Active Safety Applications, Integrated Project, Contract number FP6-507075, pp.4.

Tidwell, S., Blanco, M., Trimble, T., Atwood, J., & Morgan, J. F. (2015, September). Evaluation of heavy-vehicle crash warning interfaces. (Report No. DOT HS 812 191). Washington, DC: National Highway Traffic Safety Administration

Volvo Trucks (2013). European accident research and safety report 2013. Volvo trucks, pp.x-x
Volvobuses.se. (2016). Säkerhet | Volvo Bussar. [online] Available at: http://www.volvobuses.se/sv-se/about-us/safety.html [Accessed 15 Sep. 2016].

World Health Organisation, (2015). Global Status Report on Road Safety. Geneva: World Health Organisation.

Information Framework

A part of SASWIC: Strategy for Active Safety Warning Interaction in Coaches

Framework overview

This framework is designed to act as a flexible database with information found to be relevant to the development of human machine interaction and user interfaces for active safety warnings in coaches. It covers a wide field of aspects, from human cognition to industry benchmarking, to act as a resource that can satisfy the need for holistic knowledge. The information presented about the different aspects should be seen as concentrates of relevant research and theory. The framework is meant to be a living document that can grow when more information is acquired.

Character of content

The content of the framework consist of research findings from theory, literature, articles, user studies, product descriptions, etc, as well as analyses on influences on Active safety warnings design in coaches. The nature of the information is both empirical and theoretical. Much of the reviewed research concerns cars, trucks and city buses rather than coaches as it is a relatively small sector wherein not many specific studies have been performed.

Structure

The framework is sorted into three main chapters: User, Context and Active safety warnings. These chapters each contain a few larger research groups which are introduced with relevant theory. Within each group the research gathered during the project is divided into factors related to the development of Active safety warnings and presented in an article format.

Chapter	Group	Article
Context	Group 3 External and internal context	Article 3.1 Road and Road environment

Figure 1: Framework structure

The framework articles each concern one or a couple of closely related aspects. Each article contains brief information on the specific aspect, gathered from sources of different character. The articles are divided into six parts: Introduction & theory, implications from literature, implications from user studies, discussion, cross-references and sources. The first first three parts deal with the research findings on the aspect. The discussion presents reasoning about how the findings can influence ASW design in coaches. The cross references points the reader in the direction of articles that have strong relations, and the list of sources from where the findings were gathered. Some information can, due to its nature, be found in multiple articles, but in most cases related information is referred to through the cross-references.

Group 3
External and internal context | **Context**

Article 3.1
Road and Road environment

Introduction and theory

Due to the nature of the coach industry the environments and roads which a coach travels by varies a lot. Compared to city and transit buses that travels the same route over and over again the types of roads and environments are much more unpredictable.

Roads of main interest are are city, urban, highway and country roads. The road itself affects by the size and number of lanes, the traction, etc. The surrounding environment impacts driving through the effect on vision, with changes in the field of view and potential distractions.

Implications from literature

Campbell et al. (2007) describes how truck drivers rate the impact of different driving conditions, placing Road traction(51%) and Visibility(26%) at the top.

Implications from user studies

Some drivers drive mainly in city environment whereas others drive mainly on highways and country roads. The coach drivers generally feel a bit stressed when driving in a city environment. However, none marked that they're at the highest stress level, and some even marked that they were really relaxed. This might be due to the difference between cities and other driving conditions. They also feel attentive, stimulated and very alert, suggesting that city environment is a demanding context to drive in, requiring a high level of cognitive processing.

The coach drivers feel more relaxed when operating outside of the city environment. However, they are still very attentive and feel stimulated during their driving. The reason for drivers feeling very attentive yet relaxed during highway/country road driving can be discerned from the answers about if there's any kind of road that's more demanding to drive. 19 out of 43 drivers mentioned country lanes to be more demanding to drive. The most common reason mentioned was the narrowness of the road in relation to the buses size, but night time was also attributed as a contributing factor. 8 people also mentioned motorways as the most demanding. 12 people didn't find any road to be more demanding.

Discussion

Coaches operate in many different environments which can complicate the use of ADAS and active safety warnings as their efficiency differs depending on the environment. This is amplified further by the fact that the size of coaches makes them come very close to objects in tight environments or small lanes, setting of warnings. A potential solution could be systems with different modes for different environments. When developing an active safety warning-system it is thus important to consider in what environments it should function and how the system and user should behave in other environments.

Cross references

1.2 Attention, inattention, distraction
1.4 Workload and fatigue
3.2 Weather and time-of-day

Sources

Campbell, J. L., Richard, C. M., Brown, J. L., McCallum, M. (2007). Crash Warning System Interfaces: Human Factors Insights and Lessons Learned. (Report No. HS 810 697) Washington, DC: National Highway Traffic Safety Administration.

Context - Group 3: External and internal context - Article 3.1: Road and road environment 29

Figure 2: Framework article layout

Outline

1. Ergonomic factors
    - 1.1 Perception and senses
    - 1.2 Attention, inattention, distraction
    - 1.3 Behaviour, decisions and errors
    - 1.4 Workload and fatigue
2. Acceptance factors
    - 2.1 Trust, disuse and misuse
    - 2.2 Experience, familiarity and training
    - 2.3 Perceived hazard
    - 2.4 Mental models

3. External and internal context
    - 3.1 Road and road environment
    - 3.2 Weather and time-of-day
    - 3.3 Cab, dashboard and devices
    - 3.4 Sensoric environment
    - 3.5 Passengers
4. Tasks and accidents
    - 4.1 Accidents
    - 4.2 Driving and driving tasks
    - 4.3 Other tasks

5. Active safety warning characteristics
    - 5.1 Warning timing
    - 5.2 Warning types and stages
    - 5.3 Comparing warning modalities and multimodality
    - 5.4 Auditory warnings
    - 5.5 Haptic warnings
    - 5.6 Visual warnings
    - 5.7 Warning position
    - 5.8 User control and adaptability
6. Other
    - 6.1 Benchmarking
    - 6.2 Summary of coach driver opinions of active safety warnings

User

Introduction to chapter

This framework chapter will present research findings with a clear connection to different areas of human factors in order to create an understanding of user considerations necessary when designing Active safety warning systems. To achieve its purpose, this chapter focuses heavily on theory, presented from a user perspective, regarding human capabilities and attributes. The theory will serve as a basis for the active safety warning-system related research and user studies also presented in the articles.

The user factors presented in this chapter are divided into two bigger categories based on findings in the different research studies. These categories can be described as two major goals an active safety warning need to fulfill in order for it to be successfully implemented. Firstly, the active safety warning needs to be adapted to the human capabilities by considering different ergonomic aspects, both physical and cognitive. This is is essential for the active safety warning to fulfill its functionality and enabling use. Secondly, the active safety warning needs to gain the acceptance of the user by matching the needs, desires and expectations of the user.

By considering both ergonomic and acceptance factors, it is more likely to create an active safety warning-system both enabling use as well as making the user want to use it. Since Active Safety Warning systems in coaches often are intended to prevent collisions, it is important to enable use and deliver a clear and unambiguous warning message in a warning situation. However, this often come into conflict with coach driver desires as warnings often can be considered unnecessary, intrusive and disturbing for the passengers. Therefore, this chapter aims at providing a foundation for balanced design decisions when considering different user factors in an active safety warning development process.

Group 1
Ergonomic factors

User

Introduction to group

This group contains different ergonomic factors relevant to the development of active safety warnings in coaches. The fields of ergonomics relevant for this purpose can be divided into physical ergonomics and cognitive ergonomics. This framework will mostly focus on the latter as cognitive aspects are highly relevant when interpreting a warning in a human-machine system.

Cognition comprises all of the processes dealing with information in the human mind. It includes the collection of information through senses, the allocation of attention, the processing of information through memory as well as decision making and action taking. Cognitive processes are both serial and simultaneous and can compensate for lack of quality in the information through increased effort and reasoning. A human's conscious cognitive processing capacity is limited so to use it efficiently simplifications and generals rules are used such as pattern recognition.
In order to facilitate comprehension of the human cognitive capabilities and abilities, Wickens (2004) presented a simplified model that visualises how information is processed (Figure 3).

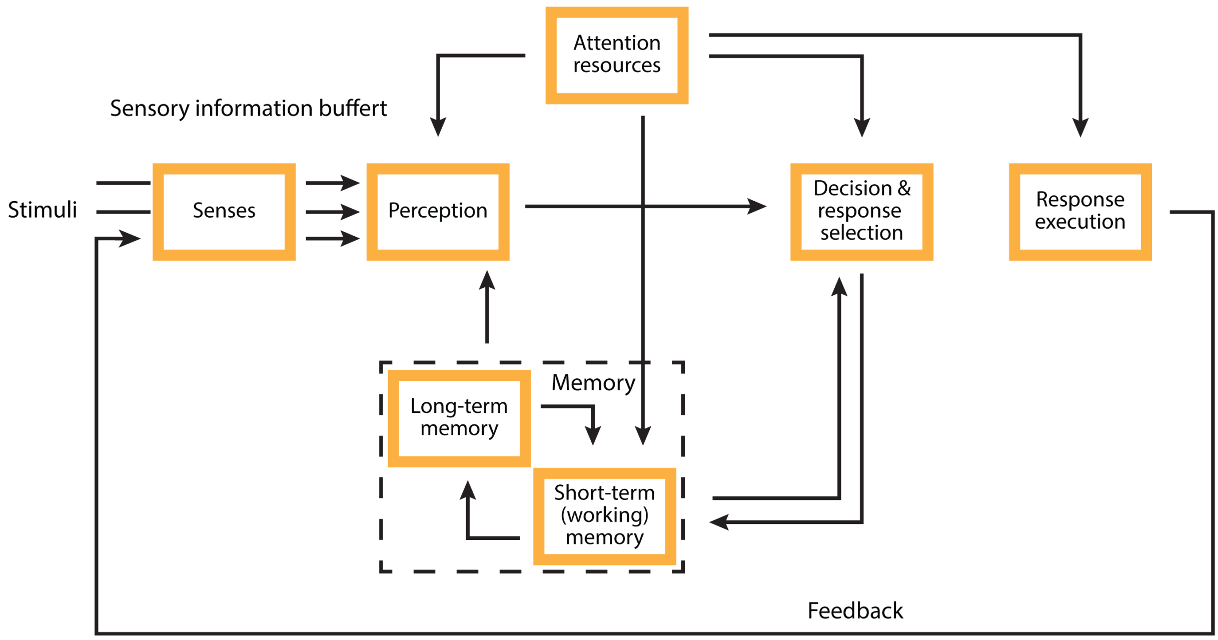


Figure 3: Information processing model (Wickens, 2004)

Wickens model describes how humans constantly gather information through stimuli from the outside world through the different senses. The stimuli is processed and interpreted in different steps in the perception, decision making process and response execution. In order to help the information processing, the human cognition also contains different resources in form of attentional and memory resources that are allocated to the different steps. These resources help sort and make sense of the incoming stimuli. However, as the cognitive resource pool is limited, the success and output of the information processing can differ depending on situation. Wickens (2004) also created a model describing the limitations of the human mental capacity. According to Wickens, simultaneous tasks and actions can interfere with each other if occupying the same dimension of the cognition. This could for example be interpreting several stimuli of the same modality, simultaneous processing of information in the same processing stage, or trying to perform several tasks using the same type of response (e.g vocal or manual).

The cognitive aspects of information processing are important to consider when developing active safety warnings as they are to be processed correctly. Having an overloaded attention or having to use too much memory resources in order to understand a warning can slow down the processing or even lead to misinterpretation and potentially dangerous situations (Bohgard et al, 2008). Since coach drivers use different senses and resources to different extent in different situations, the available resources for interpreting a warning can vary and are therefore essential to understand.

Sources

Bohgard, M., Karlsson, S., Lovén, E., Mikaelsson, L., Mårtensson, L., Osvalder, A., Rose, L. and Ulfvengren, P. (2008). Arbete och teknik på människans villkor. 1st ed. Stockholm: Prevent. Pp.341-420

Wickens. and Hollands (2004). Engineering Psychology and Human Performance - Chapter 11 Attention. Time-Sharing, and Workload.

Article 1.1
Perception and Senses

Introduction and theory

The perception is where the human becomes aware of the information from the outside world and where the stimuli collected through the senses are organised and given meaning. The process of perception is both highly individual, meaning that previous experience affect how stimuli are interpreted, as well as context dependent. Stimuli can therefore be interpreted differently depending on the context it is seen in as well as the previous experiences of the person experiencing it.

As the human processing capabilities are affected by previous experiences, individual expectations also plays a role in interpreting stimuli. Based on the context, the human brain develops expectation concerning what type of stimuli or events that are due, and can therefore more easily discern and process them once they arrive. This is called concept-driven processing and facilitates stimuli processing as the quality of the stimuli can be lower yet still be correctly interpreted due to expectations.

The visual sense is the most dominant of the human senses and accounts for 80% of the sensory input. The visual also excels at detecting movement as stimuli can be perceived within in an arch of 170 degrees. There are two ways of taking in information through the visual sense called seeking and scanning. When seeking, the eye movements are more random as the goal of the information seeking is unknown. Scanning can be a part of seeking, but is used when the goal and information searched for is clear and therefore consist of more systematic search patterns and eye movements. An increase in mental workload decreases the possibility to use seeking and eye movements become more systematic.

The auditory sense completes the visual sense as it can take in a wide range of stimuli from different directions. The auditory sense excels at grabbing attention, especially useful if the visual sense is clouded or overloaded, but can also act to direct visual attention. This is possible due to the spatial awareness the auditory sense enable. The auditory sense is less sensitive to changes in environment and time than the visual sense as different visual stimuli can be hard to detect in different lighting conditions. However, in noisy environments there's still a risk of auditory stimuli being drowned out.

The haptic sense consists of perceiving touch and pressure on skin, as well as being aware of bodily movements (Bohgard et al., 2008). The haptic sense is ideal for completing the other senses, especially if the other channels are overloaded. Vibrations, pressure or friction are examples of how the haptic sense can be used to communicate with the user.

Implications from literature

Connected to the auditory sense, a study by Osbeck & Åkerman (2010) implied that drivers use of it depends on traffic environment, with urban areas requiring more.

Implications from user studies

When driving, coach drivers use their visual, auditory as well as haptic sense to take in the surrounding. The visual sense is for obvious reasons the most important, and also the most heavily taxed. Drivers report using their peripheral vision to great extent as an essential tool in order to keep track of rearview mirrors, surrounding vehicles and road lines. Hearing is the second most important sense, but it can sometimes be difficult to discern important auditory cues due to noise from passengers or traffic. The drivers also report being irritated and annoyed by auditory warnings, not only because they're considered intrusive but also since they can disturb the passengers. The haptic sense is mostly use to feel for differences in driving functionality of the coach, and with it the drivers can sometimes discern if something is malfunctioning inside the vehicle.

Discussion

The visual sense is the most occupied sense when driving a coach and therefore also the most likely to be overloaded. This means that only using visual active safety warning could lead to potential problems in situations where the drivers get a lot of visual stimuli. However, as the coach environment can be both noisy and full of vibrations depending on environment, it is important to evaluate how salient a warning is. As the perception needs to sort through different stimuli, it is also beneficial if the active safety warning aren't using similar stimuli to the environmental stimuli already existing in the coach (for example same frequency of sound or vibration as engine produces).

Cross references

1.2 Attention, inattention, distraction
1.4 Workload and fatigue
3.4 Sensoric environment
5.4 Auditory warnings
5.5 Haptic warnings
5.6 Visual warnings

Sources

Bohgard, M., Karlsson, S., Lovén, E., Mikaelsson, L., Mårtensson, L., Osvalder, A., Rose, L. and Ulfvengren, P. (2008). Arbete och teknik på människans villkor. 1st ed. Stockholm: Prevent. Pp.341-420

Osbeck, E. and Åkerman, N. (2010). Information Hold - Ways of preventing information overload in Scania vehicles in critical traffic situations. Postgraduate. KTH Royal institute of technology.

Article 1.2

Attention, Inattention, Distraction

Introduction and theory

Attention can be defined as the division of cognitive resources in any given situation (Bohgard et al., 2008). The division is affected by different internal and external factors such as stimuli properties and the person's motives and experiences. As the cognitive pool of resources is limited, the more widespread the attention is, the less qualitative is the individual's understanding and awareness of the surroundings.

Attention can be either selective or divided. During selective attention, cognitive resources are directed at certain stimuli during brief periods of time. As a result, the quality of the information received from the stimuli is increased. Selective attention can also turn into focused attention when only one source of information is given attention at the cost of shutting out other distracting stimuli. The information chosen to be priorities and focused upon with selective attention depends on the stimuli properties, the individual's expectations, the value of the information and how effortful the information is to obtain.

Divided attention concerns the human ability to direct attention at multiple sources at the same time without the loss of information. This ability allows us to perform several tasks at the same time but is not guaranteed to work at every given situation. The success of divided attention depends on the resource demands the different tasks require, the similarity in resources needed for the tasks, as well as how easy it is to switch between the tasks. These factors are affected by an individual's experience, meaning how autonomous they are when performing the task, as well as the stimuli properties of the task and, for example, if they are presented in the same modality.

Implications from literature

Inattention is wide category where distraction is one specific subgroup (Green, 2008). What characterizes this group is that the distraction is triggered by an event.

According to D'Souza et al. (2013) distracted drivers experience "inattention blindness". They look but don't process everything necessary to efficiently monitor surroundings, identify potential hazards and respond quick enough. There is also a risk of cognitive overload. D'Souza et al. (2013) sorts distractions into three groups: external (such as road lights, construction, etc.), internal (such as daydreaming, illness, fatigue) and events in vehicle (such as conversations, use of phones).

