CHALMERS
UNIVERSITY OF TECHNOLOGY

USER ACCEPTANCE OF SPEED ASSISTANCE SYSTEMS

Design guidelines for in-vehicle nudges to influence speeding behaviour

M.Sc. Thesis in Industrial Design Engineering

EVELINA EKHOLM

JOANNA GARP

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2020

Department of Industrial and Materials Science
Division of Design & Human Factors

Thesis for the Degree of Master of Science

User acceptance of speed assistance systems

Design guidelines for in-vehicle nudges to influence speeding behaviour.

EVELINA EKHOLM
JOANNA GARP

SUPERVISOR: LARS-OLA BLIGÅRD
EXAMINER: LARS-OLA BLIGÅRD

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2020

Department of Industrial and Materials Science
Division of Design & Human Factors

User acceptance of speed assistance systems
Design guidelines for in-vehicle nudges to influence speeding behaviour.
Master of Science Thesis within Industrial Design Engineering

Chalmers University of Technology
SE-41296 Gothenburg. Sweden
Phone +46(0) 31-772 1000

Cover Photo: Joanna Garp
Printed by Chalmers Digitaltryck

Preface

This master thesis was carried out during the spring semester of 2020 at Chalmers University of Technology, at the Department of Design and Human Factors. The thesis covered 30 ECTS credits and was conducted in cooperation with Autoliv, at the department of Autoliv Research's Human Factors group.

The thesis was written by Joanna Garp and Evelina Ekholm, two students from the master's programme Industrial Design Engineering.

Acknowledgements

We would like to commence this report by expressing our gratitude towards the people that have been involved and contributed to the realisation of the project and its results.

Firstly, we would like to acknowledge all participants in our user studies for taking the time to contribute to the project. Thank you all for your engagement and generous sharing of thoughts and experiences that comprised the core of our results.

Furthermore, we would like to show gratitude to the people involved that have guided and supported us with their expertise. A special thank you to our outstanding supervisor and examiner Lars-Ola Bligård, for always being available and supporting us in the process. We want to thank Autoliv that initiated and gave us the opportunity to execute this project as well as showing a true interest for its results. From the company, we especially want to thank our supervisor Tejas Chandran and Johan Karlsson for all the weekly meetings, discussions and last-minute requests that brought the project forward.

We also want to show our appreciation for being welcomed to the department of Autoliv Research and invited to participate in workshops and team building. We are further grateful for all help from the employees at the department, assisting us with the set-up of the research vehicle used in one of our user studies, and for providing us with knowledge within your respective fields. Last but not least, we would like to thank Mikael Enänger for your help with our user studies and for giving us such a warm welcome. Our days at the office would not have been the same without your positive spirit.

Finally, we want to show our gratitude towards family and friends for support and understanding during ups and downs throughout the project. A special thanks go to our partners for sharing the home office and having patience with all the early morning and late-night meetings.

Abstract

Speed is a contributor to traffic fatalities and a critical factor in addressing traffic safety. As from 2022, all newly produced vehicles in Europe are required to include Intelligent Speed Assistance (ISA). A key element to efficiently address speeding behaviour is the acceptance of the intervention or strategy employed, which is a concern regarding existing ISA solutions. This master thesis was initiated to investigate how in-vehicle HMI nudges could be applied to an Intelligent Speed Assistance system and what factors in the interaction that should be considered for user acceptance. The project consisted of three phases of analysis, concept development and evaluation that iteratively derived problems and user needs for the interaction with a speed assistance system. Information was gathered through literature studies and qualitative user research.

The first phase was concluded in a contextual framework defining the problem and implications of a constantly changing use context where the motivation to comply with the speed limits depends on several critical factors. In the second phase, the contextual framework was used for the concept development in two iterations. This resulted in four final concepts with a common foundation for an ISA system combined with four different spark nudges, aiming to motivate drivers to comply with the speed limits. The four concepts were evaluated with drivers to investigate needs for user acceptance further.

The project deliverable was a set of design guidelines with focus on user acceptance for speed assistance systems. The guidelines were divided into categories that address intensity, tolerance, feedback, control and incentives. The categories were found essential for the interaction with a speed assistance system to be accepted and credible among drivers. The project concluded that the HMI (Human-Machine Interface) of a speed assistance system should have an intensity and tolerance that corresponds to drivers' interpretation of the violation. The value of the feedback provided by the system was also of importance, where the feedback should support the driver in the driving task. It was further found critical that the driver experiences control over the system as it should not act to counteract the driver. It was lastly determined that a system could benefit from being complemented with HMI that utilise existing motivation or create new incentives, to increase the acceptance of an ISA system.

Nomenclature

VRU – Vulnerable Road User

RU – Road User

HUD – Heads-Up Display

ISA – Intelligent Speed Assistance

HMI – Human-Machine Interface

TABLE OF CONTENT

1

INTRODUCTION

The following chapter introduces the project first by providing a background to the studied topic of speeding. The background is followed by a section defining the project scope through the aim, objectives and limitations. Furthermore, a section briefly describing the collaborating company for the project is included. The introduction is finalised with a section describing the structure of this report.

1.1 BACKGROUND

1.35 million lives are lost in traffic every year, and 20 up to 50 million people get injured as a result of road traffic crashes (WHO, 2018). The EU has adapted to Vision Zero, which is a multinational road traffic safety project with the overall goal to eliminate injuries and death in Europe. Vision Zero covers several aspects of traffic safety such as driver behaviours, infrastructure and vehicles by emphasising that several stakeholders share the responsibility for a safe traffic environment. The importance of traffic safety has made it a part of the United Nations Sustainable Development Goals. Goal target 3.6 states "By 2020, halve the number of global deaths and injuries from road traffic accidents." (United Nations, 2015, p. 21).

According to ETSC (2019), speed is a contributor to around 30% of fatal crashes in the EU, which makes it a critical factor in addressing traffic safety. The possibility of being able to react in time decreases at a higher speed. Hence the risk of being involved in a crash also increases. Speed has a significant relationship to the severity of the car crash and potential injuries (SafetyNet, 2009).

Bernard, Risser and Krems (2011) state that the development of new vehicle technology has provided new opportunities to aid traffic safety by supporting the driver in the driving task. Examples of such systems are adaptive cruise control and systems alerting drivers when falling asleep (Barnard et al., 2011). In March 2019, the European Parliament approved a regulation to improve traffic safety by requiring several safety features in newly produced vehicles as from the year 2022. ISA is one of the advanced safety systems that will become compulsory for all newly produced vehicles (Nadkarni, 2019). ISA is a collective term for systems which aim to support the driver in keeping the speed limit according to three types of categories: informative, supportive and intervening. Several studies indicate that ISA systems have the potential to improve safety performance (EC, 2016a; Spyropoulou, Karlaftis & Reed, 2014; Reagan, Bliss, Van Houten & Hilton, 2012, Harms et al., 2007) and the effects of ISA have shown to increase with the level of intrusion (EC, 2016a; Spyropoulou et al., 2014). However, concerns about the warning and intervening ISA being too aggressive and causing frustration amongst driver have emerged (Horberry, Regan, & Stevens, 2014; Spyropoulou et al., 2014; Garvill, Marell, & Westin, 2003).

Autoliv is the world's largest automotive safety supplier and the initiator of this thesis who develops safety solutions in line with both the UN Sustainable Development Goals and Vision Zero. (Autoliv, 2020). As a result of the UN Sustainable Development Goals and Vision Zero, together with ISA becoming a regulation, the market for safety systems addressing the problem of speeding is continuously growing. Autoliv is working with Nudging to address the concerns of ISA systems being too aggressive. Thaler and Sunstein (2009, p. 6) introduced the notion of nudging in 2008 and defined it as using the choice architecture to alter people's behaviour without forbidding any options. Autoliv has developed alternative means to address speeding through innovative in-vehicle human-machine interface (HMI) based nudges, including the use of LEDs on the steering wheel and seat-belt-based haptic feedback.

1.2 PROJECT SCOPE

This section defines the project scope. The first section describes the desired outcome of the project through the aim. The following section concludes how to reach the aim through the objectives, while the limitations section defines boundaries for the project.

1.2.1 AIM

The aim is to contribute to a safer traffic environment by investigating how in-vehicle HMI nudges could be applied to an Intelligent Speed Assistance system and what factors in the interaction that should be considered for user acceptance.

1.2.2 OBJECTIVES

- Conclude a set of design guidelines based on a qualitative understanding of user needs, to guide the development of ISA systems with a focus on user acceptance.
    - Identify how personality characteristics influence user acceptance through user personas.
    - Identify crucial factors for drivers' speed choice through driving scenarios.
- Conclude concepts inspired by the principles of nudging, describing the essential interaction as a starting point for Autoliv in the further development of ISA systems.

1.2.3 LIMITATIONS

Geographical constraints limit the study to the Swedish traffic system, only including private drivers originating in Sweden. The results of this study should only be used in areas with similar driving culture and traffic system.

The design guidelines only provide recommendations concerning user acceptance. Legal requirements are out of the scope for this project but must be considered when using the final guidelines for future development.

1.3 COLLABORATION COMPANY

The initiator and collaborating company for this project is Autoliv and more specifically, the department of Autoliv Research's Human Factors group. Autoliv's core vision is *"Saving More Lives*". Autoliv, one of the world's largest automotive safety suppliers, continuously work to improve traffic safety. A part of this work is to design safety systems which consider both driving context and driver state.

1.4 REPORT STRUCTURE

The structure of this report starts with the introduction, which introduces the subject and the project scope. After the introduction, the background of the theories used is presented in the related theory (Chapter 2). The methods in the project are detailed (Chapter 3) followed by a description of the project process (Chapter 4).

Chapter 5-10 follows the process of this project, starting with a description of the analysis phase, concluding the first and second empirical study according to the execution and results (Chapter 5). The findings from the analysis phase are compiled in the contextual framework highlighting important factors to consider in the design process (Chapter 6). The concept development is presented through the third and fourth empirical study (Chapter 7) followed by a description of the final concepts (Chapter 8). The concept evaluation is described through the fifth empirical study (Chapter 9) and the final design guidelines concludes the results of this project (Chapter 10).

The reflection of activities and process of the project is presented in the discussion (Chapter 11). This report is finalised with a conclusion of the results (Chapter 12).

2

RELATED THEORY

This chapter presents the literature used in this project to gain a greater understanding of the studied topic and guide the development of concepts and design guidelines. The related theory first describes the studied traffic context followed by a section which presents existing countermeasures for speeding. The chapter also includes a section which in detail describe factors related to the driver, which are essential for user emphasis. This is followed by a section summarising existing guidelines and standards for in-vehicle HMI design. The chapter ends with a section which outlines the framework for nudging used in the project.

2.1 TRAFFIC CONTEXT

When designing a system to counteract speeding, it is important to understand the context in which the system will be used. To be able to define the contextual factors defining the system, there needs to be a general understanding of the current traffic context. This section briefly presents how speeding differentiates in the EU and Sweden and the impacts in terms of fatalities. The section also defines the term speeding through laws and regulations.

2.1.1 SPEEDING STATISTICS

Studies show that around 50% of drivers exceed the speed limit (WHO, 2017; Yannis, Louca, Vardaki, & Kanellaidis, 2013). ETSC (2019) distinguishes three different road characteristics: urban roads, rural roads and motorways. Statistics show that the frequency of speeding violations is different for different road types and countries. According to ETSC (2019), as much as 35-75% of European drivers drive faster than the speed limit in urban areas. The same report shows that speeding frequency at rural roads varies from 9%-63% in Europe while the numbers for motorways is 23-59%.

Sweden is, during the time of this project, one of the global leaders in traffic safety, with 2.5 deaths per 100,000 inhabitants (ETSC, 2019), described as a result of continuous progress to achieve a safer traffic environment by adopting Vision Zero. Despite several years of progress in reducing the number of road traffic fatalities, statistics from 2018 shows an increase with 324 deaths, to 252 in 2017 (Transportstyrelsen, 2020b) and 2195 people got severe injuries in traffic crashes 2018 (Trafikverket, 2019). The Swedish Transport Administration considers speed compliance having the most potential in reducing the fatalities in traffic. According to ETSC (2019), 35% of Swedish drivers drive faster than the speed limit in urban areas. Speeding frequency at rural roads varies from 55%-58% and 23-59% for motorways.

2.1.2 SPEEDING DEFINITION

WHO (2017) distinguishes two types of speed violations; excessive and inappropriate. Excessive speed is when exceeding the posted speed limit while inappropriate speed is when the speed is unsuitable for contextual factors such as weather or presence of VRU. For this report, speeding will refer to the WHO definition of excessive speed, and violations refer to when the driver exceeds the posted speed limit.

In Sweden, the standard regulation for speed limits is defined based on contextual factors (Trafikverket, 2019). The Swedish road administration decides on the speed limit from a traffic safety perspective with regards to the road characteristics, risk and previous record of accidents as well as the distance to residential areas. Other factors are also considered, such as noise levels and pollution (Trafikverket, 2019). The maximum speed limit for urban areas is 50 km/h. For rural roads, the maximum speed limit is set to 110 km/h while at motorways, the maximum speed limit is 120 km/h (WHO, 2018, p. 241). Violation of excessive speeds is considered an offence under Chapter 2, Section 2 and Chapter 14, Section 3 of the Swedish Road Traffic Ordinance (1998:1276) and the penalty depends on the severity of the violation, meaning the amount above the speed limit in relation to eventual aggravating contextual factors in the driving situation. Table 2:1 showcase the penalty for speeding violations in terms of being fined. If law enforcement considers the violation severe, they are authorised to withdraw the driving license according to Chapter 3 section 3 of the Swedish Road Traffic Ordinance (1998:488).

TABLE 2.1 FINE PENALTIES FOR SPEEDING VIOLATIONS ADAPTED FROM ÅKLAGARMYNDIGHETEN (N.D.).

	Penalty when the speed limit is	
Violation in km/h	50 km/h or lower	Higher than 50 km/h
1-10	2000	1500
11-15	2400	2000
16-20	2800	2400
21-25	3200	2800
26-30	3600	3200
31-35	4000	3600
36-	4000	4000

2.2 SPEEDING COUNTERMEASURES

According to ETSC (2019), several integrated measures are needed for road users to take on safe speeds. In order to identify what aspects of a countermeasure that potentially can contribute to efficiency and driver acceptance, this section presents previous literature of countermeasures to be used in analysing user needs. The section provides this knowledge through a section describing infrastructural measures and the effect of enforcement measures. Furthermore, the section identifies available ISA systems as well as the potential of introducing coaching and nudging to impact speeding behaviour.

2.2.1 INFRASTRUCTURE

Wijers (2017) states that infrastructure is used as a speed reduction method. He describes that Infrastructure measures are commonly used in high-risk areas, and examples of infrastructure measures are speed bumps, raised platforms, gateways, roundabouts, narrowing of the road and optical illusions by planting trees alongside the road to increase the experience of speed. It is further described that speed bumps and raised platforms are relevant to compliance with 30 km/h speed residential limits. Gateway infrastructure treatments are used when there is a transition from a higher speed road to a built-up area, residential area or school zones and roundabouts are used to slow traffic intersections (Wijers, 2017). It can be assumed that infrastructural measures, in general, are successful in reducing speeding as most targets how the driver need to manoeuvre the vehicle, furthermore, infrastructure targets all drivers which can be expected to impact acceptance.

2.2.2 ENFORCEMENT

One approach to deal with speeding is through enforcement measures, which approaches the problem of speeding by penalising drivers exceeding the speed previously described in section 2.1.2. The effects go beyond driver who gets caught, by simultaneously targeting drivers who see and hear of others getting caught (ETSC, 2019). Enforcement can also be assumed to aid in creating positive norms and sense of responsibility among drivers. However, the development of this effect is argued to require proper and strict enforcement on controlling of speed (Javid & Al Roushdi, 2019).

There are both manual and automated enforcement countermeasures, according to Wijers (2017). Manual enforcement, by police officers or other authorised officials, is done directly after a violation has been registered. The method has been found useful for speeding, yet inefficient due to the high labour content of such operation (Wijers, 2017). Wijers find automated camera enforcement more efficient than manual, as there is no human interference, and the corrective means will be sent directly to the vehicle owner's home address. However, an automated system requires a suitable legal regime, current vehicle registration and a well-coordinated and managed government apparatus (Wijers, 2017).

Considerable efforts have been put on speed limit enforcement in the EU. However, the perception of getting caught speeding remains low among drivers (ETSC, 2019), and it can be assumed that the effects only impact speeding when there is a perceived chance of getting caught. An ESRA survey shows that 38% of the respondents perceive there is a big chance of getting caught by the police for a speeding offence (Buttler, 2016). Additionally, previous experiences of penalties have been found to impact speeding behaviour. Truelove et al. (2017) found that drivers who have received a speeding ticket were more prone to speeding, which can question the efficiency of enforcement countermeasures in changing driver behaviour. However, ETSC (2019) argues that enforcement will be essential until the problem can be solved by other measures, such as infrastructural measures and in-vehicle solutions that help drivers to comply with speed limits.

2.2.3 INTELLIGENT SPEED ASSISTANCE

An in-vehicle approach to reduce speeding is through ISA, a type of advanced driver assistance system (ADAS). ADAS aims to support drivers during the driving task with the support of safe HMI, where ISA systems focus on supporting drivers' speed choices (European Comission, 2013). ISA systems use sign-recognition video cameras or GPS-linked speed limit databases to gather information of posted speed limits in the current area (EC, 2016a).

ISA can be found in, for example, Volvo-branded cars which display a speed indicator sign in the instrument cluster similar to the illustration in figure 2:1. The speed limit indicator starts flashing when the driver exceeds the speed limit. The driver can adjust the HMI and add an audio warning, change the tolerances for the flashing of the speed limit sign or turn the feature off (Volvo Cars, 2020). The same features can be found in several car brands such as Fiat, Ford, Toyota, amongst others which are listed in a news article by ETSC (2017). In the same article, more intrusive ISA is described through the speed limiting system implemented in the Ford Galaxy where the car limits the engine power when reaching the speed limit. The driver must actively disable the feature to be able to accelerate over the defined speed limit. The same feature can be found in other car brands, for example, Honda, Renault, Volvo (ETSC, 2017).

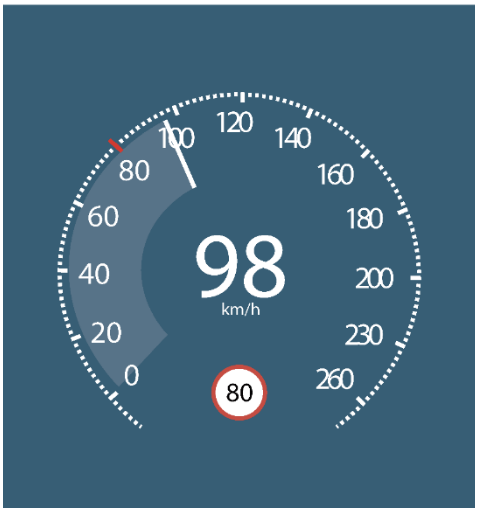


FIGURE 2:1 ILLUSTRATION OF INFORMATIVE ISA IN VOLVO CARS.

Three different HMI functional modalities within ISA are informative, warning and intervening (Spyropoulou, Karlaftis & Reed, 2014). Several studies indicate that ISA systems, in general, result in speed reduction effects (EC, 2016a; Spyropoulou et al., 2014, Reagan, Bliss, Van Houten & Hilton, 2012, Harms et al., 2007). The effects increase with the level of intrusion, and the intervening functionality modality has shown the best effect on reduced speeding behaviour while the informative has shown the least, or in some cases no effect. (EC, 2016a; Spyropoulou et al., 2014)

INFORMATIVE

Informative ISA systems present information about current speed during the drive. Effects of the Informative ISA appears to result in less significant corrective behaviour towards speeding (Spyropoulou, Karlaftis & Reed, 2014). It has however, been found useful when drivers are not aware of exceeding the speed limit (Reagan et al., 2012; Spyropoulou et al., 2014).

A study by Harms et al. (2007) investigated the relative impact of speeding based on two studied factors: ISA-information and driver motivation. Informative ISA and an economic incentive, based on discounted insurance, were used during the study. Two groups drove with the informative ISA switched-off. One group received the discount regardless of improvement of their speeding behaviour. This group did not reduce their speeding behaviour. The other group received the discount depending on their speeding behaviour. Speeding for this group was reduced by a small amount. Two groups drove with the ISA switched on, and one of the groups also received the incentive system with a discount for driving safe. The result for both groups showed substantial effects, with or without the incentive system. The authors suggest that the effects of the incentive system had less impact because the informative ISA reduced speeding so much that the incentive system did not increase the gain.

However, the authors argue that there study indicate that incentives might be critical for the long term effect with the recommendation that this is studied further.

WARNING

Warning ISA systems enhance the exceeding of the speed limit and emit a visual, auditory or tactile warning to the driver (Spyropoulou et al., 2014). Spyropoulou et al. did a study where the warning functionality of ISA systems was evaluated. It was found that Warning ISA showed effects on the speeding frequency with a reduced number of speeding violations. However, it was discovered that when the driver ignored the warning and violated the speed limit, drivers exceeded a higher amount above the speed limit than without the system. It is suggested in the paper that the used auditory warning in the test irritated drivers which resulted in higher speeds when enduring the warning. Based on the results of this study, it can be assumed that a warning ISA system should avoid annoying drivers and abort to not counteracts its purpose.

INTERVENING

Intervening ISA systems aim to prevent speeding violations by taking control of the vehicle (EC, 2016a). Different intervening ISA characters are limitation of engine power, a lowered maximum and average speed and speed deviation (Spyropoulou et al., 2014). Spyropoulou et al. suggest that intervening ISA has shown improved speed reduction effects. However, a study by Várhelyi and Mäkinen (2001) showed that several drivers adopt higher speeds when using the system compared to without it for some speed limits. This effect is suggested to be a result of drivers stop adjusting their speeds and instead delegate the speed control to the ISA system (Várhelyi & Mäkinen, 2001). Spyropoulou et al. (2014) consider it a misuse of the system when using it as a comfort function, which instead can reduce driver alertness and concentration on the driving task and thereby result in slower reaction time. Jamson, Chorlton, and Carsten (2012) also found that the use of intervening ISA system resulted in fewer overtaking manoeuvres but also resulted in that drivers abandoned the overtaking or instead spent more time in critical areas.

ATTITUDES

The extent of reduced speeding is dependent on driver attitudes towards the ISA systems (Carsten, Ezenwa, Tomlinson & Horrobin, 2020; Spyropoulou et al., 2014). In the study by Spyropoulou et al. (2014), it was concluded that the intervening ISA functionality was disliked, the warning was found irritating, and the informative ISA was the most desirable. In opposite to the studied effects of ISA systems where increase level of intrusion relates to increased effect (EC, 2016a; Spyropoulou et al., 2014). The results indicate that the perceived interference and loss of speed control, as well as the auditory signal, can be the underlying reasons for the dislike of the systems (Spyropoulou et al., 2014). ETSC (2017) find full on/off switch of the system as necessary for public acceptance at its introduction. In a report from 2016 by the European Commission, it is stated that the acceptance for informative ISA is accepted on all road types by 60-75% of European road users. And indications show a 70% acceptance for warning ISA in urban areas while non-over-ridable limiters were accepted by 58% in residential areas (EC, 2016a).

2.2.4 INCENTIVE SYSTEMS

Reagan et al. (2012) studied the effect on speeding behaviour by introducing alerting and monetary incentive systems to participants. In contrast to the study by Harms et al. (2007), presented in the previous section, the incentive system was visible to the driver in the vehicle while driving to give real-time feedback. Their study concluded that the alerting system only led to small changes in speeding behaviour, while the incentive system led to significant change. Reagan et al. suggest that the fact that the incentives were visible during the drive could explain the results of the incentive system. Harms et al. (2007) found that the incentive system received good results when paired with an alerting system but not when tested alone. It can be assumed that the effects of the incentive system are enhanced when the driver is reminded of the consequences when doing the speed choice. This indicates that for an external incentive system to reach the desired effect, it could gain from being complemented with an in-vehicle reminder.

Reagan et al. (2012) study also showed that some participants used the incentive system as a game which triggered them to follow the speed limits to win in the game. It can be assumed that participants used the external incentive system for their internal motivation. The finding indicates that an ISA system could gain drivers interest by adopting an element of gamification. Oxford Learner's dictionaries define gamification as *"The use of elements of game-playing in another activity, usually in order to make that activity more interesting."*. In another study, Steinberger, Schroeter and Watling (2017) used gamification to investigate how driver boredom could be improved. Their study showed that gamification improved speeding behaviour, while other safety aspects were affected, such as increased off-road glances and slower reaction time.

2.2.5 Coaching

Coaching drivers is considered a cornerstone in traffic safety. To be able to drive in Sweden, a person needs to pass a theoretical and practical driving test which aim to provide the required knowledge for safe driving (Transportstyrelsen, 2020a). Knowledge is considered an important aspect, but experience, attitudes, situation awareness and actual driver behaviour and skill are also essential factors to consider to improve traffic safety (Stanton, Walker, Young, Kazi, & Salmon, 2007).

Stanton et al. (2007) study on advanced driver coaching system used post-licensure programmes to measure how to educate drivers. The study mainly focused on coaching by combining skills and knowledge into a learning framework by the investigation of responses to a system based on information, position, speed, gear and acceleration (IPSGA system). The study shows potential for an increased situation awareness with the IPSGA system. However, the study does not consider drivers willingness to participate in such education. In the MebeSafe project, which is an EU funded research project focusing on nudging and coaching drivers, an app for truck driver coaching is used to study how coaching can be used to increase the use of Adaptive Cruise Control. Indications from the first delivery report show that there are potential for coaching professional truck drivers to use adaptive cruise control (De Craen et al., 2019). However, the final results of the study are yet to be concluded.

2.2.6 A nudging approach to speeding countermeasures

This project used nudging as an approach to increase acceptance for an ISA system. Hence, it was essential to identify how nudging has previously been used in traffic safety research.

Nudging is a notion that aims to guide users towards choices and behaviour that is best for them. A nudge introduces subtle changes in the way information and choices are presented, to alter people's behaviour in predictable ways. The freedom of choice is still left to the user, as a nudge never forbids any option (Thaler and Sunsteins, 2009). The nudging approach used for this project is further described in section 2.5. The term nudging is fairly new in traffic safety research, although the principles of nudging might have been used for a long time without labelling it as a nudge. Such as previously described in section 2.2.1, to plant trees along the road to enhance the experience of speed, or a regular speed limit sign could classify as a nudge.

A delivery report from the MeBeSafe project investigates how nudging can be used to slow down bicyclists in cities (Berg Alvergren et al. 2019). The report includes a section to identify how visual illusions have been used to nudge drivers to reduce speed as inspiration for the study. It was found that transverse stripes on the road reduced speeding. Longitudinal stripes were found to have a more significant effect on drivers not familiar with the road. Also painted arrows in the middle of the road affect speed. Berg Alvergren et al. (2019) also presents that studies where nudges affecting the conscious mind have been used. They identify that posters to remind drivers to drive safe have only shown temporal effects and writing words on the road to remind drivers to slow down, have not shown any effect. It is further concluded that dynamic speed signs were found to affect speeding, with increased effect if the use of colour for the current speed, and even more if combined with a message (Berg Alvergren et al., 2019)

Using visual representations to create three-dimensional illusions of an upcoming speed bump have been tested in Japan. No studied effects of such illusions were found by Berg Alvergren et al. (2019). However, it is suggested in an article by Hamill (2008) that such nudges might only reach effect short-term until drivers realise and stop adjusting their speed towards them. Hansen (2020) suggests in an article that optical illusions that drivers cannot get used to might be more effective in a long-term change of speeding behaviour. He concludes several infrastructural measures such as using narrowing roads or permitted parking on both sides of the road as measures to make drivers slow down. Further, he uses the middle lines as an example of a successful nudge to reduce drivers speed.

MeBeSafe created in vehicle nudges which aim to warn the driver of approaching bicyclists by projecting green light on the road which turns red and show which direction the bicyclist is approaching from (Bakker, Uittenbogaars, Op den Camp & Ljung Aust, 2019). Caraban et al. (2019) exemplify two studies where steering wheel feedback is used to nudge driver to more fuel-efficient and safe driving through vibrations and led lights to give driver feedback in their driving. The coffee cup symbol that appears is also a nudge to encourage drivers to take a break (Berg Alvergren et al. 2019).

2.3 DRIVER ACCEPTANCE

In order to understand user acceptance, it is crucial to identify what triggers speeding behaviour, to emphasise with the user and define user needs. This section identifies how the workload is affected by the driving task, followed by a section describing decision making processes and its impact on speed choice. Speeding behaviour is described in a section concluding factors affecting speed choice. Furthermore, there is a section concluding driver acceptance of new technology.

2.3.1 WORKLOAD

It can be assumed that some speeding violations are the result of driver workload being too high, resulting in unintentional violations due to lack of mental capacity to process the information provided by speed signs or the speedometer. Hence, the topic was of interest to investigate for this project.

The driver is continuously provided with information which needs to be prioritized based on the situation. The processing of information can increase the overall workload for the driver and result in critical situations (ISO, 2005). Most of the task components become automized with practice, and typical driving situations are considered within the limits of the attentional capacity. However, the workload is highly context-dependent, where driving on an empty routine route requires less workload than driving during rush-hours on roads with high traffic density (Campbell et al., 2016). When the workload increases, Campbell et al. argues that the driver can compensate by skipping tasks that are not immediately relevant.

Campbell et al. (2016) paper explain that driver workload is dependent on external and internal factors illustrated in figure 2.2. External factors consider the driving task and situational factors, while internal factors consider the driver's behaviour according to the selection of strategies and perception. The selection of strategies feeds into the performance, which in turn generates consequences of performance which feeds back into the internal factors through the perception. The perception can be divided into the driver's subjective experience and the driver's psychological response.

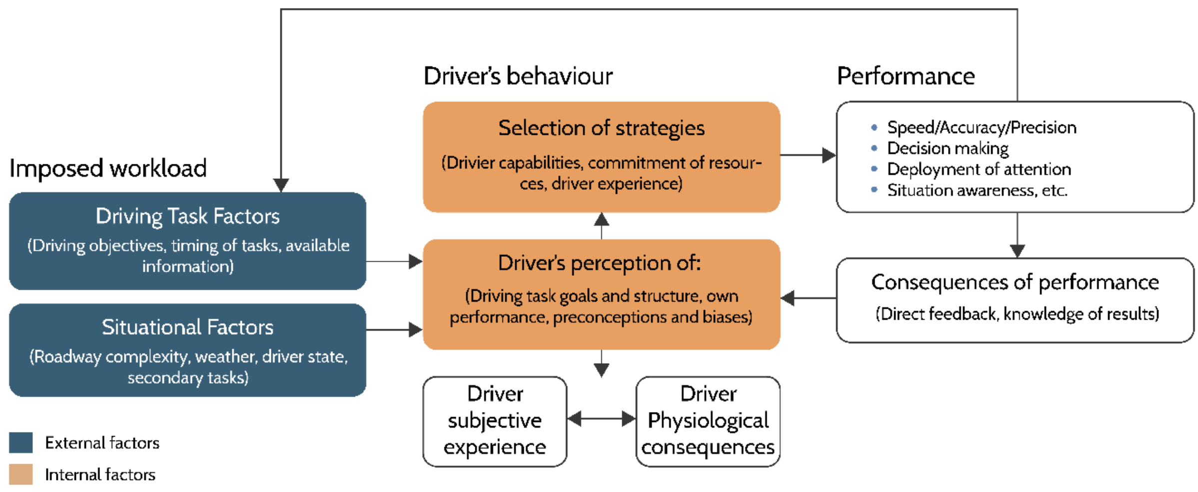


FIGURE 2:2 FACTORS AFFECTING DRIVER WORKLOAD ADAPTED FROM CAMPBELL ET AL. (2016)

The driving task requires the driver to perform several interlinked activities which contribute to the overall workload (ISO; Campbell et al., 2016). From a task/function analysis perspective, Hancock and

Parasuraman (1992) have categorised the major activities performed in a driving situation to vehicle control, navigation and collision avoidance. Wickens' (2008) multiple resource theory is based on that humans have not one single information processing source but instead, several pools which can be used simultaneously. Humans have a limited capacity to process information which creates problems when performing two or more tasks which require the same resources. The relationship between workload and performance is complex but important to consider when designing a vehicle safety system is that a high workload and use of the same resources can cause errors and slower task performance. However, a low workload can result in boredom and reduced situation awareness (Wickens, 2008).

2.3.2 Decision making

Decision Making is the cognitive process of reaching a judgement or choosing an option to meet the needs of a given situation (Crozier, Ranyard & Svenson, 1997). Rational Decision Making is the traditional perspective which describes weighing the impact of various factors and choosing the most appropriate option to maximise the expected outcome. Naturalistic Decision Making is based on studying decision making in naturalistic settings. Decisions sometimes must be made at a fast pace in a dynamic setting, which does not allow for considering all alternatives (Klein, 1998). The critical aspects to consider in decision making is the decision-maker, alternatives, choice, expected outcome and consequence. In everyday activities, many decisions are conflicting across a set of attributes (Crozier et al., 1997). When speeding, the driver could see the potential benefits of keeping the speed limit but at the same time also the perceived possibility of saving time by going over the speed limit. According to Crozier et al. (1997), this creates a conflict.

Decisions are based on motives, social context, cognitive processes and mental representations. The decision-making process is extended in time and involved information search, judgement and evaluation processes. Post-decision processes adjust the implications of previous decisions and contribute to values and goals (Crozier et al., 1997).

A part of decision making is to evaluate the available alternatives. In general humans have a hard time focusing on both negative and positive outcomes of a risky event which results in attention being put to one of them (Daniels, 2000). A study by Heino (1996) shows that some personalities are more risk-averse, while others are risk-seeking. If being a risk-seeker, generally the opportunities are in focus instead of the potential loss. The situational characteristics also impact decision making and assessment of risks. If the risks are apparent, then people tend to focus on the risk more than if they are not as apparent (Crozier et al., 1997) which can be assumed to be the case in some speeding situations where the perceived risk is low. Daniels (2000) describe that behaviours are steered by its consequences, that can be altered to reach the desired outcome. Further explaining that consequences can be divided into different combinations weather they are perceived positive/negative, immediate/delayed and certain/uncertain. Whereas immediate and certain consequences are the most effective consequence of increasing the probability of a certain behaviour to occur, while immediate and certain consequences reduce the occurrence of the behaviour (Daniels, 2000).

2.3.3 Speeding behaviour

Being able to travel at high speed is a relatively new activity for humankind. The ability to develop natural fear, similar to the experience when being exposed to heights, has not been given enough time to evolve. As a result, humans consider driving 50 km/h quite slow, while falling from a ledge at the same speed is by many considered terrifying (Wallén Warner, 2006). Not having developed a natural fear for speeding gives only an initial understanding of why drivers intentionally or unintentionally speed.

Although studies show that drivers consider speeding a critical factor for traffic safety, they openly admit to doing it (EC, 2016b). There are several underlying factors to why drivers chose to speed such as temporary motives, personality characteristics, human perceptual skills and limitations, characteristics and environment of the road, and lastly the vehicle (SafetyNet, 2009).

TEMPORARY MOTIVES

There are several reasons why drivers exceed speed limits which are connected to the driver's temporary motives. Emotions have been shown to have an impact on speed decisions where anger and boredom tend to increase the risk of speeding behaviours (Åberg, Larsen, Glad & Beilinsson, 1997). Temporary motives are also related to time, where time pressure or wanting to reach the destination faster are reasons closely linked to speeding behaviours (Javid & Al-Roushdi, 2019; Transport Canada, 2005; Åberg et al., 1997). Driving fast is generally perceived as a mean to arrive faster, which makes speeding an immediate reward for the driver (WHO, 2008).

A study from 2005 suggests that the purpose of the trip has an impact on speeding behaviours (Fleiter & Watson, 2005) which was later confirmed by Ellison and Greaves (2010) who used GPS systems to capture speeding patterns. Their result showed that speeding is most common in the morning during weekdays which agrees with Fildes et al. (1991) that drivers are likely to speed when driving to work. During weekends speeding was found to peak during the night-time (Ellison & Greaves, 2010). Yannis et al. (2013) also found that high annual kilometrage often justifies speeding and assume a relation to perceived time earned by speeding is greater for long distances.

PERSONALITY CHARACTERISTICS

Results from a paper by WHO (2017) show that 90% of drivers from several countries consider themselves a safer driver than average. It is argued in the same paper that this overestimation of one's capabilities makes drivers believe that they can speed without putting themselves at risk. A study from Transport Canada (2005) showed that many drivers do not consider speeding equivalent to endangering others or oneself. Factors related to the driver's personality characteristics have been studied in several papers (Ellison & Greaves, 2010; Truelove et al., 2017; Yannis et al., 2013).

The gender of the driver has been shown in several studies to impact speeding behaviours, where males are more likely to speed than women (Ellison & Greaves, 2010; Truelove et al., 2017; Elliott & Thomson, 2010; Javid & Al-Roushdi, 2019). Historically in Sweden, males have been dominant in the number of deaths in traffic with 74% (Trafikverket, 2019) which corresponds to numbers worldwide where 73% of all deaths in traffic are males (WHO, 2018).

Previous experiences of penalties have an impact on speeding behaviours where those who have received a speeding ticket was more prone to speeding than those who have not received a speeding ticket (Truelove et al., 2017). This behaviour could be related to the personality characteristics of someone who likes to gamble, where the chances of being caught is a part of the pleasure of driving fast (Yannis et al., 2013). A relation has also been found between the characteristics of someone who have a general enjoyment of risk-taking and speeding behaviour (Heino, 1996). The results from Yannis et al. (2013) paper shows that the participants generally enjoy driving faster at highways with the assumption that it is easier, hence giving more pleasure.

HUMAN PERCEPTUAL SKILLS AND LIMITATIONS

Young drivers have been identified to speed more often (Truelove, et al., 2017; Yannis et al., 2013; Ellison & Greaves) which is suggested to be a result of inexperience, hence a general underestimation of risks. Generally, young drivers do not have a fully developed brain, which affects the ability to estimate consequences of actions (Anund & Patten, 2010) which could impact their driving behaviour. Trends of speeding behaviour reduce with age due to the relationship with risky behaviour and previous experience of a crash.

Unintentional errors made by the driver could also explain speeding behaviour. 51% of Canadian drivers state that speeding is a result of not paying attention to the speedometer (Transport Canada, 2005), also confirmed in a study by Department for Transport (DfT, 2018) in the UK. Both studies confirm that speeding violations, to some extent, is the result of lacking in concentration or potentially miss the speed limit sign.

CHARACTERISTICS OF THE ROAD

Sometimes the reason for speeding is unintentional due to missing, hidden or covered road signs (DfT, 2018). There is also a relation between people who do not agree with the posted speed limits and speeding behaviour (Åberg et al., 1997). More recent studies show that disapproval for posted speed limits is used to justify violating the speed limits (DfT, 2018; Transport Canada, 2005).

Street characteristics seam to influence speeding behaviour where Ellison and Greaves (2010) have concluded factors such as the posted speed limit and weather conditions factors impacting speed choice. Numbers from ETSC (2019) shows that in EU speeding is generally most prevalent on urban roads, while numbers from Sweden show speeding is more common on rural roads and motorway. On roads where the driver considers the chances of getting caught by law enforcement is perceived as low, drivers are more prone not to follow the posted speed limit (DfT, 2018; Transport Canada, 2005; Yannis et al., 2013). However, worth to mention is that speeding is common on all roads, described in section 2.1.1.

ROAD ENVIRONMENT & SOCIAL INFLUENCE

The influence of others has been shown to affect drivers speed choice. It has been identified that other drivers and passengers with a positive attitude towards speeding violations increase the likelihood of speeding violations (Åberg et al., 1997). By observing other people speed, this is used as an excuse for exceeding the speed limit on all road types (DfT, 2018, p.11; Yannis et al., 2013). Javid & Al-Roushdi (2019) study showed that drivers generally overestimate others actual speed which had also previously been found by Åberg and Haglund (1997) with an average overestimation of 8-10 km/h. Both studies also found that the perceived expectations of others have effects on speeding behaviour (Åberg & Haglund, 2000; Javid & Al-Roushdi, 2019) and the study by DfT (2018) shows that the respondents prefer adapting their speed to other road users. In a study with Canadian drivers, 52% believe it to be safer to adapt the speed to other drivers as this keeps up the traffic flow, even if this requires going over the posted speed limit. It is also stated that most of the respondents believe it to be *"...just as dangerous to drive 20 kilometres under the speed limit, as it is to drive 20 kilometres over it."* (Transport Canada, 2005, p. i). Feeling pressure from drivers behind was used as a reason for driving faster than the speed limit and what feels comfortable for the driver. The reason found for this behaviour was not to annoy aggressive drivers (DfT, 2018; Transport Canada, 2005).

VEHICLE

The vehicle could potentially influence speeding behaviour. Ellison and Greaves (2010) have in their paper mapped out several studies which show that the age of the vehicle matters, where drivers of vehicles newer than five years are more likely to speed. Notably, the performance of the vehicle has been related to speeding behaviour. Similar results were found in the study by DfT (2018), where the engine capacity was likely to result in speeding behaviours. More capacity makes it easier to go faster, but there is also a general belief that newly produced vehicles are easier to slow down fast (Yannis et al., 2013). Drivers also expressed that they underestimate the power of their car, which increases the likelihood of unintentional speeding (DfT, 2018).

2.3.4 Acceptance of new technology

Horberry, et al. (2014) state that driver acceptance of new technology is closely related to the design of the system. They have in their book, Driver Acceptance of New Technology, mapped out the area of driver acceptance. It is presented that safety systems have great potential in increasing traffic safety, but the potential of saving lives with will only be realised if it is accepted by drivers. It is crucial to consider a user-centred approach to reach acceptance (Horberry et al., 2014). In driver assistance systems today, the car communicates with the driver through the vehicle HMI. The HMI can be used to evaluate acceptance towards a system, as it is the 'face' of the system and Horberry et al. (2014) exemplify studies where timing, intensity and understandability was used as factors when measuring acceptance through the HMI experience.

Drivers attitudes to new technology can be studied throughout the whole product life cycle. Before the technology even exists, only potential future reactions can be studied by collecting subjective data. In order to understand user acceptance, a basic understanding of the user needs to be reached. This includes values, actions, behaviours and human-system performance. Commonly used methods to evaluate and understand user acceptance that is described in the book are questionnaires, interviews, focus groups, system use and driving performance. The usefulness/satisfaction scale by Van der Laan, Heino and De Waard (1997) is frequently used in combination with other methods to measure acceptance. The method is further described in section 3.5 in this report.

2.4 VEHICLE HMI DESIGN

It is through the HMI that the different systems communicate with the driver (Horberry et al., 2014). When designing a new warning or assisting system, the overall workload needs to be considered, as adding new system can reduce but also potentially increase the workload (ISO, 2005). To guide HMI development, there is literature available which provides guidelines, requirements and standards when designing for automotive HMI. The following section summarises essential aspects to consider when designing a system which intends to warn or assist drivers.

2.4.1 Warning systems

The Technical Report ISO (2005) provides recommendations for how the vehicle HMI of warning systems with, a focus on assistance, should be designed with regards to efficiency and acceptance. The modalities of visual, auditory and tactile warnings are studied in design and combination.

Warnings in cars are used to influence the drivers' behaviour to prevent the driver from doing something that they would normally do, or the opposite, to do something that would otherwise have been ignored. According to ISO (2005), a warning system contains two essential parts, the system itself and the driver. The system is responsible for defining, recognising and alerting the driver while the driver is responsible for detecting, evaluating and responding to the signal from the warning system. This process can potentially be a complicated task due to the cognitive and perceptual processes of the driver. Hence, the importance of good HMI design is crucial for the overall workload, according to ISO.

Warnings are often designed with an abstract alerting function that aims to redirect the attention to a more explicit informing function. It is important to have contextual knowledge of the situation in which the warning occurs in order to understand how it is processed and perceived by the driver. ISO (2005) identifies a suitable warning when it consists of the following four characteristics; an element which attracts attention from the driver, a reason for the warning, the consequence if the warning is not followed and instructions for action.

The recommendation from ISO (2005) is that warnings should only be applied when the driver lacks in focus or when a dangerous change occurs in position or speed. This is expressed as the ideal system, and requires complex technology, continuously recognising the driver's state of attention. It is exemplified the danger in issuing a system warning while the driver is preparing to brake, which might interrupt the driver who must interpret and process the warning and might shift the attention from the initial task of braking. In this situation, the warning could potentially increase the cognitive load, add stress and delay the reaction. In order to avoid unexpected warnings, driver's expectancy should be used (ISO, 2005). The expectancy is based on previous knowledge and input from the context which influences the behaviour of the driver. ISO presents studies that have proved warnings to have low chances of overriding the beliefs and expectations of the driver. In order to be effective, the warning must be designed with compatible expectations of the driver.

CREDIBILITY

The confidence in a warning system can be affected by false, missing or conflicting signals which will impact the credibility of the system (Horberry et al., 2014, pp. 56). A warning system has rules which, based on a specific event, trigger the warning. From a safety system approach, the warning is correct if it was based on the rules of the system. However, if the driver who is responsible for the response do not consider the warning correct, the credibility of the system decreases (Green et al., 2008; Campbell et al., 2016). This can potentially cause discomfort for the driver and decrease the acceptance for the warning system (Green et al., 2008; ISO, 2005; Campbell et al., 2016), result in incorrect actions and increased reaction time for accurate warnings (Campbell et al., 2016).

The tolerance for false warnings is higher when using the visual modality only, and drivers are less likely to consider unobtrusive visual warnings annoying. To reduce the risk of false warnings affecting driver acceptance and performance, auditory and haptic warning should be used with caution. Annoyance can also be avoided by allowing the driver to adjust detection sensitivity, intensity and volume for warnings (Campbell et al., 2016). Further, a study shows that drivers are more annoyed by false alarms if they need to change strategic and proactive action based on it, such as a required route change due to false navigation, in contrast to warnings that do not have a definite impact on the driver, such as a warning for an upcoming school zone (Campbell et al., 2016).

Green et al. (2008) argue that in order to provide a system with the potential to save lives, the driver needs to accept the probability of false warnings. Additionally, Campbell et al. (2016) suggest that if the driver sees the benefits of a warning, the acceptance for more obtrusive modalities increases. Furthermore, Campbells et al. paper show that the timing of a warning has an impact on the trust that the driver has for the warning. Another study shows that early warnings decrease the number of collisions (Lee et al., 2002), but if a warning triggers too early, then the trust for it decreases (Green et al., 2008). It can be assumed that considering timing is essential for both the acceptance and credibility for a speed assistance system.

2.4.2 MODALITIES

When choosing a modality for a warning system, the drivers' task, needs and expectations should be taken into consideration. Further, the modality should reflect the criticality of the message it aims to convey to the driver. Campbell et al. (2016) have based on available research concluded a list for when to use each of the three modalities (visual, auditory and tactile). In short, it is recommended that visual messages are used when the information is complex and does not call for immediate action. Auditory messages should be used for attention and conveying short messages requiring an immediate response.

Similarly, tactile messages could be used for gaining and directing attention but also as a compliment when the visual and auditory workload is excessive.

VISUAL

Under ideal circumstances, for example on a long straight road with low traffic density and dry roads, the driver has some spare visual capacity. However, reality rarely fit into ideal circumstances. Drivers are often exposed to much visual information to process. Visual messages should only include necessary details and information in a simple manner of icons or fonts (Campbell et al., 2016).

In order to improve the intuition and mental model of visual information, the placement should be based on expectations and nature of the response. Choosing an appropriate location for the information creates stimulus-response compatibility, which will require fewer mental operations from display to response (Campbell et al., 2016).

In order to take advantage of the human visual system, flashing can be used to draw attention to visual information. Flashing should only be used for critical and sudden situations, and the flash rate should represent the urgency of the reaction. Other motion cues than flashing are not recommended, such as zooming or bouncing, as this draws too much attention and time with eyes away from the road (Campbell et al., 2016).

AUDITORY

The study from NHTSA showed that auditory warnings have potential in improving the time for response (Campbell et al., 2016). However, the characteristics of the warning are crucial, and small changes in the warning could instead increase response time. The frequency of the sound also has a strong relation to the experienced annoyance that it causes (Green et al., 2008). Auditory warnings should only be used when immediate action is required (Green et al., 2008; Campbell et al., 2016) and preferably as a final stage of a graded warning system. Auditory warnings can be perceived as annoying, which makes it less appropriate for cautionary warnings (Campbell et al., 2016).

TACTILE

Tactile messages could be used for gaining and directing attention but also as a compliment when the visual and auditory workload is excessive. Tactile alerts are often used in combination with visual or auditory information (Campbell et al., 2016). Tactile messages must be understood as to what it wants to communicate and what actions it wants to trigger from the driver. Generally, ISO (2005) concludes that it is recommended not to use tactile messages if not as part of a multi-modal system.

MULTI-MODAL WARNINGS

A multimodal warning message consists of more than one of visual, haptic and auditory modalities (Campbell et al., 2016). Research on multi-modal warnings offers a mixed recommendation (Green et al., 2008). Studies show that warnings, using three-modal stimulus (visual, auditory and tactile) or two-modal stimuli, gives faster response time and are considered more helpful. However, the recommendation is to only use multi-modal warnings in a situation where it does not introduce unnecessary complex sensory input that counteracts the intention by distracting the driver (Green et al., 2008). The severity of the situation, in terms of the danger the drivers is exposed to, should also be considered when choosing modalities for warnings as the acceptance for visual, auditory and haptic warnings differ. The suggestion is to use a sequential change in modality based on different stages using less invasive visual signals raising to more prominent warnings with auditory and haptic modalities as different modalities can be used to communicate the severity of the situation. (Campbell et al., 2016).

2.5 NUDGING

This section summaries Caraban et al. (2019) interpretation of nudging, based on Thaler and Sunsteins (2009) definition of the notion. Caraban et al. present six overall categories of nudges used in their framework, which describes how to work with nudging. The Dual Process theories are used as a concept for understanding human behaviour. The Dual Process theories are based on the concept that the human mind has two modes of thinking, automatic (system 1) and reflective (system 2). System 1 is responsible for repeated and skilled actions and is estimated for 95 per cent of our daily decisions. System 2 is only activated in situations System 1 cannot handle, to reduce effort (Caraban et al., 2019)

What decides if a nudge will be useful or not is its implementation in the specific context, where the timing and strength of the nudge are of great importance for its effects (Caraban et al., 2019). In order to succeed with a nudge, there are further opportunities with personalisation and tailoring of nudges, as some nudges are more effective for certain people or in specific contexts, according to Caraban et al. (2019). Furthermore, the paper state that nudges work best when the individual does not have a strong preference for a particular choice or ingrown habitual behaviours.

2.5.1 NUDGING MECHANISMS

Caranban et al., (2019) suggest a framework of 23 nudging mechanisms in six overall categories (facilitate, confront, deceive, social influence, fear and reinforce) with different motives that will be further elaborated below.

FACILITATE	
Nudges within this category aim to guide the decision by reducing the mental or physical effort. These nudges exploit the status quo bias that denotes our tendency to resist change and choosing the path of least resistance, where we rather stick to premade choices instead of searching for better alternatives.	Facilitating nudging mechanisms ease to make appropriate choices through: • Default options • Opt-out policies • Positioning • Hiding • Suggesting alternatives

CONFRONT	
Nudges within this category aim to guide the decision by instilling doubt and prompt a reflective choice. The cognitive bias that is exploited for these nudging mechanisms is the regret aversion bias that denotes our tendency to make more thoughtful and careful choices when we perceive higher risks.	Confronting nudging mechanisms break mindless behaviour by: • Throttling mindless behaviour • Reminding of the consequences • Creating friction • Providing multiple viewpoints

DECEIVE	
Nudges within this category aim to guide the decision towards a particular outcome by affecting how alternatives are perceived, or activities are experienced.	Deceiving nudging mechanisms uses deception mechanisms to guide the behaviour by: • Adding inferior alternatives • Biasing the memory of past experiences • Placebos • Deceptive visualizations
SOCIAL INFLUENCE	
Nudges within this category aim to guide the decision by exploiting people's desire to accommodate and comply with what they believe others expect from them.	Social influence nudging mechanisms guide the behaviour by: • Invoking feelings of reciprocity • Leveraging public commitment • Raising the visibility of users' actions • Enabling social comparison
FEAR	
Nudges within this category evoke feelings of fear, loss and uncertainty to guide the user towards a particular activity.	Fear nudging mechanisms evokes feelings of fear, loss and uncertainty by: • Make resources scarce • Reducing the distance
REINFORCE	
Nudges within this category aim to reinforce people's behaviour by increasing the presence of the actions in the individuals thinking.	The nudging mechanisms reinforce the behaviour by: • Just-in-time prompts • Ambient feedback • Instigating empathy • Subliminal priming

2.5.2 Fogg's behaviour model

According to Fogg's Behavioural Model (Fogg, 2009), a person needs to have sufficient ability and motivation, as well as a trigger for a behaviour to happen. Three triggers are identified in Fogg's Behaviour Model, facilitators, signals and sparks. Facilitators are triggers that simplify the task, which increases the ability when there is already motivation for a specific task. Signal triggers remind of the task when there is already motivation and ability for the task. Spark triggers intend to increase the motivation for a task when there is already high ability for it (Fogg, 2009).

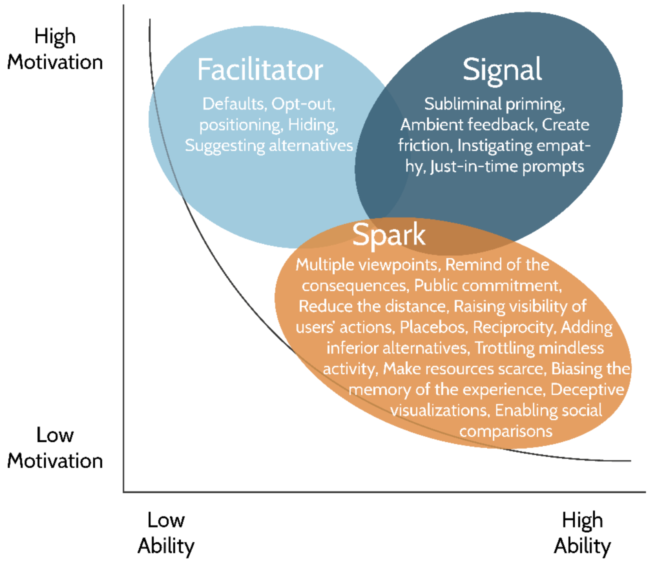


FIGURE 2:3 FOGGS BEHAVIOUR MODEL ADAPTED FROM CARABAN ET AL. (2019).

Caraban et al. (2019) use Fogg's Behaviour Model to identify what type of nudge is appropriate for different situations. Caraban et al. argue that there are nudges which fit into each category of triggers (see figure 2:3). Facilitator nudges should be used to increase the ability by making the behaviour easier, for example, by reducing physical or cognitive workload. Signal nudges can be used when there is motivation and ability to perform the task, but the users' intentions do not match their actions. Spark nudges can be used to increase motivation by adding motivational elements when there is the ability to perform the task.

3

METHODS

This chapter comprises the theoretical framework for the methods used during this project and briefly describes how each method was used. The implementation of methods in this project is thoroughly described in chapter 5-9. The methods used for theoretical and empirical studies are described as well as for data analysis, ideation and evaluation.

3.1 LITERATURE STUDIES

Literature studies provide a theoretical foundation for the studied topic. A literature study is often used in the early phases of a research project to understand the topic and terminology used. Further, initial literature studies can guide a direction for a specific research area by providing insight for research questions and scope. The exploratory phase of a literature study provides general knowledge of the topic, which further defines the outline of the scope. A focused literature study identifies gaps in knowledge where empirical research is needed. Literature studies were used throughout this project to triangulate findings from empirical studies and to provide extensive knowledge within different areas that were needed to reach the result of the project.

3.2 EMPIRICAL STUDIES

Five empirical studies were executed in this project to collect qualitative user data for the identification of user needs. The methods used for empirical studies were interviews, focus groups, surveys and sensitising. Each method is described in this section.

3.2.1 INTERVIEWS

Interviews are usually a focused verbal conversation between an interviewer and interviewee. The most common is the one-to-one interview (Wilson, 2014). The conversations in interviews can be structured, semi-structured or unstructured (Hanington & Martin, 2012). Semi-structured one-to-one interviews were chosen as a method in each empirical study during the project.

In a semi-structured interview, the interviewee uses prepared fixed questions mixed with follow-up questions for exploration. The format is useful when the interviewer wants to allow the interviewee to raise new issues (Hanington & Martin, 2012). Probes are often used in complex problems to deepen understanding and clarify answers.

When performing interviews, it is essential to consider the sampling of participants. Probability and non-probability are the two most common types of sampling (Wilson, 2014) that both were used during the project. Probability sampling was mainly used when recruiting participants for user studies in the project. Probability sampling is used when there is a need to know the probability of each selected participant. Nonprobability sampling is the most common, where the interviewer has no control over the probability of the interviewee being from the population (Wilson 2014).

3.2.2 FOCUS GROUP

Focus group is a method to collect qualitative self-reported data from users through a carefully selected group of people. Focus groups are a suitable method for collecting qualitative data from several users in an effective manner. The results from a focus group should not be interpreted as a representation of how the population feels. Based on the focus group, a hypothesis can be obtained, which should be supplemented with other qualitative and quantitative methods. (Hanington & Martin, 2012). Focus groups were used in the project to evaluate initial ideas.

An experienced moderator should lead the discussions and encourage the participants to evolve from each other’s thoughts and opinions to get past the generalizations of the individual. Hanington and Martin (2012) concludes that it is vital to create an open and comfortable dynamic for the participants in a focus group as the success lies in having an open environment for discussions.

3.2.3 SENSITISING

Sensitizing is used to prepare participants for a generative session or interview. Sensitizing can be used in many ways. How to conduct a sensitizing is dependent on the wanted outcome. Generally, the sensitizing is supposed to trigger the participant to think and reflect over the topic in their own time and environment before a generative session (Sleeswijk Visser, van der Lugt & Sanders, 2005). In the project, a sensitizing exercise prepared the participants before the second empirical study to gain more elaborate reflections during the interviews.

3.2.4 SURVEYS

A survey is a tool frequently used to collect information from a large sample of people during a short period. There are two methods for collecting survey data, either through questionnaires, where the respondent self-complete the questions or through structured interviews, where the researchers conclude the answers through interviews. The questions can be of both open and closed character, depending on the structure of the questionnaire. It is common to use surveys to gain quantitative data, and the result may not represent true feelings, thoughts or even behaviour. Hence, a survey should always be complemented with other self-reporting methods (Hanington & Martin, 2012). A self-complete questionnaire was used in the fourth study to triangulate results from interview studies.

FIGURE 3:1 SETUP FOR EMPIRICAL STUDY 2.

3.3 DATA ANALYSIS

This section describes the methods used during the project to analyse qualitative data from literature and empirical studies. The sections start with a description of affinity diagram, which was mainly used to analyse transcriptions from interviews, followed by a summary of content analysis which was used to analyse results from the user evaluation in the fifth empirical study. The section is concluded with sections describing user personas and scenarios, which were used as design tools during the concept development.

3.3.1 AFFINITY DIAGRAM

An affinity diagram is an analysis method for sorting and making sense of verbal qualitative data. By writing down observations, concerns, requirements and research-backend insights on sticky notes, the notes are then sorted and organised into themes of similar findings. The different groupings of notes are then named into research-based themes (Bergman & Klefsjö, 2010). The method is conducted bottom-up, starting with the details and then move on to creating groups and lastly the overarching themes (Hanington & Martin, 2012). Affinity diagrams were used as the method for four of the empirical studies to analyse qualitative data.

3.3.2 CONTENT ANALYSIS

Hanington and Martin (2012) describes content analysis as a method to analyses qualitative data from empirical user studies. The method uses a systematic approach to transform rich user data into descriptions of form and content. A content analysis was used to analyse findings from empirical study five when evaluating the concept with users to define the pros and cons of each concept. There are two primary approaches to content analysis methods, inductive and deductive. For inductive content analysis, a subsample of the material is studied, categories or codes are identified and named into themes. The categories or codes are then used to sort findings when studying the full content of the material. In deductive content analysis, the codes or categories are derived prior to the analysis through other material such as a theoretical framework. The result from a content analysis can be quantitative, such as counting the occurrence of a theme, phrase, word for example, or qualitative by only categorising findings into themes. For collecting qualitative data, the content analysis can be usefully supported by an affinity diagram to derive clusters of findings from the different themes (Hanington & Martin, 2012).

3.3.3 PERSONA

Persona is a method for personalising findings from qualitative research methods that have been abstracted and dehumanized during analysis (Hanington & Martin, 2012). A persona is a fictional representation of a user profile to be used in the design process to keep a user-centred focus (Wikberg Nilsson, Ericson & Törlind, 2015). A persona should be based on commonalities found during qualitative research which explains behaviour patterns and themes of users. There should always be a manageable number of personas used in the same project, usually 3-5, to keep the design-focus. During the analysis phase, four personas were created to conclude findings from empirical studies and to be used to guide the design of concepts.

3.3.4 SCENARIOS

A scenario is used to build a narrative around a specific situation to showcase complex interactions (Alexander & Maiden, 2004). Scenarios can be used to describe a situation in the current state or to describe an ideal desired future depending on the intended use of the scenario. Scenarios were used during the second empirical study to define the context for participating divers as well as a tool for concept evaluation.

3.4 IDEATION

This section describes the methods used for ideation during the project. Brainstorming was used throughout the project as a method for generating ideas for user studies, the creation of personas and scenarios as well as to conclude concepts and design guidelines. Further, Scamper was used during the creation of concepts, in the first iteration, to support the creative process for concept generation. Both methods are described in this section.

3.4.1 BRAINSTORMING

Brainstorming is a method used to generate a large number of ideas and trigger creativity. Usually, a brainstorming session is initiated by introducing the theme of the ideation session through the framing of a question. The brainstorming sessions are often performed in groups with the advantage of having group discussions to generate new ideas further. To support creativity, all participants need to feel comfortable to explore with the goal of quantity, with no focus on the quality of the ideas generated (Wikberg Nilsson et al., 2015).

3.4.2 3.4.2 SCAMPER

Scamper is a method to explore creative ideas by using the exploring the following options; substitute, combine, adapt, modify, put to other use, eliminate and reverse. Scamper uses existing ideas or ideas from previous sessions to explore other dimensions with the goal of further develop the ideas further. By going through all options, there is less chance of missing out on any aspects of the idea (Wikberg Nilsson et al., 2015).

3.5 EVALUATION

This section describes the methods used for evaluating ideas and concepts. A modified Pugh matrix was used to evaluate ideas based on research findings. The Assessment of Acceptance Scale was used during the fourth and fifth empirical study to evaluate user acceptance towards being influenced. Further, the Wizard of Oz technique was used to trigger different concepts in the research vehicle during user the fourth empirical study.

3.5.1 PUGH MATRIX

A Pugh matrix is used when there are several ideas or concepts available, and there is a need to identify the best idea or concept out of the proposed. The method is general and can be modified to fit the criteria of the evaluation. Usually, each idea or concept is evaluated towards the most critical requirements and the existing solution to the problem. If the proposed design shows improvement, then it is scored a plus sign. If the current solution is scored better, then the idea or concept is marked with a minus sign. If they are equally good, it is marked with a 0 (Pugh, 1990). The overall scores can be used to compare the different ideas or concepts against each other. During the project, a modified version of a Pugh matrix was used to evaluate the ideas towards each other and the defined scenarios to conclude which ideas had the most potential to improve each scenario.

3.5.2 Assessment of acceptance scale

Van der Laan et al. (1997) Assessment of Acceptance scale was created as a tool to measure driver's acceptance of new vehicle technology. The scale uses nine bipolar items to measure acceptance where the subject's rates on a five-point scale (see figure 3:1). It denotes both the usefulness and the satisfaction of the system evaluated. The scale can be used for comparison by calculating the mean score for each item and compare scores between different system. It can also be used to compare a system before and after a change. The tool is standardised to be easy to use and targeting driver assistance systems. The Van der Laan scale is the only validated acceptance tool based on scientific work (Horberry, Regan & Stevens, 2014).

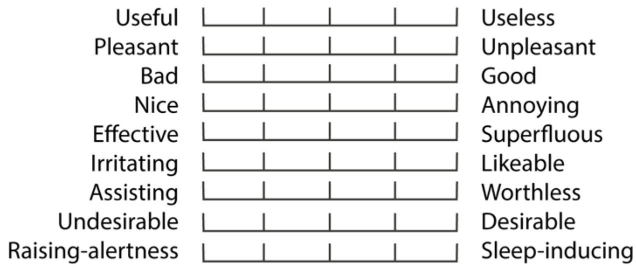


Figure 3:2 Assessment of acceptance scale.

3.5.3 Wizard of Oz

The Wizard of Oz technique is used in human-computer interaction to test prototypes, systems and technologies which have not yet been fully developed. The method is conducted by a hidden researcher which controls the interaction behind the scenes. The user interacts with the prototype unaware that the interaction is not fully functional, but instead controlled by the hiding researcher. The method is used for having the participants believe they are interacting with a fully functional prototype for a realistic experience. The Wizard of Oz technique allows for evaluations of reactions in the early phases of the design process to save both time and money before building high fidelity prototypes (Hanington & Martin, 2012).

4

PROCESS DESCRIPTION

This chapter described the process for this project. The chapter starts by introducing the overall process, which concludes how activities were planned to fulfil the project aim and objectives. The overall process is followed by sections describing the activities and deliverables for each of the three phases, analysis, concept development and evaluation, in detail.

4.1 OVERALL PROCESS

A background study initiated the project. The background study consisted of an initial literature study to understand traffic safety and speeding. Scientific papers and newspaper articles served as the primary source. Further, the background study aimed to provide an increased understanding of Autoliv's approach to traffic safety and the speeding countermeasures employed in the Autoliv research vehicle. The background study provided an increased knowledge of traffic safety and terminology. The background study was needed to define the scope and guide planning of activities for the project. Based on the background study, the project was divided into three phases of analysis, concept development and evaluation, illustrated in Figure 4:1. Each phase depended on the deliverables from the previous phase, which were defined in the contextual framework, concepts and design guidelines.

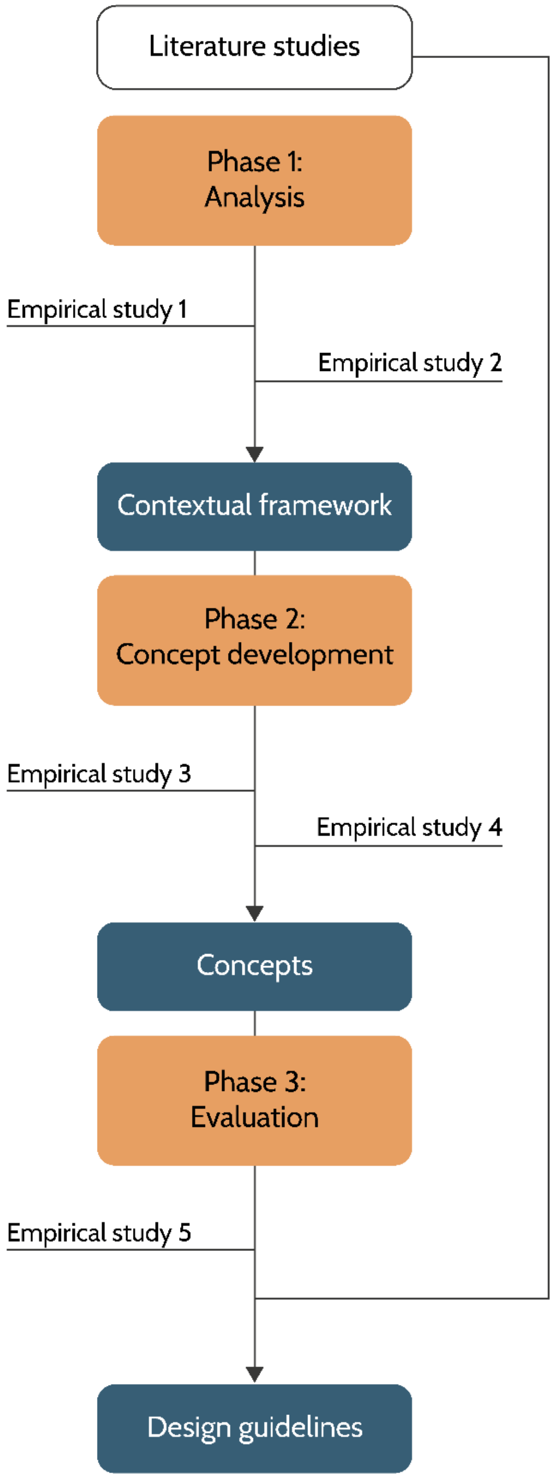


FIGURE 4:1 TIMELINE FOR PROJECT PROCESS.

The analysis phase aimed to map out the design problem by understanding user needs and use context through an investigation of current speeding behaviour. The goal was to conclude the contextual framework to be used during the second phase of concept creation. Three empirical studies were planned, to collect insights about current speeding behaviour, attitudes and motivations as well as potential acceptance towards future methods for counteracting speeding. The intention was to evaluate prototypes implemented in the Autoliv research vehicle during this phase. Due to a delay, the empirical study with the research vehicle was conducted in the second phase. Findings from the two empirical studies and literature study were concluded in the contextual framework.