Another way of sorting distractions is mentioned by Osbeck & Åkerman (2010) with the three categories: Eyes off the road, Mind off the road and Hands off the wheel. This relates to what one of Lövsund & Wibergs (2007) interviewees said: "If information is found very interesting it might lead to eyes off the road".

D'Souza et al. (2013) explains a cognitive distraction model which describes four components of cognitive distraction process: driving tasks, distracting activities, cognitive workload and driver capability. The model analyses how driving tasks and distracting activities affects cognitive workload and driver capability. One conclusion made is that drivers perceive cognitive distraction, generally from driving task combined with other task, as the highest form of distraction.

In the report "Distraction on buses", Salmon et. al. (2011) list seven different types of distraction that bus drivers can experience when driving a bus:
Technology related - Distraction caused by using technological devices whilst driving, such as cd-players and broadcast radio.
Operational related - Distraction caused by performing other tasks while driving, such as listening to broadcasts and modifying the route.
Passenger related - Distraction caused by passenger behaviour, interacting with passengers or monitoring passengers during driving.

Environmental related - Distraction caused by environmental conditions, such as windscreen glare, adjusting sun visors or adjusting driving due to road conditions.
Bus cabin related - Distraction caused by events in the bus cabin such as annoying noises and warnings or making adjustments to instruments.
Infrastructure related - Distraction caused by different features of the road infrastructure such as roadside advertising and roadside construction.
Personal related - Distraction caused by driver state, such as emotional status, fatigue and discomfort.

Salmon et. al (2011) also suggests that implementation of ADAS technology and driver training can help drivers cope with distraction as well as promote safe driving and enhance situation awareness.

Volvo Trucks (2013) presents different types of inattention in their european accident report. There, inattention is divided into impaired attention and misallocated attention, both of which are caused by different factors. The division of inattention and underlying factors are illustrated in figure 4.

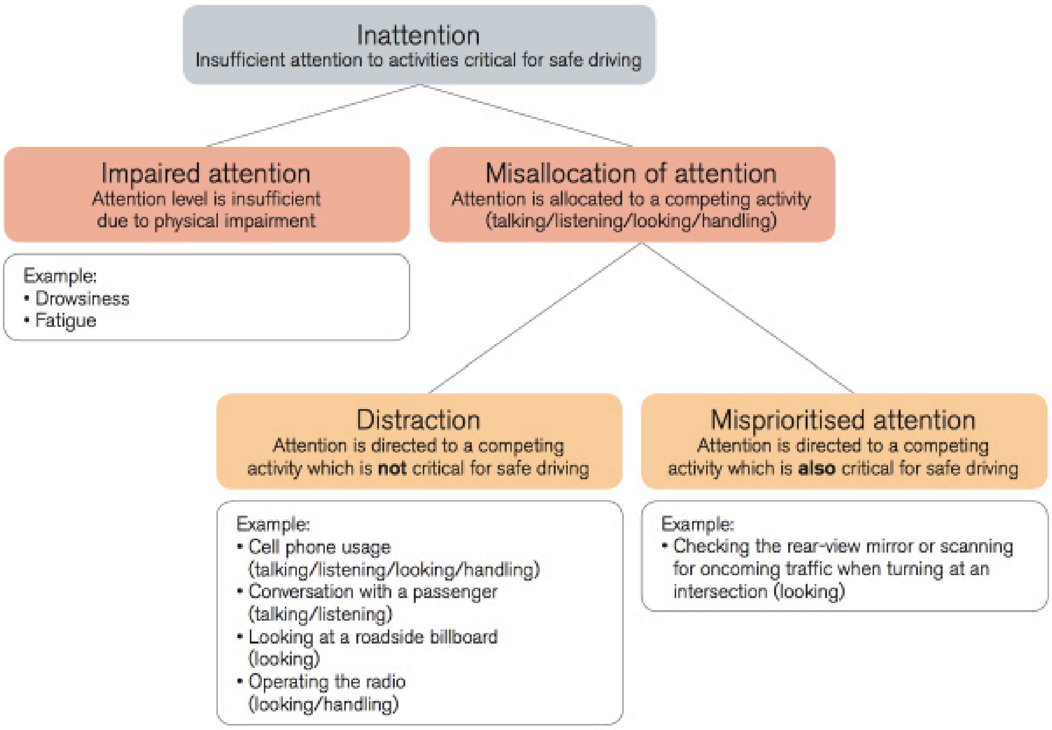


Figure 4. The taxonomy of inattention. (Volvo Trucks, 2013)

Implications from user studies

Whilst sensory input is used to properly maneuver the vehicle, it can also be a source of distraction. Certain sounds such as buzzers from warning systems can distract the drivers if they are not able to turn them off, something that also creates irritation. The behaviour of other vehicles, especially if erratic, have been described to also be sources of distraction.

Passengers shouting, playing music on stereos or using the restrooms can create sounds which are distracting for the driver when driving. However, the inteviewees also state that the noisy bus environment often is not bothersome due to the drivers experience and trained ability to filter out those noises. Apart from making noise, passengers can also be a source of distraction by simply moving around in the bus and not being strapped in their seats. As passengers moving around is a safety hazard needed to be taken into a consideration when operating the vehicle, drivers may be inclined to monitor them until they are seated, taking attention from other tasks.

Discussion

As the coach driving profession often requires divided attention between operating the coach and interacting with passengers or monitoring passengers, it is an important aspect to consider for active safety warning-system design. As divided attention can lead to mental fatigue which in turn can lead to impaired attention, alerting the driver of critical events could be considered beneficial. Furthermore, since there are a multiple of factors that can cause driver inattention, it is important to consider whether new active safety warning can be perceived by the driver during various driving conditions and types of inattention. However, as the drivers also show resistance against intrusive warnings, balancing is important for the systems to be used at all.

Cross references

1.1 Perception and senses
1.4 Workload and distraction
3.1 Road and road environment
3.5 Passengers
4.1 Accidents
5.3 Comparing warning modalities and multimodality

Sources

Bohgard, M., Karlsson, S., Lovén, E., Mikaelsson, L., Mårtensson, L., Osvalder, A., Rose, L. and Ulfvengren, P. (2008). Arbete och teknik på människans villkor. 1st ed. Stockholm: Prevent. pp.341-420

Greep, P. (2008). Driver Interface/HMI Standards to Minimize Driver Distraction/Overload. SAE Paper 2008-21-2002, in Convergence 2008 Conference Proceedings, Detroit, MI, Society of Automotive Engineers, Warrendale, PA.

D'Souza, K., Siegfeldt, D. and Hollinshead, A. (2013). A Conceptual Analysis of Cognitive Distraction for Transit Bus Drivers. Management and Production Engineering Review, 4(1).

Osbeck, E. and Åkerman, N. (2010). Information Hold - Ways of preventing information overload in Scania vehicles in critical traffic situations. Postgraduate. KTH Royal institute of technology.

Lövsund, K. and Wiberg, A. (2007). Development of an Integrated HMI-concept for Active Safety Systems. Postgraduate. IT University of Gothenburg.

Salmon, P., Young, K. and Regan, M. (2011). Distraction 'on the buses': A novel framework of ergonomics methods for identifying sources and effects of bus driver distraction. Applied Ergonomics, 42(4), pp.602-610.

Volvo Trucks (2013). European Accident Research and Safety Report 2013. Available from http://www.volvotrucks.com/SiteCollectionDocuments/VTC/Corporate/Values/ART%20Report%202013_150dpi.pdf (Downloaded October, 2016).

Article 1.3

Behaviour, Decisions and Errors

Introduction and theory

According to the SRK-model (Bohgard et al., 2008) human behaviour when performing a task can be categorized into three modes: Skill-, rule- and knowledge based behaviour (Figure 5). These modes help describe the level of conscious control and the internal processes leading to a decision, depending on the context and the experience of the human in question. From this model potential errors can be identified and classified, and presumably avoided.

Knowledge-based behaviour is the most conscious, where the completion of a task demands a big mental effort due to it being novel or different. Skill based behaviour is the least conscious, creating a more or less automatic execution of a task without almost any increase in mental workload. Specific, well-known events, such as alarms, are generally the catalysator. Rule-based behaviour is found in between these two (Embrey, n.d). Rules governing decision making connected with the task will be asserted, creating some mental strain. These rules are formed either through training or direct- or indirect experience.

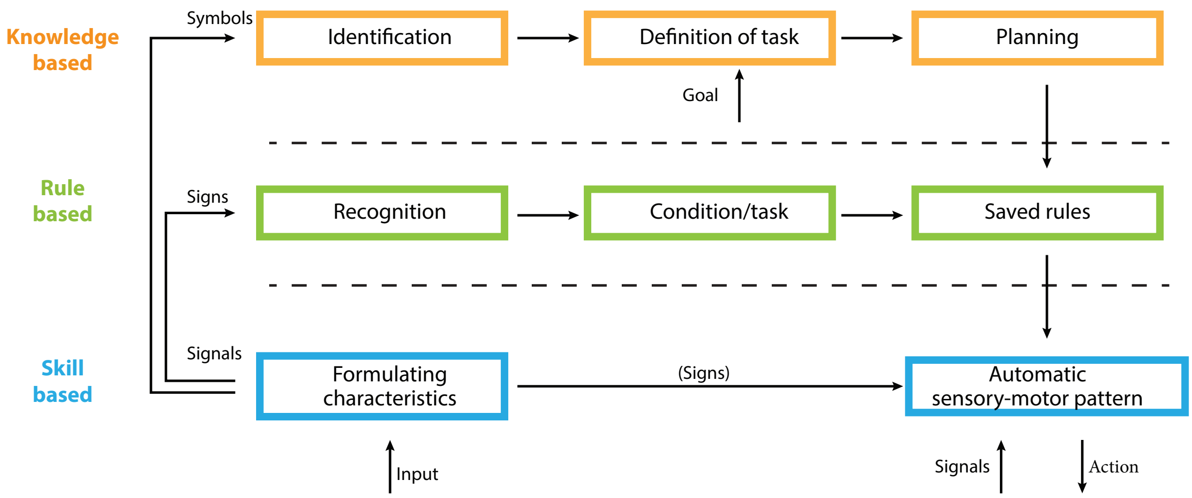


Figure 5: Rasmussen's (1983) SRK framework (Bohgard et al., 2008)

According to Norman (2002) human failure can be divided into Errors and Violations. Errors are unintentional failures whereas violations are failures caused by deliberate risk taking or rule breaking. Errors can be divided into the two groups Slips and Mistakes. Slips are errors caused when having a correct plan but the wrong action is performed, the intended action is thus completed. Mistakes are errors where the wrong plan are formed and with it the wrong actions. The intended actions can be performed according to plan, but as the plan is flawed the goal is not achieved. Mistakes can be divided into the groups Knowledge-based and Rule-based and memory-lapse. Knowledge-based mistakes are caused by invalid or insufficient knowledge leading to a misdiagnosis of the problem. Rule-based mistakes are caused by applicating the wrong action to a correctly diagnosed problem. Memory-lapse mistakes are caused by forgetting in some part of the process.

Implications from literature

According to Treat (1979) two of the most common driver errors are improper lookout and inattention.

Implication from user studies

Since coach drivers often have many years of experience driving a coach, most of them report not have to allocate much time to decision making when driving. However, they also state that beginner coach drivers often make mistakes by not estimating the space with which is needed to maneuver the vehicle. Drivers who have previously driven trucks are often said to make rule-based mistakes as they overestimate the similarities between driving the two types of heavy vehicle. The larger overhang both front and back of coaches are said to make it easier to adjust from coach to truck than vice versa.

Discussion

Regarding active safety warnings it can be said that the aim should be to induce a behaviour somewhere in between Skill- and Rule-based. A warning should provoke a specific reaction from the driver, without a considerable increase in workload or risk of confusion. The nature of the provoked reaction depends on the hazards that the warning communicates and can range from directing attention to performing a specific driving task.

If not sufficiently "intuitive" or not introduced properly, exposure to an active safety warning might induce knowledge-based behaviour with the risk of an increase in workload and a potential distraction. This is more probable in early encounters or when experience of active safety warning are low or different. With experience the driver's behaviour will develop towards skill-based and the different subtasks that is part of the interaction between driver and active safety warning will be more or less united. Though it is important to consider the interaction with all three types of behaviour.

Both violations and errors of all types and in all levels can occur when interacting with active safety warnings. This diversity in errors can partially be attributed to the complexity of active safety warning use and the multitude of different scenarios where the systems are used. As different contextual settings, both interior and exterior of the coach, can require different actions from the driver as response for the same warning, the risk for errors is palpable.

To elaborate further, drivers can perform rule-based mistakes or knowledge-based mistake where the wrong action is performed due to habit or wrongful deduction. These errors indicates that active safety warning need to be explicit in the information given in order for the driver to more easily interpret to avoid making rule-based or knowledge-based mistakes. Turning off or ignoring warnings can be considered violations, but are also common use-scenarios when driving a coach. This unwanted behaviour needs to be taken into consideration and investigated when designing a new active safety warning system.

Cross references

2.1 Trust, disuse and misuse
2.2 Experience, familiarity, training
2.3 Perceived Hazard
2.4 Mental model
4.1 Accidents

Sources

Bohgard, M., Karlsson, S., Lovén, E., Mikaelsson, L., Mårtensson, L., Osvalder, A., Rose, L. and Ulfvengren, P. (2008). Arbete och teknik på människans villkor. 1st ed. Stockholm: Prevent. pp.341-420

Embrey, D. (n.d.). Understanding Human Behaviour And Error. 1st ed. [ebook] Lancashire: Human Reliability Associates, pp.1-10. Available at: http://www.humanreliability.com/articles/Understanding%20Human%20Behaviour%20and%20Error.pdf [Accessed 30 Sep. 2016].

Norman, D. (2002). The design of everyday things. 1st ed. New York: Basic Books, pp.162-180.

Treat, J. R. (1979) Tri-Level Study Of The Causes Of Traffic Accidents. Washington, D.C.: The Administration,. Print.

Article 1.4
Workload and Fatigue

Introduction and theory

Bligård and Osvalder (2010) defines mental workload as the load on the user's information processing when performing specific tasks. This means that the mental workload will vary depending on the user who performs the task and should not be confused with task demands which classification is independent of a specific user. Bligård and Osvalder discerns six aspects affecting mental workload:

Mental processing type: On which mental level the task is performed, from skill-based to knowledge-based. This is in turn based on the experience of the user and how autonomously the perform the task.
Attention resources: How much attention is needed in order to perform the task, for example when monitoring or searching for information.
Memory resources: How much memory activity is needed in order to perform the task, for example calculating, remembering and thinking..
Processing resources: How much processing activity is needed during decision making. This is also related to thinking, calculating and searching for information.
Frustration and stress: How the user feels when performing the task. This could be negative emotions such as irritation, insecurity, stress and annoyance, but also positive emotions such as gratification, content, relaxation.
Superimposed mental activity: What the user thinks about when performing the task. This could be anything from planning ahead to the next task to monitoring parameters or having an overall goal with the use.

When explaining mental workload, Ted Megaw in Wilson and Corlett (2005) focuses on the influence of stressors on a person. Task demands, user workload and strain as well as primary task performance are all components working dynamically and can together have an influence on mental workload which is hard to foresee. External factors are also mentioned to have an impact which can be both positive and negative. For example, during long lasting monitoring tasks, external stimuli can enhance performance and thereby ease mental workload. In other cases the extra stimuli might lead to an extreme arousal level affecting mental workload, such as personal fear.

Implications from literature

Wang et al. (2015) performed research investigating if high mental workload had any effect on the visual information processing ability. According to Wangs results, there is a correlaton between high mental workload and reduced field of vision. It is therefore also suggested that important components potentially used during high workload are placed central in the field of vision.

Implications from user studies

The experienced workload of coach drivers varies depending on different factors such as the driving context or the internal motivations and experience of the driver. City driving seems to be a lot more demanding than highway driving due to the amount of pedestrians, bicyclists and other cars operating in the narrow streets. Although drivers often feel that they need to maintain a high attention in most areas, this becomes especially palpable in urban environments. A factor connected to the high attention needed at most times is claimed to be the lack of respect that coach drivers feel from other actors in the traffic. As interviewees report, other actors don't understand the complexity of maneuvering a coach, and can therefore hinder the coach drivers in their driving. This can sometimes also lead to a very hostile driving environment.

The perceived responsibility and the mental tasks performed during driving causes the mental workload to at times be described as high. This, together with the high attention, causes tiredness to arise faster than in regular driving. The scheduled breaks enforced by law to prevent driver drowsiness are generally accepted and appreciated by the drivers but can also lead to additional stress if not coinciding with the mental plan of the drivers. Other factors contributing to stress, and in turn affecting the driving, can be tasks performed before driving, or altercations had with passengers or other road users. Most drivers report the mental workload lessening with longer experience of coach driving.

When asked about mental overload, the drivers reported it to be an occasional phenomenon mostly occurring in very chaotic traffic situations in city environments. The main consequences of overload were said to be frustration and tiredness with the latter generally being induced when the overload had passed. At the other end of the workload scale, drivers reported that under stimulation can occur during extended highway driving and could also be increased by automatic systems taking over driving tasks. Several drivers expressed concerns about becoming under stimulated and therefore becoming tired or distracted if too many semi-automatic or automatic systems were implemented.

40% of the participants reported feeling mental fatigue often or always when driving. The remaining 60% reported experiencing it seldom or never (12%).