The concept development phase aimed to use the research findings concluded in the contextual framework to create a conception of the future through continuous exploration of ideas and concepts in an iterative process. The goal of this phase was to conclude concepts to be used in the third phase during user evaluations. The concept development phase consisted of two iterations. Initial planning intended for three iterations to be able to suggest a final design concept. As the constraints changed during the process (discussed in section

11.2), the deliverables of the project changed to instead conclude alternative concepts for changing speeding behaviour.

The first iteration generated ideas of different methods to influence speeding behaviour using the vehicle HMI through several generative sessions. Insights from literature studies, the third and fourth empirical study were used to evaluate, improve and exclude ideas. The first iteration was concluded by categorising the remaining ideas into different nudging categories. The remaining ideas were evaluated using a PUGH matrix. Ideas with the lowest score were excluded, and the remaining ideas were used in the second iteration. The second iteration aimed to further develop and combine ideas into concepts. The ideas were used to create concepts within each nudging category. Final concepts were created by combining concepts from each nudging category into four different concepts which all use facilitate, spark and signal nudges to impact driver behaviour. The second iteration and the concept development phase were concluded with four different concepts which aimed to nudge drivers to keep the speed limit. The concepts were used in the last evaluation phase during user evaluations.

The last evaluation phase aimed to realise design alternatives through evaluation of concepts with users. The goal was to conclude the design guidelines for future design processes within the scope of reaching user acceptance. The aim of this phase had to be changed, due to situational circumstances, from concluding one conceptual design to instead suggest different conceptual ideas within different nudging categories. The concepts from the second iterations were evaluated during the fifth empirical study with users, focusing on user acceptance. The evaluation phase concluded the project by the creation of the final design guidelines.

4.2 PHASE 1 – ANALYSIS

The first phase of the project was the analysis phase. The analysis phase aimed to understand driver needs and use context by investigating attitudes, motivations and drivers past and personal experiences regarding speeding. The goal of this phase was to compile a contextual framework concluding the findings from the first phase, to be used as a foundation in the concept development phase. The analysis phase was initiated through a literature study which encompassed three areas of speeding laws and regulations, existing speeding countermeasures and literature related to drivers speeding behaviour. Results from the literature study can be found in chapter 2.

Scientific papers were used as the primary source for the literature studies. Further, news articles and websites were used in addition to scientific journals to understand drivers speeding behaviour and upcoming technology for speed assistance systems. Understanding laws and regulations were needed to define speeding and to understand the terminology. Mapping our current methods for counteracting speeding was used to understand existing systems and what aspects of the interaction that to consider when designing a counteracting method for speeding. A thorough literature study was encompassed regarding the driver to be able to understand and emphasise with the user of the system. The literature study provided quantitative data for driver's speed choice. The literature did not sufficiently provide an understanding of attitudes, motivations and factors affecting acceptance which was needed to emphasis with the user during the design process.

The first and second empirical study filled the gap from literature with qualitative data from users. The first empirical study aimed to investigate current speeding behaviour through semi-structured interviews with users. The goal was to identify driver characteristics to create user personas and identify driving scenarios significant for speed choice. Findings from interviews were analysed through an affinity diagram where findings got categorised into themes of identified problems. Findings from the literature study were included in the affinity diagram to provide a holistic perspective of the problem. The conclusion of the analysis provided an understanding of factors which signifies speeding behaviour. Execution and findings from the first empirical study can be found in chapter 5.1. The conclusion was used for the creation of user personas to identify attitudes, goals and expectations for different driver characteristic. The personas worked as evaluation tools in the design process to emphasise with users to keep a user-centred approach.

Further, 14 scenarios were created which exemplifies different driving situations which influence speeding behaviour. The scenarios were used during the second empirical as a tool for evaluation during the design process. User personas and scenarios are presented in chapter 6.

The second empirical study aimed to investigate how different methods of influencing speeding behaviour affect user acceptance in various driving situations. The goal was to identify what situational factors affect acceptance towards informative, warning and intervening methods. The selected method for the study was a scenario-based interview where a toolkit was used to enable the participant to talk about their anticipated experience and acceptance of being influenced. A separate affinity diagram was created for this study where findings were categorised into themes which provided an understanding of factors affecting acceptance. Execution and results from the first empirical study can be found in chapter 5.2. Based on findings from this study, acceptance of being influenced was added to the persona documents as well as evolved personality characteristics.

The analysis phase was concluded by combining findings from literature and both empirical studies to define design problem and possible implications as well as user needs and requirements in the contextual framework which can be found in chapter 6. The contextual framework formed the basis for the design guidelines and was used to guide the design process. Further, a concept for a system structure was created based on findings from the second empirical study. The system structure defined acceptance in relation to the severity of the violation in terms of km/h in combination with time spent above the speed limit and aimed to concretises how requirements and needs change in different stages of speeding violations. The system structure can be found in chapter 6.2. The analysis phase was concluded by using Fogg's Behavioural Model to map out the scenarios to be able to identify how motivation and ability shift in different driving scenarios as a base for ideation using different nudging principles. Fogg's Behavioural Model is described in chapter 2.5, and the result of the model can be found in chapter 6.5.

4.3 PHASE 2 – CONCEPT DEVELOPMENT

The concept development phase aimed to use the research findings concluded in the contextual framework to create a conception of the future through continuous exploration of ideas and concepts in the process of two design iterations. The goal of this phase was to conclude concepts which could achieve the task of assisting and alerting drivers in their speed choice using the vehicle HMI. A literature study investigating existing vehicle HMI guidelines and standards was conducted to provide an initial understanding of vehicle HMI design opportunities. This was followed by an investigation of literature regarding workload in the driving context and user acceptance to new technology. The literature study served as input for the design guidelines, which were evolved to be used during ideation and evaluations of ideas and concepts. Presented findings from literature can be found in chapter 2.

In the first iteration, ideas were created during several brainstorming sessions. At this stage, no constraints were used for the ideation, to allow for new creative ways of dealing with the issue of speeding. Ideas external to the vehicle HMI and inspiration from existing solutions served as inspiration in a Scamper session to think of new ways to implement speed assistance systems. The ideation resulted in 50 + ideas which were compiled and discussed. The least feasible ideas were excluded at this stage, and a few ideas merged into one idea. Twenty-three ideas remained and were categorised based on three different nudging categories which are described in chapter 2.5. The ideas were evaluated with users during two focus group sessions. The focus group session aimed to receive initial feedback from users. Following the focus groups, the Autoliv research vehicle was used in the fourth empirical study to collect user feedback on more intrusive vehicle HMI in real traffic context. Due to situational circumstances during the project (discussed in chapter 11.2), the fourth study was extended to a digital survey format which was shared with a selected group of drivers aiming to triangulate results from studies in the research vehicle. Execution and results from the third and fourth empirical study can be found in chapter 7.2 and 7.3. The 23 remaining ideas were evaluated in a Pugh matrix against each scenario and an overall acceptance score based on the third and fourth empirical study. Ideas with the lowest score were excluded. The evaluation and Pugh matrix can be found in chapter 7.4.

The second iteration aimed to move from ideas to concepts. Concepts within each nudging category were created, followed by combining concepts from different nudging categories to create concepts which impact speeding behaviour in the different identified scenarios. This resulted in four final concepts which concluded the second iteration and the concept development phase. The personas were used to evaluate the concepts and guide a user-centred approach in the creation. Further, the concepts were continuously evaluated towards the design guidelines for continuous improvements. The final concepts were to be used in the final third phase for user evaluation. The final concepts can be found in chapter 8.

4.4 PHASE 3 – EVALUATION

The third phase aimed to conclude the design guidelines which intended to be used in the design process for reaching acceptance. The goal had to be changed from evaluating a final design concept to instead realising different design alternatives within different nudging principles and evaluate the principles of each concept. The situational circumstances only allowed for digital evaluations with users in the fifth empirical study, which intended to take place in a traffic context. Instead, each concept was animated and evaluated through digital interviews with users. The fifth empirical study aimed to investigate the user acceptance of the concepts to conclude the pros and cons of each of the concepts. Semi-structured interviews combined with animated material which illustrated the principles of each concept were used. The collected user data was analysed through content analysis.

Based on findings, potential improvements could be concluded as well as use cases and target group for each concept. The third phase concluded the project with finalised design guidelines which summarise important findings from the project as a tool to be used in the future design of speed assistance systems.

5

PHASE 1- ANALYSIS UNDERSTANDING NEEDS & USE

The following chapter describes the activities of the first phase. The analysis phase aimed to understand driver needs and use context by investigating attitudes, motivations and drivers past and personal experiences regarding speeding. The goal of this phase was to compile a contextual framework (described in chapter 6) concluding the findings from the first phase. The first section of this chapter describes the execution, results and conclusion for the first empirical study. The following section describes, in the same order, the second empirical study.

5.1 EMPIRICAL STUDY 1

The first study addressed current behaviour and aimed to investigate current speeding behaviour through semi-structured interviews with users. The goal was to identify driver characteristics to create user personas and identify driving scenarios significant for speed choice. Findings were needed to elicit fundamental interactions and situations for the design of further studies and the creation of the contextual frameworks.

5.1.1 EXECUTION

The selected method for the study was a one-to-one semi-structured interview. A prepared template with fixed questions was used during interviews (see appendix i). Follow-up questions were used to encourage elaborated answers and reflections. For questions with multiple choice, the participants were asked to reflect over their answers.

Probability sampling was used to recruit twelve drivers with different levels of driving experience according to the distribution in figure 5.1 to participate. The participant was informed before the session that the theme of the interview was speeding. The interview started with quick warm-up questions about general driving frequency and behaviour to get the participant comfortable with the setting and to encourage reflection over themselves as drivers. The following questions focused on speeding behaviour. Follow-up questions were frequently used to trigger reflection and honest answers. The interview was concluded by allowing the participants to think about their future speeding behaviour.

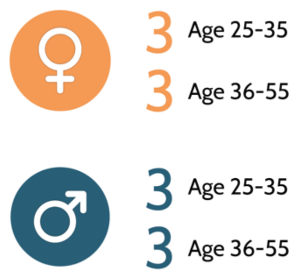


FIGURE 5:1 GENDER AND AGE DISTRIBUTION STUDY 1.

The interviews were transcribed and analysed through an affinity diagram. The affinity diagram provided an overview of identified problem areas which are described in the following section of results. The findings were combined with findings from literature and concluded in user personas which described driver characteristics to consider in the design process. Further, scenarios were created based on findings from the first empirical study, which were to be used in the second empirical study as well as a tool with the user personas in the design process. Concluded user personas and scenarios are presented in chapter 6.

5.1.2 RESULT AND DISCUSSION

When being asked to describe oneself as a driver, all participants considered themselves to be either a safe and conscious driver. Even if all participants expressed that there are positive aspects of keeping the speed limit, only one of the participants claims to never exceed the speed limits while the other admits to often or always exceed the speed limit. In general, the participants consider themselves to be good at driving and making risk assessments. The study showed that nine out of twelve drivers did not necessarily consider exceeding the posted speed limit as speeding, but rather when exceeding a certain amount above the speed limit. The first empirical study led to qualitative insights regarding what signifies speeding behaviour, to complement qualitative literature of drivers speeding behaviour. The findings showed that the contextual factors have a significant impact on behaviour, motivation and attitudes towards speeding. Three distinct categories were found during analysis which identifies speeding behaviour which is described below.

SURROUNDING FACTORS AFFECT SPEED CHOICE

It was found that all participants consciously adjust their speed according to their surroundings, rather than follow the posted speed limit. There are also indications that drivers find this assessment as more credible than the posted speed limits.

Drivers find it more important to keep the speed limit in urban areas.

9 out of 12 participants

There was an apparent attitude among participants that it is more important to keep the speed limit in certain areas. These areas were usually expressed as places where they understand the risk of crashes, usually associated with low posted speed limits, e.g. nearby a school or hospital. Accordingly, it was expressed that it is okay to speed on the highway or on an empty rural road as the risk of hurting others was considered low. This finding agreed with numbers from ETSC (2019) that speeding is more common on rural roads and motorways in Sweden.

Drivers chose a speed based on their risk assessment of the following factors:

- Presence of VRU
- Weather
- Traffic
- Road conditions
- Posted speed limit
- Familiarity of road

Participants find themselves competent enough to make their own risk assessment and consider it to be more valid than the posted speed limits. This agrees with the paper from WHO (2017) concluding that 90% of drivers consider themselves safer than average. Transport Canada (2005) found that drivers do not necessarily consider speeding unsafe. It can be assumed that drivers generally overestimate their capabilities and find it safe to speed in situations where they do not foresee any risks. Most of these participants also expressed a mistrust to the posted speed limits. They often considered it to be set to low, which have been found by DfT (2018) and Transport Canada (2005) to justify speeding behaviour. The actual travelling speed was expressed as a factor for speeding, which was also found by Ellison and Greaves (2010). At rural roads and highways, it was experienced as safer to speed than in urban areas. It was related to the characteristics of the road, where a high-speed road is often broad, straight and without the presence of pedestrians. The weather was also mentioned as a factor impacting speed choice, which further agrees with findings from Ellison and Greaves (2010).

Findings show that drivers consider their risk assessment improved on routine routes which were expressed to result in speeding behaviour. Participants found it safer to speed on routine routes as they perceived knowing all the risks. One participant expressed that he usually speeds on routine routs because he knows the road so well that he does not have to think about his driving. It can be argued that routine routes often are connected to boredom which has been found as one factor to increase the risk of speeding behaviour, according to Åberg et al. (1997).

Following the traffic flow was used to justify speeding - as it feels safer to not slow down other RU.

5 out of 12 participants

Participants expressed how they found it more relevant to follow the traffic flow than the posted speed limits. It was expressed as safer to follow the traffic flow, but also several participants expressed how they do not want to be a road blocker that annoys other drivers. Two participants told stories of how they have witnessed drivers being annoyed by people in front of them driving according to the speed limit, which have affected them to prefer following the traffic flow. This finding relates to literature concluding that the perceived expectations of others have effects on speeding behaviour (Åberg & Haglund, 2000; Javid & Al-Roushdi, 2019) and that 52% of drivers believe it to be safer to adapt the speed to other drivers, even if this requires going over the posted speed limit (Transport Canada, 2005). What is interesting to note is that Javid and Al-Roushdi (2019) found that drivers generally overestimate others actual speed with 8-10 km/h. It can be assumed that drivers unintentionally speed to keep up with the traffic, creating a chain effect on other drivers behaviour.

THE EXPERIENCE OF SPEED AFFECT SPEED CHOICE

Findings show that there is a relation between the experience of speed and speed choice. A surprising number of stories concerned unconscious speeding as a result of it being too easy and comfortable to drive fast in modern cars. Further, the experience of speed was also expressed as closely related to the overall driving experience.

Drivers find it difficult to realise speeding violations, especially in newly produced cars as it is comfortable to drive fast.

7 out of 12 participants

Participants expressed how they often do not realize how fast they are driving and get surprised when looking at the speedometer which agrees with results from Transport Canada (2005) that as much as 51% of violations could be unintentional. The participants' stories of unintentional violations were often related to the experience when driving modern newly produced cars. This agrees with literature concluding that the age of the vehicle matters, where drivers of vehicles newer than five years were more likely to speed (Ellison & Greaves, 2010). Several participants expressed how they usually look at the speedometer when they feel that they are driving too fast and the realises that they were speeding.

Drivers find it important to have control of their speed choice. 6 out of 12 participants	Findings showed that there is a general attitude of wanting to have control over one's speed choice. A few participants also expressed not having control over their speed a reason for speeding, as speeding is used as an outlet for the frustration and anger gained from being controlled. Åberg et al. (1997) found that anger tends to increase the risk of speeding behaviour which could explain the reasoning from the participants. Furthermore, speeding was justified in specific situations, such as when overtaking another car or making way for ambulance or police. Then speeding was expressed as a necessity to get out of the way.

TEMPORARY MOTIVES AFFECT SPEED CHOICE

Findings show that several temporary motives affect the participants' speed choice. Stress and routine routs were the most prevailing. The social setting in the car was also found to affect driver behaviour.

Drivers use stress to justify speeding. 5 out of 12 participants	Time pressure is used as a valid reason for speeding by most of the participants. One participant felt that the experience of saving time was enough to reduce the feeling of stress, even if knowing that is not the case. Another participant expressed that she found it important to keep the speed limits, except for when being stressed. Then saving time is more critical. Findings from literature show that humans have a hard time focusing on both negative and positive outcomes of a risky event which results in attention being put to one of them (Crozier et al., 1997). WHO (2008) stated that speeding provides an immediate positive reward to the driver by the feeling of saving time, which according to Daniels (2000) increase the probability of certain behaviour. In relation to findings by Transport Canada (2005) that many drivers do not consider speeding unsafe, it can be assumed that speeding is by some considered the best option.
Passengers have both positive and negative impact on drivers' speed choice. Positive: 4 out of 12 participants Negative: 1 out of 12 participants	Passengers seem to have an overall positive effect on the participants' speed choice were four out of twelve mentioned that they were less willing to speed if someone was with them in the car. One participant said that he would never put a passenger in the position of having to tell him to slow down. He considered it unfair to expose someone else for the risks that come with speeding. However, one participant also expressed passengers as a reason for speeding due to group pressure. The literature identifies that passengers with a positive attitude towards speeding violations increase the likelihood of speeding violations (Åberg et al., 1997).

5.1.3 Conclusion

Surrounding contextual factors were described as having an impact on speed choice. Based on findings, it can be assumed that there are already more substantial incentives to keep the speed limit in urban areas where the risks of hurting VRU's are prominent. Most participants had a general consideration for other people. It can be assumed that the knowledge of what risks are associated with speeding is enhanced by the presence of passengers and other VRU. Consideration must be taken to the fact that in some situations, speeding feels safer than driving by the posted speed limit. These factors affected drivers' decision-making, in some cases, even drivers who consider keeping speed limits important could not find the motivation to do so or felt pressured to go against their own values.

During interviews, several driver characteristics were recognised. The driver characteristics had an impact mainly on the attitudes towards speeding. There were reasons to believe that speeding behaviour is closely related to personality and driver characteristics. The driver characteristics were concluded in the driver personas, which are described in section 6.3. It was important to realise the differences amongst drivers early in the process to be able to identify relationships between driver characteristics and acceptance towards being influenced to keep speed limits.

Several situational factors were found to impact speed choice. The main factors were related to the driving context and the emotional state of the driver. Scenarios were created to identify critical situations for speed choice, presented in section 6.4.

5.2 EMPIRICAL STUDY 2

The second empirical study addressed anticipated future experiences of being influenced to keep the speed limit in different driving situations. Findings from the first empirical study pointed out several factors necessary for speed choice as well as attitudes towards speeding. This study aimed to explore how different factors affect the acceptance of various strategies to counteract speeding. The findings from the study aimed to provide an understanding of what aspects are essential to consider for acceptance.

5.2.1 EXECUTION

The selected methods for this study were semi-structured interviews (see appendix iv) supported with a creative toolkit (see appendix iii) and a preparatory sensitizing (see appendix ii). Nine drivers in the age span of 25-55 years were recruited for the study through probability sampling according to the distribution in Figure 5:2. In order to prepare participants and be able to strengthen reflections during interviews, a sensitizing assignment was used. It consisted of questions where the participants were asked to, during a drive, reflect over how they think they would experience being influenced through information, warnings or being limited to keep the speed limit.

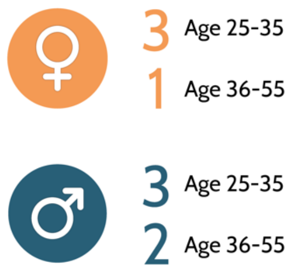


FIGURE 5:2 GENDER AND AGE DISTRIBUTION STUDY 2.

The interviews were executed in a car. The car worked as a mediating object, and the participants were encouraged to use the interior to elaborate on their answers. The participants were shown a picture of a traffic scenario together with the posted speed limit, where they were asked to imagine exceeding the speed limit. They were later asked to resonate about how a desirable system could be like in that specific situation and what in the situation affected their answers. Each scenario was then added with the precondition of driving under time-pressure, or the image representing a routine route. These aspects were found crucial for speed choice during the first empirical study. The participants were asked to elaborate on how their acceptance would change under the new circumstances. During this process, follow-up questions were asked to get them to further reflect over their decisions so that attitudes towards different strategies and situations in traffic could be elicited.

As it can be hard for people to resonate about open-ended questions regarding systems that they have not yet experienced, a creative toolkit was used to support the reflection. The creative toolkit was not only used to stimulate creativity and trigger reflection. It further focused the conversation towards categories that the first empirical study, together with related literature, found as potential design variables of a system affecting both acceptance and effectiveness. The toolkit consisted of a board with suggestions within four different design variables: ISA type, timeline, tolerance and modality. Prepared suggestions were chosen and combined from each category, describing a suitable system to assist them to keep the speed limit from their perspective as a driver. The participants were also allowed to come up with their own suggestions for each of the categories. The results of the study were analysed through an affinity diagram. The affinity diagram resulted in three main categories which are presented in the following section. To communicate findings, the term intensity of stimuli was defined as a combination of how intrusive the used modality was perceived, the level of perceived control the user experienced and to what extent the sematic characteristics prompted the user. Drivers mostly considered subtle visual information as low intensity while high intensity was associated with stimuli that called for their attention that they were not able to ignore.

5.2.2 Result and discussion

The results from the study identified three categories of factors affecting acceptance of a speed assistance system. The findings indicate that the credibility of a system has a great impact on driver acceptance for different interventions strategies. Participants found it necessary to understand and relate to any intervention strategy employed, both in terms of when and how it is applied. There were further concerns about a speed assistance system could disturb the driving experience. Findings show that the acceptance of an intervention is related to its intensity, usually expressed as being dependent on the modality used in combination with which ISA type as well as its semantics. The intensity is perceived increasing from information to warning to limitation, similarly from visuals to auditory or haptics which agrees with recommendations from Campbell et al. (2016) in section 2.4.2. The acceptance of high-intensity interventions varied depending on the situation and perceived severity of the violation, usually described as km/h above the speed limit in relation to which area they were driving in. Furthermore, a solution that prompts the driver too intense when it is considered justified to speed is interpreted as less credible and can create frustrations. This agrees with literature concluding that timing and user expectations are important factors to consider when designing a warning system (see section 2.4.1).

SITUATIONAL FACTORS AFFECT ACCEPTANCE

The acceptance for interventions was found varying according to situational factors, where the severity of a violation was perceived differently and more or less justified to speed. Many contributing factors for increased and decreased acceptance are related to the findings in empirical study 1 in section 5.1.2, regarding the impact of surrounding factors and temporary motives.

Situational factors increasing acceptance

- **VRU**
- **30 km/h speed limit**
- **Risk of enforcement**
- **Bad road conditions**
- **Bad weather conditions**

Acceptance for interventions of a higher intensity was found in areas where VRU’s are usually present. In agreement with findings from the first empirical study, the participants found it more important to keep the speed limit in the presence of VRU’s, which was also argued to result in increased acceptance. Participants accepted, and some also appreciated, more intensive interventions in a 30 km/h-speed zone. Participants expressed that they find it important to keep the speed limit at 30 km/h-speed zones as they trust the limit being set for a reason. The acceptance was also increased if the chances of being fined or losing the driving license are high, where the consequences were perceived worse in low-speed zones. Other mentioned factors increasing acceptance was bad road conditions and weather changes that would impact the safety of travelling at high speeds.

Situational factors decreasing acceptance

- **Routine routes**
- **Traffic flow**
- **Stress**

On routine routes, drivers expressed they would be annoyed if being prompted to keep the speed limit. Findings from the first empirical study suggest that drivers generally are more prone to speed at routine routes. It can be assumed that the fact that the perceived improved risk assessment on routine routes results in less acceptance for being prompted to keep speed limits.

However, participants also claimed routine routes being the roads where they speed the most and are in need of an intensive intervention to change behaviour, important to note is that this should not be misinterpreted as being accepting of warnings.

Participants expressed that they would find it annoying and, in some cases, stressful with intensive intervention strategies when driving in traffic flow. Drivers expressed how they would choose to follow the traffic flow regardless of the intervention system. Findings from Transport Canada (2005) and the first empirical study showed that drivers consider it safer to follow the traffic flow. It can be assumed that drivers would interpret prompts as going against their beliefs of what is considered safe driving. ISO (2005), further argues that warnings opposing drivers' beliefs and expectations can be expected to have a lower effect. It was also expressed by participants that following the traffic flow meant that they could speed without risk getting caught by the police, as other drivers also are speeding. This could potentially add to the understanding of findings from ETSC (2019) and Buttler (2016) that drivers perceive the chance of getting caught for speeding as low.

During stress, the acceptance for interventions of higher intensity was lower, and participants expressed how they would ignore an intervention strategy if possible. It was also stated that the experience of driving fast is calming, and interventions instead would increase the stress level. ISO (2005) recommends that warnings should be used with caution, as a warning can increase the cognitive workload for the driver, which is described to induce stress.

SYSTEM TOLERANCE FOR SPEEDING AFFECT ACCEPTANCE

Findings show that tolerance of an intervention, for all but visual information, is important to reach acceptance among drivers. Participants found it ridiculous if a system would prompt them precisely when exceeding the limit, which would affect the credibility of the system.

Drivers wanted to be able to correct their speed before being warned.

7 out of 9 participants

It was expressed that participants want to be able to adjust their speed before being told by the car to do so. It was expressed annoying and inducing feelings of lost control if a warning were triggered too early and often. Spyropoulou et al. (2014) found loss of control one of the reasons for drivers not to appreciate ISA systems.

Drivers found a need for tolerances if high intensity of an intervention 8 out of 9 participants	Tolerance was expressed closely related to the intensity of the intervention strategy. High-intensity intervention strategies needed a high tolerance according to all participants, for it to be credible. The exception was situations where there is a greater risk, in agreement with factors increasing acceptance in the previous category.
The need for tolerance differed according to the speed limit 8 out of 9 participants	The posted speed limit seemed to be important for perceived appropriate tolerance among participants. This seemed to be related to the attitude against higher speed limits, where it was considered less severe to exceed as well as the higher limits for enforcement. A wish for an intervention strategy which reduces the chances of receiving speeding tickets was expressed. The ideal system was described to act when driving in a speed potential for receiving a fine, and with higher intensity when the driving licence could be withdrawn.

MODALITY AFFECT ACCEPTANCE

Modality was found contributing to the experienced intensity of a speed assistance system as well as provoking emotions among participants. The visual modality was considered lower in intensity than auditory and haptic modalities.

Drivers preferred visuals as it allowed them to stay in control 8 out of 9 participants	It was found that drivers prefer being influenced by visual intervention strategies, as they, to a large extent, can be ignored so that the driver stays in control. Findings showed that drivers found it important to maintain control of their driving in the sense of making their own choices. Participants appreciated getting aware of their speeding but wanted to keep the control and determine what was best according to the situation. The control also included having control over the intervention itself as well as the ability to ignore an intervention. This agrees with Campbell et al. (2016) recommendation that visual messages should when there is no need to call for immediate action.
Auditory warnings disturbed the driving experience and decreased the sense of control 7 out of 9 participants	Auditory intervention strategies were found irritating as it disrupts the driving experience and by some, expressed unwanted. Auditory feedback was associated with aggressive intervention strategies and compared with being physically limited, as sounds cannot be ignored. It was only accepted in situations where there were apparent risks or as a part of an increasing strategy where other interventions had been ignored. Green et al. (2008) and Campbell et al. (2016) recommend only to use auditory warnings when an immediate response is needed, with the argument that it can

	be perceived as annoying, which agrees with the expectations from participants in this study.
Drivers were sceptical to haptic feedback as it was anticipated to feel unpleasant and associated with problems with their car 4 out of 9 participants	Participants were sceptical to haptic feedback as they associate it to a problem with the car. They expressed that it could be hard to understand its meaning and what was causing it. Further, it was anticipated to feel scary and make them feel insecure. ISO (2005) highlights that tactile warnings must be understood not to increase the workload. However, a person who was used to his smartwatch was much more positive towards haptics as it was familiar to him. The same participant also appreciated the Lane Departure system in his car, where the steering wheel vibrated while assisting the driver to stay in the right lane. It can be assumed that haptic feedback is relatively rare in the driving context. The fact that drivers are not used to haptic feedback could affect the perceived acceptance.

ISA TYPE AFFECT ACCEPTANCE

The different ISA types impacted the acceptance towards being influenced to keep the speed limit amongst drivers. Information was the most accepted method, while warnings were accepted with several exceptions. Intervening, by limiting engine power was not accepted by most participants, only a few participants could imagine being limited in specific traffic situations.

Informative was the most accepted ISA type, without the need for tolerances. 9 out of 9 participants	Informative was the most accepted method to influence speeding behaviour which agrees with findings from EC (2016a) and Spyropoulou et al. (2014). Participants expressed that they would appreciate it without tolerances for all traffic scenarios if being able to ignore it. Information was mainly described as visual feedback by participants and could hence be assumed to allow them to stay in control, as the findings in the previous table in this section elaborated.
Information supporting the driving task at hand was perceived useful. Otherwise it could risk being ignored. 5 out of 9 participants	Participants expressed a wish only to receive information relevant to them for the driving task at hand. What was considered relevant differed amongst the participants. However, all participants appreciated receiving information about the current speed limit. Some of the participants would appreciate receiving information to help them prepare for different tasks in their driving. For example, information about an upcoming roundabout or upcoming change in speed limit before approaching the sign.

Warnings are perceived as annoying but are more accepted if there is a perceived risk 8 out of 9 participants	Participants associated warnings with annoyance and described their interpretation of warnings as irritating sound or visual flashes that were hard to ignore. However, warnings were considered acceptable for all participants in situations where there is a high perceived risk. This agrees with the reasoning by Campbell et al. (2016), that argues that the acceptance for more obtrusive modalities increase when the drivers see the benefits of a warning.
The acceptance of warnings was related to its tolerance 8 out of 9 participants	The acceptance for warnings was found closely related to the tolerance of the HMI. Most drivers expressed acceptance if speeding a certain amount, usually referred to as 5-10 km/h over the posted speed limit at 50 km/h and 0-5 km/h at 30 km/h.
The acceptance of warnings was increased if they could act on HMI of lower intensity before they were applied 7 out of 9 participants	Participants found it important to get a chance to act on lower intensity. The warning itself was preferred to increase in its intensity, where the most aggressive, often considered as sound, should be used for severe violations. This reasoning agrees with Campbell et al. (2016), that argues that auditory warnings can be perceived as annoying and preferably should be used as a final stage of a graded warning.
Limitation of the engine was the least 9 out of 9 participants **accepted ISA type as it was anticipated to have a negative impact on the driving experiences.**	Participants expressed that limiting engine power when exceeding the posted speed limit would induce stress, anxiety and worries about problems with the car. It was also expressed to induce a negative experience of being counteracted by the car. All drivers considered it necessary to maintain the control and be able to override any limitations which agree with findings from Spyropoulou et al. (2014) that found a relationship between loss of control and dislike for a system. One participant expressed that he did not want to be limited, as it would impair the driving experience. He appreciated adjusting speeds to accommodate to the surroundings and remaining control over the car.
The acceptance of the intervening ISA type was increased in relation to risks of harming other people. 4 out of 9 participants	The main incentives for accepting being limited was the risk of harming other people. Generally, the findings show that in 30 km/h speed zones people are more accepting of being limited engine power. In 50 km/h zones, the ones expressing they could potentially accept being limited, expected it to be a specific risk such as pedestrians. On a 50 km/h empty road, the participants did not want to be limited.

The acceptance of the intervening ISA type was increased if it applied to all RU. 4 out of 9 participants	Several participants expressed that they would have an increased acceptance knowing that it applied to all drivers. It can be assumed that if having the choice of remaining in control, drivers prefer not to be limited. However, many drivers consider speed bumps acceptable, as they impact all drivers. It can be assumed that participants found similar reasoning for being limited engine power. One participant expressed wanting to have speed-limiting zones, where all cars were limited in those specific areas.

5.2.3 Conclusion

A speed assistance system needs to consider different driving situations in order to reach acceptance from users. Each driving scenario presented to the users was found to affect user acceptance, which only shows that acceptance is highly situational. It can be assumed that for situations where the motivation to keep speed limits is considered low, such as on a routine route, the acceptance towards warning and intervening ISA is low. In these situations, any kind of prompt to keep the speed limit could gain from being combined with means to remind or increase motivation.

In situations where social factors affect speed choice, it is important to acknowledge the impact of social influence. If drivers consider it safer driving according to the traffic flow, it can be assumed that an intense HMI trying to prompt for opposite behaviour would impact the credibility. As recommended by ISO (2005), a warning system needs to comply with the beliefs of the drivers (see section 2.4). Findings suggested that acceptance towards a speed assistance system was highly dependent on the design of the system. Considerations must be made regarding the choice of sensory and ISA functional modality to reach acceptance. High-intensity feedback was, by most, only accepted in specific situations where there was a perceived level of risk. A matter that Campbell et al. (2016) further address by suggesting that the acceptance for more obtrusive modalities increase when the drivers see the benefits of a warning. Findings suggested that a system with tolerances have greater potential to be accepted as it leaves time for correction before escalation. An issue further addressed in ISO (2005), that stress the danger of interrupting when the driver is about to brake that could increase the cognitive load, add stress and delay the action. Further, the intensity needs to correspond to the perceived severity of the violation to reach acceptance. The findings implied that drivers need a system that supports them in their driving without adding intense judgement and reprimands.

The acceptance for intervening ISA functionality can be assumed to be low, based on the findings from this empirical study. Previous research showed that the effects of an ISA system are greatest for the intervening functionality (EC, 2016a; Spyropoulou et al., 2014). However, the functionality has been shown to be disapproved by users (Spyropoulou et al., 2014). Several drivers also adopt higher speeds with the functionality compared to without it for some speed limits, suggested to be a result of drivers delegate the speed control to the ISA system (Várhelyi & Mäkinen, 2001). As the focus of the thesis is to reach user acceptance, the following work focuses on investigating how in-vehicle nudges could be used to inform and warn drivers and encourage them to choose a lower speed choice without limiting their speed.

6

CONTEXTUAL FRAMEWORK

This chapter concludes results from empirical studies and related literature studies in the analysis phase. The chapter encompasses a section for problem identification and implications and a section describing a system structure to guide the creation of concepts, highlighting user insights on intensity and tolerance. Further, the chapter presents user personas which describe different driver characteristics and scenarios which was identified as critical for speed choice. In the following section, the scenarios are categorised based on Fogg's Behaviour Model to define strategies for changing speeding behaviour.

6.1 PROBLEM IDENTIFICATION AND IMPLICATIONS ON SPEED ASSISTING SYSTEMS

The following section presents the identified problem areas found to affect drivers speed choice. The section provides an understanding of users' needs and implications for the design of a speed assistance system. Further, the section describes user needs regarding the direct value, feedback and control.