How mental fatigue affected the participants varied, but the most mentioned effects were the following (in order):
Problems thinking clearly (42%)
Slower reactions (35%)
More difficult noticing sounds (20%)
More difficult noticing visual input (20%)
More difficult noticing haptic input (15%)

The contributing factors for mental fatigue were rated by the participants as following:
Traffic conditions (58%)
Rowdy/disturbing passengers (49%)
Weather conditions (44%)
Holding conversations (16%)

Weather conditions were rated as contributing less to mental fatigue than disturbing passengers. However, the interview revealed that demanding weather conditions occur more often, meaning that weather condition is more often a contributing factor, but with slightly less impact.

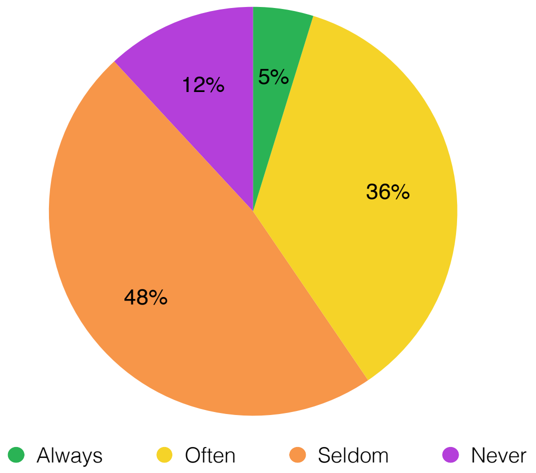


Figure 6: Reported experience of mental fatigue among coach drivers

Discussion

Mental workload is closely related to and affected by other important aspects of cognition such as attention and emotional mental processing. As the coach driver profession includes many different tasks and elements potentially taking up cognitive resources, (e.g, disturbing passengers, mentally planning route, trying to monitor blind spots), the risk for high mental workload is palpable. This makes it an important aspect to consider when designing for active safety warning. If, as stated, coach drivers with high workload find it more difficult to think clearly they might have a harder time interpreting warnings. The increased reaction time experienced during mental fatigue can also have very critical consequences in a warning situation. It is therefore important to consider which mental resources the user has available, and weigh it against how much prioritisation should be given to a specific warning. If a warning is very critical, it needs to be perceived and easily interpreted even during high workload. The fact that coach drivers rely heavily on their peripheral vision to detect objects in their surroundings coupled with the useful field of vision shrinking when under high mental workload could also be problematique. This indicates that critical visual cues or warnings not should be placed too far out in the drivers field of vision.

Cross references

1.1 Perception and senses
1.2 Attention, inattention, distraction
3.1 Road and road environment
3.5 Passengers
4.1 Accidents
4.2 Driving and driving tasks
4.3 Other tasks

Sources

Bligård, L-O. & Osvalder A-L. (2010) Methodology for prediction and identification of mismatches in the interaction between user and artefact, Chapter 4. Chalmers University of Technology, Göteborg, Sweden.

Wilson, J.R. & Corlett, N.C. (2005) Evaluation of Human Work, Chapter 18: The definition and measurement of mental workload, author of chapter Ted Megaw.

Wang, J., Ohtsuka, R., Yamanaka, K., Shioda, K. and Kawakami, M. (2015). Relation between Mental Workload and Visual Information Processing. Tokyo, Japan. In: Procedia Manufacturing, Volume 3, pp.5308-5312.

Group 2

Acceptance factors

User

Introduction to group

This group contains information regarding different aspects affecting how and if a user will accept new systems. This is tightly linked to the active safety warning development in coaches as coach driving is a service profession with responsibility for others' safety, therefore there are many different aspects deciding the degree of acceptance of coach drivers. Below follows a brief introduction to area of acceptance.

When introducing new technology to users it is important to consider how well it will be received. There have been many attempts at creating models for showcasing which factors affect the acceptance of users, one of the most notable being the Technology Acceptance Model (TAM) (Davis, Bagozzi and Warshaw, 1989). A version of the model is often used in the motor-vehicle industry to describe the acceptance of autonomous driving technology as the shift towards autonomous vehicles has become more palpable. Another modification of the The Technology Acceptance Model for ADAS has been proposed by has Patrik Planning (2013). Planning's model (Figure 7) depicts that the intention to use ADAS is a result of the perceived safety and comfort benefits the system brings, the general innovativeness of the user and the desire to exert control. In addition, three background variables in form of experience with ADAS, age and gender is said to have an effect on the overall acceptance.

By studying the model in comparison with coach specific user findings, the model can be said to accurately describe the acceptance of ADAS system in coaches. The perceived usefulness and perceived safety of the system is an important factor in coaches in particular as the drivers are responsible for the safety of their passengers. The experienced responsibility can also be discerned with the coach drivers desire to exert control as they express concerns regarding handing over control to more autonomous ADAS systems.

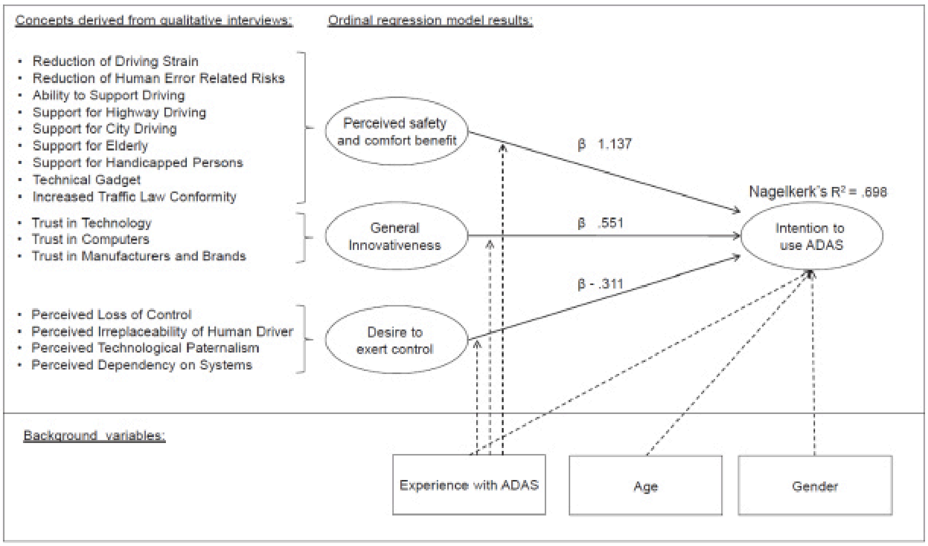


Figure 7: Technology Acceptance Model for ADAS (Planning, 2013)

Sources

Davis, F., Bagozzi, R. and Warshaw, P. (1989). User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. Management Science, 35(8), pp.982-1003.

Planing, P. (2013). Innovation Acceptance, The Case of Advanced Driver-Assistance Systems. 1st ed. Stuttgart: Springer Gabler, pp.262-268.

Article 2.1
Trust, Disuse and Misuse

Introduction and theory

Trust is an important factor when implementing automation as it will affect the acceptance, reliance and continuous use of a system. Parasuraman and Riley (1997) presented categories an operator's use of a machine/system where the two categories Misuse and Disuse are central. Misuse describes use that is erratic or outside the intended use, whereas disuse is the result of not using the system at all. Too much trust (or overtrust) in an automated system can result in misuse whereas inadequate trust (or undertrust) might lead to disuse.

Lee and See (2004) defines trust as: "...the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability". In other words they label trust an attitude that, combined with other attitudes such as subjective workload, perceived risk and self-confidence, produces intentions which affects acceptance and reliance.

Important to note is that when speaking of warning systems, reliance should be complemented with compliance as the function of the system is to provoke an action rather than to let the system act on its own (Meyer, 2001). Reliance is still important because, as with overtrust, overreliance might lead to the operator failing to perform his tasks properly.

To achieve correct use Lee and See (2004) propose the need for a calibrated trust. Calibration describes the conformity between the capabilities of the system (i.e. trustworthiness) with the operator's trust in it. Trust can vary in its dependence on particular components of the system, something Lee and See calls specificity.

Implications from literature

Lövsund & Wiberg (2007), developing a human-machine interaction concept or active safety systems, explains that new systems generally are trusted at first use since the initial expectation is that the system to work properly. This level of trust can decrease quickly for different reasons. For example, in the user-interviews of Lövsund and Viberg it was also mentioned that drivers felt a distrust towards the blind spot-indicator system as it was blinking too often.

Literature also discusses some of the risks regarding trust namely the concepts of complacency and behavioural adaptation (Wiener 1981, Muir 1994). These occur when the user trusts the system too much and therefore stops monitoring it sufficiently or does not take control when necessary.

Implications from user studies

In questionnaires sent out to coach drivers, the overall response was that they feel safe and somewhat confident when operating a coach with active safety systems installed. However, interviews also revealed some uncertainties concerning the systems, affecting their overall trust of the technology. Drivers expressed doubts concerning whether systems could assess critical situations using the same number of factors that the drivers take into consideration when driving. In these cases, drivers were particularly concerned about passenger safety and passenger activity inside the vehicle. They were doubtful regarding whether warning systems would recommend the action best for the passenger, and were highly sceptical towards mechanical intervention, for example automatic brakes.

Many drivers also reported disuse being a common occurrence with active safety warning-systems. This was partly attributed to an undertrust in system capabilities. Drivers also indicated difficulties in understanding system functionality, especially within which parameters a system would trigger a warning. This lead to a decrease in trust as the systems felt uneven and erratic. With the drivers sense of service mindedness and responsibility, the were also concerned that more assisting systems could lead to a loss of skill, or possible overtrust in the systems.

Discussion

A coach driver's trust in new active safety warning-systems is heavily affected by their experienced responsibility for and dedication to their passengers. New active safety warning-systems therefore need to consider the driver's desire to remain in control. For an active safety warning-development process this could mean bringing users into the development process for a better understanding when evaluating new concepts. It could also suggest to be extra careful when considering semi-automated systems with mechanical intervention such as automatic braking or steering wheel torque.

An aspect heavily affecting the trust is also how reliable the system feels. As the drivers often mention that it is difficult to understand active safety warning-system limits as in what environments and within what parameters a warning till trigger, it is reasonable to assume that this is a major source for system distrust. Communicating the active safety warning-system status (when it is turned on/off, within what speed interval it is activated etc.) could be one way to counter the perceived unreliability.

Cross References

1.3 Behaviour, decisions and errors
2.4 Mental model
3.5 Passengers
4.2 Driving and driving tasks
5.8 User control and adaptability
6.2 Summary of coach driver opinions of active safety warnings

Sources

Parasuraman, R. and Riley, V. (1997). Humans and Automation: Use, Misuse, Disuse, Abuse. Human Factors: The Journal of the Human Factors and Ergonomics Society, 39(2), pp.230-253.

Lee, J. and See, K. (2004). Trust in Automation: Designing for Appropriate Reliance. Human Factors: The Journal of the Human Factors and Ergonomics Society, 46(1), pp.50-80.

Meyer, J. (2001). "Effects Of Warning Validity And Proximity On Responses To Warnings". Human Factors: The Journal of the Human Factors and Ergonomics Society 43.4: 563-572. Web.

Lövsund, K. and Wiberg, A. (2007). Development of an Integrated HMI-concept for Active Safety Systems. Postgraduate. IT University of Gothenburg

Wiener, E.L. (1981). Complacency: is the term useful for air safety? In Proceedings of the 26th Corporate Aviation Safety Seminar. Denver, CO: Flight Safety Foundation.

Article 2.2
Experience, Familiarity, Training

Introduction and Theory

Familiarity, training and experience deals with how prior events can influence interaction and use of a system.

Implications from literature

Findings in literature (Ford Motor Company, n.d) shows that the efficiency of one warning increases with presence of other warnings, indicating a potential for shorter reaction time to rare warnings. The training effect is probably depending on warning accurrcy, with false warnings from one system resulting in overall negligence of warnings. Tests showed that experience of LDW improved reaction to different types of FCW. Distracted drivers' reactions to warnings correlated to the degree of previous exposure and type of warning. This training effect could also be achieved through information about capabilities such as regular demonstrations, verbal warnings and harmonization in development of warnings with different frequency of use. They also found that drivers without previous exposure to warnings reacted well to abstract warnings in extreme test situations.

Literature states that when in contact with a hazard or warning, there are existing beliefs and attitudes shaped from experience, psychology and prior encounters (Riley, 2014). This familiarity and experience can decrease perceived risk of a critical situation.

In literature about regular warning signs (Laughery & Wogalter, 2014) it was found that that compliance increase with familiarity and familiarity reduces likelihood of seeking/reading warning on same or similar product.

Implications from user studies

In a survey with 43 participants about 50% answered that they have more than 20 years of experience driving coach. Only 20% had between 0-10 years. The drivers with more years of experience driving coach were in general somewhat more positive towards active safety warning-systems.

The active safety systems that most participants had experience in buses were:
Lane Departure Warnings (LDW) (54%)
Forward Collision Warning (FCW) (49%)
Active Cruise Control (ACC) (37%)
BLIS (26%)

The most common types of warnings that the participants had experienced were as following:
Seat vibrations (68%)
Visual warning message (68%)
Auditory signal (57%)
Warnings lights (53%)

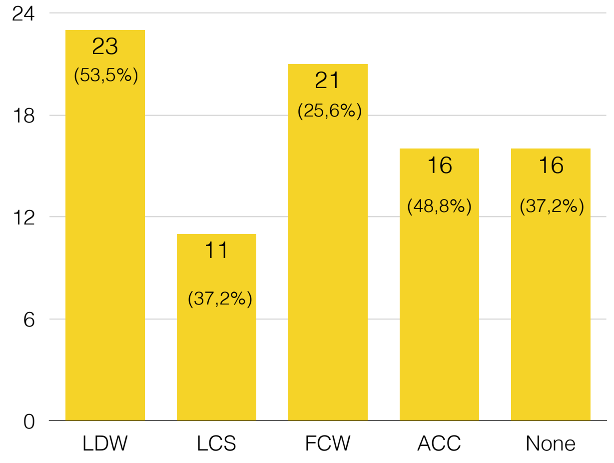


Figure 8: Reported experience of Active safety systems

Discussion

Experience with active safety warning-systems having an effect on the driver's reaction time and overall use performance of active safety warning-systems indicates that drivers increase their performance over time which could compensate for some difficulties at first time use. However, the success and experience of first time will shape the driver's attitude towards the system. The fact that younger drivers with less driving experience were somewhat more negative towards active safety warning-systems, despite presumably also being somewhat more experienced with technology, could indicate how current active safety warning-systems are experienced compared with other technological systems. This could mean that increased experience with technology creates a more negative attitude towards active safety warning-systems as they have been stated to sometimes cause annoyance. However, this correlation needs to be investigated further.

The notion that increased experience and familiarity with a risk situation can cause a decrease in perceived risk can have consequences for active safety warning-systems. This could indicate that having an active safety warning-system alerting the driver of a risk situation whilst simultaneously helping the driver avoid it can cause a decreased risk awareness and affect driver behaviour.

Cross references

1.3 Behaviour, decisions and errors
2.3 Perceived Hazard

Sources

Ford Motor Company, (n.d.). The influence of study design on results in HMI testing for active safety. Pp.1-8.

Riley, D. (2014). Mental models in warnings message design: A review and two case studies. Safety Science, 61, pp.11-20.

Laughery, R., Wogalter, M. (2014). A three-stage model summarizes product warning and environmental sign research, Safety Science, 61, pp.3-10

Article 2.3
Perceived hazard

Introduction and Theory

Perceived risk/hazard is the subjective idea and perseverance of how dangerous something is, independant on statistical risk. According to Wilde's Risk Homeostasis Theory (Wilde, 1994) perceived risk is continuously compared to acceptable risk or "target risk", followed by reduction of the gap in between them to maintain a constant balance. If the perceived risk does not match the target risk compensation through activities might occur both to decrease and increase risk. Perceived risk is therefor a source of of behavioural adaptation.

Implications from literature

According to a review on literature concerning warning signs (Laughery and Wogalter, 2014), perceived hazard increase the chance that the user seeks warning information. Correlations between ratings of hazardousness, likelihood of injury, severity of injury, likelihood of compliance and carefulness (referencing Drake et al, 1998) indicated that users are measuring a single construct: injury potential, according to Wogalter, Conzola, Smith-Jackson (2002).

Further, extensive literature reviews about warnings signs (Riley, 2014) suggests that warnings may reduce the level of perceived risk. Either by increasing trust in manufacturer, increasing perception of controllability, voluntariness or familiarity, or by confusing urgent warnings with messages of less significance. On the positive side it also found implications that warnings can increase hazard perception.

On a similar theme Lövsund and Wiberg (2007) mentions that some of the truck drivers that had been interviewed had doubts about using ACC due to potential negative effects on the driver such as decrease in concentration and focus. They continue by discussing that for an active safety system to be effective maybe it should "scare" the driver to react fast and intuitively rather than being liked.

Interesting to note is also that there is a relation between perceived risk and perceived benefit, linked to positive/negative influence associated with an activity. Activities and technology are judged on thoughts and feelings. If an activity is liked the risk will be perceived as low and benefit as high (Alhakami and Slovic, 1994).

Implications from user studies

Coach drivers generally feel safe when operating a coach, even more than they do driving a car. This is mainly since they feel that they are more focused due to their responsibility for the passengers. Coach drivers have also expressed that the perceived hazard is greater when driving in high speed areas due to the possible consequences of an impact. However, they have also expressed that the perceived risk, that is the risk of an accident happening, is much greater in low speed but crowded environments, such as inner city environments.