6.1.1 DIRECT VALUE

Results from empirical study one and two showed that the consequences of exceeding the speed limit were perceived differently among drivers in different situations, which affected the acceptance of a speed assistance system. According to Daniels (2000), the consequences that have the most significant influence on behaviour is those we perceive as positive and negative consequences that are immediate and certain. Based on findings from empirical studies, it can be assumed that the consequences of speeding are for many positive, immediate and certain. Arriving earlier to the destination, without need to monitor the speedometer and instead drive in a speed that feels good were all positive consequences that can be perceived as immediate and certain and hence have a big impact on the speed choice.

Drivers expressed that they were aware of the negative safety aspects of exceeding the speed limit, but still chose to exceed it. Many participants expressed that speeding is not considered unsafe in all situations and that it in some cases could be perceived safer to exceed the speed limit than keeping it, which agrees with the study from Transport Canada (2005). The negative consequences of speeding were found uncertain in many situations, and according to Daniels (2000), that implies less impact on the behaviour. Situations, where the risks were perceived uncertain, was when the road conditions were good, on routine routes where drivers felt familiar with the risks, also found by Åberg et al. (1997), and when there were no pedestrians at risk. It was further perceived safer to take on a higher speed in traffic flow, overtaking another car or making way for ambulances. The literature further suggests that humans do not necessarily associate a high speed with danger due to our biological nature (Wallén Warner, 2006) and that drivers estimate it easier to slow down fast in newly produced vehicles (Yannis et al., 2013). Further, WHO (2017) found that 90% of drivers consider themselves safer than average. These are factors that can be assumed to further contribute to the uncertain negative consequences of speeding, decreasing the probability of keeping the speed limits, according to Daniels (2000) theory.

User studies found that drivers did not necessarily consider speeding a violation and described themselves as safe drivers even if they usually exceeded the speed limit, agreeing with findings from WHO (2017). Instead, participants considered themselves good at doing risk assessments and based their speed choice on the prevailing external conditions, where uncertain negative consequences seem to justify a higher speed. For situations where the risks were perceived uncertain and less important to keep the speed limit, many drivers intentionally exceeded the speed limit. In these situations, it was found less likely to reach acceptance for a speed assisting system. The findings agree with ISO (2005) that a warning system has low chances of overriding the beliefs of the driver. Empirical study two showed that an alerting speed assistance system would be perceived as irritating in situations when the negative consequence is uncertain, as it would oppose the driver's attitudes of what a violation is.

The literature presented recommendations from Campbell et al. (2016) that if the driver sees the benefits of a warning system, the system is more likely to reach acceptance. Participants expressed some positive aspects of keeping the speed limit. Near VRUs, in school areas and 30 zones, the positive consequences were described as immediate and more certain, as participants valued the safety of others and the moral aspect of keeping the speed limit in these situations. Furthermore, positive social and monetary consequences were described in situations where there is a risk for enforcement and to lower the fuel consumption as well as to make their passengers feel comfortable with their speed choice. However, these positive consequences were not perceived as certain and immediate, which according to Daniels (2000) can be assumed to result in other consequences that already are perceived immediate and certain to have more influence over the behaviour.

Possible implications:

- The varying context should be considered not to prompt drivers when the negative consequences is perceived uncertain.
- Alerts in situations where the motivation to keep the speed limit is high can create value for drivers.
- A speed assistance system could make positive aspect of keeping the speed limit appear as more immediate and certain to have a greater impact on the behaviour
- Possibilities of creating new incentives to comply with the speed limits could be explored

6.1.2 Feedback

For a speed assistance system to be accepted, user studies showed that it should consider what feedback is presented as well as how and when it is presented. Participants expressed that they did not want to be overloaded with information they did not find relevant to them, in situations where they did not need it. Campbell et al. (2016) paper add to this finding by stating that when the workload increases, the driver can compensate by skipping tasks. It can be assumed that a speed assistance system providing perceived unnecessary information would be likely to negatively impact the credibility, in agreement with findings from Green et al. (2008) and Campbell et al. (2016), and also the acceptance according to ISO (2005).

The timing of an HMI in combination with its intensity was found important for a warning to be credible and accepted. Further, Campbell et al. (2016) and Green et al. (2008) stated that the timing of a warning has an impact on the trust that the driver has for the warning. The timing should correlate with drivers' perceived severity of the violation to match the expectancy of the situation and be understood. It was expressed that for intense HMI to be accepted, it had to be justified by a severe situation. Participants did not necessarily consider themselves doing a violation immediately when exceeding the speed limit. However, drivers found it more severe to exceed the speed limit near vulnerable road users, schools, roads with speed limits of 30 km/h, areas where crashes commonly occur and when there was a risk of enforcement. In these situations, drivers even found smaller violations as sever and hence could find HMI with higher intensity and lower tolerance as credible. These would, according to Campbell et al., be situations where the drivers see the benefits of warnings.

The following sections will elaborate on the differences in identified problems of feedback type, intensity and tolerance. The section will we concluded with possible implications for acceptance for all areas.

TYPE
Most of the participating drivers found themselves good and safe drivers, and it was not appreciated if the car would continuously instruct behaviour. Participants instead described that they would like a speed assistance system to increase their sense of security. Feedback that facilitates to assess the current speed in relation to the speed limit was expressed, adding value to the drivers. Situations, where a solution could be perceived as counteracting, was during temporary speeding to overtake another car or in situations where the driver is already decelerating. Prompting drivers to lower their speeds in these situations was expressed risking that the system is being turned off. Additionally, ISO (2005) stated that issuing a warning in such situations could be potentially dangerous.

INTENSITY
User studies showed that the intensity of feedback had a significant impact on attitudes and acceptance. Increased intensity was expressed in relation to concerns regarding experienced loss of control over choices and attention, also foud by Spyropoulou et al. (2014), as well as disturbance of the driving experience. The intensity was perceived increasing from visuals to haptics to sound as well as from information to warning to limitation.

Visual information was widely accepted among the interviewed drivers, as they could choose when to attend to and act on it. Literature shows that informative ISA was the least effective method for speeding. Warnings and intervening ISA have shown more significant effects (EC, 2016a; Spyropoulou et al., 2014). Intervening ISA was however described as unwanted by participants in this study, as it was interpreted controlling, similar to someone telling what to do and decide when to bring attention to the speed, where they rather use their risk assessment. Participants were instead more accepting of the HMI and lowering their speed if they decide on their own, with support of information they can choose when to attend. User studies showed that high-intensity HMI was more accepted if used in a raising intensity system, and when the intensity corresponded to the perceived severity of the violation. However, it is crucial to consider that a too high-intensity warning could result in more aggressive speeding behaviour based on indications from the study by Spyropoulou et al. (2014) therefore it is important to investigate further what level of intensity is accepted for a raising system.

TOLERANCE
Many drivers did not consider exceeding the speed limit as speeding, but rather when exceeding a certain amount above the speed limit. Furthermore, drivers did not appreciate their speed being precise and steered and expressed that they found it important to get the chance to adjust their behaviour on their own before a speed assistance system was interrupting them.

User studies showed that the higher intensity of the HMI, the higher tolerance were needed for it to match the expectancy of the situation. The credibility of the speed limit 30 km/h were widespread among participants, where some would accept no tolerance for warnings if going above the speed limit, as the risks were perceived high. When the risk of hurting others was perceived low, the HMI was expressed in need of higher tolerance to be accepted. The posted speed limit also affected the sense of appropriate tolerance of an intervention. I can be assumed to be related to the findings from study one and Ellison and Greaves (2010) that posted speed limit is an important factor for speed choice. As drivers considered it safer to exceed the speed limit when already driving fast, there was an expressed need for higher tolerances to match users' expectancy for higher speed limits.

Possible implications:

- Making it easy for the driver to assess if they are keeping the speed limit or not can create value.
- A speed assistance system could benefit from having a supporting character**,** rather than counteracting or demanding drivers to comply with a certain action.
- A speed assistance system could benefit from being responsive and abort in case of ignorance and during temporary speeding situations.
- A speed assistance system could benefit from using nudges that triggers motivation or an automatic response to reach effects with low intensity.
- A speed assistance system could utilize the increased acceptance of higher intensity in a raising grade system.
- Several characteristics for tolerances were found to have potential to increase acceptance and credibility:
    - Percentage of km/h above the speed limit - to consider the varying acceptance for high and low-speed limits.
    - Time spent above the speed limit - to allow the driver to adjust the speed before being prompted.
    - Based on traffic situations - to adapt to the situational factors where drivers find it more important to keep the speed limit: in the vicinity of VRU, schools-zones and 30 km/h speed limit roads.
    - Based on individual driving style, to adapt the high-intensity nudge to the maximum violation the specific driver usually does during the prevailing external conditions.

6.1.3 Control

The results from user studies agree with Spyropoulou et al. (2014) which found loss of control one of the reasons for drivers not to appreciate ISA systems. Even if user studies showed that drivers appreciated being able to take part in speed-related information, many found it important to be able to ignore interventions to feel in control. Being able to remain in control was commonly associated with HMI of low intensity by participating drivers. They expressed acceptance towards intense HMI with the condition of having control over the system and tolerances.

Campbell et al. (2016) argue that annoyance can be avoided by allowing the driver to adjust detection sensitivity, intensity and volume for warnings. If remaining in control, a few participants in the study expressed they would accept sound signals as well as being limited, which was expressed as undesirable without control. It can be argued that if a driver commits themselves to not drive above a certain speed, a warning and limiting system can be perceived as positive since they no longer want to ignore it. During those conditions, a speed assistance system would assist and not counteract the driver as it facilitates to fulfil self-set goals and create value for the user. Furthermore, user studies showed that different drivers of the same car could have different preferences regarding what support they prefer to use.

Possible implications:

- The adherence and acceptance of a speed assistance system could benefit from allowing the driver to remain in control.
- Providing the opportunity to alter the tolerances of the HMI could provide the user with the control that is needed to accept a solution.
- Making it easy for every driver of the same car to drive with a system according to their preferences can utilize the potential of a speed assistance system.

6.2 INTENSITY DEFINITION STRUCTURE

The previous section concludes that acceptance depends on the intensity and tolerance, aspects that need to be considered in a speed assistance system. This section describes an intensity structure that was created. Followed by a section describing each intensity level with regards to what effects the level wants to achieve and how the user and the solution will cooperate to reach the effects. The structure was used as a framework for ideation during the concept development phase, which is described in chapter 7.

6.2.1 SYSTEM

Based on findings described in section 5.2, it was assumed that a solution could potentially act on four intensity levels within certain tolerance spans while still withholding acceptance by most drivers. The concluded levels vary in intensity that increases from level 0 to 3. Level 0 is present within the speed limit, while 1-3 is triggered above the speed limit. Level 1-3 are further active within certain tolerances based on time spent and percentage of km/h above the prevailing speed limit.

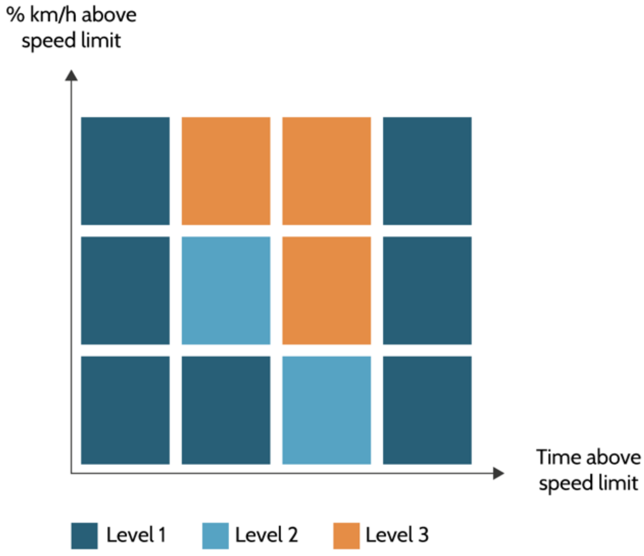


FIGURE 6:1 SYSTEM INTENSITY STRUCTURE FOR LEVEL 1-3.

Findings suggest that drivers were more accepting of higher intensity solutions when driving in urban areas, with low-speed limit roads. With a system that bases its tolerance for a violation on a percentage of the posted speed limit, consideration can be put to the fact that drivers perceive violations differently depending on the speed limit. Furthermore, it was found that drivers want to be able to correct their actions based on low-intensity feedback before receiving increased intensity feedback. Therefore, by allowing a certain time tolerance, the system allows the driver to act before being prompted. The time tolerance should also be used to allow for temporary violations which were found important for drivers to accept a system.

The intensity raise of the HMI will behave differently depending on the drivers speeding behaviour, where a faster acceleration above the posted speed limit will result in HMI of higher intensity faster, which is displayed in fig 6.2, where the lines resemble four different acceleration patterns. If the driver accelerates quickly up to high % above the speed limit and stays there, line c describes the escalation pattern. If the driver accelerates quick up to medium % above the speed limit and stays there, line b describes the escalation pattern. If the driver accelerates quickly up to low % above the speed limit and stays

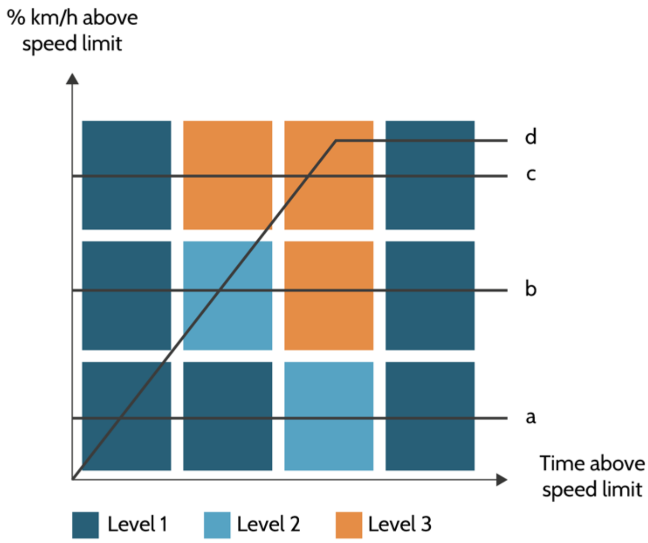


FIGURE 6:2 SYSTEM INTENSITY STRUCTURE FOR DIFFERENT SPEEDING BEHAVIOUR.

there, line a describes the escalation pattern. If the driver steady accelerates above the speed limit, line d describes the escalation pattern.

To further give the driver control over the system as well as positive feedback for one's behaviour, intensity level 2-3 aborts instantly when the car is decelerating, or the driver releases pressure from the gas pedal, and return to level 1. In order to avoid annoyance, level 2-3 should recognise and not trigger during situations such as over takings, where the driver could be distracted by the HMI.

6.2.2 Level description

Level 0 is only present when the driver follows with the speed limit. At this point, the user can choose when to attend to the information, not to distract the driver's mental resources when they are not in need to correct any action. At this level, the aim should be to encourage the driver to keep the speed limits with positive feedback to make it interpreted as more satisfactory to keep the speed limit without prompting a behaviour.

Recommended sensory and ISA functional modality:

- Visual information

Level 1 is the first and lowest level of intensity to influence the driver when speeding using prompts. This level should aim to notify the driver of exceeding the speed limit and nudge to lower the speed. The level should create contrast from the preferred state in level 0, to steer the driver's attention to the violation and make the action be perceived as entering a dissuaded state.

The level is active as soon as the driver exceeds the speed limit, and levels of higher intensity will never be triggered before the driver has gotten time to react to level 1. This level will be present together with HMI of higher intensity at level 2 and 3, to inform the driver why level 2 and 3 are triggered and provide feedback on the correct action to avoid warnings. It is further the level the system returns to when level 2 and 3 have been ignored to avoid annoying the driver and induce perceived loss of control.

Level 1 can only be aborted by lowering the speed below the speed limit, to make it easy for the driver to determine that they are driving above the speed limit while instilling doubt over their speed choice. For level 1 to be accepted while constantly being present, the intensity of the HMI must be subtle so that the driver can ignore it and focus on the driving task and merely being informed rather than prompted.

Recommended sensory and ISA functional modality:

- Visual Information
- Visual low-intensity warning

Level 2 is the second intensity raise and attempt to affect the driver. At this level, the higher intensity should aim to motivate and draw attention to the violation through a subtle intensity raise. It should make sure that the violation is noticed by changing the placement, while still obtaining an informative character to corresponds to the driver's expectation of the situation and enhance a supportive character.

The level is activated for violations of a certain percentage of the speed limit. It remains for a few seconds before either going back to level 1 if the driver maintains the speed, abort if the driver lowers the speed or trigger level 3 if the driver accelerates further.

Recommended sensory and ISA functional modality:

- Visual Information
- Visual medium-intensity warning

Level 3 is the third intensity raise and last attempt to affect the driver. At this level, the sensory modality as well as placement are changed to make sure that attention is drawn towards the violation. The intensity and characteristics of the HMI should be perceived as calling to action, as a correction is needed urgently.

The level is activated for violations of high percentage of the speed limit. It remains for a few seconds before either going back to level 1 if the driver maintains the speed or abort if the driver lowers the speed.

Recommended sensory and ISA functional modality:

- Visual information
- Auditory high-intensity warning
- Tactile high-intensity warning

6.3 PERSONA

Four personas were created based on personality traits that were found during the empirical studies. The personas mainly highlight the different driver characteristics, attitudes and motivations that were found during the first phase. Further, the personas explain how the goals and expectations vary between different drivers' characteristics. The personas were only intended as a tool to emphasise with different driver characteristics to adopt a user-centred concept development. In real life, drivers often shift between different personas depending on situational factors, which needs to be considered when using the personas.

Emma

Age: 25 Female
Occupation: Student
Driving frequency: Low

Goals

- To have a good atmosphere in the car.
- To feel supported by the car.

Frustrations

- Driving situations where a lot is going on.
- Navigating in unfamiliar environments and not finding her way.
- Being disrupted in stressful situations.

Biography

Emma is a semi-experienced driver. She borrows a car from her parents a couple of times a month to pick up friends for shopping. Occasionally she visits her friends in another city but doesn't appreciate driving the far distance on her own. Emma is an emotional driver and gets easily influenced by others in the car. She usually stays just above the speed limit but sometimes gets bored, which makes her more impulsive.

Emma finds the new safety systems cool, and she is impressed by what cars are capable of today. She doesn't know what safety systems her parents have but have experienced some of them in situations where she felt that she needed it.

Personality

Reflective — Impulsive

Careful — Careless

Focused — Distracted

Planned — Unplanned

Acceptance ISA

Informative

Warning

Intervening

Motivations to keep speed limit

Others safety

My safety

Law enforcement

Economic incentives

Environmental incentives

Jacob

Age: 32 Male
Occupation: Engineer
Driving frequency: High

Goals

- To arrive at the predetermined time.

Frustrations

- Having to search for parking.
- Bad road conditions.
- Others driving below the speed limit.
- Busy roads.

Biography

Jacob is an experienced driver and drives every day to work after leaving his kids at kindergarten. He actively tries to drive safe when the kids are in the car, but generally, Jacob is a risk-taker. He thinks it's more important to arrive at a particular time than keeping the speed limits.

Jacob appreciates the safety systems in his car but thinks that they generally have too low tolerances, which sometimes makes them annoying. He has already changed the tolerances for the systems with manual adjustments.

Personality

Reflective – Impulsive

Careful – Careless

Focused – Distracted

Planned – Unplanned

Acceptance ISA

Informative

Warning

Intervening

Motivations to keep speed limit

Others safety

My safety

Law enforcement

Economic incentives

Environmental incentives

Sandra

Age: 55 Female
Occupation: Saleswoman
Driving frequency: Medium

Goals

- To arrive safe.

Frustrations

- Other drivers not paying attention and being careless.
- People driving up close from behind.
- Not feeling in control over the driving situation.

Biography

Sandra is an experienced and conscious driver who consider safety in most driving situations. She prefers driving by the posted speed limits but generally follows the traffic flow on faster roads to avoid being the one slowing other down. On smaller roads and in cities, Sandra always tries to keep the speed limit, and violations are usually unintentional.

Sandra knows that her car is well equipped with different safety systems but have never experienced most of them. She appreciates using the adaptive cruise control, which makes the driving task easier.

Personality

Reflective — Impulsive

Careful — Careless

Focused — Distracted

Planned — Unplanned

Acceptance ISA

Informative

Warning

Intervening

Motivations to keep speed limit

Others safety

My safety

Law enforcement

Economic incentives

Environmental incentives

Michael

Age: 40 Male
Occupation: Project manager
Driving frequency: High

Goals

- To feel in control while driving.
- To make his own risk assessments.

Frustrations

- Driving behind someone who drives according to every speed limit or below.
- Others commenting on his driving.
- Drivers who don't use the light signal.

Biography

Michael is an experienced driver and commutes long routine distances too work every day. Michael considers a certain amount over the speed limit okay as long its proper road conditions. He doesn't always agree with the posted speed limit and prefers driving based on situational factors and his own experience rather than frequently checking the speedometer.

Generally, Michael finds the safety systems in his car too intense. He has turned off the red warning light for front collision as it lightening up all the time. Michael appreciates the new lane departure system in his car, which subtly guide him only when necessary.

Personality

Reflective — Impulsive

Careful — Careless

Focused — Distracted

Planned — Unplanned

Acceptance ISA

Informative

Warning

Intervening

Motivations to keep speed limit

Others safety

My safety

Law enforcement

Economic incentives

Environmental incentives

6.4 SCENARIO

The driving experience has a constantly changing use context, where the driver has varying attitudes towards different traffic situations that are encountered. The attitudes and temporal motives among different drivers result in a dynamic context with many needs to consider in the design process. With the defined personas and the perceived different consequences of speeding as a basis, 14 scenarios were created to describe common speeding situations and how they are perceived by the driver. The scenarios are divided into five categories which are described in Table 6.1 that describe the reason for exceeding the speed limit in the included scenarios. The full description of scenarios begins at the following page. Each scenario is mapped to the personas that are most likely to end up in the described scenario, as well as the road characteristics.

TABLE 6.1 CATEGORISATION OF SCENARIOS.

INATTENTION/DISTRACTION SCENARIO 1-4	Scenarios where the driver unintentionally exceeds the speed limit due to lack of focus on the driving task. The scenarios range all from a total absence of awareness of the correct speed to lost focus on one's speed.
RISK ASSESSMENT SCENARIO 5-9	Scenarios where drivers use their risk assessment to justify speeding behaviour. Even if all scenarios are intentional, they vary in how much the driver intends to exceed the speed limit as the motivation to stick to the speed limits are still higher for some scenarios.
HABITS SCENARIO 10 & 11	Scenarios closely related to the previous category of risk assessment, but these scenarios highlight the impact that habits have on the speed choice. User studies found that drivers had a clear knowledge of their driving style, with low intentions of changing it, due to it being habitual.
SOCIAL INFLUENCE SCENARIO 12	A scenario of social influence, that has shown to have an impact on the speed choice when following the traffic flow for certain personas while a similar scenario was put in the risk assessment or inattention category for other personas. The violation is intentional where the motivation to adhere to the social influence out concurs the motivation to lower their speed the few km/h.
TEMPORAL MOTIVES SCENARIO 13 & 14	Scenarios where the driver chooses a higher speed as other motives are perceived as more important in that situation. The scenarios describe situations where the driver intentionally exceeds the speed limit, and the experience of keeping a higher speed is experienced more satisfying or appropriate to deal with the situation which makes them comfortable with the speed choice. Hence, the motivation to adhere to the speed limit is very low, and they find it hard as the circumstances are perceived requiring it.

6.4.1 INATTENTION/DISTRACTION

1 Distracted in an urban area

A driver is driving on an empty 50 km/h road in an urban area. The driver finds it important to keep the speed limit in urban areas for the safety of others, no matter what. However, the driver gets distracted by the news on the radio and slowly deviates from the speed limit unintentionally without realising. The driver starts feeling that she is driving too fast and check the speedometer, only to realise she was driving way over the posted speed limit.

PERSONAS: Sandra

ROAD CHARACTERISTIC: Urban

2 Distracted outside a school

A driver is driving in a 30 km/h zone outside a school. There are children playing on the pavement next to the road. The driver finds it very important to keep the speed limit in 30 km/h speed zones, especially when there are children present. However, the driver gets distracted talking to a passenger in the car and unintentionally exceeds the speed limit when not looking at the speedometer.

PERSONA: Sandra, Jacob, Emma

ROAD CHARACTERISTIC: Urban

3 Miss the sign

A driver is driving on a road new for the driver. He does not pay attention and miss that the speed limit is changed to a lower speed limit. The driver keeps driving in the same speed as before 20 km/h faster than allowed, without a clue of doing such a severe violation that one would never do intentionally. The driver realises the mistake and decelerates to a more appropriate speed.

PERSONAS: All

ROAD CHARACTERISTIC: Urban, rural, highway

4 Experience of speed

A driver is driving in his or her new car on a straight empty rural road. The driver usually intends to keep the speed limit on this road, knowing animals can quickly appear in front of the car. The new car drives smoother than the driver's old car which makes the driver slowly deviate from the speed limit without knowing. The driver finds it hard to keep the speed limit in this car as she does not experience the velocity change due to the good conditions.

PERSONAS: Sandra, Emma

ROAD CHARACTERISTIC: Rural, highway

5 No obvious risks in a 30 zone

A driver drives on a 30 km/h road. The driver cannot find any reason for the low-speed limit, as there is no school in the area and no other obvious risks. As the driver does not foresee any risks, he lowers the speed to 38 km/h, just to be sure not to lose her/his driver's license in case of passing a police officer.

PERSONAS: Michael

ROAD CHARACTERISTIC: Urban

6 Low-risk assessment

A driver enters an urban area with pedestrians. The speed limit is set to 50 km/h. The driver finds it important to show respect to the pedestrians and keep a lower speed due to the safety aspect. However, the pedestrians are walking in a separate walkway and the driver assesses that they are safe and choose to keep driving above the speed limit only slightly lowering the speed in the moment of passing the pedestrians.

PERSONAS: Michael, Jacob, Emma

ROAD CHARACTERISTIC: Urban

7 Good driving conditions

A driver is driving on an empty 80 km/h road on a sunny day. The conditions are perfect for driving and the driver uses his experience to decide for appropriate speed, way over the speed limit. The driver does not see any benefits of keeping the speed limit during the good prevailing conditions. The driver chooses to trust her/his own risk assessment and intentionally exceeds the speed limit.

PERSONAS: Michael, Jacob, Emma

ROAD CHARACTERISTIC: Rural, highway

8 Traffic flow – safety

A driver is driving in a traffic flow that keeps a steady velocity of 5 km/h above the speed limit. The driver chooses to follow the traffic flow and exceeds the speed limit, as she or he perceives it safer to follow the traffic flow than keeping the speed limit and disrupting the traffic rhythm. The risks of enforcement are also perceived lower, which makes the driver feel comfortable with the speed choice.

PERSONAS: Jacob, Michael, Emma

ROAD CHARACTERISTIC: Urban, rural, highway

9 Bad road conditions

A driver is driving a certain amount above the speed limit when he notices that the driving conditions are worsened as it starts snowing outside. The driver knows that he should slow down but still feel in control over the vehicle, so the driver only slows down a bit, still driving above the posted speed limit. The driver still considers it safe as he usually drives much faster on this road.

PERSONA: Jacob, Michael

ROAD CHARACTERISTIC: Urban, rural, highway

6.4.3 Habits

10 Routine routes

A driver is driving to work the same route that he drives every day. The driver knows every part of the road and that there are never any risks with exceeding the speed limit on this road. Nothing has ever happened before. The driver chooses a speed higher than the speed limit as he always does when there is no perceived value by driving slower and arrive later to work.

PERSONAS: Michael, Jacob, Emma

ROAD CHARACTERISTIC: Urban, rural, highway

11 Risk of enforcement

A driver is driving too fast on a rural road. The driver always keeps at least 5 km/h above the speed limit. The driver does not want to receive a fine but does not notice the road sign warning about the up-coming speed camera. The driver sees the camera when approaching it and hit the brake to slow down the car just in time to pass. The driver then accelerates again to previous speed, now knowing to focus more on signs for speed cameras.

PERSONA: Michael, Jacob, Emma

ROAD CHARACTERISTIC: Rural, highway

6.4.4 Social influence

12 Traffic flow – speed blocker

A driver is driving in a traffic flow, that steady keeps about 5 km/h above the speed limit. The driver does not feel fully comfortable in keeping the same speed but choose to do it as he does not want to be a speed blocker for others. The drivers find it uncomfortable being the one to slow down others, having them do aggressive overtaking.

PERSONAS: Sandra, Emma

ROAD CHARACTERISTIC: Urban, rural, highway

6.4.5 Temporal motives

13 Stress

A driver is late to a meeting and chooses to exceed the speed limit to catch up for the lost time. The driver knows that he does not necessarily gain time from speeding but finds the higher speed as stress-reducing in itself as the perceived saved time is soothing.

PERSONAS: Michael, Jacob, Emma

ROAD CHARACTERISTIC: Urban, rural, highway

14 Overtaking

A driver drives behind a car that is driving just below the posted speed limit. The driver decides to overtake the car in front and chooses to exceed the speed limit to get past fast. As the driver is only exceeding the speed limit temporary, he does not consider it a violation, rather a safety measure.

PERSONAS: All

ROAD CHARACTERISTIC: Urban, rural, highway

6.5 NUDGE DEFINITION MATRIX

The defined scenarios described intentional and unintentional speeding situations, where the driver's motivation to comply with the speed limits, as well as the perceived ability to do so, varied. The scenarios were categorised according to Fogg's Behavior Model (Fogg, 2009) to define what was needed in the concepts to change the existing behaviour in the identified scenarios (see Figure 6:3).

For most speeding situations, it was identified that the driver had a high ability to keep the speed limits. Only a few scenarios represented situations when the ability was low. However, the motivation to keep the speed limit was found to be different for the identifies scenarios.

For situations where users already have the motivation and ability to comply with the speed limit, a signal nudge should be applied according to Caraban et al. (2019). What was found common for these driving scenarios was the presence of VRUs' at risk and law enforcement. Furthermore, signal nudges were found an appropriate approach for the identified personas that always find it important to comply with the speed limit, but unintentionally deviates from the speed limit due to the lost focus and not realising their high speed.

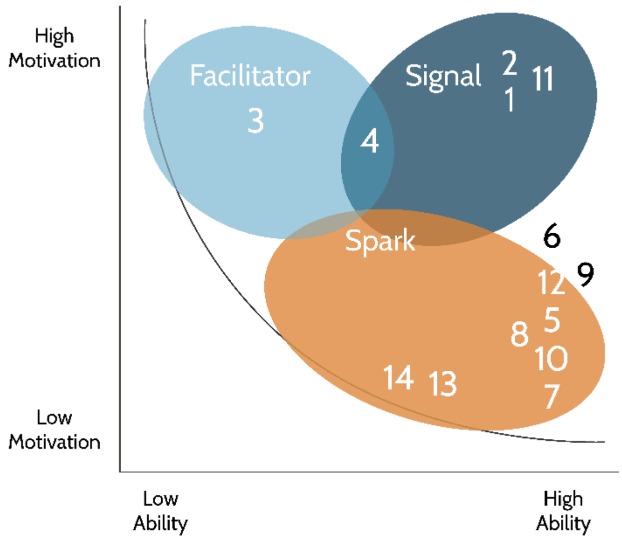


FIGURE 6:3 SCENARION MAPPED OUT ON FOGG'S BEHAVIOUR MODEL.

The motivation to comply with the speed limit decreased for some users in certain contexts. When the motivation was low while the ability still was perceived high, spark nudges was assumed to be appropriate to target the behaviour and spur the motivation, based Caraban et al. recommendation. The scenarios that were identified with low motivation and high ability had in common that the positive consequences of speeding were immediate and certain due to arriving faster when the driver was stressed, or that a higher speed was perceived safer by the driver. Additionally, this category consists of scenarios where the negative consequences were perceived uncertain due to good driving conditions or perceived knowledge of the risks.

Situations where the ability was perceived low while the motivation high, Caraban et al. recommended using nudges within the facilitate category. Scenarios that were found to fit into this category were situations where the driver fails to notice the posted speed limit and when the experience of speed is misleading, resulting in unintentional violations.

Based on the identification of scenarios according to Foggs Behavior Model (Fogg, 2009) and Caraban et al. (2019) recommendation of appropriate nudging principles, it was concluded that an in-vehicle HMI should consider all the different nudge-categories but targeting different driving situations. This insight was further used during the concept development in phase 2 explained in the following chapter.

7

PHASE 2 – CONCEPT DEVELOPMENT
CONCEPTION OF THE FUTURE STATE

The concept development phase aimed to use the contextual framework to create a conception of the future through continuous exploration of ideas and concepts in the process of two design iterations. The chapter is introduced with a section describing the first iteration, where ideas are created and described. This is followed by a section describing the third and fourth empirical study in detail. The chapter is concluded with the second iteration, where the creation of concepts is described.

7.1 FIRST ITERATION – IDEAS

The first iteration aimed to explore potential future states with the goal of generating a set of ideas to build the foundation for the creation of concepts. The first iteration is described in this section.