As the drivers are more focused when diving with passengers, they often feel in control of most of the possible risk situations, decreasing their perceived hazard of the event.If warnings are triggered even though the driver is not perceiving the situation as riskful, this will cause annoyance and sometimes lead to warning systems being turned off.

Discussion

When developing a warning system it is important to calibrate the communicated criticality to match the user's perceived hazard of the riskful event, as best as possible. If the mismatch or gap is too big it can have consequences such as frustration, annoyance and that the user feels displeased with the system. This is something frequently mentioned by the drivers and should therefore be considered in every active safety warning-development project.

However, a potential risk if the warning communicates too low criticality is that the driver's perceived risk of the concerned situations might decrease. This can also happen as a long term effect of ADAS when facilitating driving and making the driver feel safer. Due to compensation of risk the driver might then start to take more risks.

Cross references

1.3 Behaviour, decisions and errors
2.2 Experience, familiarity and training
2.4 Mental models

Sources

Wilde, G. J. S. (1998). Risk Homeostasis Theory: An Overview. Injury Prevention, 4.2, pp.89-91.

Laughery, R., Wogalter, M. (2014). A three-stage model summarizes product warning and environmental sign research, Safety Science, 61, pp.3-10

Wogalter, M., Conzola, V., Smith-Jackson, T. (2002). Research-based guidelines for warning design and evaluation. Applied Ergonomics, 33(3), pp.219-230.

Lövsund, K. and Wiberg, A. (2007). Development of an integrated HMI-concept for Active Safety Systems. Postgraduate. IT University of Göteborg.

Alhakami, A. S. and Slovic, P. (1994), A Psychological Study of the Inverse Relationship Between Perceived Risk and Perceived Benefit. Risk Analysis, 14: 1085–1096.

Riley, D. (2014). Mental models in warnings message design: A review and two case studies. Safety Science, 61, pp.11-20.

Article 2.4
Mental models

Introduction and Theory

Jones et al. (2011) describes mental models as cognitive representations of external reality. Within a human-machine system, the mental model can be the user's internal representation of how the machine functions, and will help the user make decisions and predict the machine responses. Jones describes mental models as being flexible and dynamic as they are represented in the working memory of the cognition. There the mental models will change as an operator performs tasks, drawing knowledge and previous experience from the long term memory and processing new information.

According to Richardson and Ball (2009), using a mental model requires the use of the cognitive processes also needed for hypothetical thinking, and they stress the fact that a mental model is a dynamic representation in the working memory. The mental model is also described as the mediator of task performance and source of error, meaning that a user can possess incorrect knowledge but it is ultimately the mental model that will use that knowledge when making decisions and predicting correct actions. User's can sometimes have a difficulty overcoming incorrect mental models if it requires too much memory capacity.

Implications from literature

n/a

Implications from user studies

From the conducted user studies, several situations where mental models are used by coach drivers in a way that needs to be considered when developing active safety warning-systems can be discerned. Firstly, the driver's mental representation of critical situations are often influenced by their perceived sense of control. This means that the drivers most often feel capable of predicting outcomes and staying in the loop as well as anticipating coach response when performing operative maneuvers. This results in the driver's mental model of what a risk situation is to often differ from active safety warning-system functions. An example is Forward collision warnings (FCW) or Lane departure warnings (LDW) where warnings can be triggered when drivers are deliberately driving close to a vehicle for an overtake or driving over lanes to better handle a curve. In these situations, the driver does not perceive the situation as perilous and will therefore respond negatively to warnings given.

Another type of mental model used when driving a coach is the mental representation of how an active safety warning-system work. For example, several drivers had difficulties understanding what would trigger a warning, something that was observed during actual use of active safety warning-systems as drivers tried to trigger a warning. There was even a mismatch observed between the driver's mental model and the reality concerning if the system was turned on or off. The driver in this case though the light on the power button meant that the system was turned on, when in reality it was vice versa.

Discussion

Mental model is an important phenomenon to understand when designing new active safety warning-systems for coaches. If the internal representation of how the systems function mismatch with the actual function, drivers can become frustrated or annoyed when presented with warnings they do not consider necessary. A mismatch can also lead to accidents due to the driver responding wrong to the situation. As nuisance warnings are troublesome in coaches and often result in systems being turned off, it is essential to investigate the drivers' mental models regarding active safety warning functionality. One way of doing this is by user studies such as usability tests or simple interviews, mapping possible interaction problems or problems related to when the system should produce a warning.

Cross references

1.3 Behaviour, decisions and errors
2.1 Trust, disuse and misuse
2.3 Perceived hazard
3.3 Cab, dashboard and devices
5.8 User control and adaptability
6.2 Summary of coach driver opinions of active safety warnings

Sources

Jones, N.A., Ross, H., Lynam, T., Perez, P., Leitch, A. (2011) Mental Models: An Interdisciplinary Synthesis of Theory and Methods, Ecology and Society 16(1): pp.43-46.

Richardson, M. & Ball. (2009) Internal Representations, External Representations and Ergonomics: Towards a Theoretical Integration. Theoretical Issues in Ergonomics Science, Vol. 10, No. 4, pp.335–376.

Context

Introduction to chapter

This part of the framework deals with important aspects that together constitutes the context in which the human machine interaction between user and active safety warning-system happen. This concerns both objects and events in the environment, outside and inside of the coach, as well as tasks that are part of coach driving.

Contextual aspects can affect the interaction in a number of ways. Some of them have direct influences on the user's abilities such as perception and workload, whereas others more indirectly create complexities governing where and how warnings should be issued to be of use.

The research is divided into the groups External & internal context and Driver tasks & Accidents. The articles are included due to the findings made in this project and can of course be completed with many more aspects.

Group 3
External and internal context

Context

Introduction to group

These articles concern physical phenomenons inside and outside the coach that can have influence on the interaction with active safety warning. External aspects concern the environment in which the coach travels: the road, the weather and time, whereas internal aspects concern the environment in which the driver actually is sitting.

Article 3.1
Road and Road environment

Introduction and theory

Due to the nature of the coach industry the environments and roads which a coach travels by varies a lot. Compared to city and transit buses that travels the same route over and over again, the types of roads and environments are much more unpredictable.

Roads of main interest are are city, urban, highway and country roads. The road itself affects by the size and number of lanes, the traction, etc. The surrounding environment impacts driving through the effect on vision, with changes in the field of view and potential distractions.

Implications from literature

Campbell et al. (2007) describes how truck drivers rate the impact of different driving conditions, placing Road traction (51%) and Visibility(26%) at the top.

Implications from user studies

Some drivers drive mainly in city environment whereas others drive mainly on highways and country roads. The coach drivers generally feel a bit stressed when driving in a city environment. However, none marked that they are at the highest stress level, and some even marked that they were really relaxed. This might be due to the difference between cities and other driving conditions. They also feel attentive, stimulated and very alert, suggesting that city environment is a demanding context to drive in, requiring a high level of cognitive processing.

The contacted coach drivers feel more relaxed when operating outside of the city environment. However, they are still very attentive and feel stimulated during their driving. The reason for drivers feeling very attentive yet relaxed during highway/country road driving can be discerned from the answers about if there is any kind of road that is more demanding to drive. 19 out of 43 drivers mentioned country lanes to be more demanding to drive. The most common reason mentioned was the narrowness of the road in relation to the buses size, but night time was also attributed as a contributing factor. 8 people also mentioned motorways as the most demanding. 12 people did not find any road to be more demanding.

Discussion

Coaches operate in many different environments which can complicate the use of ADAS and active safety warnings as their efficiency differs depending on the environment. This is amplified further by the fact that the size of coaches makes them come very close to objects in tight environments or small lanes, setting of warnings. A potential solution could be systems with different modes for different environments. When developing an active safety warning-system it is thus important to consider in what environments it should function and how the system and user should behave in other environments.

Cross references

1.2 Attention, inattention, distraction
1.4 Workload and fatigue
3.2 Weather and time-of-day

Sources

Campbell, J. L., Richard, C. M., Brown, J. L., McCallum, M. (2007). Crash Warning System Interfaces: Human Factors Insights and Lessons Learned. (Report No. HS 810 697) Washington, DC: National Highway Traffic Safety Administration.

Article 3.2
Weather and Time-of-day

Introduction and theory

This articles describes how weather and and time-of day can influence coach driving.

Implications from literature

n/a

Implications from user studies

Interviewees mentioned that heavy side winds and slippery roads are complications due to weather. Strong sunshine can also be problematic making visual stimuli harder to detect, both in terms of warnings and external events. Weather conditions were reported to often contribute to high mental workload or mental fatigue by 19 out of 43 participants of a survey among coach drivers.

Discussion

The weather have strong influences on coach driving in itself. The influences on active safety warnings are more indirect through the effects that ice, rain, light can have on a system. It is important that these effects are communicated to the driver.

Weather conditions also offer a possible area for future active safety warnings. Systems that communicate risk for low traction or heavy winds can potentially help coach drivers during conditions that can become dangerous.

Cross references

3.1 Road and road environment
3.4 Sensoric environment

Sources

n/a

Article 3.3
Cab, Dashboard and Devices

Introduction and theory

Aside from the driving controls and dashboard there are other devices and objects in the coach that can demand attention from the driver. This can be a sound system, radio, entertainment systems, cell phones, GPS, etc.

Implications from literature

n/a

Implications from user studies

The driver environment and driver interface look similar between different brands of coaches, but the featured functions and their location and appearance can vary depending on the buyer's wishes. This creates a lack of consistency between coaches, making it more difficult for the driver to adapt when switching between coaches. One interviewee therefore expresses the wish for standards for control placements and symbols for the different functions, to facilitate switching between vehicles. The driver interface is also typically very traditional with physical buttons for every function instead of more modern designs with digital interfaces. In most coach models however, there is one digital screen in the middle of the dashboard with some limited functions that can be accessed by a lever behind the steering wheel.

Interviewees reported there are essential differences between trucks and coaches, both in driver environment and in driving. In a truck, the driver is generally placed higher which has been described as something positive since it allows for a better overview when driving. However, windshields in a bus is bigger and, together with the front, right hand side door, allows for slightly better outlook.

As the driver is seated directly above the wheelhouse in a truck whereas in a bus there is a larger overhang, the driving also differs. One interviewee explained it like this: "It's no problem going from driving a bus to driving a truck, but the opposite can be tricky". The interviewees also mentioned that coach drivers work shorter shifts which was deemed preferable, and that truck drivers experience more pressure of driving economically, and eco-friendly. However, the interviewees also pointed out that passengers in a coach are more demanding than goods in a trailer, meaning that the demands on driving smoothly and being flexible and accomodating were higher.

Discussion

The difference in cab design and system design between different brands of coaches or different types of vehicles is a point to take in consideration when designing new active safety warning-systems. If the already existing systems are well known, the drivers might be used to them making the acceptance of new systems with differing functionality more difficult to obtain. The design of similar product and systems should always be considered as to not cross conventional design principles.

Cross references

2.4 Mental models
5.7 Warning position
5.8 User control and adaptability
6.1 Benchmarking

Sources

n/a

Article 3.4
Sensoric environment

Introduction and theory

This article addresses the overall sensoric environment (auditory, haptic and visual) inside a coach and similar vehicles. The sensoric environment should be considered so that stimuli from warnings do not get masked.

Implications from literature

According to a summary regarding the sensoric environment in transit buses (Campbell et. al, 2007), the visual environment is highly variable depending on things like roadway lighting, in-vehicle lighting and the time-of-day. There have been requests for the ability to control warnings display lighting to adjust them to nighttime driving (Wang et al., 2003). The auditory environment include sounds from for example the engine, passengers, surrounding traffic, air brakes and pneumatic doors. There is a relatively high level of ambient noise according to Reinach and Everson (2001). Finally, the haptic environment is said to include high levels of vibration. Wang et al. (2003) cites drivers that experience rear-end fatigue and numbness after long hours of driving, and that describes the driver seat mentioned to move periodically.

Implications from user studies

The big windshield makes the driver very exposed to light sources and sunscreens are used to block out excessive light. The presence of passengers, such as groups of youths, can at times generate a very noisy environment.

Discussion

The sensoric environment in coaches is complicated and dynamic due to factors such as passengers, the big windshield, blindspots, night driving, type of road, etc. All three stimulus can reach high levels with the risk of distracting the driver, causing high workload or hiding a warning. Warnings systems should be designed to work during all of these conditions.

A potential conflict in the design is to make the warning strong enough to be perceivable during the most intense situations but not too intrusive or startling in calm situations. One potential solution is warning systems automatically can adapt their intensity to the sensoric environment.

Cross references

1.1 Perception and senses
3.2 Weather and time-of-day
5.4 Auditory warnings
5.5 Haptic warnings
5.6 Visual warnings

Sources

Campbell, J. L., Richard, C. M., Brown, J. L., McCallum, M. (2007). Crash Warning System Interfaces: Human Factors Insights and Lessons Learned. (Report No. HS 810 697) Washington, DC: National Highway Traffic Safety Administration.

Wang, X., Chang, J., Chan, C-Y., Johnson, S., Zhou, K., Steinfeld, A., et al. (2003). Development of requirement specifications for transit frontal collision warning system. Washington, DC: Federal Transit Administration.

Reinach, S. and Everson, J. (2001). Driver-vehicle interface requirements for a transit bus collision avoidance system (SAE Paper No. 2001-01-0052). Society of Automotive Engineers 2001 World Congress.

Article 3.5
Passengers

Introduction and theory

This article concerns passengers riding in a coach.

Implications from literature

n/a

Implications from user studies

Passenger experience benefits from smooth bus movements and gentle braking. However, warnings from driver assistance systems can also affect the experience negatively if they're audible for the passengers. Several interviewees have stated that buzzers and other auditory warnings can disturb and even alarm passengers.

The interviewees also pointed out that passengers in a coach are more demanding than goods in a trailer, meaning that the demands on driving smoothly and being flexible and accomodating were higher. However, the drivers also stated that their feeling of responsibility for the passengers kept them attentive and that the risk for incidents due to driver distraction or fatigue therefore were low. 21 out of 43 participants reported rowdy/disturbing passengers as a factor that often contribute to a high mental workload or mental fatigue.

As coaches often are hired for different associations, sporting teams or school classes etc, the behaviour of the passengers can differ a lot in between tours but also from other types of buses. As the passengers in coaches often are familiar with each other, they tend to move around more, potentially being inebriated or rowdy. They can also listen to loud music, use the restroom or use microwaves for their food. Passengers moving around and acting unpredictable is something affecting how coach drivers operate the vehicle. How the passengers behave have been stated to control driving decisions, in order to maximise comfort and avoid risking passengers safety through falling accidents.

Discussion

The fact that a coach carries passengers can have great influences on active safety warnings. The first is the potential distraction passengers can create potentially leading to an accident. The second is how passengers perceive the active safety warning, together with how drivers think the passengers perceive it. Due to the service mindedness and responsibility that coach drivers show towards their passenger, they are concerned that warnings might be disturbing, especially audial. A third aspect is systems intervening with automatic functions (such as braking), which could result in harm if passengers are moving around in the vehicle.

Cross references

1.2 Attention, inattention, distraction
1.4 Workload and fatigue
2.1 Trust, disuse and misuse
4.2 Driving and driving tasks

Sources

n/a

Group 4
Tasks and Accidents

Context

Introduction to group

This chapter of the framework contains descriptions of tasks connected to driving coaches as well as to accidents. This can offer a better understanding of what the driver is occupied with and in what situations an active safety warning could be considered useful.

Article 4.1
Accidents

Introduction and theory

This article presents common accidents and accident causes related to traffic in general and coaches and heavy vehicles in particular. Accidents are often a result of a number of factors related to the man-machine-system and its context.

Implications from literature

In 10% of investigated truck accidents technical issues with the vehicles contributes to road accidents, whereas environmental conditions contribute in 30% (Volvo Trucks, 2013). Human errors from driver are said to contribute in as much as 90% of the cases. Many accidents involve all three. Main problem areas when the truck driver was the cause of the accident are: Inattention, Misjudgement of speed and misjudgement of the risk in a particular traffic situation. “Failure to look properly” and “Failure to judge another road user’s path or speed” are mentioned to be the most prominent user errors.

There are indications that one tenth of drivers are distracted at the time of an accident according to D’Souza. et al. (2013).

Implications from user studies

When questioned about accidents, the interviewees were in consensus that whilst minor mechanical failures are normal, larger incidents or accidents seem to be rare. When larger incidents do occur, they were attributed to factors such as actions from other drivers, tiredness or inattention.

According to one interviewee, incidents due to inattention or tiredness occurred after they had offloaded the passengers and finished their assignments as they start to relax and their attentiveness decreases.

Discussion

It can be presumed that distraction and inattention are common causes of accidents in coaches as both research and user studies points in that direction. There are indications that active safety systems and active safety warnings can offer support to the driver and at times compensate these problems, potentially reducing the risk of accidents. At the same time the implementation of these systems and warnings should carefully consider the potential risk of creating new causes of human errors, acting as distractions and increasing workload, etc. The balance in between warning systems that are toned down in order to not disturb or distract, with the potential of not being perceived when needed, and system that are guaranteed to be detected but run a high risk of contributing to distraction, is hard to reach.

Cross references

1.2 Attention, inattention, distraction
1.3 Behaviour, decisions and errors
1.4 Workload and fatigue
3.1 Road and road environment
4.1 Accidents
4.2 Driving and driving tasks
5.3 Comparing warning modalities and multimodality

Sources

Volvo Trucks (2013). European Accident Research and Safety Report 2013. Available from http://www.volvotrucks.com/SiteCollectionDocuments/VTC/Corporate/Values/ART%20Report%202013_150dpi.pdf (Downloaded October, 2016).