7.1.1 IDEA GENERATION

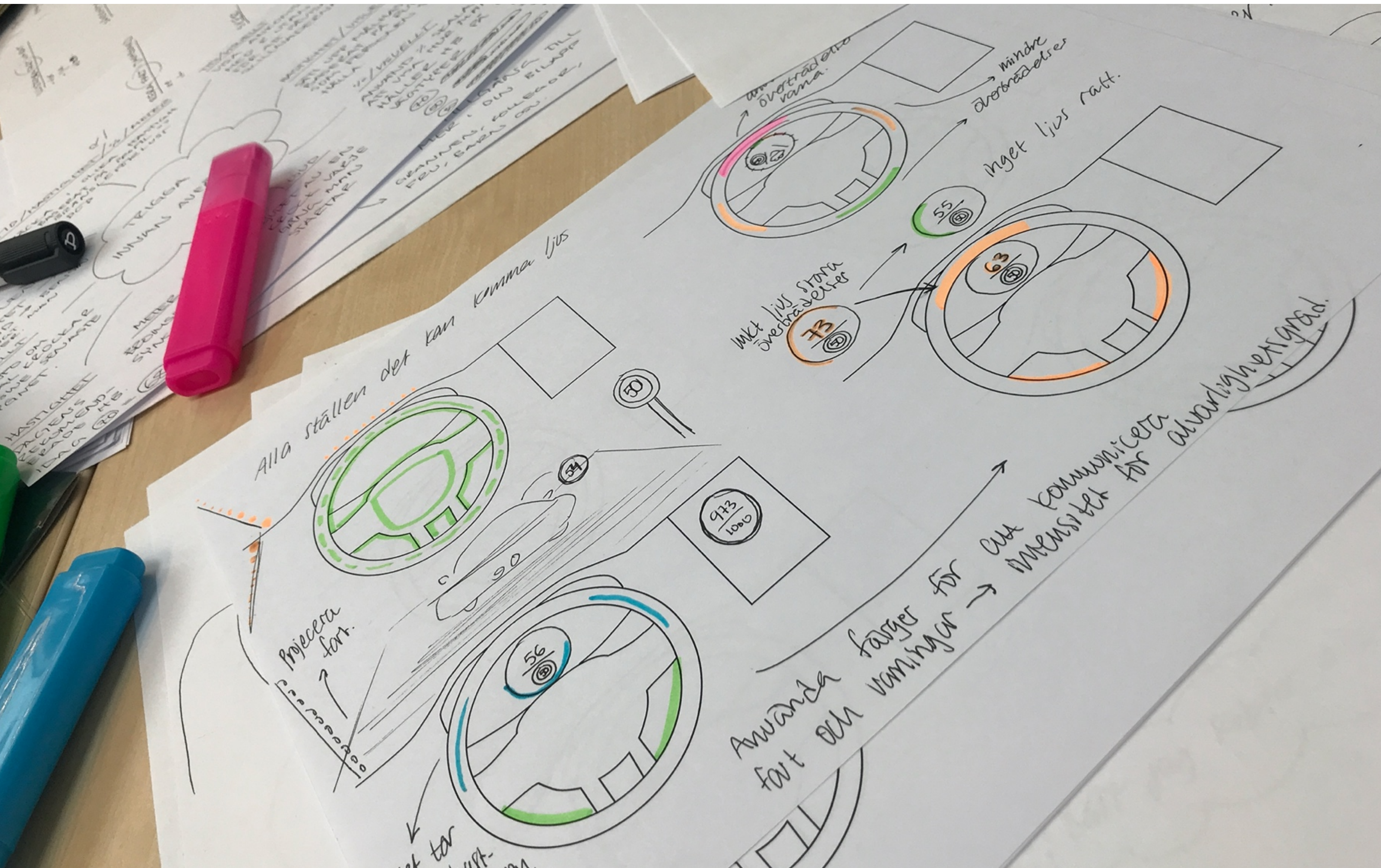
Brainstorming was used to generate a large number of ideas on how to support god speed choices. Initially, the brainstorming was performed without any constraints but was later limited to only in-vehicle HMI solutions. Scamper was used for ideas that were not intended for vehicle HMI, to elaborate on how these could adapt to an in-vehicle solution. In the Scamper session, existing solutions to counteract speeding from the related theory section in chapter 2 was also used to think of how successful external countermeasures could be implemented in the vehicle HMI.

A majority of the ideas were excluded, due to low feasibility or lack of potential to affect speeding behaviour, while similar ideas were merged. The remaining ideas were grouped and categorised into spark, facilitate and signal nudging categories. The nudging categories were identified based on the mapping of scenarios using Fogg's behavioural model, which is described in chapter 2.5.2. Based on inspiration from different nudging mechanisms within each category, the ideas were further improved and concluded in the following section.

7.1.2 IDEAS

This section describes the ideas that were concluded from the first ideation. The ideas are presented according to the identified nudging categories of facilitating, signal and spark described in chapter 2.5.1.

FIGURE 7:1 IMAGE OF RESULTS FROM IDEATION.



FACILITATOR NUDGES

Ideas in this category aimed to increase the ability for the driver to make correct assumptions about current and posted speed limit, mainly by how it was presented to the driver. The ideas mainly targeted scenarios where the driver was motivated to keep the speed limit but had a low ability to do so.

1

Numerical speedometer

BACKGROUND: This idea was inspired by the nudging mechanism *hiding*. In contrast to a conventional speedometer, which shows not only current speed but also available speeds, the idea was that the numerical speedometer would hide the available speeds not to present them as an option for the driver.

EXPECTED OUTCOME: The idea of a numerical speedometer was that a violation would become more prominent when being presented numerically. By hiding available speed indications, a numerical speedometer had potential to nudge the driver to focus on the current speed and not relate it to the available speeds which could create incongruity.

2

Placement of speedometer

BACKGROUND: Findings showed that many people considered it hard to keep the speed limit in modern cars, as they do not notice the violation immediately. This idea was inspired by *positioning nudges* and was based on the placement of the speedometer as an important aspect of counteracting speeding behaviour.

EXPECTED OUTCOME: By placing the speedometer in the line of sight in the HUD, it would be harder to ignore, which could counteract unconscious speeding. It would also make the driver more aware of the information provided by the speedometer.

3

Inform about upcoming speed limit

BACKGROUND: Findings showed that some speeding violations were the result of decelerating too late. The *suggesting alternatives* nudging mechanism was used as inspiration to draw attention to the speed limit in advance and nudge the driver to start braking before passing the speed limit sign.

EXPECTED OUTCOME: The idea was that by proactively inform of reduced speed limits, the drivers could be coached to start decelerating in advance.

4

Size of speed limit indicator

BACKGROUND: The idea was that the size of the speed limit indicator communicates the importance to keep the speed limit. This idea served as a *positioning* nudge as it altered the visual arrangement of available options to nudge the driver to prioritise the speed limit indicator in their speed choice.

EXPECTED OUTCOME: By changing the size, the speed limit indicator would receive different levels of attention. By making it larger while the driver is speeding the importance of the message that the speed limit indicator wants to communicate would be enhanced.

5

Speed limit indicator and current speed design

BACKGROUND: This idea was based on creating a relationship between the current speed and the speed limit indicator by working with colours and shape to enhance the message that the two should be similar when driving over the posted speed limit. This idea was inspired by the *suggesting alternatives* nudging mechanism.

EXPECTED OUTCOME: The relationship between current and posted speed was intended to be presented as the preferred alternative to encourage speed choice based on the speed limit.

6

Resistance in pedals

BACKGROUND: Findings show that it was considered hard to keep the speed limit even if intending to do so. Still, participants would not appreciate being limited engine power as this would reduce their control. By changing the resistance in the acceleration pedal when reaching the speed limit, the driver could still experience being in control over the speed while actively having to increase the effort to increase the speed. This idea was inspired by *opt-out policies* as it assumed that the driver wants to keep the speed.

EXPECTED OUTCOME: To drive over the speed limit would require and opt-out of the feature by increasing pressure on the pedal, which would make keeping the speed limit as the easiest choice.

SIGNAL NUDGES

The ideas in this category aimed to alert the driver to raise awareness of speeding violation. In order to alert the driver of violations, it was important to consider different modalities and intensity of alert as different scenarios requires different signals depending on the driving situation and mental workload. The ideas mainly targeted scenarios with high motivation and ability to keep the speed limit.

7

Lights at the steering wheel

BACKGROUND: This idea was based on the principles of *just-in-time prompts* by using LED-light on the steering wheel to communicate a violation. The steering wheel had the potential to work as a mean of communicating the severity of the violation. The steering wheel could further work as a spark according to the *raising visibility of actions* nudging mechanism where the steering wheel is visible to others.

EXPECTED OUTCOME: By using lights on the steering wheel, the idea was that the violation could be communicated without drawing attention from the road.

8

Vibration

BACKGROUND: In a similar manner as the steering wheel, this idea was that vibrations could be used to caught attention from the driver as a *just-in-time prompt*. Vibrations could be implemented in several areas of the car such as the seat, seatbelt, steering wheel or pedals. Literature shows that the drivers visual and auditory capacity are overloaded in some situations (Campbell et al., 2016). Using haptic feedback could potentially relieve the driver from visual and auditory information.

EXPECTED OUTCOME: The driver will be informed of violations and prompted to lower the speed without overloading visual and auditory input.

9

Sound

BACKGROUND: Sound could be used to catch drivers attention as a *just-in-time prompt*. In this idea, a voice was intended to be used to create a bond between the car and the driver by continuously giving the driver feedback. Findings showed that sound had the potential to be effective in catching drivers' attention. However, the acceptance towards sound was considered very dependent on how and when it was used. Furthermore, sound could work as *raising visibility of actions* nudge similar to the steering wheel.

EXPECTED OUTCOME: The driver gains a relation to the car, which increase the commitment to information provided by the car.

10

Tone out everything else

BACKGROUND: This idea was based on the *create friction* nudging mechanism. By removing other information surrounding the speedometer, the car could assist the driver to prioritise information and raise awareness of current speed.

EXPECTED OUTCOME: By fading out other information not related to speed, the idea was that the driver would focus the attention on what is important in that moment, which is to lower the speed.

11

Flashing lights/changing size

BACKGROUND: This idea was based on *ambient feedback* nudges by using flashing lights to catch attention. The similar impact could be reached by using size changes. By changing the size, it could catch attention and be communicated what information to prioritise in a speeding situation.

EXPECTED OUTCOME: The idea of using flashing lights was to catch and steer the attention towards the information.

12

Showing only posted speed

BACKGROUND: This idea was based on having a speedometer which only shows the value up to the posted speed limit. Studies show that many drivers consciously decide to drive in a speed where they consider it to be out of risk for being fined or losing their driving licence. By removing the option of making such judgements, the idea was that the more risk-taking drivers would lower their average speed to avoid being fined.

EXPECTED OUTCOME: The idea was that the values up to the posted speed limit would be interpreted as the available speeds while driving over the posted speed limit would induce more uncertainty and work as a *create friction* nudge.

13

Colour of the speedometer

BACKGROUND: The idea of using colour for the speedometer was that colour could be used to communicate different messages to the driver. Colours could also be used as a method to nudge the driver to make the appropriate decision. Findings show that many drivers chose speed based on their emotion, rather than frequently checking the speedometer.

EXPECTED OUTCOME: By using colours which makes keeping the speed limit more aesthetically appealing, inspired by a *create friction* nudge, the driver could be encouraged to keep the posted speed limit. This idea also used colour to simplify the judgement of speed as a *just-in-time prompt* to communicate deviated behaviour.

SPARK NUDGES

The ideas in this category aimed to trigger drivers by working with different nudges to remind them of and increase the motivation to keep speed limits. The ideas targeted situations where the driver have the ability but low motivation to keep the speed limit.

14 Dynamic speedometer

BACKGROUND: In cars today, the maximum speed indication exceeds the maximum posted speed limit by large, which makes exceeding as much as 10 km/h above the speed limit appear as a small violation due to the proportions of the speedometer. This idea was based on a dynamic speedometer where the maximum value of the speedometer always is the posted speed limit. It was suggested that the driver would interpret a lower speed as more appropriate by changing the proportions. This idea was inspired by the *deceive* nudging mechanism.

EXPECTED OUTCOME: By adjusting the speedometer based on the speed limit, the proportion between the current speed and the speedometer would change since the speedometer would indicate maximum value when the speed limit is reached. The idea could potentially change the way a violation is interpreted by the driver.

15 Lowering maximum indication in conventional speedometer

BACKGROUND: In this idea, the maximum speed indication on the speedometer was lowered to fit the maximum speed limit, which in Sweden is 120 km/h (WHO, 2018, p. 241). Similarly to the Dynamic speedometer, the idea was that the proportions would change, and a violation would be interpreted as larger if covering a larger part of the speedometer.

EXPECTED OUTCOME: The idea was inspired by *deceive* nudges, as only providing the driver with a legal speed limit on the speedometer would change the proportions for how violations are perceived.

16 Proportion of speedometer

BACKGROUND: The idea was to use a speedometer which changes proportions during violations. The idea was inspired by *adding inferior alternatives* and *create friction* nudging mechanisms. Like colouring, this idea was based on creating the desired state more ascetically appealing for the driver.

EXPECTED OUTCOME: The idea of changing proportions on the speedometer was that this would nudge the driver to keep the speed limit as it creates the most satisfying interface.

17 Placement of speed limit indicator

BACKGROUND: The idea was that the placement of the speed limit indicator could impact how it is perceived. This idea would work as a nudge by *adding inferior alternatives*, creating a preference for the speed limit indicator. This idea could also work as a positioning nudge to facilitate keeping the legal speed limit.

EXPECTED OUTCOME: By placing it close to the current speed indicator, the idea was that it would create a closer relationship between the two which will encourage the driver to keep them on the same level.

18 Visualization of situational factors

BACKGROUND: In this idea, situational factors were used to enhance the incentives for the driver to keep the speed limit by reminding of the safety of others and other factors affecting speed choice. This idea intended to work as a *remind of the consequences* nudge to spark motivation as findings showed several situational factors which motivated to keep speed limits.

EXPECTED OUTCOME: By visualizing current situational factors in relation to the speed, the driver would potentially become more aware of the traffic context and lower the speed.

19 Visualizing gas consumption

BACKGROUND: This idea was based on creating an incentive to keep the posted speed limit by visualising the advantages and disadvantages of gas consumption. Findings showed that drivers consider the loss of gas or energy as an incentive not to speed.

EXPECTED OUTCOME: The idea was that visualising gas consumption for speeding would make the consequence be perceived as more immediate and work as a *remind of the consequences* nudge to relate speeding to the environmental impact and economic loss for the individual. This idea would also have possibilities to work as a *make resources scarce* nudge to evoke a fear of loss to make the driver pursue to keep the speed limit.

20 Visualizing braking distance

BACKGROUND: Findings showed that drivers were aware of the risks related to speeding and how it has an impact on the brake distance. However, this did not seem to have an impact on drivers speeding behaviour as these risks became abstract for each time they speed without being exposed to the risks. This idea was inspired by the *remind of the consequence* nudging mechanism.

EXPECTED OUTCOME: By visualising the change in braking distance when speeding, the driver would be reminded of the risks that they expose themselves to. The idea was that this would make the consequences more certain and enhance the incentive of one's own and others safety.

21 Social proof

BACKGROUND: Findings showed that it was experienced as more important to keep the speed limit when having passengers. This idea worked as *raising the visibility of users' action* nudge and increase the effect of people, in general, acting in ways they believe other people expect them to. The idea was that making violations visible would enhance the feeling of being responsible for the passengers in the car but also put more shame into speeding. This idea could also potentially increase the passenger's control over unsafe driving and intended to enhance the passenger's ability to affect the driver to lower the speed.

EXPECTED OUTCOME: By making violations visible for passengers in the car, the idea was that the driver would feel more obligated to lower the speed.

Visual Illusions

22

BACKGROUND: Literature suggested several successful illusions strategies implemented in the external traffic environment. Findings showed that respondents often lowered their speed when they felt that they drove too fast, which was often after severe violations. The idea was that illusions could induce this emotional state earlier to make the driver lower the speed and keep the speed limit as a *deceptive visualization* nudge.

EXPECTED OUTCOME: To enhance the feeling of speed to make the driver want to lower the speed.

Seatbelt tightening

23

BACKGROUND: Many individuals considered it easier to speed in newly produced vehicles as they include advanced safety systems and great experience in fast velocities. This idea was based on changing the experience from comfortable driving when keeping the speed limit, to more tightened and restricted driving while speeding. This idea was inspired by *placebo* nudging strategies, by inducing feelings to improve the mental response to speeding. The idea would also work as a *memory of past experiences* nudge by imitating the feeling that the seatbelt gives by accelerating fast.

EXPECTED OUTCOME: By tightening the seatbelt while speeding the idea is that the driver will interpret speeding more severe and not as comfortable as driving by the posted speed limit.

7.2 EMPIRICAL STUDY 3

The third empirical study aimed to evaluate initial ideas with users to gain more insight into user needs and requirements for further development. The insights were needed to be able to improve the design guidelines and exclude less feasible ideas.

7.2.1 EXECUTION

Two focus groups were conducted as the method for this study to allow for effective collection of user feedback. Both focus groups consisted of three driver participants and one participating moderator in the age span of 25-55 years. The participants were presented with different ideas from ideation one by one. The themes for discussion was predefined to be used by the moderator to ensure investigated topics were covered. Each idea was discussed based on the perceived acceptance and how effective it was considered to change the participants speeding behaviour. The discussions were mainly unstructured. The moderator used follow-up questions for interesting topics that came up during the discussions.

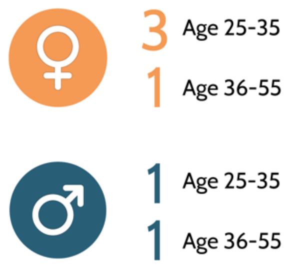


FIGURE 7:2 GENDER AND AGE DISTRIBUTION STUDY 3.

7.2.2 RESULTS AND DISCUSSION

The results from the focus groups showed that the ideas received very different feedback depending on the general attitude towards being influenced. Drivers who do not generally appreciate being told what to do preferred ideas within the facilitate and spark categories, which can be considered to have a lower intensity than the ideas within the signal category. Drivers who generally try to keep the speed limit was positive to most of the ideas. Overall, the participants had a hard time reflecting over ideas which they have never experienced anything similar. Especially ideas with haptic feedback and illusions were hard for the participants to evaluate as they had trouble imagining what it would be like while driving. Generally, these ideas received more negative feedback. Ideas that were similar to current HMI solutions implemented in the participant's private vehicles received more positive and detailed feedback.

FEEDBACK FOR IDEAS WITHIN THE FACILITATE CATEGORY

Drivers appreciated the ideas within this category due to low intensity. 6 out of 6 participants	Ideas within the facilitate category were appreciated by all participants as they found the ideas relevant for speed choice and to guide them in their driving. Especially ideas which simplified to read current speed and posted speed limit was appreciated.
Drivers did not expect the ideas to make them change behaviour. 3 out of 6 participants	Participants were hesitant regarding the effectiveness of the ideas in this category and expressed that the ideas would rather make them notice violations more than change behaviour. All participants agreed that using the HUD would be efficient for unintentional violations. Campbell et al. (2016) argue that a placement that corresponds to the expectations of the driver requires less mental workload. It can be assumed that participants generally want to know their current speed and that the idea of using the HUD would make speed easier to assess.

FEEDBACK FOR IDEAS WITHIN THE SIGNAL CATEGORY	
Ideas with low-intensity visual feedback were most appreciated. 5 out of 6 participants	Participants were accepting of ideas within the signal category of low-intensity visual feedback as they were considered it easy to ignore.
Acceptance for high-intensity feedback was dependent on modality. Visual: 5 out of 6 participants Haptic: 3 out of 6 participants Auditory: 3 out of 6 participants	Three participants appreciated haptics over auditory and three participants the other way around. This could be a result of the modalities similarity in intensity Campbell et al. (2016). However, visual signals were the most accepted of the intrusive methods by all but one participant. One participant firmly believed haptic being more accepted than intensive visual feedback as this would cause more workload for him. He also expressed that he already turned off several visual warning systems in his car due to disturbance. Three participants also preferred auditory warnings when they were eager to keep the speed limit.
Drivers find the signal-ideas in need for tolerances. 6 out of 6 participants	The acceptance appeared to be very dependent on the design of any signal system in agreement with findings from ISO (2005), and participants in the focus groups agreed that any type of signal system would need a tolerance. Participants expressed they would not accept to be prompted by intensive feedback immediately.

FEEDBACK FOR IDEAS WITHIN THE SPARK CATEGORY	
The acceptance was dependent on several factors: - **Values** - **Personal preferences** - **Motivations**	The acceptance towards different spark ideas seemed to be very dependent on motivation, values and personal preferences. The acceptance towards most of the ideas was considered high, but the effectiveness of several was questioned, especially long-term effectiveness. However, five participants appreciated the principle of having the focus drawn from the violation to something of value for them. Results from Harms et al. (2007) and Reagan et al. (2012) showed that incentive systems had potential to impact speeding behaviour while Steinberger (2017) showed that gamification also reduced speeding frequency. These studies could argue for user’s appreciation for a system which not only highlights the violation but also adds value.

GENERAL	
Drivers needed to experience value in the feedback for accepting the solution. 6 out of 6 participants	Participants generally expressed disapproval for some of the ideas with the argument that if felt unnecessary for them. It can be assumed that the participants favoured ideas that they believed would create value to them, which agrees with findings from previous studies concluded in the contextual framework (see section 6.1.1). It can be assumed that a solution which does not provide added value impacts the acceptance towards being influenced. For example, the participants found the idea to inform about upcoming speed unnecessary as they receive the information from the speed sign already, and if missing information from the sign, the speed limit indicator would provide them with that feedback when they needed it.
Experience of control was essential for acceptance. 6 out of 6 participants	Control was mentioned as a contributing factor to the disapproval of ideas. Lack of control was used to express a dislike to ideas where the participants believed they would lose the freedom of choice. For example, auditory feedback was expressed to remove the feeling of control if the signal would force to lower the speed, comparing it to the sound when the seatbelt is not attached which agrees with findings in Spyropoulou et al. (2014) study. However, three participants also explicitly mentioned the potential benefits of sound when it alerts about the information that the driver wants to receive, hence provide the driver with more control.

7.2.3 Conclusion

Based on findings from the focus groups, it could be concluded that preferences for different ideas and principles were highly dependent on personal preferences. No definite conclusions could be drawn based on the results from the session alone, which only aimed to provide quick user feedback in early ideation. However, findings from empirical study two regarding intensity, tolerance, direct value and control were further addressed in this study, which supports the credibility of earlier conclusions and its implications for acceptance. The focus groups provided an overall understanding of which ideas received the least acceptance. The insights were used, in combination with results from empirical study four, in the Pugh matrix evaluation described in section 7.4.

7.3 EMPIRICAL STUDY 4

The fourth empirical study aimed to investigate the acceptance of being influenced by intensive vehicle HMI. The goal was to be able to define acceptance regarding different levels of intensity as well as the modalities of haptic, visual and auditory feedback, to be used in the evaluation of ideas and the final design guidelines. The insight from the study was needed to understand further the impact of intensity and tolerance on user acceptance.

7.3.1 AUTOLIV PROTOTYPE DESCRIPTION

The Autoliv concept consists of three levels to impact speeding behaviour. The instrument cluster, steering wheel and seatbelts are used to communicate violations to the driver.

Figure 7:3 shows the amber alert, which is presented as an early alert to the driver to attend to the current and posted speed in advance. The current speed and speed limit indicator turn to an amber colour. Also, the steering wheel lights up one time with amber light to steer attention to the message in the instrument cluster.

FIGURE 7:3 INITIAL AMBER ALERT.

Figure 7:4 shows the red alert that is triggered to the driver when passing the speed limit. At this stage, the amber colour on the instrument cluster turns to red, and the speed limit indicator moves back and forth to the centre of the instrument cluster and increases in size. The steering wheel also lights up in red at this stage and flashes.

FIGURE 7:4 SECOND RED ALERT.

Figure 7:5 shows the third alert. At this stage, the driver still received the red lights as well as a warning sign at the speed limit indicator. The number within the speed limit indicator blinks while the seatbelt tugs at the driver. At this level, auditory alerts were added as an alternative alert to the seatbelt to evaluate auditory feedback.

FIGURE 7:5 THIRD RED AND SEATBELT ALERT.

7.3.2 Execution

Two different methods were used for the study. One group of participants participated in an observation and interview study. The participating drivers experienced the visual, haptic and auditory prototypes implemented in the Autoliv research vehicle. Another group of participating drivers received a questionnaire. Fifteen drivers in the age span of 25-55 years participated in the study where four of the participants tested prototypes implemented in the vehicle, and 11 answered through the digital questionnaire.

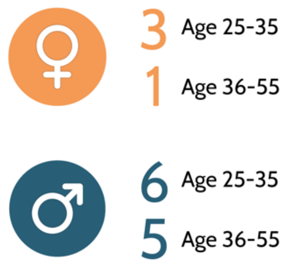


Figure 7:6 Gender and age distribution study 4.

The study in the research vehicle consisted of observations and interviews. The participants were first introduced to the car, and the prototypes implemented in it followed by a short interview regarding current driving behaviour. The participants were then asked to drive a specified route while experiencing the prototypes. The Wizard of Oz method was used to trigger the prototypes in different driving situations. The participants were encouraged to talk about their emotions towards each prototype while experiencing them. The session ended with an interview, including open-ended questions for each prototype. Further, Van der Laan et al. (1997) acceptance scale was used as a tool for the participants to elaborate on their experience. The participants were asked to conclude the scales and talk loudly about their reasoning for each score.

A questionnaire was used to triangulate results from the study in the research vehicle. The questionnaire has a similar structure to the first part of the study. Participants were introduced to the prototypes, following questions about current speeding behaviour. The participants were then showed video recordings of the prototypes and asked to write down reflections. The Van der Laan et al. (1997) was used to rate acceptance with follow-up questions to understand the reasoning for the ratings.

Data from the study were analysed through an affinity diagram, where transcriptions from interviews and answers from the survey were used to sort and organize findings into similar findings. The groupings were then used to name findings based on underlying user needs.

7.3.3 Results and discussion

It was assumed that the results from the fourth empirical study were affected by the way the study was executed and who was participating, due to the difference in results from the two groups of participants. In general, the participants who experienced the prototypes were more positive than the drivers who participated digitally. Therefore, the results are marked to identify from which group the findings originates. The validity of the study is discussed in section 11.4.

GENERAL

The drivers who experienced the prototypes were generally more positive than those who only watched videos. Vehicle and questionnaire	Participants who got the chance to drive the research vehicle did not perceive the instrument cluster nor the steering wheel as irritating. At the same time, those who looked at the videos and in combination found them distracting and annoying. It can be assumed that the experience could potentially change in a real context environment where the attention is divided between the traffic and the warning or that the combination

	of the warnings in the video increased the perceived intensity. Furthermore, it can be assumed that the light intensity was affected by daylight. The participants drove the vehicle in sunlight while the videos were recorded so that the focus was on the vehicle HMI.
Drivers appreciated the principles of the instrument cluster and the steering wheel as it simplified the driving. Vehicle: 4 out of 4 participants	Participants from the in-vehicle study expressed that they found being aware of the current speed limits, as well as become aware of exceeding them, valuable. The instrument cluster in isolation was expressed appreciated as it caught attention while still being able to be ignored. The movement and size change in the screen were considered important for detection while driving. While it seems appreciated that the HMI can be ignored, participants further expressed that they like that a solution consists of several communication platforms to be sure that they become aware in case of inattention.
Drivers found tolerances necessary for all the evaluated prototypes. Both too low and too high tolerances were perceived, reducing credibility. **Found appropriate tolerances for driving 50 km/h were:** • **1st: 0-5 km/h** • **2nd: 5-10 km/h** • **3rd: 10-15 km/h** Vehicle and questionnaire	The severity of the violation was described in terms of km/h above the speed limit and time spent above the speed limit in relation to which area they were driving in. It was considered more sever to speed the lower the speed limit and in relation to VRUs, where participants expressed that the tolerances could be lower. To have tolerances for warning agrees with the recommendation from ISO (2005) that warnings should only be applied when the driver lacks in focus or when a dangerous change in speed occurs. While it was expressed important to have tolerances, the opposite, having too high tolerances, was also considered contradicting. It was expressed opposing if the HMI did not catch their attention before reaching the limit of law enforcement penalties. Horberry et al. (2014) argue that confidence in a warning system reduces if the dangers are missed by the system. It can be assumed that drivers would experience a similar response if the warning is perceived to be triggered too late. For the red alerts and steering wheel, participants expressed a need for at least 5-10 km/h tolerance. The belt was considered more intense, and it was expressed a wish for a tolerance of 10-15 km/h. Auditory feedback was by most not appreciated, which agreed with Green (2008) and Campbell (2016). A few participants found it useful if other warnings had been ignored.

	The expressed tolerances were based on a 50 km/h speed limit road which was used as the speed limit in both groups. A few participants expressed a need for higher tolerances on rural and highway roads.

1ST AMBER ALERT

Drivers found the amber warning unnecessary and reducing the effect of *"true"* warnings. Vehicle: 2 out of 4 participants Questionnaire: 5 out of 11 participants	The early amber message was perceived as a low-intensity warning, not adding judgement. However, early messages were considered by participants to reduce the effect of the red warning message. This effect seems to occur as both messages are quite similar, which makes the state of the HMI less alerting before and after exceeding the speed limit. As the HMI continuously provides warnings drivers expressed that they would stop paying attention to them. A lack in communication was experienced for the amber message as several participants could not understand what message it wanted to convey. One participant commented on the message *"Why the hell am I warned before I drive to fast?".* It can be assumed that the participants did not expect to be warned before the violation which resulted in contradiction to the expectations and ISO (2005) argues that the warning must be designed with compatible expectations of the driver.

2ND RED WARNING

Drivers found the red warning alert triggered too early. Questionnaire: 4 out of 11 participants	Participants especially found the red alerts as to intensive for just passing the speed limit. It was not experienced as justified to be warned with that level of intensity for the violation. One participant stated that *"It feels like receiving the red card for an offside*". The red warning was considered medium intensity and should, based on recommendations from Green et al. (2008), Campbell et al. (2016) an ISO (2005) be triggered with caution.
Drivers found the steering wheel increasing the intensity of the warning. Questionnaire: 6 out of 11 participants	The red warning message from the instrument cluster and steering wheel were interpreted as a warning message as it alerts for attention by several modalities which agree with ISO (2005). The steering wheel was expressed as providing a severe alert. However, it was new to the participants and therefore caught more attention, while drivers had previous experience from instrument cluster alerts.

The red alert lacked in intuition. Vehicle: 1 out of 4 participants Questionnaire: 4 out of 11 participants	Participants found the red instrument cluster as lacking in intuition, further it was confused for an alarm that pointed out something wrong with the car. It was further expressed lacking in communicating the correct action.
3RD SEATBELT OR SOUND ALERT	
Drivers found the belt and sound accepted only for severe violations. Vehicle: 3 out of 4 participants	The belt and sound were described as more intense and only accepted for severe violations which agree with findings from ISO (2005) and Campbell et al. (2016). These modalities were experienced irritating if appearing every violation as well as if they do not abort after a particular time as they are hard to ignore. Campbell et al. advise only to use auditory and haptic warnings with caution.
Drivers found the belt and sound unpleasant. Vehicle: 2 out of 4 participants Questionnaire: 6 out of 11 participants	The belt received varying experiences between different participants in both groups. Eight drivers found it palpable, unpleasant or irritating. However, the belt was described as less disrupting than sound.
Drivers found the belt effective but not desired. Vehicle: 4 out of 4 participants Questionnaire: 7 out of 11 participants	The unpleasant experience of the belt was by some participants described as a good thing. One participant explained that he did not need it personally, but he believed it to be necessary for others to change. Another participant expressed how it was useful and necessary while stating he would never choose it as an option when buying a new car.
Drivers found the belt alerting but lacking in communicating the cause. Vehicle: 2 out of 4 participants	Participants in the vehicle study found the seatbelt alerting, incinerating that it was a dangerous situation and that something was about to happen, which agrees with ISO (2005). However, the belt tug did not communicate that the sever situation was due to the speeding behaviour and needed additional information to be understood which agrees with ISO (2005) recommendation that haptic feedback should only be used as a part of a multi-modal system as it is limited communicating the message of the warning.

7.3.4 Conclusion

Only four participants experienced the prototypes in the research vehicle and evaluated real experiences while the others evaluated anticipated experience. Additionally, the participants in the vehicle study were Autoliv employees and potentially biased. Due to the limitations of this study, few conclusions could be drawn, that is further discussed in section 11.2 and 11.3. However, some results agreed with results from previous studies which can be assumed to increase the validity of those results.

Findings from both groups suggest that the ambers warning was unnecessary and triggered too early. It can be assumed that drivers generally only want to receive information, without any intensity level, before violations. In general, the participants found value in being informed about violations. However, the initial red warning was also considered triggered too early based on the intensity of it. While it was appreciated by many of the participants, participants suggested it should be triggered with a tolerance.

Based on findings from the study, it can be assumed that the instrument cluster was considered low in intensity regardless of colour and size changes. However, participants still expressed a need for tolerance for such HMI solutions. The steering wheel was considered by participants as average intensity, while the auditory and haptic feedback was perceived as high intensity. This agrees with findings from literature regarding HMI in warning systems described in chapter 2.4. However, the study did not conclude whether users would accept being prompted with haptic seatbelt feedback as the ones experiencing it was positive towards it, while the other group were not. Further research is needed to conclude if the seatbelt is appropriate to communicate speeding violations.

7.4 PUGH MATRIX EVALUATION

A Pugh matrix was used to evaluate the 23 ideas and finalise the first iteration (see table 7:1). Ideas were evaluated towards the scenarios to understand how well each idea solve the identified problem. The ideas were given a score from 0-3, not at all fitted – very well fitted. As acceptance was considered an important aspect of a potential solution, an acceptance score was multiplied for each idea based

on user input from the third and fourth empirical study.

The ideas were divided into three categories: facilitate, signal and spark. As each category targets different scenarios, according to the mapping using Fogg's behavioural matrix, it was necessary to define the categories in the matrix for a fair evaluation of ideas. The Pugh matrix showed that some ideas were very dependent on the situation as they received the highest score in targeted situations and the lowest score in others. Some of the ideas received a good score in almost all situations but a low score on acceptance. The ideas with a low acceptance score were excluded as well as ideas with a score lower than 30. The exception was the idea of a numerical speedometer. This idea was kept as it was considered to generate a greater impact as a part of a concept. Also, feedback from focus groups showed that the numerical speedometer was appreciated amongst the participating users.

TABLE 7.1 PUGH MATRIX EVALUATION.

Scenario Ideas	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Acceptance	Total
1	2	2	0	0	0	0	0	0	0	0	3	0	0	0	3	21
2	2	3	3	3	0	0	0	0	1	0	3	0	0	0	3	45
3	0	2	3	0	0	1	1	1	0	0	0	0	0	3	2	22
4	2	2	3	2	1	1	0	0	0	1	1	0	1	0	2	28
5	1	2	2	2	0	0	0	0	1	0	2	0	0	1	3	33
6	2	3	3	3	2	2	2	2	2	2	3	2	0	0	2	56
7	3	3	3	3	2	2	1	1	2	2	3	2	0	0	2	54
8	3	3	3	3	1	2	1	1	2	2	3	1	0	0	2	46
9	3	3	3	3	1	2	1	1	2	2	3	2	0	0	1	26
10	2	0	1	2	1	1	1	0	2	0	1	1	2	0	2	28
11	3	2	3	3	2	2	1	1	2	2	2	2	0	0	1	25
12	0	1	2	2	0	0	0	0	1	0	0	2	0	1	1	9
13	2	2	2	2	1	1	1	1	2	1	2	1	0	1	3	57
14	0	2	2	2	1	1	0	0	1	1	2	2	1	2	1	17
15	0	1	0	0	1	1	2	2	1	0	0	1	0	1	3	30
16	0	1	2	2	1	1	1	1	2	0	1	1	0	0	3	39
17	2	3	3	3	1	1	1	1	1	0	2	1	0	1	3	60
18	0	1	0	0	2	3	0	0	3	3	3	2	3	3	3	69
19	0	0	0	0	3	3	3	3	1	3	0	3	0	2	3	63
20	0	0	0	0	1	3	1	1	3	1	0	3	2	0	2	30
21	2	0	3	3	2	3	3	3	3	2	0	3	3	0	2	60
22	3	0	0	3	1	2	3	3	2	1	1	2	2	0	2	46
23	3	0	0	3	0	1	3	3	2	2	1	2	2	1	2	48

7.5 SECOND ITERATION – CONCEPTS

The second iteration aimed to conclude design concepts to be evaluated towards users to gain further insights for the final design guidelines. The second iteration is described in this section, starting with using the system structure from chapter 6.2 to identify levels for each idea. This is followed by a section where the process for the concept creation is described. The results of the concept generation are described in the following chapter 8.