D'Souza, Kelwyn A., Denise V. Siegfeldt, and Alexa Hollinshead. (2013) "A Conceptual Analysis Of Cognitive Distraction For Transit Bus Drivers". Management and Production Engineering Review 4.1

Article 4.2
Driving and Driving tasks

Introduction and theory

This article describes the operation of a coach and driving tasks that comes with it, both in terms of cognitive and physical tasks.

Implications from literature

In an analysis of transit bus driver tasks, driving task are divided into physical and cognitive (Salmon et Al. 2011). Physical tasks "include steering the bus, operating the accelerator and brake pedals, changing gears and operating indicators and other vehicle controls". Cognitive vehicle control tasks "include planning, checking the mirrors, monitoring other road users and pedestrians, forecasting and anticipating other road users' behaviour, navigation, perceptual and decision-making tasks, and tasks required for situation awareness achievement and maintenance".

Research by Volvo has shown that driving heavy vehicles can be very strenuous, with common reports of discomfort in neck, back and shoulders. (Volvobuses.com, 2015)

According to Donges there are three levels of driving tasks corresponding to Knowledge based, Rule based and Skill based behaviour: Navigation, (planning routes), guidance (determining correct speed and direction) and stabilisation (making sure guidance task is fulfilled). (Donges, 1982)

Implications from user studies

In the user studies driver described that when operating the coach, they try to stay ahead in their planning, and are very active in monitoring. As a part of this, driver's are actively checking the rearview mirrors to keep the vehicle inside the roadline, and to check for surrounding traffic. As a result, the drivers also report using their peripheral vision to great extent when driving.

The large size and weight of a coach affects the way of handling the vehicle when compared with cars or smaller vehicles. In a coach, sudden movements and veerings are avoided as it's more difficult to keep track of surrounding objects and vehicles. As a result, the view mirrors are one of the most important tools used when driving to assess situations, and they are also the first thing consulted when receiving different types of active safety warnings. Although the mirrors are an important and well liked, drivers sometimes also feel that their size can obstruct the view.

Tiredness arises faster than in regular driving, and there is a general acceptance of the importance of breaks, though taking them exactly according to plans/rules can complicate things.

As the coach drivers are responsible for the passengers safety, some interviewees have stated that quick reactions and braking to avoid collisions aren't always the best option. One interviewee used a front collision scenario as an example and stated that it sometimes could be better to risk the lives of the people in the vehicle in front by not braking, rather than risking the lives of their 50 passengers by hard braking and swerving. The aspect of drivers assessing risk and their surrounding before acting can come into conflict with automated systems such as the forward collision emergency brake, and cause frustration if the systems action aren't aligned with the driver's mental model.

Discussion

Both physical and cognitive tasks during coach driving can be very demanding depending on the situation, with complex and tiresome maneuvering, continuous planning of routes and the comfort of the passenger at mind. This means that it can require lots of resources from the driver. The addition of active safety warning should be designed not to add more aspects that burdens the driver which highlights the importance of an understandable system that not disturbs the driver if it not is necessary.

Cross references

1.4 Workload and fatigue
2.1 Trust, disuse and misuse
3.5 Passengers
4.1 Accidents
5.1 Warning timing

Sources

Salmon, P., Young, K. and Regan, M. (2011). Distraction 'on the buses': A novel framework of ergonomics methods for identifying sources and effects of bus driver distraction. Applied Ergonomics, 42(4), pp.602-610.

Volvobuses.com. (2015). Home : Volvo Buses. [online] Available at: http://www.volvobuses.com/bus/global/en-gb/_layouts/CWP.Internet.VolvoCom/NewsItem.aspx?News.ItemId=151113&News.Language=en-gb [Accessed 6 Feb. 2017].

Donges E (1982) Aspects of active (primary) safety in motor-vehicle guidance. Automob Ind 27:183–190

Article 4.3
Other tasks

Introduction and theory

Aside from maneuvering the vehicle the driver has a number of other tasks to address before, during and after driving. These tasks can be both mental and physical.

Implications from literature

In an analysis of transit bus driver tasks, five types of non-driving tasks were defined (Salmon et Al. 2011).
Preparation tasks. Performed before starting a route. Examples are: Walkthrough when checking the vehicle state and instrumentation. Adjustments of seat, mirrors, etc.
Route/timetabling tasks. Examples are: Checking route journal, time and schedule, continuously planning route.
Passenger-related tasks. Examples are: Managing the doors, the height of the bus, the ticket machine as well as monitoring and assisting passengers.
Communication tasks. Examples are: Maintain contact with transport operations centre. Listening to broadcast and reporting incidents and emergencies.
Personal comfort tasks. Examples are: Tasks to maintain comfort throughout the day. Eating and drinking, seat and sun visor adjustments and use of entertainment system.

Implications from user studies

Interviewed coach drivers explained that the job description of a coach driver involves more than just the maneuvering of the vehicle. As the drivers are responsible for the external representation towards paying customers during chartered trips, they are sometimes also responsible of the cleanliness and care of the coach, as well as customer service. However, the service minded focus of the driver might also lead to the mental planning of routes, stops and bookings whilst driving, to maximise customer comfort.

The physical tasks that is mentioned to be performed alongside driving is controlling the radio and communication with passengers, guides or with other parties over the phone. The telephone conversations are said to be frequent and coach drivers are generally equipped with headsets. Although this is more or less accepted as an activity, the specific driving situation affects if the driver undertakes this kind of action whilst driving. One of the situations where interacting with passengers were described as having an affect driver abilities is when the passengers are rowdy or inebriated.

Discussion

The main potential impact on active safety warning interaction from non driving tasks is that the driver might be experiencing a high mental workload from having to handle many small tasks simultaneously. Many of these activities can be said to have a limited effect on the driving capabilities of the coach driver due to most occurring before or after trips or when the bus has stopped.

Cross references

1.4 Workload and fatigue

Sources

Salmon, P., Young, K. and Regan, M. (2011). Distraction 'on the buses': A novel framework of ergonomics methods for identifying sources and effects of bus driver distraction. Applied Ergonomics, 42(4), pp.602-610.

Active Safety Warnings

Introduction to chapter

This chapter of the framework present research findings regarding how active safety warning systems and their user interfaces can function and which that are found in coaches today.

The articles presented in this chapter are divided into two bigger categories based on findings in the different research studies.

The first category of articles, Active safety warning characteristics, deals with aspects that define how the active safety warning user interfaces function and act, such as modalities, position and warning stages. The main source of information is the report Crash Warning System Interfaces: Human Factors Insights and Lessons Learned (Campbell, 2007), which is strongly recommended to address in more detail during development due to its extensive content.

The second group of articles looks at the active safety warning system sector comparing available active safety warning user interfaces in different coach brands and presenting some systems of interest from other vehicle types and aftermarket. A summary of coach drivers opinions on different systems are also included. This group of articles does not follow the regular article structure.

Sources

Campbell, J. L., Richard, C. M., Brown, J. L., McCallum, M. (2007). Crash Warning System Interfaces: Human Factors Insights and Lessons Learned. (Report No. HS 810 697) Washington, DC: National Highway Traffic Safety Administration.

Group 5
Active safety warning characteristics

Active Safety Warnings

Introduction to group

This chapter of the framework describes aspects that define how the active safety warning user interfaces function and act, such as modalities, position and warning stages. The main source of information is the report Crash Warning System Interfaces: Human Factors Insights and Lessons Learned (Campbell, 2007), which is strongly recommended to address in more detail during development due to its extensive content.

Article 5.1
Warning timing

Introduction and theory

The timing describe when the warning should be presented relative to the potential dangerous event. The timing is related to Warning stages as the presence of consecutive steps can affect how much time the driver need to respond.

Implications from literature

Timing in collision warning systems should take into account aspects such as predicted response time, intent to change lane and deceleration level (Campbell et al., 2007). Heavy vehicles require earlier warnings due to longer braking distances.

Incorrect timing might distract the driver from the event it actually should highlight (Hanowski et al.,1999).

Implications from user studies

Some users expressed that warnings should not come to late as than there will not be time to respond. Other said that early warnings was unnecessary and could confuse them.

Discussion

The timing should be set to allow enough time for the driver to react. This means that the driver must be able to perform all of the user tasks perceive, recognize/interpret, form intention and perform action. Together with the low maneuverability of coaches (including long braking distance) this suggests that early warning are favourable. The consequences can be confusion, frustration and distraction due to warnings in situations that drivers could have avoided on their own.

Cross references

4.2 Driving and driving tasks
5.2 Warning types and stages

Sources

Campbell, J. L., Richard, C. M., Brown, J. L., McCallum, M. (2007). Crash Warning System Interfaces: Human Factors Insights and Lessons Learned. (Report No. HS 810 697) Washington, DC: National Highway Traffic Safety Administration.

Hanowski, R. J., Gallagher, J. P., Kieliszewski, C. A., Dingus, T. A., Biever, W., Neale, V. (1999) Development of human factors guidelines for advanced traveler information systems (ATIS) and commercial vehicle operations (CVO): driver response to unexpected situations when using an in-vehicle information system. (Report No. FHWA-RD-99-131) McLean, VA: Office of Safety and Traffic Operations R&D.

Article 5.2
Warning types and stages

Introduction and theory

Warning stages describe the development of a warning output within a warning system during a hazardous event. With each stage the criticality is generally meant to increase. Warning types describe the role of the warning.

Implications from literature

A division of warning types used in ADAS development in general and and collision warning development specifically are into the two groups "Cautionary warnings" and "Imminent warnings". Campbell et al (2007) describes them as the earlier require immediate attention but not necessarily a corrective action, and the latter require immediate corrective action. A one-stage (collision) warning only present an imminent warning, whereas a two-stage system first presents a cautionary warning and then a imminent. There is also the option of continuous or multi-stage warnings, with more than two stages.

Table 1: Advantages and disadvantages of using one- versus two-stage warnings. (Campbell, 2007)

	ICW Only (One-Stage)	CCW + ICW (Two-Stage)
Advantages	• May best address distracted-driving situations. • May be simpler for drivers to comprehend.	• May minimize requirements for hard braking (has value for buses and heavy vehicles). • May assist drivers in developing a coherent mental model and better awareness of the CWS device. • May reduce startle effects from ICWs alone. • May aid drivers in maintaining safe headway and in anticipating potential crashes.
Disadvantages	• May provide less time for the driver to recognize and respond to an emerging crash situation.	• May increase likelihood of real or perceived false alarms. • May reduce driver trust and use of the system due to false alarms.

Campbell et al (2007) summarizes advantages and disadvantages regarding the two different types in the table above (Table 1). According to Campbell one-stage warnings are favourable if a high rate of false alarms are expected from two-stage systems, as it might increase frustration and reduce driver trust in the warnings system. Two stage warnings are suitable where the hard braking associated with one-stage system can have undesirable effects and when braking distance is long, like in heavy vehicles. It's also specifically recommended for Lane Change Warnings.

Donmez (2007) mentions that early warnings can enhance effectiveness collision warnings but that they can be annoying and non-useful if drivers are more likely to avoid hazards on their own.

Implications from user studies

Out of the survey participants, 51% were of the opinion that warnings only should be given at high risk situations, 32% wanted consecutive warnings before a high risk situation with different degrees of urgency and the remaining 17% were not sure.

There is a general consensus that warnings only should be presented when there's an imminent risk. The notion of gradual warnings or different levels of intensities are also thought to generate annoyance and even confusion. Instead, according to the interviewees, having one well timed salient warning is more desirable. Non-urgent warnings from other systems (e.g. minor malfunctions, system status, systems checks) in general are a big cause of annoyance. Many of them are interpreted as unimportant during driving (e.g. no actual consequence or unclear cause).

Driver also expressed that warnings of different risk should have different types of stimuli for the driver, for example buzzers or vibrations for urgent warnings

Discussion

There is conflict in the selection of timing and warning stages for active safety warning in coaches. Factors such as the long braking distance, limited maneuverability and risk of standing passengers, suggests the presence of early or "cautionary" warnings to allow time for thought through actions. On the other hand early warnings, either through timing or multiple warning stages, are known to cause frustration as drivers might detect the risk themselves and occurrence of warnings probably will increase. With more warnings the risk of distraction also increases. A potential consequence is deactivation of the warnings system which could make the imminent warnings unavailable as well. A guideline is that if included early/cautionary warnings should be carefully designed to be non-obtrusive to not distract the driver from the driving tasks. The warning can be seen to act as a discrete support that does not try to steal the driver's attention.

Cross references

5.1 Warning timing
5.8 User control and adaptability

Sources

Campbell, J. L., Richard, C. M., Brown, J. L., McCallum, M. (2007). Crash Warning System Interfaces: Human Factors Insights and Lessons Learned. (Report No. HS 810 697) Washington, DC: National Highway Traffic Safety Administration.

Donmez, Birsen, Linda Ng Boyle, and John D. Lee. (2007). "Safety Implications Of Providing Real-Time Feedback To Distracted Drivers". Accident Analysis & Prevention 39.3 : 581-590. Web

Article 5.3

Comparing warnings modalities and multimodality

Introduction and theory

A central aspect of an active safety warning is the modality used to convey the warning. The modalities used in warnings today are haptic, visual and auditory. Research have tried to address what modalities, in different applications, are most efficient and if combining them (multimodality) increase efficiency.

Implications from literature

According to Campbell et al. (2007) redundant visual-auditory warnings are prefered in collisions warnings. Combining auditory and visual warnings generally provide the best response to imminent collisions warnings in heavy vehicles.

In the extensive literature review “Multimodal warnings to enhance risk communication and safety” Haas and van Erp (2014) compares different modalities as well as combinations of them. On a general level they found implications that warning modality has little effect on driver and that multimodality primarily is more effective during high workload. Trimodal displays enhanced perception and did not induce higher workload or secondary task performance. They also found that problems such as slower response time can arise from modality shifting.

In comparisons between modalities the following implications could be derived:

- Haptic signals were prefered to audial in terms of trust, overall benefit to driving and annoyance.
- Tactile interruption signals induced faster response than audial, but more complex and urgent interruption signal were better as audial.
- Tactile as well as tactile-auditory displays produced shorter response time and rated lower workload than audio in demanding driving cross-country driving.
- Audio and tactile are useful when visual field was heavily taxed, potentially from bad lighting or a general visual clutter.
- Visual-auditory feedback is most effective in single-task scenarios with normal workload. Visual-tactile is more effective during multiple tasks with high workload.
- Tactile feedback led to highest speed of action.
- Audial feedback led to highest accuracy.

Implications from user studies

Regarding multimodality it was expressed to be liked in warnings of critical nature. Some users even expressed that in very critical situations a warning should probably use all means possible to alert the driver.

User in general expressed that they prefer visual warnings to haptic and auditory. The preferences comparing haptic and auditory were not as evident with both types raising issues.

The most liked types of warnings were as following:
Warning message on display (23 ppl)
Warning lights (23 ppl)
Auditory signal (18 ppl)
Seat vibration (17 ppl)
Head up Display (14 ppl)

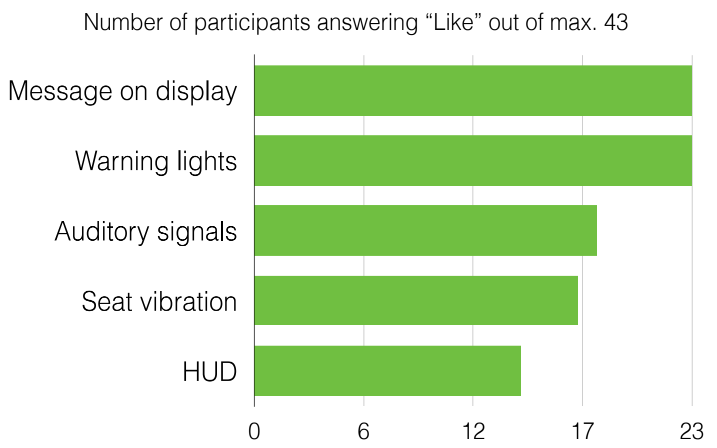


Figure 9: Most liked types of warnings

The most disliked types of warnings were as following:
Steering wheel vibration (10 ppl)
Seat vibration (9 ppl)
Seat belt pulling (9 ppl)
Pedal vibration (8 ppl)
Auditory speech (8 ppl)

Worth noticing is that seat vibration is both among the most liked, and most disliked system. This might be due to the high answer rate (less 'No opinion') as the participants have more experience with that type of warning in comparison with the other warnings. Worth noticing is also that 4 out of 5 of the most disliked warnings are all haptic, whereas 3 out of 5 of the most liked are visual and 1 is auditory.

Discussion

Multimodality has strong support in literature as means for successfully grabbing attention and communicating. User opinions indicated it to be appropriate in critical warnings.

Multimodality is recommended for critical warnings where a single warning stimuli risk being missed. Generally the combination of visual with either haptic or auditory is advised. Though adding more stimulus should be done with care and the risk for confusing a stimuli with one from another warning should be considered. See discussions in the chapters concerning the individual types of warnings.

Cross references

1.2 Attention, inattention, distraction
4.1 Accidents
5.4 Auditory warnings
5.5 Haptic warnings
5.6 Visual warnings

Sources

Campbell, J. L., Richard, C. M., Brown, J. L., McCallum, M. (2007). Crash Warning System Interfaces: Human Factors Insights and Lessons Learned. (Report No. HS 810 697) Washington, DC: National Highway Traffic Safety Administration.

Haas, E. and van Erp, J. (2014). Multimodal warnings to enhance risk communication and safety. Safety Science, 61, pp.29-35.

Article 5.4
Auditory warnings

Introduction or theory

Auditory warnings are warnings presented through sound. There are a number of different types of auditory warnings such as earcons, simple tone, auditory icons, speech warnings.

Implications from literature

Auditory warnings have many applications depending on its configuration. According to Lerner (1993) it is generally accepted that aural warnings are a requisite in imminent emergency alerts. This is supported by responses from drivers interviewed by Lövsund and Wiberg (2007). Similarly, best uses are when visuals are cluttered and the message is short and simple according to (Wogalter, Conzola, Smith-Jackson, 2002). If non-verbal they are most useful if they can be associated with the problematic condition itself according to Haas and van Erp (2014). Further implications from their comprehensive literature review mentions that multitone warnings can be easier to learn thanks to distinctive patterns in pitch and tempo and that single tone warnings are easy to recognize and connected to hazards.

Potential problems can be that auditory icons produce greater number of inappropriate responses (car horn sounds like warning) (Haas and van Erp, 2014). And that drivers and experts imply that sound should be used with caution since it could easily be annoying (Osbeck and Åkerman referencing Davidsson, 2010).

About speech warnings it is said that advantages are specificity, ease of understanding, when listener has no training in coded signals, if workload/stress can lead to forgetfulness, if need for two-way info exchange and for future events that need preparation (i.e. countdown) (Haas and van Erp, 2014). According to (Wogalter et al, 1991) speech warnings increased compliance.

Implications from user studies

Auditory warnings are commonly disliked, first and foremost due to catching the attention of and disturbing passengers. Many drivers mentioned that buzzer are going off frequently or for non-urgent issues. In discussions coach drivers expressed that sound only should be used in very critical situations, as occurrences where it was seen as unnecessary would have negative influence on their view of the system.

Discussion

Auditory warnings can be said to be most effective in grabbing attention and quickly communicating hazard, as they are easy to perceive in most positions even during high visual workload. This is also their big drawback in application in coaches as they run a high risk of reaching passengers, something found to be very problematic according to drivers. To prevent drivers from deactivating the system in case of frequent warnings, auditory warnings can be said to be "saved" for the most critical situations.

Cross references

1.1 Perception and senses
3.4 Sensoric environment
5.3 Comparing warning modalities and multimodality
5.5 Haptic warnings
5.6 Visual warnings
5.7 Warning position

Sources

Lerner N, D. (1993). Brake reaction times of older and younger drivers. Proceedings of the Human Factors and

Ergonomics Society 37th Annual Meeting.1: pp.206–210.

Lövsund, K. and Wiberg, A. (2007). Development of an Integrated HMI-concept for Active Safety Systems. Postgraduate. IT University of Gothenburg.

Wogalter, M., Conzola, V., Smith-Jackson, T. (2002). Research-based guidelines for warning design and evaluation. Applied Ergonomics, 33(3), pp.219-230.

Haas, E. and van Erp, J. (2014). Multimodal warnings to enhance risk communication and safety. Safety Science, 61, pp.29-35.

Osbeck, E. and Åkerman, N. (2010). Information Hold - Ways of preventing information overload in Scania vehicles in critical traffic situations. Postgraduate. KTH Royal institute of technology.

Article 5.5
Haptic warnings

Introduction and theory

Haptic warnings are warnings presented through the haptic sense. Haptic warnings types can be vibrations, brake pulses and steering wheel torque.

Implications from literature

The following guidelines regarding auditory warnings are presented by Campbell et al. (2007):
• To present high priority alerts and warnings.
• To provide a warning to drivers in situations in which they may be distracted or looking away from a visual display.
• To draw attention directly to the location of a potential crash threat.
• As the primary modality in an imminent collision warning, where it can be used in conjunction with visual (or haptic) displays that provide redundant cues to the driver.
• To indicate the onset of a system malfunction or limitation. Use a brief auditory tone followed by a continuous visual message.
• To augment a visual warning display in a non-time-critical situation.

The literature suggests a number of positives regarding tactile signals. In their extensive literature review Haas and van Erp (2014) found that tactile warnings lead to faster reaction than some visual and auditory, especially with time critical tasks or high workload. It was suggested that non-directional tactile warnings are well suited for imminent collision avoidance warnings, for example rear-end collision. There were also implications that spatial tactile warning and localized vibrations can help the user take appropriate action and reduce shift in spatial attention.

Other interesting findings were that, as means during drowsy driving, seat belt vibrations had shown high effectiveness and acceptance (Bekiaris et al., 2004), and that steering wheel vibration and torque proved most effective for LDW warnings (Kozak et al., 2006).

Lövsund and Wiberg (2007) mentions that the sense of touch requires contact with the interface which can create an “emotional closeness” with the interaction, something other modalities lack. One of their interviewees also said that vibrations is a sign of a machine malfunction which could lead to misunderstandings.

Implications from user studies

Many of the asked coach drivers had experience of tactile warnings, mainly from seat vibrations. A majority were positive towards seat vibrations (17 out of 29 in survey). Recurrent positive aspects mentioned by drivers was that haptic warnings do not disturbs passengers and that they are not as annoying as auditory warnings. When asked more closely some interviewees mentioned that the warnings at times can be hard to clearly distinguish, for example after long hours of driving. This was disputed by others who instead said that they are a good way of grabbing attention and provoking the driver response of monitoring the mirrors. Seat vibrations were also said to sometimes induce pain for drivers with back problems or other physical afflictions, which not is unusual among coach driver according to an interviewee. Another opinion was that seat vibrations was said to come to frequent. A concern was that haptic warnings could be mistaken for natural vibrations from driving or malfunctions in the coach, especially if placed in pedals or steering wheel. Similarly the risk that vibrations could be masked by natural vibrations was mentioned.

Discussion

A strong benefit with haptic warnings in coaches is that they offer the possibility to communicate with the driver without affecting passengers. Haptic warnings can also be distinguishable when visual and auditory senses are heavily taxed and are measured to induce very fast reaction. The varying haptic environment with much vibrations and the long hours of driving make coach drivers experiences physical fatigue and strain, which risk masking haptic warnings.

If haptic warnings are frequent they might also increase fatigue and strain. Haptic warnings can thus be said to be a powerful tool in coaches that should be used with caution to not waste the advantages they offer.

Cross references

1.1 Perception and senses
3.4 Sensoric environment
5.3 Comparing warning modalities and multimodality
5.4 Auditory warnings
5.6 Visual warnings
5.7 Warning position

Sources

Haas, E. and van Erp, J. (2014). Multimodal warnings to enhance risk communication and safety. Safety Science, 61, pp.29-35.

Bekiaris, E. and Nikolaou, S. (2004). Towards the development of design guidelines handbook for driver hypoviglance detection and warning. Hellenic Institute of Transport, pp.314-320.

Kozak, K., Pohl, J., Birk, W., Greenberg, J., Artz, B., Blommer, M., Cathey, L. and Curry, R. (2006). Evaluation of Lane Departure Warnings for Drowsy Drivers. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 50(22), pp.2400-2404.

Lövsund, K. and Wiberg, A. (2007). Development of an Integrated HMI-concept for Active Safety Systems. Postgraduate. IT University of Gothenburg.

Article 5.6
Visual warnings

Introduction and theory

Visual warnings are warnings presented through the visual sense. Visual warnings types can be lamps, HUD-lights, discrete displays, icons.

Implications from literature

The following guidelines regarding visual warnings are presented by Campbell et al. (2007):
Use visual warnings to provide continuously available information in situations where it is not critical that the visual warning will be relied upon to capture the driver's attention.
• Providing redundant or supplemental information that accompanies a primary auditory or haptic imminent collision warnings.
• Providing primary warning information in a situation in which drivers can reasonably be expected to see the visual warning as part of the regular information-acquisition process
• Providing continuous lower-priority information such as a cautionary collision warnings.

Most stimuli are visual when driving and Bekiaris et al. (2004) mentions that there is a risk of overload or distraction from visual warnings. It is suggested to be the initial signal in warnings systems. According to Bekiaris et al. (2004) it should not be the main stimuli if the driver is inattentive, especially if it concerns a imminent warning, as it might go unnoticed.

Another frequent recommendation is that it should be placed close (about 15-30 degrees) to the line of sight to increase chance of it being detected and minimize eyes of the road (Bekiaris et al., 2004) (Cacciabue and Martinetto, 2006). This is increasingly important as, according to Wang et al. (2015), line of sight might decrees during high workload.

Literature (Laughery, 2006) (Cacciabue and Martinetto, 2006) also mention that pictorials can help grab attention and ergonomic characteristics (such as color and size) relative to other displayed information should be chosen to favour perception, interpretation and execution. Regarding text, Bekiaris et al. (2004) states that one should minimize information to be read. There should be no entire paragraphs and the number of words acknowledgeable depend on workload.

It is important to provide adequate luminance and contrast to account for difficult display conditions, the most prominent being daytime with low standing sun. Drivers often use sunglasses which goes unaccounted for (Bekiaris et al., 2004). Haas and van Erp (2014) states that offloading an overworked visual channel to other modalities reduced cognitive processing efforts for effective task performance.

Implications from user studies

Visual warnings are the most liked type and considered to be adequate in most cases.

Regarding color the coach interfaces usually use traditional colour coding of green, yellow and red and drivers stressed the importance of standard color coding. However, they also stated that different colour codings have different interpretations and emphasis in different countries. For example, a yellow light indicating a possible malfunction could cause drivers in Germany and England to directly stop the coach until fixed, whereas swedish drivers would have it checked out once their tour was over.

Discussion

Visual warnings are prefered among coach drivers, probably due them being easier to screen out in cases where the warning is redundant. This is both the positive and negative aspect of visual warnings, as they risk being missed or overloading the visual sense. Visual warnings are therefore suitable for warnings of low criticality but should be easily noticeable when needed, though not to distracting. They are recommended to be complemented with either haptic or auditory warnings in highly critical warnings. Visual warnings should use shapes and colors in traditional ways to be easy to interpret.

Cross references

1.1 Perception and senses
3.4 Sensoric environment
5.3 Comparing warning modalities and multimodality
5.4 Auditory warnings
5.5 Haptic warnings
5.7 Warning position

Sources

Campbell, J. L., Richard, C. M., Brown, J. L., McCallum, M. (2007). Crash Warning System Interfaces: Human Factors Insights and Lessons Learned. (Report No. HS 810 697) Washington, DC: National Highway Traffic Safety Administration.

Haas, E. and van Erp, J. (2014). Multimodal warnings to enhance risk communication and safety. Safety Science, 61, pp.29-35.

Bekiaris, E. and Nikolaou, S. (2004). Towards the development of design guidelines handbook for driver hypoviglance detection and warning. Hellenic Institute of Transport, pp.314-320.

Wang, J., Ohtsuka, R., Yamanaka, K., Shioda, K. and Kawakami, M. (2015). Relation between Mental Workload and Visual Information Processing. Tokyo, Japan. In: Procedia Manufacturing, Volume 3, pp.5308-5312

Laughery, K. (2006). Safety communications: Warnings. Applied Ergonomics, 37(4), pp.467-478.

Cacciabue, P. and Martinetto, M. (2006). A user-centred approach for designing driving support systems: the case of collision avoidance. Cognition, Technology & Work, 8(3), pp.201-214.

Article 5.7
Warning position

Introduction and theory

The warning position describes from where a warning is emitted. The position of course depend on the specific layout of the coach but is also influenced on what modality the warning uses, the specific task the warning should fulfill and type of message it should convey.

Implications from literature

A reaccuring guideline (Bekiaris et al., 2004) (Cacciabue and Matinetto, 2006) is that warnings should be placed close (about 15-30 degrees) to the line of sight to increase chance of being detected and minimize eyes of the road.

Campbell et al. (2007) mentions that the position of the warning should correspond to the desired driver response, for example the side of the vehicle linked with the hazard, to allow for spatial compatibility. Other recommendations in the report are: Display location must be compatible with trained and appropriate visual scanning behaviors. LCW primary displays should be closely aligned with the driver's line of sight to side-view mirrors. Avoid locating visual collision warnings on the instrument panel of large vehicles.

Implications from user studies

Warnings positioned in the dashboard generated mixed opinions. Some drivers found them to be easy to detect and distinguish whereas others mentioned that it was time consuming and possibly distracting to have to shift attention downwards. To place warning light on top of the dashboard was suggested to amend for this by one driver. When asked about positions for LCS-warnings the two prefered options were in the mirrors and in the windshield (HUD).

Discussion

As the warning will draw attention the position should make sure that the warning diverts attention in an appropriate direction to make its cause understandable and/or the advised driver response intuitive, without drawing too much attention away from driving or masking other important stimuli. The position should also ensure that the warning is detectable when needed to be, something that depends a lot on the modality of the warning. Position of haptic warnings requires direct physical contact which limits the options. Position of auditory and most importantly visual warnings should consider the fact that the driver's head is frequently moved and turned. Warnings positioned outside of a driver's monitoring loop risk go undetected or generate new monitoring behaviour that might impede driving.

Cross references

3.3 Cab, dashboard and devices
5.4 Auditory warnings
5.5 Haptic warnings
5.6 Visual warnings

Sources

Bekiaris, E. and Nikolaou, S. (2004). Towards the development of design guidelines handbook for driver hypovigilance detection and warning. Hellenic Institute of Transport, pp.314-320.

Cacciabue, P. and Martinetto, M. (2006). A user-centred approach for designing driving support systems: the case of collision avoidance. Cognition, Technology & Work, 8(3), pp.201-214.

Campbell, J. L., Richard, C. M., Brown, J. L., McCallum, M. (2007). Crash Warning System Interfaces: Human Factors Insights and Lessons Learned. (Report No. HS 810 697) Washington, DC: National Highway Traffic Safety Administration.

Article 5.8
User control and Adaptability

Introduction and theory

User control and adaptability concerns if and in what ways warnings should be controllable or adjustable, either by the driver or by themselves.

Implications from literature

A number of papers (Marberger, Widlroither and Bekiaris, 2004) (Ford Motor Company, n.d) (Bekiaris et al., 2004) mention adaptability as important as the interaction should be tailored to frequency of use, impairments and preferences to give the driver adequate information when they need and want it.

Bekiaris et al. (2004) suggests easily accessed profiles that adjusts factors such as intensity and type of warning for certain systems. Factors such as brightness, volume, etc should be adjusted automatically according to environment.

In their paper regarding a system mitigating drowsy driving Marberger, Widlroither and Bekiaris (2004) suggests automated adaption in three levels according to the driver state. An alert driver would only get imminent active safety warnings, a slightly drowsy driver would get a lower threshold for active safety warnings and the potential of an drowsy driving warning and a clearly drowsy driver would get a drowsy driver warning and an even lower threshold for active safety warning.

Implications from user studies

Today's coach interface leaves little adaptability for the driver to work with. According to the interviewees, the only adaptable features in the coach cab are light intensity settings and in some cases the information in the dashboard interface display. Some interviewees ask for even more personalised adaptability in what is shown in the dashboard, as well as in the information presented from the active safety systems.

The most user common example of user control of active safety systems is deactivation. The interviews showed that almost all drivers have turned off active safety systems during driving, or know of other drivers who usually do. The main reasons for turning the systems off are warnings being experienced as disturbing or systems being deemed to not function as the driver wants them to, usually when driving under certain conditions. When the systems are triggered in controlled situations, drivers often become annoyed and deactivate the systems.

When asked about the possibility to configure active safety systems, responses were mixed. If possible it was noted that they always should be reset to a default setting after the vehicle has been turned off, so that other users not would be confused.

Discussion

There are indications that adjustability of safety systems is positive as the systems can be made to act according to a driver's mental model and preferences. As coach drivers drive for extensive hours, exposure to warnings can be frequent and adjustability to preferences can be seen as suitable. Some coach drivers drive the same vehicle whereas others change frequently. Problems such as confusion can occur when a driver interacts with a system that is adjusted to someone else's preferences, something that could happen when a driver changes vehicle.

One solution is that the system is reset at startup. This would have the consequence that settings need to be repeated over and over which could create frustration or confusion, if forgotten. Another potential solution is user profiles that are easily accessed by different drivers so that adjustments can be changed with minimal effort. The user profile system would have to be available in most coaches, which can be problematic as coaches are in service a long time and bought from many different manufacturers. Another solution is to present information about the settings of systems at startup.

Cross references

2.1 Trust, disuse and misuse
2.4 Mental models
3.3 Cab, dashboard and devices
5.2 Warning types and stages

Sources

Marberger, C., Widlroither, M. and Bekiaris, E. (2004). User centered HMI development in the AWAKE - project. In: IEEE International Conference of Systems, Man and Cybernetics. Stuttgart, pp.170-175.

Ford Motor Company, (n.d.). The influence of study design on results in HMI testing for active safety. Pp.1-8.

Bekiaris, E. and Nikolaou, S. (2004). Towards the development of design guidelines handbook for driver hypovigilance detection and warning. Hellenic Institute of Transport, pp.314-320.

Group 6
Other

Active Safety Warnings

Introduction to group

This group of articles looks at the active safety warning system sector comparing available active safety warning user interfaces in different coach brands and presenting some systems of interest from other vehicle types and aftermarket. A summary of coach drivers opinions on different systems are also included. This group of articles does not follow the regular article structure.

Article 6.1
Benchmarking

Introduction

This article describes active safety systems and their interfaces available in coaches from different manufacturers differen. Information was collected from the coach manufacturers websites.