7.5.1 SYSTEM MAPPING

The system structure was used to identify and map out what level each remaining idea was active on according to Table 7.2 Mapping of ideas according to system structure. This was done to ease the concept generation as it made it clear how the ideas could be combined into concepts that would cover different levels, for the respective nudge category.

TABLE 7.2 MAPPING OF IDEAS ACCORDING TO SYSTEM STRUCTURE.

Nudge category	Idea	Level from system structure
Facilitate	Numerical speedometer	0-3
	Placement of speedometer	0-3
	Speed limit indicator design	0-3
	Resistance in pedals	1
Signal	Lights Steering wheel	2
	Vibration	3
	Colour of speedometer	0-3
Spark	Social proof	0-3
	Visualizing gas consumption	1-3
	Visualizing situational factors	0-3
	Seat belt-tightening	2
	Visual Illusions	2-3
	Proportion speedometer	0-3
	Lowering maximum indication in conventional speedometer	0-3
	Placement of speed limit indicator	0-3

7.5.2 CONCEPT GENERATION

The concept generation aimed to conclude concepts based on nudges within all three categories of facilitate, signal and spark so that each concept would cover as many of the speeding scenarios as possible. Initially, ideas within each nudging category were randomly combined to create sub-concepts. This was followed by combining sub-concepts targeting scenarios of high motivation as ideas within the facilitate and signal categories targets similar scenarios. Since the ideas within the facilitate and signal nudge categories aim to facilitate for the driver to make right assumptions for speed choices and alert the driver to raise awareness of speeding violations, the sub-concept was used as a foundation for an ISA system.

The ideas within the spark category were challenging to combine as they trigger situations where individual preferences base the motivation to comply with a behaviour. The four initial ideas of social proof, gas consumption, situational factors and visual illusions were refined and resulted in four different sub-concepts targeting the low motivation scenarios. The remaining ideas within the spark category were used as inspiration to develop the ISA system concepts further.

The initial concept generation resulted in 5 different concepts combining the remaining ideas from the first iteration, which is illustrated in Figure 7:7. The creation of the concepts was supported by the mapping of ideas according to the system structure, described in section 7.5.1, to identify which ideas would have the potential to be combined to cover all levels of the system structure and not overlap ideas with similar effects.

To further target several of the speeding scenarios, the concept for the ISA system was combined with the concepts in the spark category. The concept generation phase resulted in four final concepts which are described in the following chapter. The concepts were not intended to define any details. The aim was to use the concept as a mean to evaluate the principles of each concept towards users to gain further insight into acceptance for design guidelines.

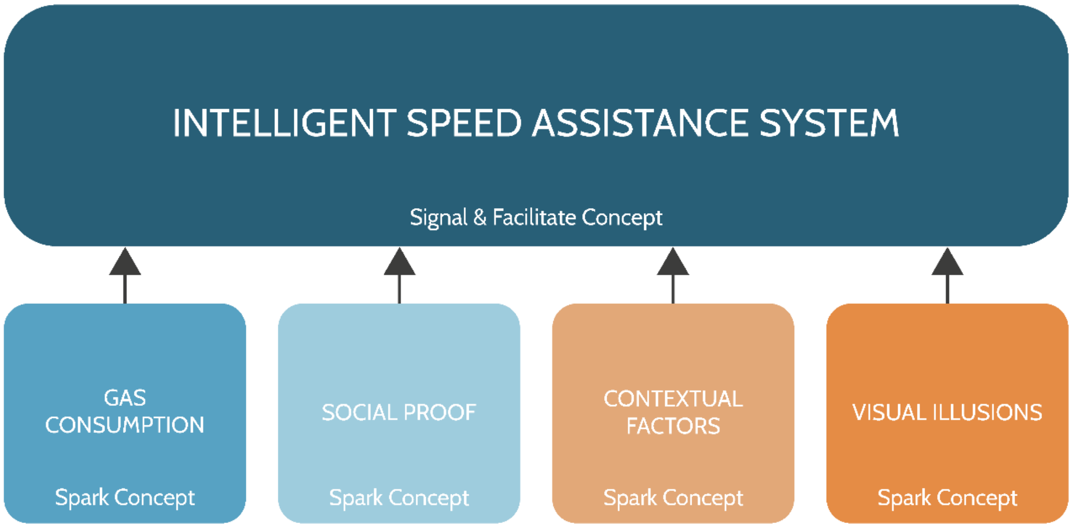


FIGURE 7:7 DESCRIPTION OF CONCEPT GENERATION FOR COMBINING IDEAS.

8

CONCEPT DESCRIPTIONS

This chapter presents the four concepts that were created during the concept development phase. The concepts aimed to be used during the evaluation phase to investigate user acceptance and essential aspect for acceptance further. The concepts were not to be used as final recommendations to future designs for speed assistance systems, but rather as inspiration for nudging principles for further development. The first section describes the common features for all concepts which base the foundation for an ISA system created with the guidance of the system structure defined in chapter 6.2. After that, the final concepts are described where the ISA system is combined with four different spark nudges to motivate drivers to comply with the speed limits.

8.1 INTELLIGENT SPEED ASSISTANCE SYSTEM

For all four concepts, the HUD is used to visualise current speed and posted speed limit. The idea of using the HUD is that the information will become more central in the driver's attention and facilitate the driver to comply with the speed limits. By placing the speedometer in the HUD, more intrusive methods to catch attention can be avoided as the information is already in the line of sight.

A numerical speedometer is placed centrally in the speedometer. Just below the numerical speedometer, the speed limit indicator is placed, illustrated in figure 8:1. They are placed close to each other to create a relation between the two which should be similar. Surrounding the two is a dynamic speedometer bar, where the speed limit always is reached when the speedometer bar reaches the top. The bar is used to facilitate the monitoring of the speed. The idea of the speedometer is mainly based on the hiding nudge mechanism, where other alternatives are not be displayed to the driver as an option for speed choice.

When violating the speed limit, there is a gradual colour change in both the numerical speedometer and the bar, to signal the violation. The colours are used to communicate the violation to the driver with low intensity. The gradual colour change works to communicate the severity of violation without adding too much judgement to the message. The speedometer bar also changes in proportions during violations to spark the driver to keep the speed limit by enhancing the feeling of doing a violation and create friction.

All concepts also share the same visual function at the steering wheel. The steering wheel intends to work as a visual signal nudge with increased intensity. In order to reach acceptance, the steering wheel intends to work as a signal which assumes early warnings from the speedometer have unintentionally been missed. Therefore, the steering wheel temporarily lights up to notify the driver that one is speeding and steers the attention to the speedometer. The steering wheel signal aborts after a few seconds or immediately when the driver reduces pressure from the gas pedal as it only intends to ensure the driver received the information provided by the speedometer, and not to force action.

FIGURE 8:1 ISA CONCEPT DESCRIPTION.

Three of the four concepts also share the same haptic feedback from the seatbelt. The idea is that by changing communication stimuli, it reduces the chances of unintentional violations if the driver's visual workload is overloaded and previous warnings have been missed. It also adds a judgement to severe violations and prompts the driver to reduce the speed as it cannot be ignored to the same extent.

The speedometer, steering wheel and seatbelt creates the foundation for each concept through an informative and warning ISA system which aims to change speed behaviour. The ISA system was created based on the defined system structure in chapter 6.2. A flow chart of the system acts when the driver accelerates to exceed the speed limit, continues to violate with increased speed or spend time on the same level, responds to braking, is displayed in Figure 8:2 Flowchart of the ISA system. In the project, it was found several indications that a system only alerting speeding behaviour have a low potential for being accepted by drivers in a majority of the identified speeding scenarios. Therefore, the signal system has been combined with four different spark nudges which aim to remind the driver of existing motivations to comply with speed limits to enhance the value and credibility of the signal system for the driver. The following sections describe the concepts through a speeding violation, according to how the system acts for each intensity level.

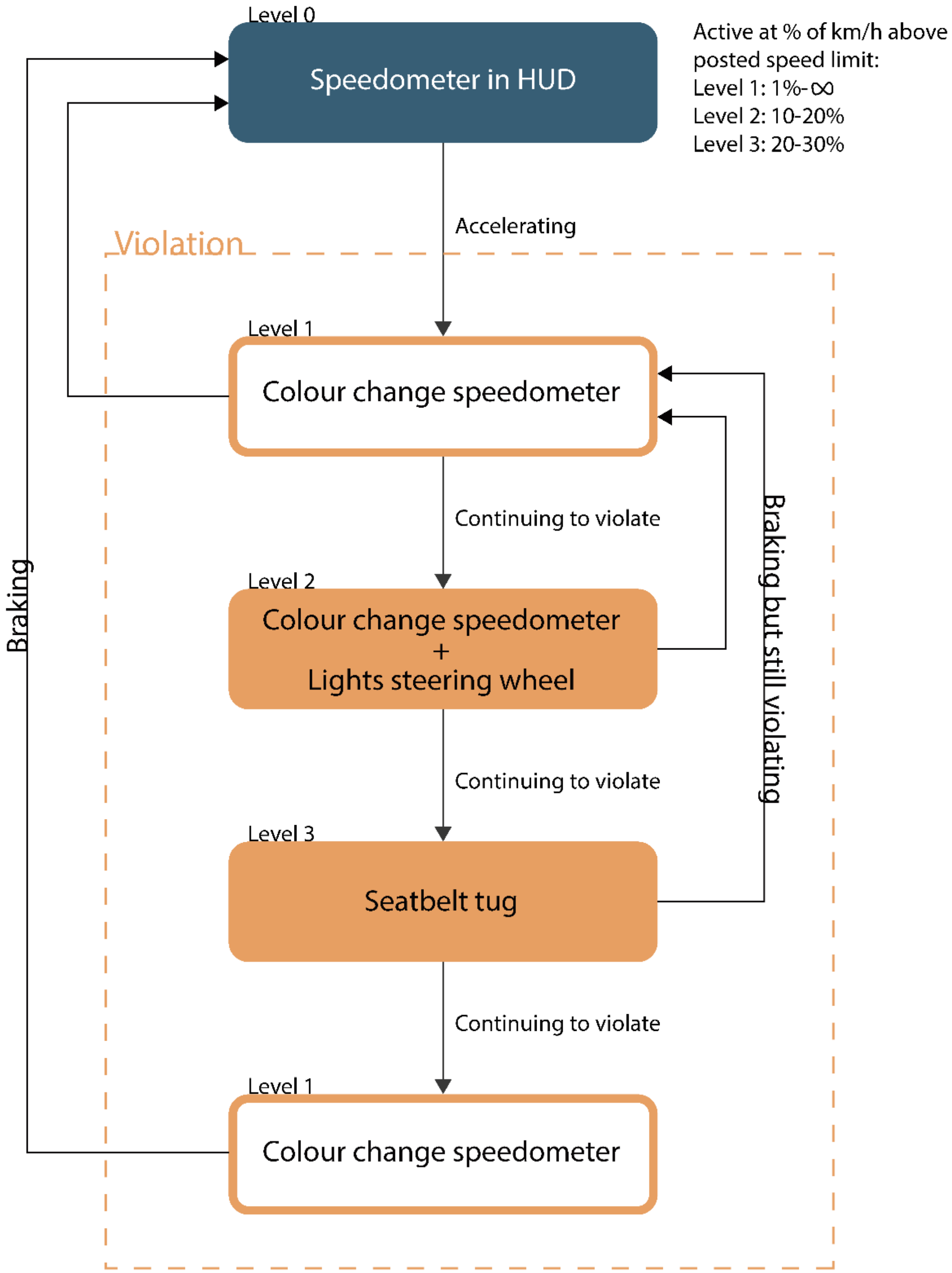
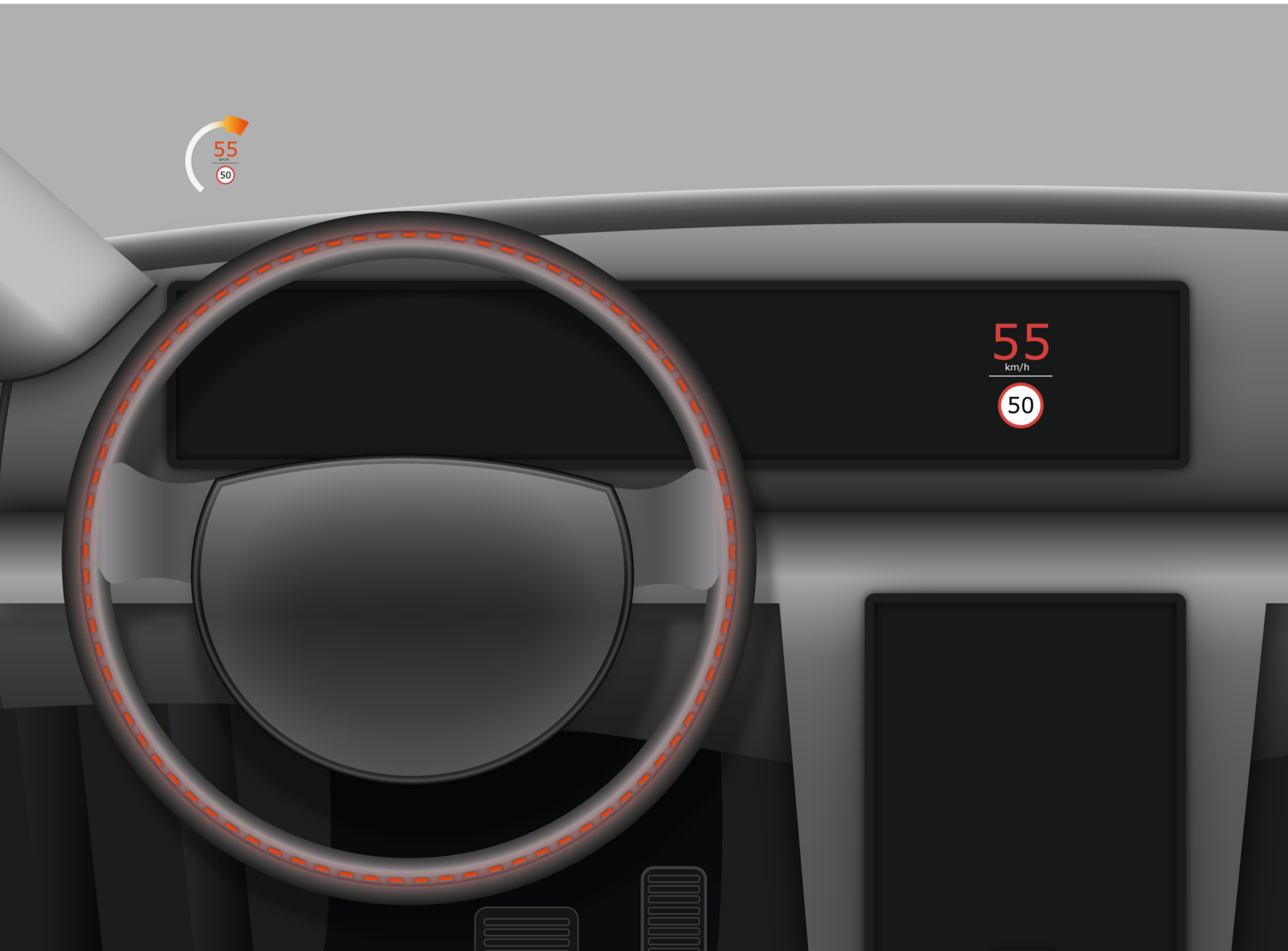


FIGURE 8:2 FLOWCHART OF THE ISA SYSTEM.

8.2 SOCIAL PROOF

The driver is responsible for the safety of everyone around and inside the car. As a passenger, one must trust the driver to behave in the best interest of everyone in the car when it comes to speed choice. The principle of this concept is to make the speed available for everyone in the car to enhance the incentives for the driver to keep passengers safe and increase the effect of people, in general, acting in ways they believe other people expect them to. As speeding expose both driver and passengers for increased risk of severe injuries or a fatal outcome, it is of everyone's interest that the driver keeps the speed limits. This concept does not only motivate the driver, but it also aims to allow passengers to feel more in control of their safety. The concept structure is described in figure 8:4.

FIGURE 8:3 VISUALISATION OF SOCIAL PROOF CONCEPT WITH SPEED INDICATOR IN THE CENTRE STACK.



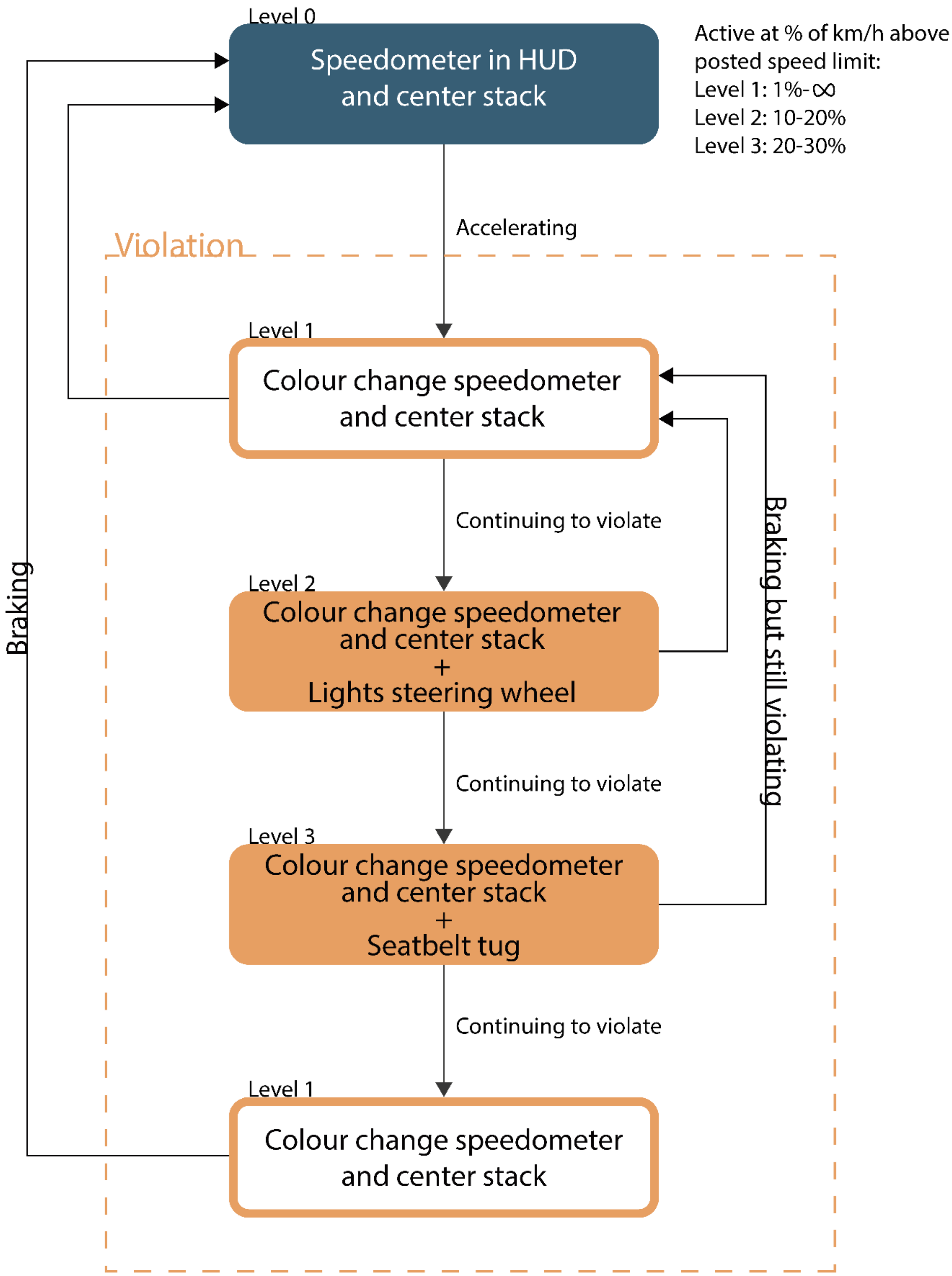


FIGURE 8:4 FLOWCHART FOR SOCIAL PROOF CONCEPT.

Level

0

0-51 km/h: The driver is informed of the current speed In the HUD through the speedometer. Simultaneously, the current speed is visible in the centre of the car to make it visible for everyone in the car.

Level

1

51-55 km/h: When the driver exceeds the speed limit, the current speed indicates the violation by changing colour from a neutral to amber, indicating caution to inform that that the driver is now violating the speed limit. The same colour change appears on the centre stack to visualize to everyone in the car that the driver is now exceeding the speed limit. The driver now has the chance to decide if to decelerate or continue speeding. There is also a chance for passengers to observe that the driver is exceeding the speed limit and comment on it to ensure ones own safety.

Level

2

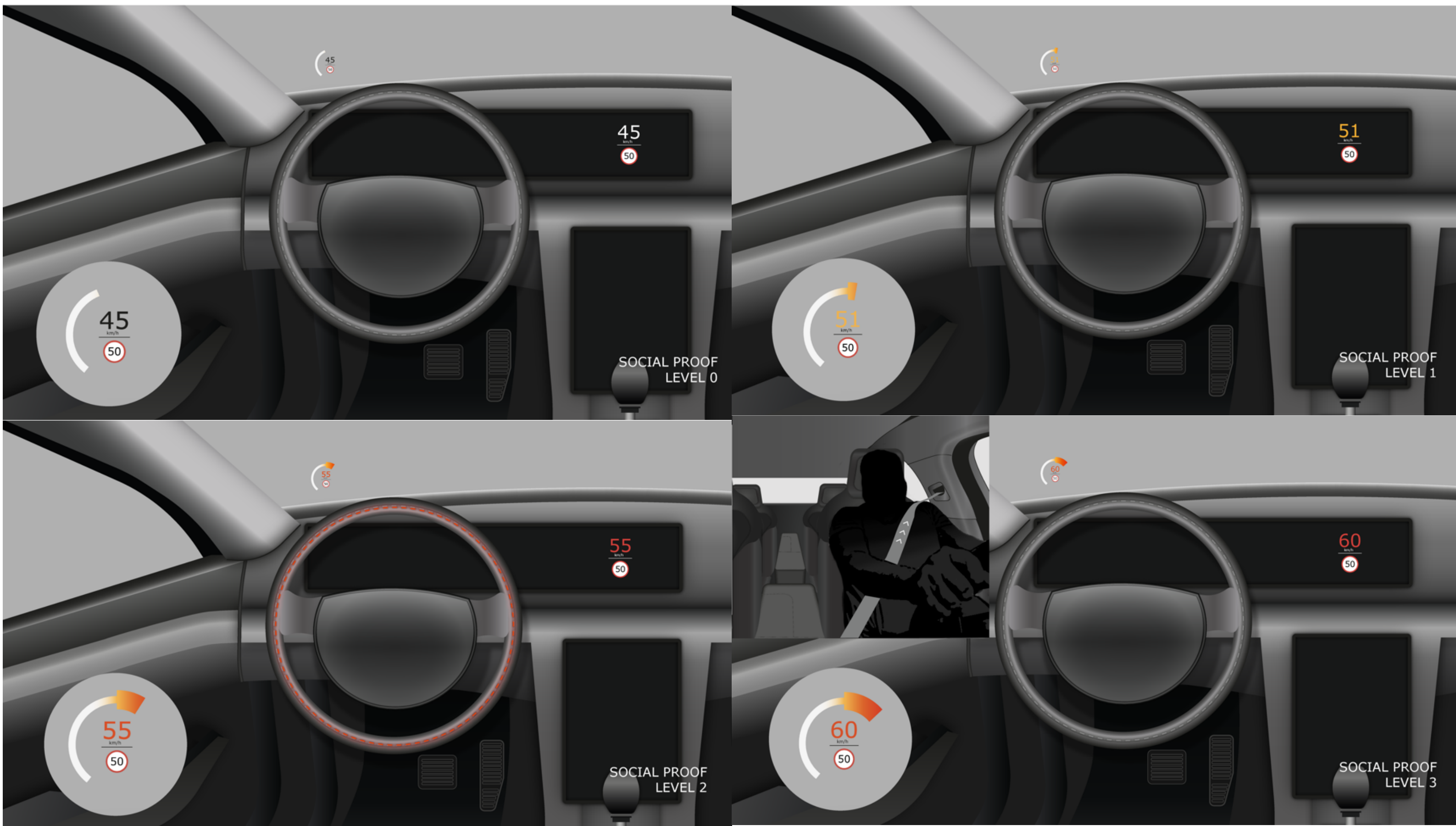
55-60 km/h: The speedometer gradually changes to red and if no feedback from the driver, the steering wheel lights up. The steering wheel adds another element of visibility for the violation.

Level

3

60 km/h: The visual signals can be assumed to have been ignored or missed by the driver so as a final prompt, the seatbelt gives the driver haptic feedback one time.

FIGURE 8:5 VISUALISATION OF THE ESCALATION FOR THE SOCIAL PROOF CONCEPT.



8.3 CONTEXTUAL FACTORS

Findings show that one of the main reasons for keeping the speed limit is the contextual factors. Weather, pedestrians and road type is examples of factors that were found to affect drivers speed choice as it impacts the motivation to keep oneself and others safe. However, many drivers expressed that for these factors to affect speed choice, they still need to be considered a risk, and sometimes drivers are unaware of the current factors around them.

The principle of this concept is to use the fact that drivers already feel motivated to a safer speed choice when they find that the contextual factors require it. By introducing dynamic situational factors through the vehicle HMI, the idea is that the driver will become more aware of the surrounding and have an increased acceptance for being prompted by the ISA system to lower the speed during violations. By having the situational factors present, the driver will reflect more over their risk assessment and make more reliable speed choices as they would not go against their own moral of speeding during the prevailing contextual factors. The concept structure is described in figure 8:7.

FIGURE 8:6 VISUALISATION OF THE CONTEXTUAL FACTORS CONCEPT.

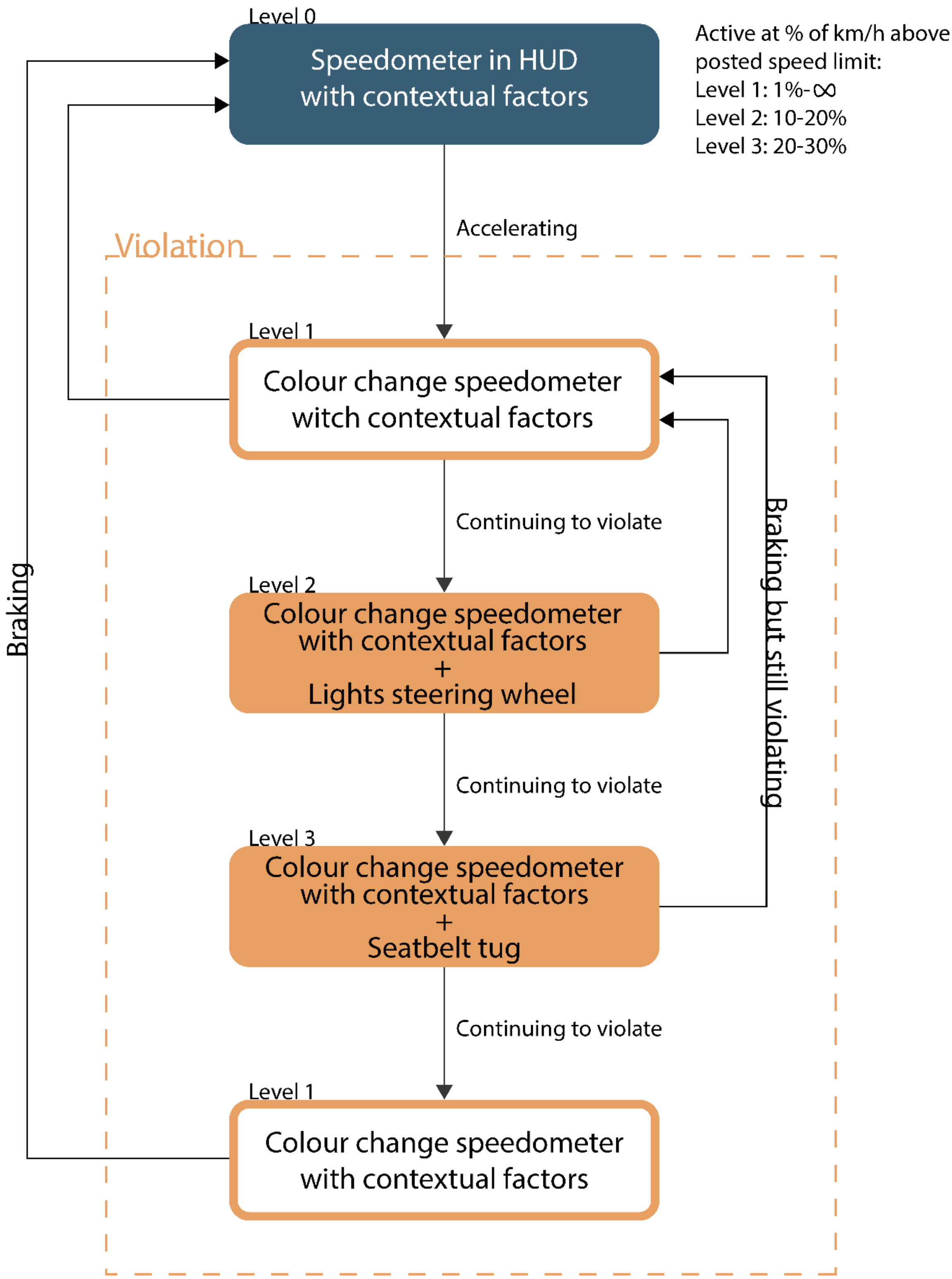


FIGURE 8:7 FLOWCHART FOR CONTEXTUAL FACTORS CONCEPT.

Level 0

0-51 km/h: In this concept, the situational factors are presented in relation to the speedometer as well as the road characteristics.

Level 1

51-55 km/h: When the driver exceeds the speed limit, the current speed indicates the violation by changing colour from a neutral to amber, indicating caution to inform that that the driver is now violating the speed limit.

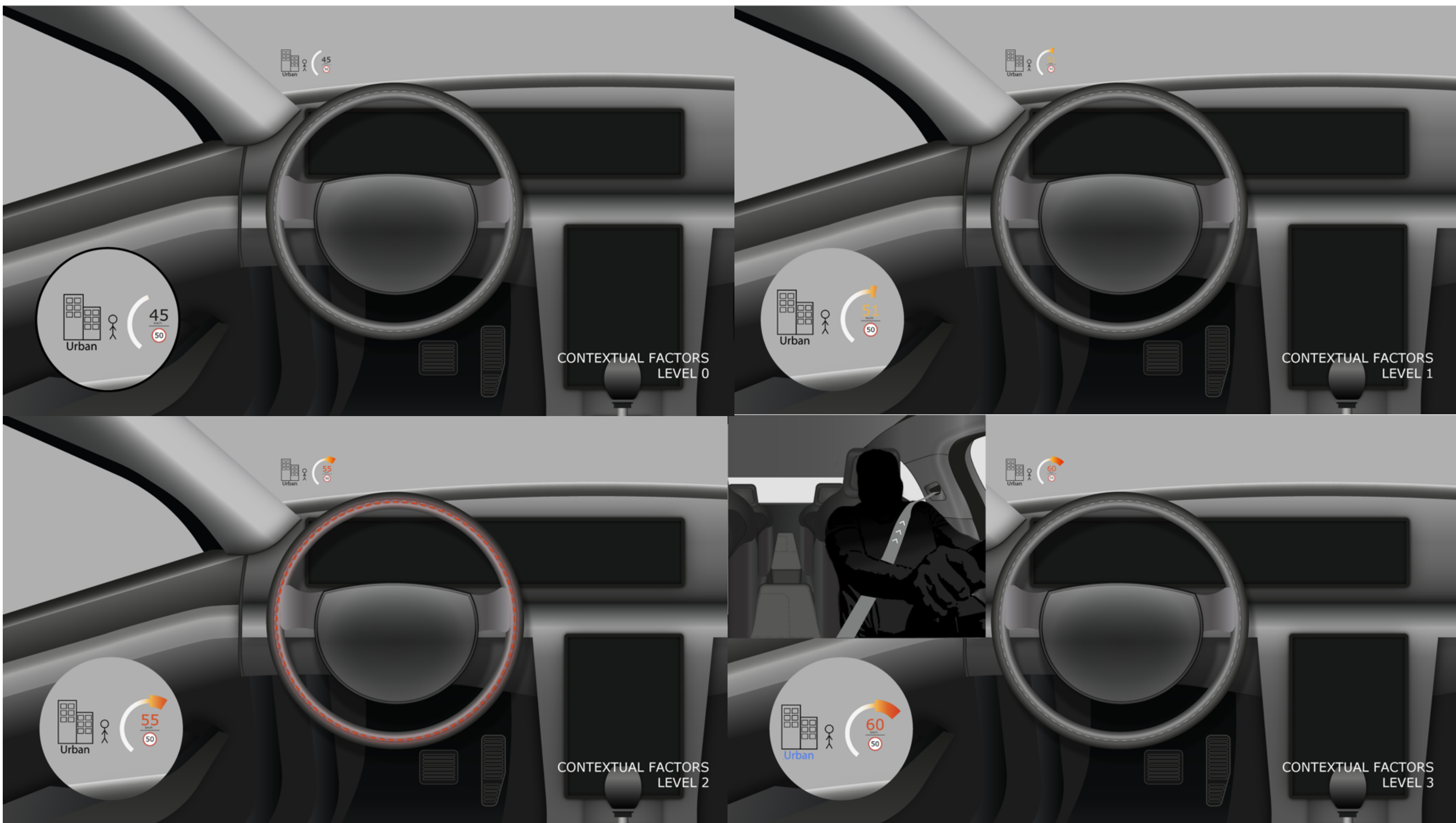
Level 2

55-60 km/h: The speedometer gradually changes to red and if no feedback from the driver, the steering wheel lights up. The steering wheel adds another element of visibility for the violation.

Level 3

60 km/h: The visual signals can be assumed to have been ignored or missed by the driver so as a final prompt, the seatbelt gives the driver haptic feedback.

FIGURE 8:8 VISUALISATION OF THE ESCALATION FOR THE CONTEXTUAL FACTORS CONCEPT.



8.4 GAS CONSUMPTION

The safety of others and oneself is the most prominent motivation to keep speed limits amongst the participants in this project. However, findings show that there are situations where the motivation to keep the speed limits are considered low and where the safety aspect is not perceived as a factor for speed choice. In these situations, many drivers drive based on their risk assessment instead of driving by the speed limit signs. Findings show that even some drivers, who value driving by the speed limits, find themselves in situations where they do not find reasons for complying with the speed limit.

The principle of this concept is to make a connection between the speeding violation and increased gas consumption to motivate the driver to keep the speed limits. The concept structure is described in figure 8:10. Many drivers already have an economic incentive to not over speed and get fined, and others argue that they value the environmental impact of gas consumption. With this concept, the economic and environmental incentives of gas consumption are used to increase the acceptance for the ISA system, as the prompts not only relates to the speeding violation but also to something that the driver finds of value. By visualising the gas consumption will also make the loss be perceived more immediate, which it usually is not perceived today

FIGURE 8:9 VISUALISATION OF THE GAS CONSUMPTION CONCEPT.

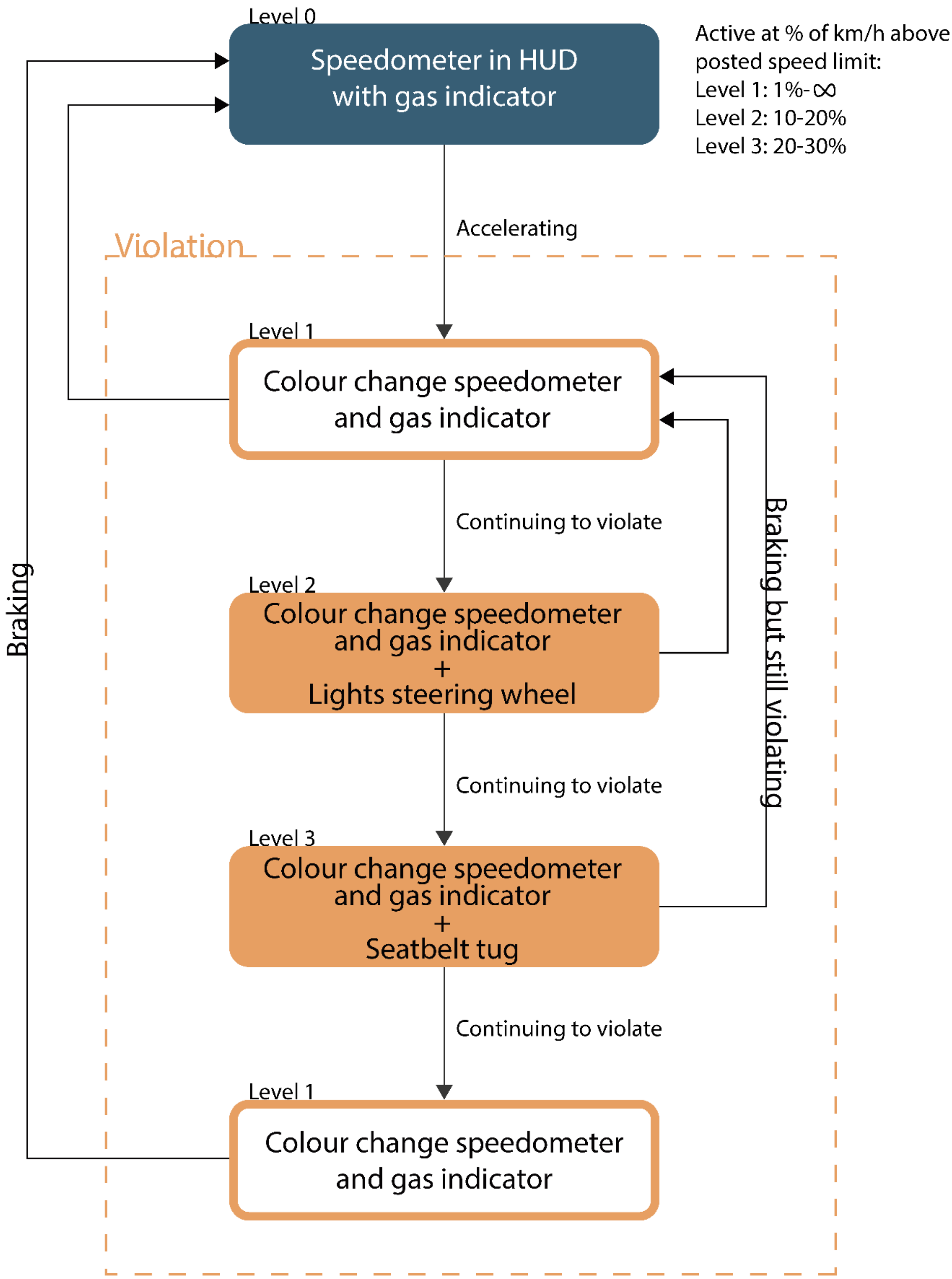


FIGURE 8:10 FLOWCHART FOR GAS INDICATION CONCEPT.

Level

0

0-51 km/h: In this concept, the indication for gas is also placed in the HUD, in relation to the speedometer.

Level

1

51-55 km/h: When violating the speed limit, the amber indication also applies to the gas indicator to communicate the relationship between speed and gas consumption.

Level

2

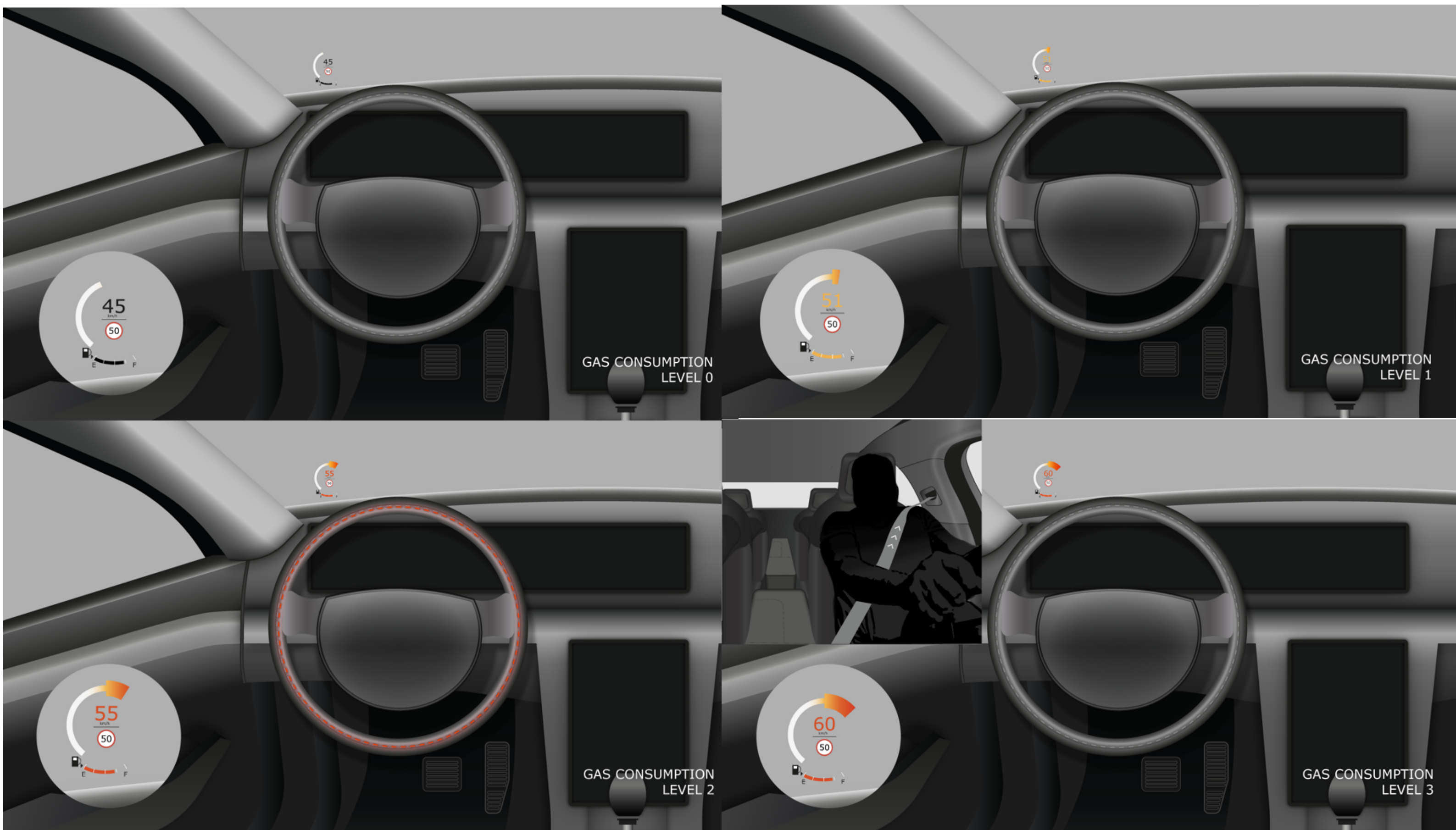
55-60 km/h: The speedometer gradually changes to red simultaneously as the gas indicator to make it easy for the driver to draw the connection. If no feedback from the driver, the steering wheel lights up. The steering wheel adds another element of visibility for the violation.

Level

3

60 km/h: The visual signals can be assumed to have been ignored or missed by the driver so as a final prompt, the seatbelt gives the driver haptic feedback.

FIGURE 8:11VISUALISATION OF THE ESCALATION FOR THE GAS CONSUMPTION CONCEPT.



8.5 VISUAL ILLUSIONS

Findings from empirical studies and literature show that it is experienced challenging to keep the speed limit in newly produced cars. It was expressed that the smoot driving in new cars change the experience of speed and reduces the ability to recognize when speeding. Several drivers also expressed an increased feeling of safety with all the safety systems that are included in newly produced cars, which negatively impacts speed choice as it feels safe to drive fast when being protected by advanced safety systems.

The literature illustrates several successful examples of using illusions to nudge drivers to keep the speed limits which can be found in chapter 2.2.6. The principle of this concept is to change the in-vehicle experience of speed to create the perception of driving faster than one is. The concept structure is described in figure 8:13. Findings show that many drivers drive based on their experience of speed, and drivers lower their speed when feeling that they drive to fast. By inducing that feeling earlier, the idea is that it will be more comforting driving by the posted speed limit.

FIGURE 8:12 VISUALISATION OF THE VISUAL ILLUSIONS CONCEPT.

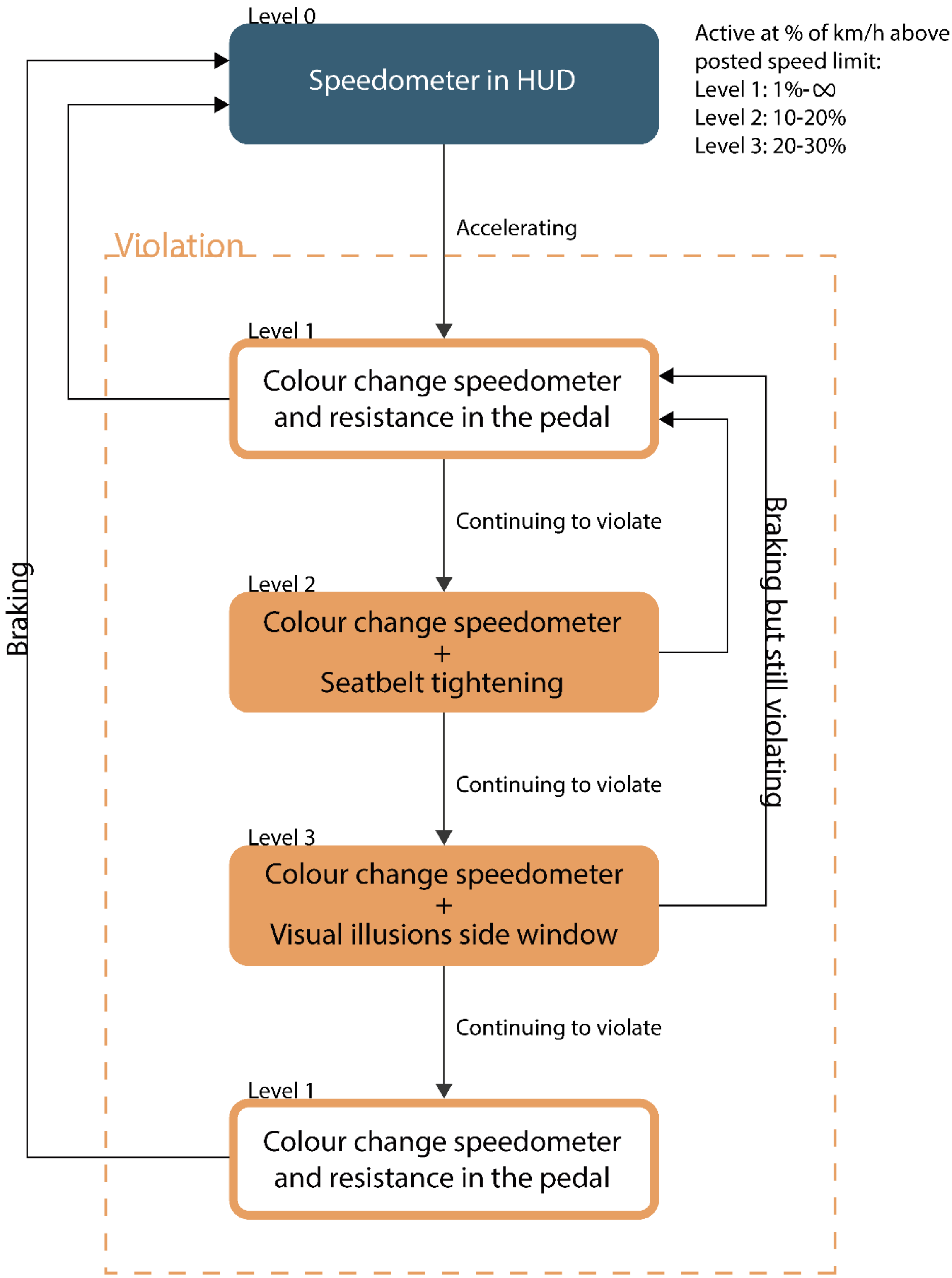


FIGURE 8:13 FLOWCHART FOR ILLUSIONS CONCEPT.

Level

0

0-51 km/h: The driver is informed of the current speed In the HUD through the speedometer.

Level

1

51-55 km/h: When reaching the speed limit, there is a slightly subtle change in resistance from the pedal and less capacity from the engine. The driver needs to press a little bit harder to continue accelerating at the same pace. Simultaneously, the amber alert is active to inform of the violation.

Level

2

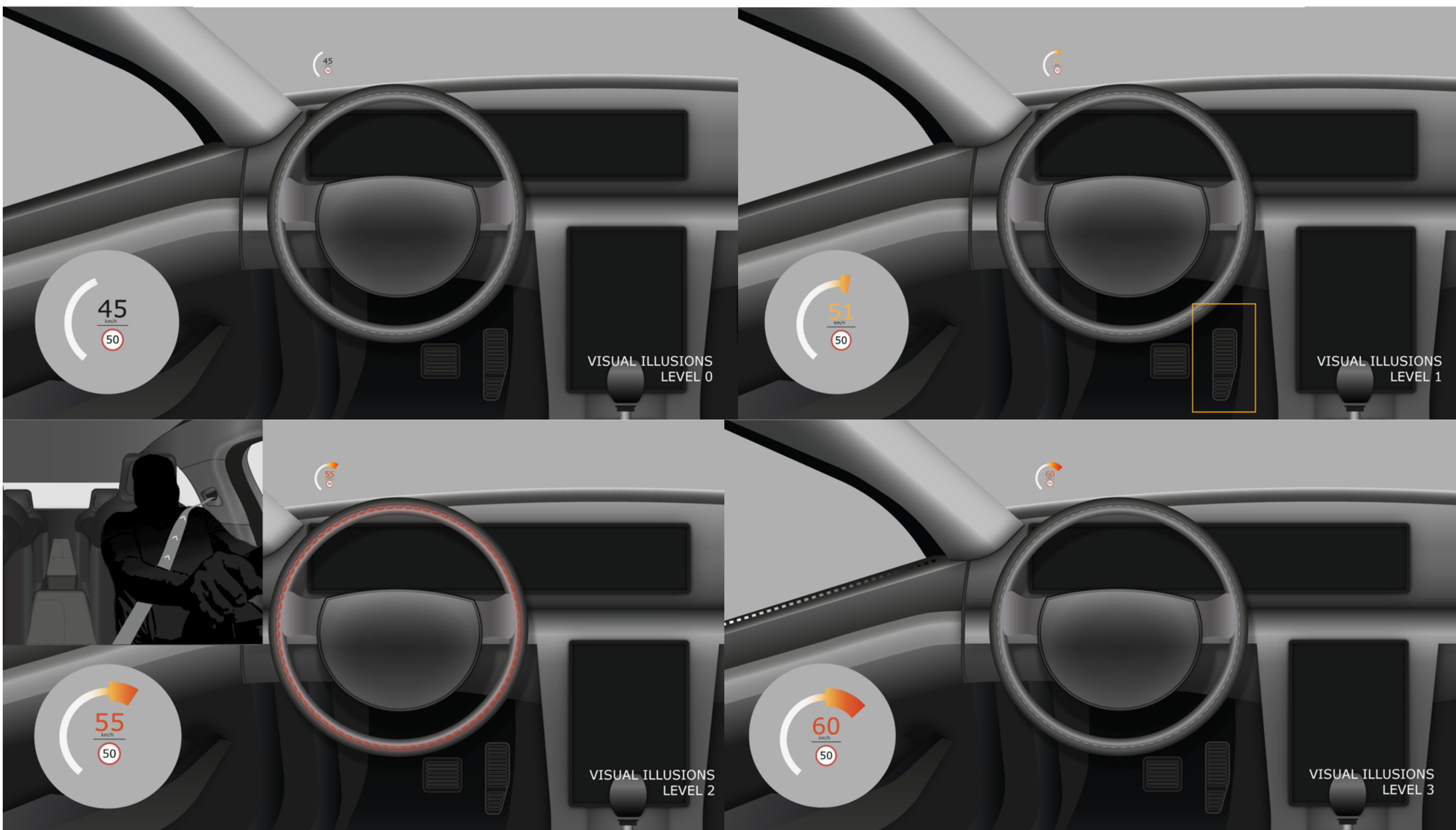
55-60 km/h: The feeling of driving fast intensifies by tightening the seat belt gradually to straighten the driver and give the feeling of leaning closer to the seat, similar to the feeling of accelerating fast and being pushed into the seat. Simultaneously, the red alerts activate.

Level

3

60 km/h: Visual illusions in the side window are activated, which moves in the opposite direction to enhance the feeling of speed. This visual illusion is intended to be subtle and not draw attention.

FIGURE 8:14 VISUALISATION OF THE ESCALATION FOR THE VISUAL ILLUSIONS CONCEPT.



9

PHASE 3 – EVALUATION
CONCEPT EVALUATION WITH USERS

The last evaluation phase aimed to realise design alternatives through a user evaluation of concepts to gain insights for the final design guideline. The concepts were evaluated in the fifth empirical study, which is described in this section first by introducing the execution of the study, followed by results and conclusion.

9.1 EMPIRICAL STUDY 5

The fifth empirical study aimed to evaluate the concepts towards users. The goal was to receive feedback to conclude the pros and cons of each concept and suggest improvements for future development. The study collected qualitative data regarding the anticipated experiences of the concepts to explore if the principals of the concepts have the potential to change speeding behaviour in different contexts as well as reach acceptance.

9.1.1 EXECUTION

The selected method for the study was a one-to-one semi-structured interview. A prepared template with fixed open-ended questions and Van der Laan et al. (1997) scales were used to evaluate and compare four animated concepts on video, that were shown to the participants digitally (see appendix X). The participants were able to see the videos and the questions on their screen during the interview, while follow-up questions were frequently used to encourage them to elaborate their answers and reflections. The scales were mainly used as a tool to encourage the participants to talk about the different key values of the method. No calculations of the perceived usefulness and satisfaction based on the answers were made due to the small number of participants.

Probability sampling was used to recruit ten drivers with different levels of driving experience and driving frequency in the age span of 25-55. The participant was informed of the interview theme without knowing who was responsible for the design of the different concepts they were to evaluate. The session started with a short introduction and short initial interview about their speeding behaviour and how they view themselves as drivers. The initial interview was used to introduce the participants to the subject as well as gain an understanding of how their current behaviour may have an impact on how they experience the concepts. The interview started with an evaluation of the four different spark concepts individually, followed by a part where the participants were asked to compare them. The session ended with an evaluation of the ISA concept, where the system and different HMI modalities were evaluated.

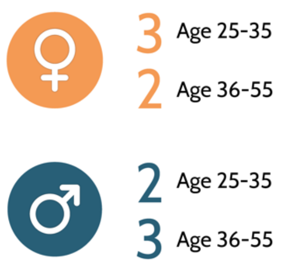


FIGURE 9:1 AGE AND GENDER DISTRIBUTION STUDY 5.

The answers were noted down in the evaluation sheet while the interview was executed. The answers were analysed with card sorting, where answers describing Pros and Cons for each concept and individual elements were sorted accordingly. The data within the categories were further sorted based on the content, which was used to draw conclusions of what areas should be considered in the further development of a final solution.

9.1.2 Results and Discussion

	Social Proof	
Pro	**Drivers want to show respect to their passengers.** 7 out of 10 participants	Participants expressed that they want to pay respect to their passengers and would find it embarrassing to show them that they are doing something wrong. The visibility was expressed to make participants more observant of their speed and more careful not to exceed in the first place or correct it faster, to show passengers that you are a responsible driver.
	Drivers consider it everyone's right to have a say about speed choice. 7 out of 10 participants	The concept was expressed to make it more tangible that the driver exposes others to danger and is responsible for others safety. Participants consider it the passengers right to have a say in the speed choice for everyone to feel safe, where the concept would make it easier for passengers to express themselves. Participants additionally expressed it as an appreciated feature if the roles were changed and considered it good to know for their safety. The evaluation also showed that participants would consider speaking up and that they already look over the driver's shoulder in order to find out what speed they all are driving in.
	Others can assist the driver when they unintentionally exceed the speed limit. 7 out of 10 participants	The concept was described as a way to detect violations if the driver is unintentionally exceeding the speed limit, where a passenger would have the opportunity to remind and help the driver to become aware of a violation, as an additional element to warnings to make sure that it will be detected. It could be argued that the concept could potentially relive the driver from a part of the workload of driving.
Con	**Some passengers could annoy the driver.** 3 out of 10 participants	There were expressed concerns about passengers inducing stress and irritation in some situations. Some participants expressed that it could result in discussions that distract the driving task. Åberg et al. (1997) stated that anger is often related to speeding behaviour. It can be assumed that displaying the speed could end up in arguments between passengers and driver, hence result in speeding behaviour due to the emotional state. One participant also expressed concerns of passengers prompting the driver to speed but further elaborated that he would not pay attention to it. Åberg et al. found that passengers with a positive attitude to speeding already have a negative impact on speeding behaviour. The concept could potentially add to that.
	Drivers prefer HMI directed to themselves 4 out of 10 participants	Four participants expressed that they still preferred HMI that was directed to the driver, to make the speed choice based on what they see and experience themselves. Drivers were not confident that it would make a significant difference for them that it is visible for passengers. If warnings have low chances of overriding the beliefs of passengers (ISO, 2005), it can also be assumed that

		for some drivers, being told by passengers would not either reach effect on the behaviour.
	GAS CONSUMPTION	
Pro	**Drivers are motivated to lower their gas consumption** 8 out of 10 participants	Participants expressed that the concept would motivate them as it visualizes how they can save more money by keeping the speed limit. Raegan et al. (2012) and Steinberger et al. (2017) found similar effects in their studies by introducing incentives and gamification. A few participants expressed that they care more about economic incentives than devote to speeding and further expressed that it would feel *"painful"* to speed while seeing that it costs. The environmental impact was also a motivating factor of gas consumption. It was found that participants do not find the danger itself of choosing a higher speed as having a direct influence on them. Participants, therefore, liked that the concept connects their speed to money, that is something they consider having a direct influence on them. It was further expressed to have potential in situations where the driver does not have a motive for speeding. It can be assumed that in these situations, the gas consumptions may impact the choices architecture by lowering the positive aspect of speeding.
	Drivers would lower their speed & become more aware of their driving. 9 out of 10 participants	Participants described how they would experience the feedback as positive and react by lowering their speed and drive according to the optimal gas consumption level. Additionally, a few participants expressed they would become more conscious and aware of the negative economic impact of their driving behaviour.
	It is useful when drivers keep the same speed for a longer time. 2 out of 10 participants	The concept was considered more useful on highways or when the driver is keeping the same speed for a longer time. It was perceived as less useful for urban driving, according to some participants. Two participants expressed that they would be triggered when driving routine or longer routes as they usually become bored, and then could focus on trying to lower their gas consumption, similar to the findings from Reagan et al. (2012). Åberg et al. (1997) found that boredom tends to increase the risk of speeding behaviour. Hence, it can be argued that a concept which could stimulate the driver in situations of vigilance is positive for speeding behaviour.
Con	**Drivers already find themselves aware of the increased gas consumption** 2 out of 10 participants	Two participants already considered themselves aware of the economic and environmental aspects of speeding and thereby considered the feature unnecessary. However, the same interviewees expressed that they would not necessarily think about it when exceeding or driving above the speed limit. Hence, it could be argued that even these participants could be triggered by a reminder which would make the negative consequences of

		speeding more immediate and certain according to Daniels (2000) theory.
	Some drivers are not motivated by gas consumption 2 out of 10 participants	It was found that not everyone was motivated by gas consumption, but mainly the violation itself. One participant stated that she does not pay for gas, as she usually borrows her parents' car. For her, the concept was not motivating as she would not be affected by the consequences.
	It is not always helpful to drivers 3 out of 10 participants	It was further expressed by participants that it would not be useful in all driving situations, as they did not always consider themselves to be able to choose speed based on economic incentives. Participants expressed that when driving in urban areas, the attention needs to be directed towards the traffic rather than the gas consumption. It can be assumed that the workload in these situations is too high to add another element (Campbell et al., 2016; ISO, 2005) One participant also stressed that it would not make a difference if she had a desire to speed, as the positive consequence of arriving earlier outweighs the saving gas aspect. One participant also thought that the concept would be less effective with a full tank, but most effective when it was less than half empty.
	How it is presented can make a big difference to the effect 4 out of 10 participants	Participants elaborated that the concept needed to show numbers of consumption for it to have an effect. Changed colour to indicate loss was not enough. A few participants expressed a need to see how much that was lost in relation to other costs or savings over time.
	It could impact the driving experience 1 out of 10 participants	One participant expressed that the concept could decrease the pleasure of driving, as it would not be possible to experience speeding as positive if showing how costly it is. Yannis et al. (2013) found that drivers gain pleasure from driving fast. It can be assumed that the participant has a similar approach and would consider the concept reducing his possibilities of this pleasure.
	CONTEXTUAL FACTORS	
Pro	**Drivers will reflect on their behaviour** 5 out of 10 participants	The concept was described to remind the driver about speeding in an already high-risk situation. By visualising situational factors, participants experience the risks as more tangible. It was also expressed that the concept makes its more concrete that they behave in a way that goes against their own moral, that participants described could induce emotions of bad conscience and hence lower their speed. The concept was described to increase the attention and reflection of speed choice.
	It increases the acceptance of intense HMI	Some participants expressed that the presentation of VRUs in the area could increase the acceptance for more intense HMI

	3 out of 10 participants	prompts, as they would understand why it is important to keep the speed limit. However, one participant explained that the more intense HMI would not be needed, as he already would be notified and motivated to keep the speed limit if HMI showed that there were risks for VRUs.
	It helps drivers assess uncertain traffic situations 4 out of 10 participants	There were situations where participants expressed that the concept could assist them with the driving task. Participants found it harder to assess road conditions due to weather, where participants could consider going below the speed limit if they were alerted. One participant also stressed that the concept could inform him about driving on a road where there is an increased risk for crashes. Participants further expressed that it would be good if not noticing VRUs, but generally found themselves good at assessing this risk, which will be further elaborated in the next section.
Con	**Drivers dot not consider it useful** 6 out of 10 participants	Many participants expressed that they found the concept as unnecessary and did not believe that it would affect or add anything to them. Drivers already found themselves good and experienced in assessing risks. It was further elaborated that it might be more suitable for inexperienced drivers or when driving in new areas. Participants further described a need for only being assisted with tasks where they need support, and VRUs' is described as something they already pay attention to.
	Drivers consider it annoying if it warns for everything 4 out of 10 participants	Participants expressed that the concept would be annoying if it notified too often, especially when driving in urban areas with VRUs present. If it would continually update the information, participants stated that they might stop paying attention to it. Additionally, participants expressed concerns about the concept would disturb the driving task, as there is too much going on in the HUD. The recommendation from Campbell et al. (2016) is to only present warnings to the drivers that do not risk enhancing the workload. A visual warning should be used with caution due to an already strain visual workload (ISO, 2005).
	VISUAL ILLUSIONS	
Pro	**Drivers appreciate the avoidance of warnings.** 3 out of 10 participants	Participants expressed that they preferred illusions over warnings, as it was perceived as more subtle. This was further elaborated to be useful to avoid that a warning draws attention from the driving task.
	Drivers like to avoid making the decision and drive in a speed that feels good 4 out of 10 participants	Participants believed that they would appreciate that the concept act to make them unconsciously choose a lower speed, which they further thought could solve the problem of ignoring prompts that required reflective choices. Participants expressed that they would probably lower their speed or not exceed the speed limit to be able to drive comfortably. One participant compared it with

		driving an older car, where they would choose a lower speed to avoid the vibrating feeling that comes with choosing a higher speed.
Con	**Drivers perceive it as unpleasant & distracting** 6 out of 10 participants	Participants expressed that it would feel unpleasant to not get the effect they anticipate by pressing the gas pedal, especially in situations where they would need to make a manoeuvre to avoid a dangerous situation. It can be argued based on ISO (2005) paper that it would harm the credibility of the system. It was further expressed to induce emotions of lost control which Spyropoulou et al. (2014) argue could result in a dislike of the system. Other participants found it as a good feature to assess if they had reached the speed limit without monitoring the speedometer. That could, in agreement with Spyropoulou et al., be considered a misuse of the system and potentially result in drivers stop reflecting over their speed. Two participants voiced that the belt-tightening could feel claustrophobic, while other participants found it as a good way of inducing a feeling that will have an impact on their choice. The light illusions in the side window were perceived differently among the participants, where it was perceived as distracting while to other as something positive. Participants expressed concerns that the concept could make them lose focus on the driving task due to all impressions. As the intention of the concept was that it should be subtle changes in the experience, it should be noted that there are concerns about drastic changes in the speed experience. However, the participants found it hard to determine without experiencing the concept if they would appreciate it or not.
	Drivers rather use something that makes them reflect 2 out of 10 participants	While some participants expressed that they liked to be making the speed choice without reflection, there were also a few who would prefer a system that makes them become aware and reflect over their speed instead. These were drivers that expressed a value in keeping the speed limit and frequently looks at the speedometer. These drivers did not consider the enhanced feeling of speed as an advantage but believed it would scare them.
	ISA SYSTEM STRUCTURE TOLERANCE	
Pro	**A good reminder when drivers unintentionally exceed the speed limit** 10 out of 10 participants	Participants expressed it as easy to exceed the speed limit unintentionally. The ISA system was described as a good reminder for unintentional violations. It was further expressed appreciated being warned to reduce the risk of being fined.
	Raising intensity from different elements catches drivers' attention	Participants expressed appreciation for the intensity of the HMI gradually increasing and switch element depending on the severity of the violation, which is also recommended by Campbell

	5 out of 10 participants	et al. (2016). This was expressed by participants to make the HMI credible as well as drawing their attention. However, some participants expressed that the intensity raise would be enough if it stopped at the red indications of the speedometer in the HUD or the steering wheel, as they did not find higher intensity than that necessary for them to detect and lower their speed. Participants expressed the seat belt as too intense, and one participant further preferred if the HMI continued to alert with another visual HMI rather than switching modality.
	Tolerances increase the acceptance 8 out of 10 participants	During the interview, participants expressed concerns about being prompted at 5-10 km/h above the speed limit at higher speeds than 50 km/h, which would result in the system being turned off. Participants explained that the acceptance for being prompted increased when they understood that the concept would have a tolerance based on % km/h and time above the speed limit for the steering wheel and seat belt.
Con	**Maybe not fully effective for all drivers** 1 out of 10 participants	One participant responded that she would keep speed within a span that did not trigger the steering wheel, but maybe not lower her speed to the speed limit.
	It is annoying to drivers when they intentionally want to exceed the speed limit 5 out of 10 participants	Participants described that the system could annoy them if they were exceeding the speed limit for an overtaking or when a higher speed was not putting others but themselves at risk. Spyropoulou et al. (2014) stated that annoyance must be avoided for the system to serve its purpose. One participant further explained that he wanted to be able to turn off the system to drive for pleasure sometimes on empty roads while always keeping it on in urban areas. Participants expressed concerns for a warning system in an emergency, when they consider speeding important for safety reasons, such as when someone is sick or to get out of the way for ambulances, even if that was also expressed as unusual situations.
	Can be annoying for drivers that already consider themselves good in driving 1 out of 10 participants	One participant explained that the system could be annoying in the long run, as he already found himself as a good driver, and warnings have low chances of overriding the beliefs of passengers (ISO, 2005),
	STEERING WHEEL	
Pro	**It makes sure drivers detect that they are speeding** 7 out of 10 participants	The most prominent pro of the steering wheel was expressed as its potential to alert for violations and assist in detecting violations. It was described most valuable when the speedometer-nudge in the HUD was not noticed, as some found

		the red indicator in the speedometer as providing the same function which they preferred over the steering wheel.
Con	**It can be intrusive to drivers' personal space** 1 out of 10 participants	One participant explained that he did not like the fact that people outside the car could see the steering wheel and that he was driving too fast. The participant described that it was intrusive as he found the car as a very personal space. The same participant did not appreciate the steering wheel as he interpreted it as telling him what to do and reprimanding instead of recommending him to slow down.
	It can distract drivers 2 out of 10 participants	Some participants had concerns that the steering wheel could be distracting and affect their driving.
	Light and blinking can be perceived as annoying 4 out of 10 participants	Some participants expressed that they found light as annoying, while others merely would like to remove the blinking part of the feature.
	It is triggered too early 3 out of 10 participants	Three participants expressed that the steering wheel was triggered a bit early. One driver stressed that it was an appreciated feature, provided that it was not triggered all the time.
	SEATBELT	
pro	**Drivers appreciate that they will always detect it** 2 out of 10 participants	The positive aspect of the seatbelt was expressed as the fact that it would always be noticed. It was considered appropriate after no reaction to the visual warning, which also agrees with the recommendation from ISO (2005) for haptic warnings.
Con	**Drivers disapprove of it** 8 out of 10 participants	A majority of the participants expressed disapproval of the seat belt feature that they anticipated being too intense, annoying and unpleasant to use. The belt awakened strong emotional reactions among the participants, and many expressed that they would not want it in their car and anticipated an intrusive experience. This was not unexpected, as both Campbell et al. (2016) and ISO (2005) stated in their papers that haptic feedback should be used with caution and only for severe situations.
	It could affect the driving task 3 out of 10 participants	Some participants found the tugging as risky as it could startle them, which could affect how they manoeuvre the car.