Table 2: Benchmarking of types of interface for Active safety warnings among different coach brands

Benchmarking	**Active Safety system with warnings**		
	Lane departure	Drowsy driving	Forward collision
Manufacturer	**Interface**		
Volvo	Seat vibration / dashboard light & sound		HUD light and sound
MAN	Sound		
Scania			
Irizar	Seat vibration	Seat vibration	Seat vibration
NEOPLAN	Description n/a		
SETRA	Seat vibration	Auditory and visual	Sound and visual
Mercedez-Benz	Seat vibration	Description n/a	

Implications from user studies

Mercedez-Benz coaches have a dedicated part of visual interface in instrument panel screen specifying the type of active safety warning triggered during a warning event. The screen will automatically show the specific part of the interface during an event.

Article 6.2
Summary of coach driver opinions of active safety warnings

Introduction

This article presents a summary of findings on what problems active safety warnings was found to cause according to coach drivers, based on interviews and a survey.

Implications from user studies

Coach drivers generally have a positive attitude towards safety systems and are in consensus that they have a positive effect on driving safety. However, many drivers have had bad experiences with active safety systems and stress the importance of them being both accurate and if possible, adjustable. The systems are stated to work well in traffic scenarios, such as highway driving, but can be experienced as annoying or unreliable in more complex situation such as queueing and city-driving. In these situations the systems are reported to trigger even though drivers have not made a violation and feels they are in control of the situation.

In a survey directed towards coach drivers with 43 participants the most common problems experience with Active safety systems were reported as following:
Unreliable - The system doesn't always warn for similar situations (45%)
Too loud - Warning signals are disturbing me/passengers (38%)
Too often - The system warns too often (35%)
Too discreet - The warnings are difficult to detect (24%)
Too bright - Warning lights are blinding (14%)

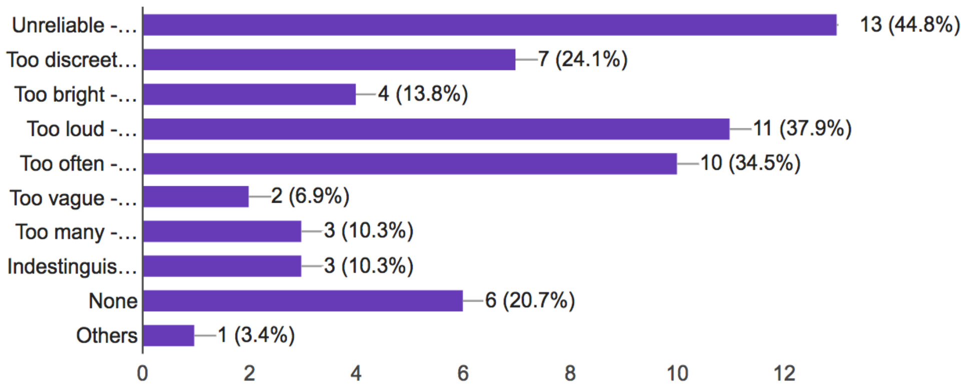


Figure 10: Reported experience of problems with warnings from Active safety systems among coach drivers

From the same survey it was found that less than 10% found the warnings hard to distinguish from each other, hard to understand or found that they were too many different kinds of warnings. 20% answered that they never had experienced any warnings from Active safety systems. The fact that 45% experienced the warning systems as being unreliable coupled with 24% experiencing missing warnings could rely in the systems feeling unsafe, and might be a contributing factors to them being turned off.

In addition to the data above, the most described scenario where active safety warning are negative or unnecessary is a false alarm scenario where there's no real risk. This is pictured to happen when driving on narrow lanes and swerving over lines by choice, triggering Lane departure warnings, or when passing parked cars or stationary objects, triggering Forward collision warnings. The coach drivers also expressed that more explanatory information regarding the nature of the warning is most likely redundant.

The two active safety systems being switched off the most are Lane departure warnings and Forward collision warnings. Due to the size of coaches and the focus on passenger comfort, coach drivers often cross side lines on certain roads and use the brakes gently in dense traffic. This enhances the passenger experience but at the same time risks triggering the previously mentioned active safety systems. When the systems trigger in these controlled situations, drivers often become annoyed and turn the systems off.

Appendices

I. Gantt-schedule

II. Questionnaire 1

III. Questionnaire 2

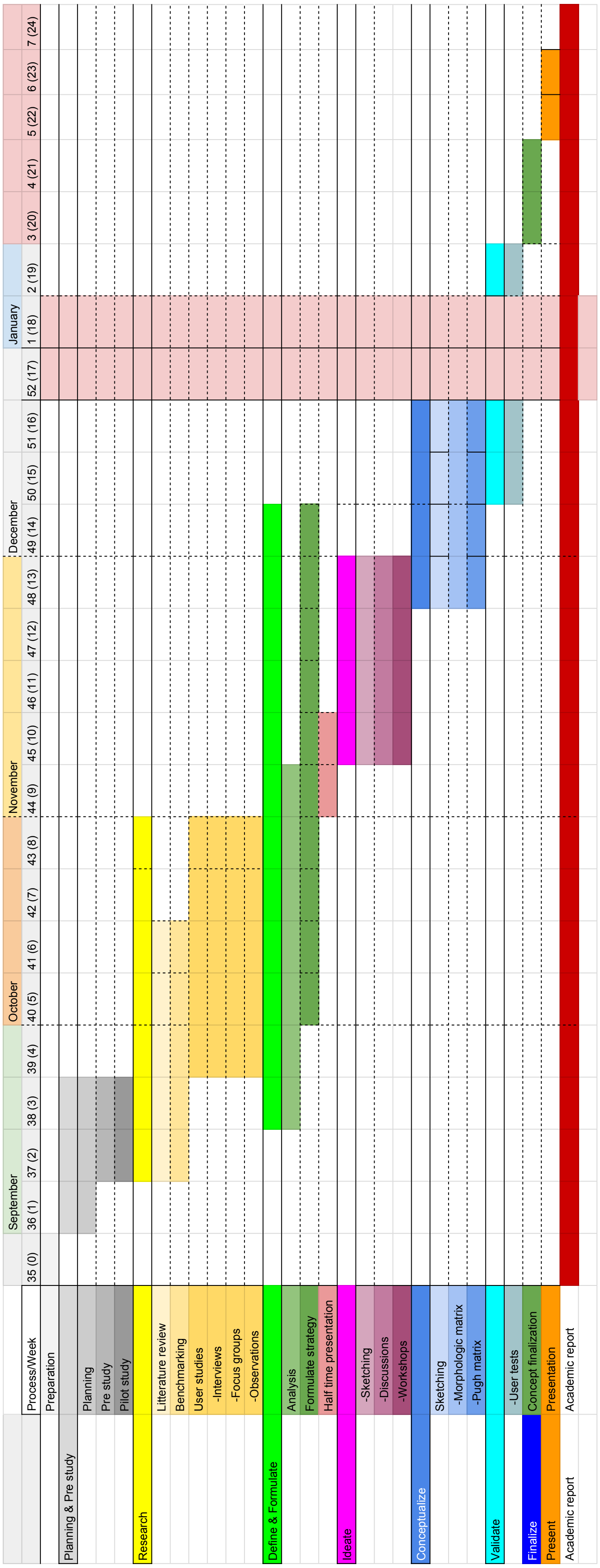
IV. Interview template

V. Strategy workshop template

VI. Coach driver workshop template

VII. Volvo workshop template

I. Gantt-schedule



II. Questionnaire 1

General questions

1. **1. What's your age?**
   Markera endast en oval.

   - 18-30
   - 30-40
   - 40-50
   - 50-60
   - 60-70

2. **2. How many years of experience do you have as a coach driver?**
   Markera endast en oval.

   - 0-5 years
   - 5-10 years
   - 10-20 years
   - more than 20 years

Concerning coach driving

3. **3. How do you feel when driving in a city environment?**
   Markera endast en oval.

	1	2	3	4	5	
Relaxed						Stressed

4. *Markera endast en oval.*

	1	2	3	4	5	
Attentive						Distracted

5. *Markera endast en oval.*

	1	2	3	4	5	
Stimulated						Bored

6. *Markera endast en oval.*

	1	2	3	4	5	
Excited	⬭	⬭	⬭	⬭	⬭	Calm

7. *Markera endast en oval.*

	1	2	3	4	5	
Alert	⬭	⬭	⬭	⬭	⬭	Tired

8. **4. How do you feel when driving on a highway or a country road?**
Markera endast en oval.

	1	2	3	4	5	
Relaxed	⬭	⬭	⬭	⬭	⬭	Stressed

9. *Markera endast en oval.*

	1	2	3	4	5	
Attentive	⬭	⬭	⬭	⬭	⬭	Distracted

10. *Markera endast en oval.*

	1	2	3	4	5	
Stimulated	⬭	⬭	⬭	⬭	⬭	Bored

11. *Markera endast en oval.*

	1	2	3	4	5	
Excited	⬭	⬭	⬭	⬭	⬭	Calm

12. *Markera endast en oval.*

	1	2	3	4	5	
Alert	⬭	⬭	⬭	⬭	⬭	Tired

13. **5. Are there any type of roads you find more demanding outside of city driving (eg. highways, country roads)**

14. **6. How often do you experience high mental workload or mental fatigue when driving a coach?**
Markera endast en oval.

- ( ) Always
- ( ) Often
- ( ) Seldom
- ( ) Never

15. **7. In what ways do high mental workload or mental fatigue affect you?**
Markera alla som gäller.

- [ ] It gets harder to notice sounds (e.g. passangers talking)
- [ ] It gets harder to visually notice things
- [ ] It gets harder to notice tactile input (e.g. vibrations)
- [ ] I react slower than usual
- [ ] It gets harder thinking clearly
- [ ] Others

16. **If others, what?**

....
....
....
....

17. **8. Are there any factors that often contribute to a high mental workload or mental fatigue?**
Markera alla som gäller.

- [ ] Rowdy/disturbing passengers
- [ ] Weather conditions
- [ ] Traffic conditions
- [ ] Conversating with passengers/on phone/with guides
- [ ] None
- [ ] Others

18. **If others, what?**

....
....
....
....

Concerning active safety systems

19. **9. What active safety systems have you experieced?**
Markera alla som gäller.

- [ ] Lane Departure Warnings
- [ ] Adaptive Cruice Control
- [ ] Lane Changing Warnings (Blind spot sensors)
- [ ] Forward Collision Warning
- [ ] None
- [ ] Others

20. **If others, which?**

....

If you answered none, please skip questions 10 to 15

21. **10. How do you feel when driving with active safety systems?**
Markera endast en oval.

	1	2	3	4	5	
Satisfied	◯	◯	◯	◯	◯	Unsatisfied

22. *Markera endast en oval.*

	1	2	3	4	5	
Calm	◯	◯	◯	◯	◯	Frustrated

23. *Markera endast en oval.*

	1	2	3	4	5	
Safe	◯	◯	◯	◯	◯	Unsafe

24. *Markera endast en oval.*

	1	2	3	4	5	
Insecure	◯	◯	◯	◯	◯	Confident

25. *Markera endast en oval.*

	1	2	3	4	5	
Attentive	◯	◯	◯	◯	◯	Distracted

26. *Markera endast en oval.*

	1	2	3	4	5	
Annoyed	( )	( )	( )	( )	( )	Helped

27. **11. Have you ever turned off an active safety system when driving a bus?**
Markera endast en oval.

( ) Yes
( ) No

28. **If yes, why? (and how often?)**

....

....

....

....

29. **12. What kind of warnings from active safety systems have you experienced?**
Markera alla som gäller.

- [ ] Auditory Signals
- [ ] Auditory Speech
- [ ] Warning message on display
- [ ] Seat Vibrations
- [ ] Seat Belt pulling
- [ ] Steering Wheel Vibrations
- [ ] Pedal Vibration
- [ ] Head up display
- [ ] Warning lights
- [ ] Others

30. **If others, what?**

....

31. **13. What do you think of the different warnings?**

Markera endast en oval per rad.

	Like	Dislike	No opinion
Auditory signals	◯	◯	◯
Auditory speech	◯	◯	◯
Warning message on display	◯	◯	◯
Seat vibration	◯	◯	◯
Seat belt pulling	◯	◯	◯
Steering wheel vibrations	◯	◯	◯
Pedal vibration	◯	◯	◯
Head up display	◯	◯	◯
Warning lights	◯	◯	◯
Others	◯	◯	◯

32. **14. Have you experience any of the following problems with warnings for active safety systems?**

Markera alla som gäller.

- ☐ Unreliable - The system doesn't always warn for similar situations.
- ☐ Too discreet - The warnings are hard to detect
- ☐ Too bright - Warning lights are blinding
- ☐ Too loud - Warning signals are disturbing me/passangers
- ☐ Too often - The systems warn too often
- ☐ Too vague - The warnings are hard to understand
- ☐ Too many - There are too many different kinds of warnings
- ☐ Indestinguishable - The different warnings are hard to distinguish from each other
- ☐ None
- ☐ Others

33. **If others, what?**

....

....

....

34. **15. Are there any situations where you have found active safety warnings unnecessary and negative?**

....

....

....

35. **16. For active safety systems. Do you want:**
Markera endast en oval.

- Consecutive warnings before a possible risk situation (resulting in a higher occurance of warnings, but of different degrees of urgency)
- Warnings only in high risk situations
- Not sure

36. **17. Do you have any other comments, thoughts or opinions about the subject, feel free to write them here!**

37. **18. If you're interested and willing to answer more questions regarding the subject, please enter your email address below.**

Thank you for your participation!

III. Questionnaire 2

Active Safety Systems in coaches

Hello! This is a questionnaire regarding active safety systems in coaches.

Active safety systems can be described as the systems that are meant to detect driving critical factors and warn the driver about them. Examples of active safety systems are "forward collision warnings" and "lane departure warnings".
Active safety systems do NOT include system warnings such as “check brakes”, “low level of …”.

The questions are related to key factors found in earlier research. Your participation is of great importance to us and the future development of active safety systems in coaches!

1. **1. What is your age?**
   Markera endast en oval.

   - 18-30
   - 30-40
   - 40-50
   - 50-60
   - 60-70

2. **2. How many years of experience do you have as a coach driver?**
   Markera endast en oval.

   - 0-5 years
   - 5-10 years
   - 10-20 years
   - More than 20 years

General questions regarding Active Safety Systems

3. **3. Choose the alternative that describes you the best**
   Markera endast en oval.

   - I am positive towards warnings from active safety systems
   - I am neutral towards warnings from active safety systems
   - I am sceptical towards warnings from active safety systems

4. **4. Choose the alternative that describes you the best**
   Markera endast en oval.

   - I always turn off active safety systems when I drive
   - I often turn off active safety systems when I drive
   - I seldom turn off active safety systems when I drive
   - I never turn off active safety systems when I drive

5. **5. When I turn off active safety systems it's generally because:**
Markera endast en oval.

- The warnings are too many and annoying
- The system isn't working as it should, it feels illogical and confusing
- I know from experience that they're not working properly in certain environments so I turn them off preemptively
- I don't need them
- I never turn them off
- Other

6. **If other, what?**

7. **6. Do you want active safety systems that:**
Markera endast en oval.

- Only alerts
- Alerts and intervenes (if problem persists)
- I don't want active safety systems
- No opinion

8. **7. Do you think that you are more prone to turning off active safety systems with intervening functions (such as automated braking or resistance when turning) than systems that only give you a warning?**
Markera endast en oval.

- Yes
- No
- No opinion

9. **8. Would you like to receive training/introduction when trying out a new active safety system for the first time?**
Markera endast en oval.

- Yes
- No
- No opinion

10. **9. Should active safety warnings be complemented with explanatory information? (e.g. in a display)**
Markera endast en oval.

- Yes
- No
- No opinion

11. **10. Do you think that different warnings can make use of the same stimuli (e.g. a certain vibration, light or sound) without too much confusion?**
Markera endast en oval.

- Yes
- No
- No opinion

12. **If no, would it be possible if there is a complementary differentiating stimuli? (e.g. a common warning sound or seat vibration, complemented with a unique light)**
Markera endast en oval.

- Yes
- No
- No opinion

Questions regarding Blind Spot Information System

Blind spot Information System is a system where sensors detect vehicles or objects located in the blind spots, and informs the driver with a warning.

13. **11. Do you have any experience of driving with a Blind Spot Information System (BLIS) in a car?**
Markera endast en oval.

- Yes
- No (or not sure)

14. **If yes, what did you think about the BLIS?**

15. **12. Do you feel that there is a need for BLIS in coaches?**
Markera endast en oval.

- Yes
- No
- No opinion

16. **13. Do you think there are certain changes that need to be done to a BLIS if implemented in coaches? Which?**

17. **14. When do you want to receive an indication (not necessarily obtrusive) from the BLIS?**
Markera endast en oval.

- (Alternative 1) Whenever someone/something is in my blind spot
- (Alternative 2) Only when I show initiativ to turn, i.e turning my blinkers on, and something is in my blind spot
- I don't want BLIS in my coach
- No opinion

18. **15. How critical do you concider a warning indicating Alternative 1 to be? (Whenever something is located in your blind spot):**
Markera endast en oval.

	1	2	3	4	
Not critical at all					Very critical

19. **16. Do you think that an indication of Alternative 1 should be given:**
Markera endast en oval.

- Visually (e.g. lights, symbols)
- Auditory (e.g buzzer, tonal signal)
- Haptic (e.g vibrations)
- Visually and Auditory
- Visually and Haptic
- Auditory and Haptic

20. **17. How critical do you consider a warning indicating Alternative 2 to be? (When I show intiative to turn and something is located in my blind spot)**
Markera endast en oval.

	1	2	3	4	
Not critical at all					Very critical

21. **18. Do you think that an indication of Alternative 2 should be given:**
Markera endast en oval.

- Visually
- Auditory
- Haptic
- Visually and Auditory
- Visually and Haptic
- Auditory and Haptic
- No opinion

22. **19. Where would you prefer to have a visual blind spot warning located?**
Markera endast en oval.

- A-pillars
- Mirrors
- Dashboard
- Head up display (lights on windshield)
- Other
- No opinion

23. **If other, where?**

24. **20. Do you have any other thoughts or reflection about the subjects touched upon in this questionnaire?**

Thank you for participating!

IV. Interview template

Introduktion

Hur länge har du kört buss?

Hur trivs du med att köra buss?

Hur mycket turistbuss/långdistansbuss har du kört?

Har du kört något annat tungt fordon förutom turist/långdistansbuss?

Hur upplever du ditt yrke?

Arbetsbörda

Medans du kör bussen, har du andra uppgifter att sköta?
- Vilka?
- Hur påverkar de dig?

Interagerar du med andra under färd? T.ex. passagerare och/eller “buss-central”
- På vilka sätt?
- Hur mycket?

Hur upplever du arbetsbördan medan du kör buss?
- Hög/låg?
- Jämn/ojämn?

Hur upplever din aktivitet/stimulans medan du kör buss?
- Passiv/aktiv?
- Fokuserad/ofokuserad?
- Uttråkad?

Hur upplever du det mentala arbetet du har medan du kör buss?
- Mycket/lite att hålla i huvudet?
- Blir det ibland väldigt lite eller väldigt mycket?
- Överbelastning?

Hur upplever du användadet av olika sinnen när du kör buss?
- Vilka?
- Hur mycket?
- Något mer än andra?

Förarhytt och interface

Hur upplever du långdistansbussars förarhytt?

Hur upplever du instrumentpanel, ratt och övriga gränssnitt?
- Användbara?
- Tydliga/otydliga?
- Hanterbara?

Hur upplever du informationen som förmedlas genom olika gränssnitt som mätare, ikoner, skärmar, lampor och ljud?

Upptäckbar?
Tolkningsbar? -Tydlig/otydlig?
Hanterbar mängd?
Välbalanserad?

Brukar gränssnitten vara anpassningsbara på något sätt?

Hur?
Positivt?
Om inte, skulle det vara önskvärt?

Signaler/Varningar

Vilka typer av signaler/varningar riktat till bussföraren har du stött på när du kört buss?

Hur upplever du de signaler/varningar som funnits i bussar du kört?
standardiserade?

relevant eller onödiga?
många/få?
fungerande?

Har det funnits aktiva säkerhetssystem i någon buss du kört (t.ex. Kollisionsvarning eller väglinjesupport, alltså system som upptäcker händelser/objekt runt bussen och meddelar föraren)?

Vilka?

Vad tycker du om dessa system?

Fungerande?
Logiska?
Upptäckbar?
Tolkningsbara?
Tydlig/otydliga?
Välbalanserad?
Irriterande?
Hjälpsamma?
Pålitliga?

Hur tror du passagerare upplever signaler/varningar riktade till busschafbören?

Olyckor

Ur trafiksäkerhetssynpunkt, hur upplever du tryggheten när du kör buss?

Hur upplever du risken för incidenter/olyckor?

Har du varit med om några incidenter/olyckor? (Kanske påpeka att vi inte försöker sätta ditt någon och att svaren behandlas anonymt)

Vad?
Orsak?

Vad upplever du kan vara vanliga orsaker till incidenter/olyckor?

Vad tror du kan göras för att undvika dessa incidenter/olyckor?

Hur ser du på att få information från system i bussen för att undvika incidenter/olyckor?
Bra/Dåligt?
Rådgivande? Ofta?
Alarmerande? Akut?

Skillnader mellan buss och andra fordon

Vad upplever du är stora skillnader mellan att köra långdistansbuss och bil?
Arbetsbörda?
Risker?
Förarhytt och gränsnitt?
Signaler/Varningar?

(OM CITYBUSS)
Vad upplever du är stora skillnader mellan att köra långdistansbuss och citybuss?
Arbetsbörda?
Risker?
Förarhytt och gränsnitt?
Signaler/Varningar?

(OM LASTBIL)
Vad upplever du är stora skillnader mellan att köra långdistansbuss och lastbil?
Arbetsbörda?
Risker?
Förarhytt och gränsnitt?
Signaler/Varningar?

V. Strategy workshop template

Workshop 19/10/2016

Moderatorer: Maksim Hansén Goobar, Jonas Isaksson
Deltagare: Erik Aremyr & Martin Jönsson, Cornelia Jönsson
Plats: TD-Gul/Grön
Material: Papper, pennor, lappar med diskussionsfrågor, bilder av strategier,

Part 1

- Presentera oss
- Presentera vårt uppdrag kort:
    - Next gen HMI for Active Safety Warnings: skapa en strategi som ska underlätta Volvos arbete med kommande HMIn. Tillämpa strategin på ett kommande system.
- Diskutera frågor:
    - Vad är en (bra (design)) strategi?
    - Vad vill man ha ut av en produkt(HMI)utvecklingsstrategi?
    - På vilka olika sätt kan en produkt(HMI)utvecklingsstrategi hjälpa en att få ut dessa "saker"?
- Släng in bilder på strategier, forsätt diskussion

Part 2

- Berätta lite om vad det finns för tips/definitioner för strategier:
    - Besvara: Var är vi idag? Vart vill vi vara? Hur tar vi oss dit?
    - Skapa ett övergripande tillvägagångssätt för hur de hinder och utmaningar som identifierats i diagnosen ska lösas.
    - Utveckling av insikt och diagnos, som definierar den aktuella utmaningen, samtidigt som det bidrar till att förenkla den komplexitet som vi normalt befinner oss i.
    - Utveckling av en uppsättning sammanhängande och samordnade aktiviteter som bygger på varandra och ska åstadkomma det som behöver göras enligt den diagnos och "guiding policy" som upprättats.
    - Premeditation. Anticipation. Design Of Coordinated Action.
- Presentera vad vi har idag.
    - Vilken typ av information vi har samlat - vilken typ av källor:
        - Implikationer från användare
        - Implikationer från litteratur om tester av specifika system
        - Information från litteratur om mänskliga förutsättningar
        - Information från litteratur om kontext
        - Olika uppsättningar av guidelines för varningar
- Beskriva hur Volvo bussar är och jobbar idag.
- Diskutera frågor:
    - Hur kan vi utforma en strategi utifrån dessa komponenter?
        - Som kan hjälpa oss i att utveckla LCS
        - Vilka olika "saker" vill man ha ut av en produkt(HMI)utvecklingsstrategi?
        - På vilka olika sätt kan en produkt(HMI)utvecklingsstrategi hjälpa en att få ut dessa "saker"?
    - Hur kan strategin visualiseras för att vara lättillgänglig (och snygg)?
    - Dessa komponenter har Volvo önskat som en del av strategin? Hur?
        - Framtida system (?)
        - Scenarion
        - Konkurrenter

VI. Coach driver workshop template

Planering - Workshop med Bussförare

Mål för LCS-utveckling: Få en bättre förståelse för problem kring blindspot, få input för till designen av användandet, få input för förkroppsligandet av användandet.

Mål för strategin: utvärdera innehåll, viktiga frågor som missats?, problem i strukturen av stegen.

Material som behövs

Kaffe, Kakor, Mjölk, Vatten, Té
Pennor, Papper, Post-Its,
Interiör "skisser", Scenario-bilder (toppvy),
Bilder av exempel på WDs (lampa i a-stolpe, lampa i dashboard, HUD, Skärm, vibrerande ratt, vibrerande stol, Ljudikon, Talbubbla, Noter)
Whiteboard tavla med bussinteriör
Bussväg + kapacoach

Upplägg

- Presentera oss och kort om projektet: strategi för hur aktiva säkerhets/varningssystem ska utformas för att passa i turistbussar. Vi vill främst bidra med mer användarförståelse och få Volvo att sätta lite mindre fokus på tekniken.
- Fråga om vi får spela in!
- Låt deltagarna presentera sig.
- Berätta lite om upplägget på workshopen, att den har några olika delar, att fokus ligger på varningssystem och blindspot-problematik. Visa en agenda.

Öppen diskussion? Eller skriva på lappar, berätta sina tankar och sen diskutera.

Del 0. Bakgrund (presentation)

Namn?
Erfarenhet av att köra buss, främst "turistbussar"?
Erfarenhet av Active Safety? (Vi återkopplar till detta)

Del 1. Kopplad till steg 1 - Utforska döda vinkeln-problem 20 min

(Håll högt tempo, led diskussionen vidare med frågorna)
Finns det problem kopplade till döda vinkeln i turistbussar?
Hur kan problemen yttra sig?
Typiska scenarier?
Miljö (stad, landsväg, motorväg), inblandade fordon (bil, motorcykel, cykel?), körsituationer (filbyten, sväng från stillastående)?
Andra faktorer som bidrar? Utöver att fordonet inte syntes? (sikt, trafik, distraktioner)
Tror ni att ett varningssystem kan bidra till att minska problemet? (hmm, kort? Avbryt följande diskussion)

Del 2. Kopplad till steg 2 20 min

Om det ska finnas ett varningssystem hur ska det "fungera",
försök att inte tänka på hur varningen ska se ut: lampa, ljud, osv,
utan mer när den ska göra något och vad den kan hjälpa till med.

Till hjälp har vi detta scenario (visa scenario toppvy)
en bil befinner sig i döda vinkeln till höger om bussen, samtidigt som bussen snart ska byta till höger fil för en kommande avfart.

- Vad ska utlösa varningen? När och vad är det föraren ska bli uppmärksammad på.
- Vi har dessa tre förslag, och vill höra tankar kring dem.
- Någon typ av indikering så fort ett fordon hamnat i döda vinkeln
- En indikering när blinkers slås på och ett fordon befinner sig i döda vinkeln
- En indikering när en sväng påbörjas och ett fordon befinner sig i döda vinkeln
- Nått mer? Ska alla inkluderas?
- Vi ser det som att dessa tre motsvarar en ökande kritiskhet.
- Är det generellt sett bra med flera steg, från låg kritiskhet till hög? Eller är det bättre med färre varningar som bara ger info vid hög kritiskhet?
- Hur går en förares tankar och handlingar när det kommer en varning?
- Vad måste framgå av varningen?
- Behövs feedback/återkoppling "efter" en varning?
- Skulle det vara en fördel att kunna göra inställningar kring funktionerna i varningen?

Del 3. Kopplad till steg 3 20 min

Vi tänkte nu undersöka lite hur själva varningen kan vara utformad till det yttre. Det berör bland annat vilka sinnen som kan användas och vart den kan vara placerad.

- Hur ser ni på olika typer av varningar kopplade till olika sinnen: Vibrationer, ljus, ljud.
  - Fördelar/Nackdelar?
  - Bra att använda flera sinnen?
- Hur kan det det som vi tidigare pratade (varning av olika typ för döda vinkeln) kommuniceras genom en varningen på ett bra sätt?
  - Hur tror ni att kritiskheten ska signaleras?
  - Hur tror ni att det kan bli tydligt att det gäller just det problemet?
- Vart kan en varning sitta för att fungera bra? Vart vill ni ha fokus i en sådan situation?
- Har ni några tankar om problem som kan uppstå kring användandet?
- Vad kan göras för att föraren inte upplever att stänga av varningen är lösningen?
- Hur ser ni på risker och konsekvenser: Missförstånd? Distraktion? Irritation?
- Skulle ni vilja anpassa varningarna efter era önskemål?
- Vad skulle ni då vilja anpassa?

Länkar till lösningar

https://www.youtube.com/watch?v=2-eBUZP0FJ0

https://www.youtube.com/watch?v=p4eBkwUpQys

https://www.youtube.com/watch?v=mSM3JiazWxE

VII. Volvo workshop template

Planering Workshop m. Volvo

När:
Vecka 3, 18/1 kl 10.00-12.00 2h.

Mål för workshop:
Få volvo med på bussen.
Introducera strategi mer hands-on
Testa om mindre ändringar/förtydlingar kan underlätta användning av strategi
Eventuellt få lite feedback på LCS-koncept

Upplägg:
Fokus på nått steg, eller en del av ett steg
Vi har gjort förarbete och presenterar en del info
Vi väljer vissa frågor som vi diskuterar/idégenererar kring
Testa användbarheten hos ACIA

Material:
Pappersvägar + bilar, hyttlayout (gärna A3), ev. bilder av modaliteter etc,
Filer offline: Framework..? Process..? ACIA…?

Steg 1

Blir typ introduktion, vi berättar om "problemet"
Presentera "mallen" för stegen, att varje steg innehåller 4 saker.

Vi kan presentera svar på stegets frågor genom sånt vi hittat (t.ex från workshop):

- Döda vinkeln
  - Stort problem! Finns framåt, bakåt, bakom, och alla är besvärliga.
- Skiljer sig mycket mellan olika kontexter: Stad/Motorväg
- Olika körscenarion i dessa kontexter
  - Omkörningar på motorväg ansågs vara en av de farliga.
  - Körning i trånga utrymmen ansågs vara vanligt förekommande.
- Varför/hur sker olyckor med BS
  - De monitorar speglar etc, men bli störda, eller kan inte se en viss sak.
- Presentera nån typ av effekt/systemmål (ska de ha inslag av "långtidseffekter"?)
  - "System ska fungera i kontext X för att kunna lösa körscenarion A,B,C. Inom dessa ramar ska systemet inte orsaka (användnings)faktorer Y, Z i för stor grad (då det leder till att systemet ej är önskvärt)."
- (Presentera centrala utvärderingsaspekter?)

Steg 2

- Presentera main function redan utsatt (Informera föraren om objekt i blindspot på motorväg/större vägar)
- Utforska scenariot genom att försöka dela upp det i steg/delscenarion
  - Utforska hur kritiska de olika stegen/delscenariona är
  - Utforska hur dessa steg/delscenarion kan överlappa med ickeriskfulla händelser?
  - Utforska hur ofta de sker (med ickeriskfulla händelser beaktade)?
- Utforska delfunktioner och stödfunktioner (eventuellt)
- Utforska "funktioner, tasks, messages" i förhållande till de olika identifierade stegen.
- Sätt deliverables
- (Utvärdera)

Steg 3

- Utifrån steg/delscenarion från steg 2: kolla hur varje delscenarios delfunktioner/kommunikation kan få en lämplig fysisk form.
  - Välj några av dem att fokusera på (om vi definierat flera)?
  - Använd ACIA…?
- Utforska hur modalitet, position, teknisk princip kan samverka för att motsvara funktionerna som bestämts för de olika delscenarionarna.
- Vi agerar framework
- (Utvärdera)

LCS-frågor (som vi lite skulle vilja ha svar på)

Lampor i speglar en möjlighet?

Allmänt

- Var vi är och vad vi gör just nu och fram till slutpresentation.
  - Vi håller på att knyta ihop säcken.
  - Visualisera
  - Skriva rapport (eftersom det är förutsättning för att få presentera)
  - Fortsätta fylla frameworket med infon vi hittat
  - Vi kommer inte tillföra nya saker eller göra stora ändringar
- Slutpresentation
  - Satt till tisdagen den 21/2 13.00.

Delar av designprocessen att använda:

STEP 2

Exploration

Function

- What is the main function of the active safety warning?
- Can the risk scenario be divided into stages?
- Does the criticality and risk differ in the different stages?
- Should there be any subfunctions/side functions?
- Are the different functions divided into different warning stages?

Interaction and tasks

- What actions should the user perform in order to solve the situation in the different stages?
- Does the driver need to direct attention anywhere to solve the problem?
- What actions should the machine perform in order to help the user solve the situation in the different stages?
- What does the interaction procedure look like?
- What problems can arise in the interaction procedure?
- What should be communicated in order to make the interaction procedure possible?

Misc

- How does the user perceive the situation?
- What possible consequences could occur if a warning is missed?
- What possible consequences could occur if a warning is false?
- Are there any similar warning systems in the coach?
- Should the user be able to control the system in any ways?
- What effect does a warning have on other stakeholders (passengers and other road users)?

Deliverables

Function

- Main function
- Subfunctions
- Extra functions
- Supportive functions

Warning stages

- Number of stages
- Function for each stage
- Message in each stage

Warning characteristics

- Warning type (cautionary, imminent)
- Criticality
- Prioritization
- Desired direction of attention
- Desired driver action

User control

- Functionality
- Availability of user control

Contradictory design aspects to be considered

STEP 3

Exploration

Similar systems and integration

- In what ways will the system be integrated with current systems? Combine devices, prioritize warnings?
- Are there embodiments of similar systems in other applications that should be considered? (Experience, inspiration)

Warnings (for each warning stage)

- Which senses can and are suitable to use?
- Should multiple senses be used?
- Which positions can and are suitable to use?
- What technical principle can and are suitable to use?
- Can multiple tasks be combined in the same warning device

User control

- Should specific warning devices be possible to control?
- Which positions can and are suitable to use?
- What technical principle can and are suitable to use?
- Should more variables be controlled in same location?
- How will the control be made understandable?

Deliverables

Number of warning devices (For each warning stage)

Warning device properties (For all Warning devices in each warning stage)
- Tasks
- Modality + type
- Position

User control
- Position
- Type of input device
- “Explanatory info”

Conflicting design aspects to be considered

Phone: + 46 (0)31 772 10 00
Web: www.tekniskdesign.se