	Drivers focus more on how it feels rather than why it is triggered 2 out of 10 participants	Participants further expressed that it would uptake their attention differently as they would feel the belt tug but not see it, which could make them lose their focus.
	SPEEDOMETER	
Pro	**Drivers feel in control over their decisions** 1 out of 10 participants	One participant expressed that he appreciated the speedometer as it left the decision to him. The feature was interpreted as a humble way of informing him about driving above the speed limit.
	It motivates drivers to keep the speed limit 3 out of 10 participants	Three participants expressed that the speedometer could trigger competitiveness. It was explained that they would react by trying to keep their speed so that the coloured field was not triggered or stay on the top/middle line, as a competition against themselves. The numerical presentation of the speed was further elaborated to amplify this experience, where participants expressed that they have an inherent will to be exact and keep the speed at the posted speed.
	The placement in the HUD facilitate for drivers to keep the speed limit 8 out of 10 participants	Participants appreciated that the speedometer was placed in the HUD as it would make it easier for them to keep track of their speed. It was further expressed that the placement would make them reflect more over their speed as it is always present.
	Drivers find colour as a good indication of speeding 8 out of 10 participants	Drivers expressed that using colour was an appreciated and pronounced way to indicate violations, which would catch their attention. Some further expressed that the colours added indications of what was right and wrong.
	The dynamic visualization facilitates for drivers to keep track of their speed 6 out of 10 participants	The fact that the speedometer is dynamic was expressed to facilitate for the driver to monitor their speed, as it always means that they have reached the speed limit if the speedometer is at the top centre. Participants expressed that this meant that they felt confident in keeping the right speed and made it more apparent for them if they would exceed and what the correct action then would be, without the need of closely monitoring it.
Con	**Drivers may ignore it in the long run** 1 out of 10 participants	One participant expressed that the speedometer may be too subtle to have an effect in the long run. He expressed that he may ignore it in the future if he would like to exceed the speed limit.

9.1.3 CONCLUSION

ISA SYSTEM

The findings indicate that the ISA signal system could be accepted in situations when drivers unintentionally exceed the speed limit. When drivers are not motivated the keep the speed limit, it could be perceived annoying. Furthermore, the signal system itself may not be efficient enough to have them lowering their speed down to the speed limit in all situations. In seems that spark nudges are needed for intentional speeding situations for a system to have the potential to become fully efficient while being accepted.

Signal nudges should be used to remind the user about an action they already have the intention to do (Caraban et al., 2019). Only three out of ten participants expressed that they could consider having all signal nudges in their car. The strongest disapproval was for the seat belt. Five out of ten participants would not consider having it in their car while eight out of ten still would still anticipate it as annoying and unpleasant. The seat belt was perceived as intense and drivers did not find the high intensity as necessary to detect and lower their speed. It can be assumed that a less intensive signal would be beneficial to reach both effect and acceptance. However, it can be assumed that participants need to experience the belt to be able to fully evaluate it as the results from empirical study four did not show strong disapproval. Further evaluation would be needed with representative participants in a real context before excluding the belt. Findings showed that participants appreciated the steering wheel as it drew attention towards the information in the speedometer, which also agrees with the recommendation from ISO (2005).

The study indicated that the steering wheel was perceived of higher intensity than the red indications on the speedometer, while participants find them satisfying the same need for being alerted. As the participants preferred the speedometer, the steering wheel could be perceived as redundant.

In the displayed concepts, the red indications in the speedometer and the steering wheel are displayed at the same time. It should be investigated if a higher tolerance for the steering wheel could increase its usefulness. It should further be investigated if the steering wheel has the potential to replace the seatbelt for higher intensity warnings. The flashing of the steering wheel was experienced prompting. According to Campbell et al. (2016), flashing should only be used to represent severity and urgency to take action. It should therefore be investigated if the steering wheel would be more accepted among users if the feature did not blink.

As the speedometer was appreciated and anticipated to have both effect and reach acceptance, future work should be to test the feature in a realistic setting further to see if the effects will correspond with the findings of this study.

The following use cases are recommended for further development:

- Urban areas
- Highway and rural roads in combination with a spark
- Targeting driver personas Sandra and Emma
- Targeting scenarios of high motivation

SOCIAL INFLUENCE

Participants were approving of the passengers right to have access to the speed indication, and the acceptance was considered high. Visualising speed to everyone in the car seems to have the potential to increase the motivation to comply with the speed limits and work as a spark for the behaviour as drivers find it irresponsible towards the passengers to speed. However, this study, in agreement with the study by Transport Canada (2005), shows that drivers do not necessarily consider excessive speed a violation, but rather when reaching a certain km/h above the posted speed limit. It can be assumed that this also applies to passengers, which then in agreement with findings from Åberg et al. (1997) could result in passengers negatively impacting speeding behaviour. However, findings from this study show that there is potential that merely the visibility of one's speed could have effects, without passengers commenting on the speed choice.

Future work should consider how the negative aspects of visibility of speed could be reduced to enhance the positive aspects of drivers sense of responsibility towards passengers. Using in-vehicle social influence is also constrained to situations when the driver has a passenger, which needs to be considered in further development.

The following use cases are recommended for further development:

- Urban, Rural and Highway
- Targeting driver personas Emma, Sandra, Jacob
- Targeting scenarios of both high and low motivation

GAS CONSUMPTION

Visualising gas consumption was the most appreciated concept amongst participants. It was found that participants could be more motivated by economic and environmental incentives than to the speed itself. The spark seems to be most efficient for habitual speeding behaviour on rural roads and highways. Participants expressed that for roads when keeping the same speed for a long time, the concept would allow them to reflect and adjust their driving to reduce gas consumption. Based on findings from Reagan et al. (2012) and Steinberger et al. (2017) which both found that drivers were triggered by adding an element of gamification to the driving, it can be assumed that visualising gas consumption could trigger the same behaviour if designed properly.

Participants further claimed that they are aware of that higher speed means an increased gas consumption, but that they did not reflect on it happening in the moment of their decision. This indicates that the concept could impact the behaviour by visualizing the negative consequence in a way that makes it more immediate and certain.

In urban areas where there is a lot of external stimuli to take into account, the concept could potentially add to the overall workload by adding yet another factor to consider for the driver. The concept also seemed not to override the impact of stress, and participants expressed they would ignore it during stress. Further, the concept will only affect those who are motivated by any aspect of gas consumption, such as economic or environmental. However, based on findings from this study, it can be assumed that many drivers do find motivation in such incentives.

Future work should focus on how gas consumption could be visualised to reach the greatest impact on driver motivation and explore how the feature can be used to enhance the long-term incentives to keep speed limits.

The following use cases are recommended for further development:

- Routine routes
- Highway and Rural roads
- Targeting driver personas Michael and Jacob
- Targeting scenarios of low motivation

CONTEXTUAL FACTORS

Using contextual factors as a spark was the least appreciated concept. Many considered it as a superfluous feature, as they already find themselves able to see the risks and thereby only draws their attention from the road. The evaluation of the concept, however, showed that there could be potential in creating a relation between the drivers' behaviour and their morals to trigger reflection. The concept seems to have the greatest acceptance in uncertain risk situations where the driver needs assistance in the judgement of perceived risks. The concepts could make the risks be perceived as more certain and thereby have a larger impact on driver behaviour. These situations are, however few since drivers perceive themselves as good at making risk assessments.

The concept seems to be targeting those who have respect for the impact of speeding, but sometimes find excuses to exceed. As for an example when a driver keeps up with the traffic flow to avoid slowing down other cars, the concept could encourage the driver to keep the speed limits by reminding of the potential consequences of not doing so, to make it more certain and immediate according to Daniels (2000) theory. The concept is, however, assumed to have less impact on those who have a strong belief in their driving capability.

For future development of the concept, it is recommended to investigate if it could be refined not to be experienced as disturbing the driver. It is also recommended to investigate further if visualising contextual factors could increase the acceptance for an ISA system by designing it less as a tool for risk assessment.

The following use cases are recommended for further development:

- Urban, rural highway roads
- Targeting driver persona Sandra
- Targeting uncertain risk situations of high and low motivation

ILLUSIONS

For this concept, the participant had different opinions. The main conclusion is that this concept needs to be evaluated in a realistic setting to gain further understanding of acceptance, as it is supposed not to trigger reflective behaviour change but rather work unconsciously. Berg Alvergren et al. (2019) showed in their study that visual illusions are effective in reducing speeding behaviours, so it can be assumed that the same could apply to in-vehicle solutions if designed properly. However, based on findings, it can be assumed that such a concept would need to be designed with subtle interference to allow the driver to remain in control of their speed choice to be accepted. This study showed that participant who found it important to keep the speed limit would rather appreciate a concept which triggered the reflective thinking and that changing the experience of speed would feel unpleasant for them.

Future work should investigate further if there is potential in changing driver behaviour by changing the experience of speed through in-vehicle user studies.

The following use cases are recommended for further development:

- Urban, rural and highway roads
- Targeting driver persona Michael, Jacob and Emma
- Targeting driving scenarios of low and high motivation

10

DESIGN GUIDELINES

In this chapter, the final result of this project is concluded in the design guidelines, which identifies important aspects to consider for speed assistance systems to be accepted and credible among drivers. The design guidelines aimed to guide researchers and designers within the automotive field targeting in-vehicle speed assistance systems. The guidelines are divided into five categories: intensity, tolerance, feedback, control and incentives, each described in this section. The result should be used in addition to legal requirements, that are left out of the scope of this project. Each guideline is colour-coded to illustrate which studies that contributed to the respective guidelines.

Literature study	●	●	Empirical study 1
Empirical study 2	●	○	Empirical study 3
Empirical study 4	●	●	Empirical study 5

10.1 INTENSITY

User studies show that the intensity of the HMI has a great impact on attitudes towards speed assistance systems and hence the acceptance of it as a part of their everyday driving routine. Drivers are sceptical about introducing warning systems in their car and should hence be used wisely to avoid rejection of a solution. Increased intensity show less acceptance among participants, as it affects the perceived control over choices and attention as well as the driving experience. Additionally, a proper intensity level is important for the credibility of a system, which in turn is essential for adherence. However, high intensity could be crucial for the HMI to be effective so that the attention will be steered towards the violation.

The HMI should allow the driver to act on low-intensity HMI

Before the HMI presents warnings of high intensity, the driver should have the opportunity to act on those of lower intensity. By allowing the driver to decide with support of information, they can choose when to attend to it and hence find themselves in control. This will increase the probability of acceptance for the HMI as well as a lower speed.

The intensity of the HMI should match the driver's interpretation of the violation

The acceptance for different levels of intensity is related to the driver's perceived severity of a violation in terms of km/h above the speed limit. The acceptance commonly increases with increased km/h above the speed limit and in urban areas. A gradual rise of intensity is recommended to reach acceptance for HMI of higher intensity but is considered less important in relation to VRU in urban areas.

The main function of intense HMI should be to make the driver aware of the violation

Drivers find themselves as good and safe and trust their risk assessment. If warnings go against what the driver find appropriate, it can create frustrations. Hence, increasing intensity should not be used as a strategy for the purpose to persuade the user to change speed choice when the driver already is aware. Letting the main function be to make the driver become aware and steer the attention to the violation will induce a supporting character allowing the driver to remain in control of their choices. To make sure the violation will be detected, the HMI could make use of shifting communication platforms as well as creating a contrast between the state of adhering and exceeding the speed limit.

10.2 TOLERANCE

The system tolerances for speeding showed to be a crucial feature for acceptance as well as the credibility of a solution. The level of tolerance, in combination with intensity, is important for a warning to be credible and accepted. The tolerance must correlate with the driver's perceived severity of the violation to match the expectancy of the situation. Many drivers do not consider themselves speeding instantly when exceeding the speed limit, which should be considered to reach acceptance and adherence for a speed assistance system.

The tolerance should increase with the intensity of the HMI
User studies show that the higher intensity of a warning, the higher the tolerance is needed for it to match the driver's expectancy of the situation. The tolerance of the HMI should hence adapt the tolerance to the intensity of different features of the HMI.

High-intensity HMI should have a tolerance based on km/h above the speed limit
Many drivers do not consider themselves speeding until a certain amount above the speed limit is reached. A tolerance based on km/h above the speed limit would increase the probability of the HMI to be triggered in situations where drivers consider themselves speeding and hence be accepted and credible. Furthermore, while it is important for the HMI not to have a too low tolerance nor is it credible with a too high tolerance that triggers the HMI when the driver would risk withdrawal of the driving licence.

Intense HMI should have a tolerance based on time spent above the speed limit
In order to allow drivers to remain control over their speed choice and not trigger intense HMI for temporary deviations from the speed limit, a tolerance based on time is recommended to reach acceptance. This would mean that intense HMI is not constantly triggered, which otherwise could create annoyance and lower the credibility of the system. When the tolerance is based on time above the speed limit, the HMI further targets continuous violations.

The tolerance should be situation based
Drivers find it important and are more motivated to comply with the speed limits in some situations than in others, which affect the perceived severity of a violation. The tolerances could benefit from being dynamic and considering the needs for situations where it is accepted to be alerted earlier. It should further adapt according to the area and posted speed limit, as drivers are more motivated to comply with the speed limits when they perceive there is a greater risk of hurting VRU, such as in urban areas.

The tolerance could adapt to the individual driving behaviour
To reach further acceptance and credibility, the system could adapt the tolerances according to how the driver usually behave. This would mean that HMI of high intensity would not be triggered as often and the credibility for that HMI would increase, along with the increased acceptance of being assisted with lower intensity for more common speeding situations to the specific driver.

10.3 FEEDBACK

User studies show that a solution should consider what feedback is presented as well as how it reacts to user actions to reach acceptance. The selection of feedback is important to avoid overloading the driver with information that can result in the driver stops paying attention to it. Drivers do not want to be overloaded with information they do not find relevant to them for the driving task at hand. The feedback of a solution further affects the driver's perceived control in their driving, which is of importance for acceptance.

Feedback should add value to the driver

For a solution to be accepted, it needs to consider the content of the feedback that is presented. The acceptance increases if the HMI provides an added value or facilitates the driving task to complements the driver's abilities.

The HMI should make it easy to assess current speed in relation to the posted speed limit

Whether drivers keep the speed limit or not, it is of value to the driver to notice and easily assess their current speed in relation to the speed limit. The HMI should provide the driver with feedback for deviating the speed limit as well as when the speed is appropriate.

The HMI should create a contrast between right and wrong behaviour

An intensity contrast between the desired and undesired state will focus the attention towards the speeding behaviour that needs to be corrected. It is recommended to make use of positive feedback for driving within the speed limit to create a contrast between right and wrong behaviour.

The HMI should communicate the correct action

When providing feedback of that the driver's speed does not correspond to the speed limit, the HMI should communicate or steer attention towards the information of the correct action to correct it. To enhance the effects and reach acceptance among users, different HMI features prompting a lower speed should also be accompanied with information of the correct action needed to abort the warnings. The HMI could further create an added value of making it easy to assess how much to lower the speed.

The HMI should be responsive to user actions

To avoid that the system is perceived to counteract rather than assist the driver, the HMI should be responsive to user actions. When the driver already made the decisions to adhere to or ignore the HMI, a solution should respond to the user's actions by aborting intense HMI. When ignored, it can be assumed to no longer have the potential to affect the driver without affecting the acceptance. If in deceleration, the HMI should assume that the driver chose to adhere to the HMI. Furthermore, a solution should not trigger intense HMI during overtaking as well as abort after a certain time to respond to ignorance.

10.4 CONTROL

Control was a constant theme through all user studies, where drivers showed concerns that a speed assistance system could counteract them and that they would lose control over attention and choices. Drivers find themselves good in making risk assessments and suited in making decisions of how to manoeuvre the car safely. Without control, the driver could feel counteracted by the system that could lead to a system being rejected. If drivers feel they can influence the system features, it can increase both the acceptance and adherence. Drivers could feel committed to not drive above a certain speed, and a speed assistance system hence would facilitate for the driver to fulfil self-set goals.

The HMI should have an assisting character

Drivers do not appreciate the car telling them what to do. Participants instead described that they imagine an appreciated speed assistance system as a system that helps them feel more secure in their driving.

The HMI should allow the driver to adjust the HMI settings

Giving the driver control over settings of a solution has shown to increase the acceptance for a speed assistance system, as it will be perceived as assisting them rather than counteracting them when they have been involved in the decisions. Drivers may hence feel committed to not drive above the self-set speed, and a greater effect, as well as acceptance, could be expected.

The HMI should support the driver in choosing proper settings

For drivers to further feel in control of the system, it should be easy to adjust according to their preferences. As drivers already find themselves as good drivers, the HMI should assist and nudge the driver to choose proper settings so that a solution still could fill its purpose of affecting speed choices.

The HMI should leave the freedom of choice over one's speed to the driver

A speed assistance system should allow the driver to make their own decisions and not restrict the speed to the speed limit without consent from the driver. A restricted speed was described as unpleasant in some traffic situations while it could be considered valuable in others. Drivers still consider themselves better in making informed decisions based on the prevailing situational factors, and it is perceived unpleasant if the car does not behave as expected. Furthermore, drivers find the adjustment of one's speed as a part of the driving task they still want control over to enhance the driving experience. When the driver, however, has committed to a certain speed, restrictions of the speed can be perceived as valuable to unload their attentional resources.

10.5 INCENTIVES

User studies show that the consequences of exceeding the speed limit are perceived differently among drivers in different situations, where the motivation to comply with the speed limits vary. The motivation can decrease for some users in certain contexts, where the risks are perceived low or when it is considered safer to exceed the speed limit. If the driver is prompted when there is no motivation to lower one's speed, a system would be perceived as counteracting the driver. The strategy might be effective, where the driver would lower one's speed just to get rid of the warnings, but it would have a negative impact on the driving experience as well as acceptance of a solution.

Whether the driver has incentives to comply with the speed limit or not affects what strategy to be used to target the behaviour, that is essential for a system to be effective and accepted as a whole in all speeding situations. In this study, no incentives to never exceed the speed limit was found, which makes tolerances needed for the HMI to be credible but also limits the effects on speeding behaviour.

The HMI should comply with existing incentives to keep speed limits

Drivers already have stronger incentives to keep the speed limit in urban areas, where the risks of hurting VRU are prominent, and in areas with risk of law enforcement. In these situations, more intense HMI can create value and be perceived positive among users as it corresponds to their attitude towards the situations and can assist them in keeping an intended speed.

The HMI should enhance incentives in situations of low motivation

Most drivers have motivations to comply with the speed limit, yet they can decrease and not be reflected over or prioritized in certain contexts. When the negative consequences are perceived uncertain due to the favourable driving conditions or familiarity of the risks on the route, the positive consequences of speeding will have a large impact on the behaviour and the motivation to comply with the speed limits decrease. The HMI should hence remind about the existing motivations or make them appear as more immediate and certain to give them a greater influence on the behaviour. A lower speed could hence be preferred, which would increase the acceptance for alerts as it would be perceived as assisting the driver to comply with a behaviour they are motivated to follow. Furthermore, if the preference of a higher speed is low, nudging mechanisms would have a greater potential to affect the behaviour.

The HMI could support an external incentive system

When the driver has a strong preference for a higher speed choice, nudging mechanisms are not as effective to target the behaviour. In this case, an external incentive system that drivers are willing to engage in might has a greater effect on the behaviour, where a new value of a lower speed can be created and hence increase the motivation to comply with the speed limits. In order to instil the motivation in the moment of the decision, in-vehicle nudges should be used to communicate real-time feedback and increase task engagement.

The HMI should make the right speed choice easier

The HMI should alter the way the speed choice is presented, to make the speed limit be perceived as the preferred state and hence make the speed choice easy. If a solution is tapping onto automatic thinking, it is less dependent on the driver's motivation to comply with the speed limits. The experience of a too high speed could be a way for drivers to adjust their speed to a level automatically they find appropriate, both through the physical experience and though deceptive visualizations of the speedometer.

11

DISCUSSION

This chapter examines different aspects of the project through a discussion. In the first section, the project aim and final result are discussed to argue how the final result fulfilled the project aim. Following section discuss how the spread of the Covid19 virus impacted on the project. The methodology is examined regarding the selection of methods and participants as well as the validity of results. The final sections discuss ethical and sustainability-related concerns. The chapter is concluded with a recommendation for future work for the continuation of this project.

11.1 AIM & FINAL RESULTS

The aim of the project was to contribute to a safer traffic environment and increase the knowledge of which factors of an ISA system that are essential to consider for acceptance. The aim is believed to be fulfilled as the final design guidelines identify and argue for several important aspects to consider for the interaction with a speed assistance system to be accepted and credible among drivers. The results are based on qualitative user studies and add to the existing literature by guiding design decision regarding tolerance, intensity, feedback, control and incentives, dedicated for speed management and instilling a positive user experience. As the acceptance and credibility are essential for implementation and adherence of a speed assistance system and the guidelines provide guidance to enhance this in design, the results can be considered to have the possibility to contribute to a safer traffic environment.

The main objective was to conclude a set of design guidelines to guide the development of ISA systems with a focus on user acceptance. In this, it was included to identify crucial factors for drivers' speed choice through driving scenarios as well as represent how personality characteristics influence user acceptance through user personas. To further explore how principles of nudging could be applied, concepts describing the essential interaction was introduced as a part of the project. The scenarios were proved useful in the entire process to organize a constantly changing use context, that has a significant impact on the speed choice. The scenarios were used to identify how the needs are changing depending on how drivers interpret different situations, based on both internal and external factors. Many of the internal and external factors contributing to a higher speed choice could be validated by literature, which implies that the scenarios are representative, while the user studies further elaborated how different scenarios affect acceptance to a speed assistance system. The explorative concepts could further confirm that different situations have diverse needs and thereby various demands on nudging principles. Hence it could be argued that the final design guidelines are informed and adapted to meet the continually changing needs among drivers in different situations.

The four final concepts presented in the report should be perceived as explorative and not final solutions based on the presented guidelines. The four concepts were used to explore possible ways to increase the acceptance of a speed assistance system by enhancing existing motivations and to validate findings, that further complemented the final design guidelines. The limitations in user evaluations due to Covid19, limited the possibilities to draw further conclusions regarding the acceptance of the steering wheel and seat belt features used in the concepts. However, indications of possible use cases for the respective spark concept could be found.

It can be assumed that the driving task itself and other HMI in the car will have an impact on how the HMI of the different concepts are perceived and hence acted on. The evaluation of concepts could only be executed out of context due to the circumstances of Covid19, which makes the effects of the concepts in combination with other HMI and the driving task hard to foresee. It is possible that some features that were described as distracting, as the steering wheel, would not be perceived equally while driving, as the attention is directed elsewhere. Furthermore, the speedometer that showed high acceptance could be perceived differently and more distracting than anticipated when driving due to its placement in the HUD. The effects of the real context were noticed in study three, where the participants elaborated more about the implications of the driving task and how it could fit into their everyday driving.

While a system would not get a chance to affect speed choices if it is not adopted by users, it can be argued that it might not reach enough effects without affecting the acceptance in some situations. Hence it is difficult to determine to what degree acceptance should be reached for a speed assistance system to still fulfil its purpose. This is further a question of ethical consideration which is discussed in chapter 11.4, where it can be questioned if a speed assistance system should prompt or even intervene against the driver's intentions in order to do what is best for them from a safety perspective.

The project mainly focuses on correcting behaviours rather than preventing them, which had an impact on the results of the project. Users stated that they did not find it appropriate to draw attention to the speed while behaving appropriate, and users further found it essential not to be overloaded with information that was not relevant to them. Hence, it can be argued that the approach of correcting behaviours was suitable to the problem. However, the opportunities for using a preventing approach cannot be excluded based on the results of the project.

11.2 LIMITATIONS

Due to the prevailing circumstances of Covid19, no face-to-face empirical studies were allowed with users external to the Autoliv organisation as from the middle of the second phase of this project. Therefore, planned methods in the project had to be compromised. Compromises were made both in terms of selection of participants and method for empirical studies, which affected the validity in the fourth and fifth empirical study. The digital format and lack of representative participants limited the ability to conclude findings. Participants found it hard to imagine intense HMI without experiencing them and those who experienced the prototypes might have been biased, working within the Autoliv organisation. The spreading of the virus further implied cancelling of already planned user studies, which meant lost time to generate results for the project. Due to the lost time and uncertainty of results from compromised user studies, the direction of the project was changed from resulting in one final concept to explore the potential of explorative concept further to generate input for design guidelines and future work.

11.3 METHODOLOGY

The project was introduced with a literature study that initiated the beginning of phase one. The empirical studies were initiated before the literature study was fully complete. Hence, the questions asked in the interviews could possibly have been more specific if the literature was concluded. However, an elaborated screening process of the literature that could define knowledge gaps was completed before the empirical studies were started, which implies that the empirical studies were adding to existing literature and hence guide the project in the right direction.

The empirical studies executed in the project included 9-12 participants in each study. As the studies in the project were explorative and not meant to contribute to a final design solution, the sample sizes were instead determined when enough level of saturation was considered reached within the limited time frame. By planning the studies with few participants, the project could instead include multiple empirical studies which enabled an iterative and data-oriented process where each study provided a better understanding of what needed to be investigated in the next. As the project was to provide a qualitative foundation to a broad problem formulation, the approach could be considered suitable due to its explorative character. The foundation of the project could to some extent be validated due to the repeating occurrence of user needs in several studies and comparison with literature, but it should be noted that the project has not been validated with quantitative measures which can question the reliability of the results.

The ideas that were to be evaluated in the first iteration of phase two were on different abstraction levels, where some could be perceived more as concepts or approaches while others were less developed ideas. This had an impact on the results of empirical study three, where it can be assumed that participants found it easier to express their thought about the more elaborated ideas. It was further hard to assess the potential impact each abstract idea could have on the scenarios for the Pugh matrix. Hence these evaluation methods were merely used to guide and not determine which ideas to bring forward to the second iteration phase.

Empirical study four was one of the studies that were compromised due to Covid19. User studies with drivers external to the Autoliv organisation were performed digitally, evaluating high fidelity prototypes on video recordings. The answers from digital studies received contradicting results from similar user studies with the research vehicle in the real context that were executed with employees from the Autoliv organisation. The Autoliv employees were significantly more positive towards the evaluated concepts. It cannot be determined if the contradicting results were due to the dissimilarities of participants, where Autoliv employees might have been biased, or if the experience of the prototypes were crucial for the response. The study further used the method Wizard of Oz to trigger the different prototypes to be evaluated in the test car. The control to trigger the prototypes were however limited, where each prototype was triggered for a certain simulated speed. This meant that the driver was not driving in the speed that was displayed in the dashboard and the tolerances of the prototypes did not match Autoliv’s design of the system. This might have impacted the experience, as participants were not able to relate the intensity of the prototypes to their actions. The results of the study were hence used carefully to avoid drawing conclusions that would not correspond to real user needs.

The limitations in visualisation and prototyping for user studies further affected empirical study five. The possible effects of the concept based on illusions were harder to evaluate digitally than the other concepts that prompted a reflective choice. Hence not many conclusions could be drawn regarding the potential of the concept. The evaluation of the four concepts also evaluated all features within the concept foundation and the different sparks separately in the same interview. Even if the evaluation managed to investigate each of the features separately, it resulted in time-consuming sessions that possibly affected the results. It can be assumed that it affected the engagement for the participants as the details of the reflections decreased at the end of the interviews.

11.4 ETHICAL & SUSTAINABILITY CONSIDERATIONS

The thesis can be considered to contribute to the UN Development Goals for a better and more sustainable future through a safer traffic environment. The thesis is considered to contribute to this by providing insights on drivers speeding behaviours and presenting design guidelines for user acceptance of speed assistance systems, which enables systems to coach drivers out of dangerous driving situations. The thesis further considers the ethical beliefs of everyone's right to move safely in communities as well as the designer's role to take responsibility for ensuring safe systems for mobility.

The project is of behaviour changing character, where ethical aspects should be discussed. It can be questioned if influencing driver's decisions is ethically correct and if it is up to the designer to decide whether a behaviour is right or wrong, while potentially restricting drivers' experiences while driving. However, the intended effects of using the presented design guidelines can be considered ethically defensible as it contributes to a safer traffic environment, which can be argued to be of greater importance than any other benefits of driving over the speed limit. However, it can be questioned whether it is ethical to influence drivers in emergency situations. In order to consider this ethical tension, the design guidelines stress the importance of freedom of choice and by always allowing drivers to choose a higher speed for the purpose of reaching user acceptance. However, there is an ethical dilemma in allowing drivers to choose speeds above legal requirements and the guidelines should be used carefully so that the HMI design complies with laws and regulations.

This thesis addresses the problem of speeding above the legal speed limit. It can be argued that this is not always the appropriate speed, as the speed needs to be adapted according to situational factors for it to be safe. For this reason, the design guidelines do not oppose speed choices below the posted speed limit but neither encourage it which could be questioned from an ethical point of view.

Ethical dilemmas related to the process of the project occurred in the situation of studying speeding behaviours. Hence, no users were asked to drive above the speed limit for the purpose of the project. Other ethical considerations regarding the process of the project were taken regarding gathering and saving of personal information from user studies, which was done according to the General Data Protection Regulation.

11.5 FURTHER WORK

As mentioned in the earlier sections, user studies in the project had to be compromised, which made it difficult to draw conclusions regarding the actual perceived intensity of different HMI modalities. Further studies are thereby needed to explore the perceived intensity in a realistic setting to determine how they can be used while still withhold acceptance. The studies should conclude if there are any modalities that should be avoided and what can be considered a proper intensity level to make sure that a violation is detected while still withholding acceptance. Further work should also investigate the impact of semantics, to determine if it can increase the acceptance for modalities that in general, is perceived as intense.

Further work will also be needed to determine more specific tolerances for the HMI. As proper tolerances were partly related to the intensity of the HMI that was to be presented, the tolerances should be derived iteratively alongside the development of the HMI features. The parallel development of the two design variables is needed to make sure that the tolerances will correspond to the intensity of the HMI. Similarly, it needs to be ensured that the designed intensity will not require a too high tolerance for it to be accepted that no impact on speeding behaviour will be reached.

In the previous section, the limitations of using a correcting approach for the project was discussed. Further work could hence benefit from investigating what value preventing approach could offer in terms of user acceptance and effectiveness. It can be assumed that a preventing approach could mean less exposure to warnings, which based on the results of this project would increase acceptance.

The results from the project indicate that in-vehicle nudges may not solely target the problem of speeding when there is a strong preference for a particular choice. As presented in the final design guidelines, the usefulness of nudges could be enhanced by connecting them to an external incentive system. Thus, the preference for speeding can be assumed to be weaker, and the nudges could have a greater impact. As external incentives were excluded in the scope of this project, further work could continue exploring its possibilities and compare the effects of enhancing already existing motivations of keeping the speed limit and thus determine how nudging best address the problem. An external incentive system would require drivers' willingness and engagement, which would not be required with a solution using in-vehicle nudges that enhance already existing motives. It can be assumed that such an incentive system limits the appropriate audience. Further work should hence investigate what audience an external incentive system could target.

The focus of this thesis was to investigate how in-vehicle nudges could be used to inform and warn drivers to encourage them to choose a lower speed, without limiting their speed. It can, however, be assumed that the result of using the presented design guidelines could have a positive influence on the acceptance of variants of the intervening ISA functionality, where the driver would have an incentive to keep a lower speed and stay in control of the system. Further studies could investigate these potential effects and further explore the potential of using nudges to increase the use of the function.

12

CONCLUSION

The final result of this project is presented in the design guidelines within the identified areas of intensity, tolerance, feedback, control and incentives, that aim to contribute to speed assistance solutions that are accepted by drivers. This chapter finalises the report by drawing conclusions from the final results of this project.

12.1FINAL CONCLUSION

The constantly changing use context can be concluded to have a significant impact on speed choices, that is perceived differently among users depending on personality characteristics and situational temporal motives. The use context is essential to consider when designing a speed assistance system, for it to be accepted and credible among drivers and hence have effects on speeding behaviours. Drivers motivation to keep speed limits was found to differentiate amongst drivers and situations, which contributed to speeding behaviour in many of the defined scenarios. The presence of motivation or not was found a crucial factor for the choice of strategy to address speed choices while still withholding acceptance in all situations. As it was found frustrating to be alerted in situations with low motivation, it can be concluded that an alerting system could benefit from being complemented with HMI that brings attention to existing motivations or creates new incentives. However, the effects of enhancing incentives should be tested in future work to validate its impact on the adherence of a speed assistance system.

The project can conclude that the HMI of a system should have an intensity and tolerance that corresponds to drivers' interpretation of the violation, to comply with user expectations. Incentives to *never* exceed the speed limits are weak. Minor violations are not perceived as severe as the consequences are perceived uncertain, which makes the tolerances essential for a system to be perceived credible. However, it can be assumed that changed attitudes towards speeding will make tolerances less crucial for a system to be accepted. This was further the case for existing traffic situations where drivers already found it more important to keep the speed limit. The value of the feedback provided by a system can also be concluded to be of importance for acceptance, where the content should complement the driver in the driving task and abort when it is considered not needed. It is furthermore of importance to let the driver feel in control, where the freedom of choice should be left to the user and not have the car counteracting their actions. This will let a system have a supporting character, and a system could be accepted as a part of their car.

13 REFERENCES

Aarts, L., & Schagen, I. V. (2006). *Driving speed and the risk of road crashes: A review. Accident Analysis & Prevention*, 38(2), 215–224. DOI: 10.1016/j.aap.2005.07.004

Alexander, I. & Maiden, N. 2004. *Scenarios, Stories, Use Cases: Through the Systems Development Life-Cycle*. John Wiley & Sons.

Anund, A., Patten, C. 2010. *Trötthet vid ratten* (VTI rapport 688). VTI, Linköping.

Autoliv. (2020). *Innovation and Research*. Retrieved May 20, 2020, from Autoliv.com: https://www.autoliv.com/innovation-and-research/research

Bakker. B, Harre. M-C, J. Uittenbogaard, O. Op den Camp, M. Ljung Aust. (2019). *Vehicle Measures evaluation.* (Deliverable 2.1). Retrieved March 15, 2020, from: https://www.mebesafe.eu/results/.

Barnard, Y., Risser, R., & Krems, J. (2011). *The safety of intelligent driver support systems: design, evaluation and social perspectives*. Farnham: Ashgate.

Berg Alvergren, V. et al. (2019). *Specification of nudges* (Deliverable 3.1). Retrieved from MeBeSafe website March 15, 2020, from: https://www.mebesafe.eu/results/

Bergman, B. & Klefsjö, B. 2010. *Quality from Customer Needs to Customer Satisfaction*. 3rd ed. Lund: Studentlitteratur.

Buttler, I. (2016) *Enforcement and support for road safety policy measures*. ESRA thematic report no. 6. ESRA project (European Survey of Road users' safety Attitudes). Warschau, Poland: Instytutu TransportuSamochodowego.

Campbell, J. L., Brown. J. L., Graving, J. S., Richard, C. M., Lichty, M. G., Sanquist, T., … & Morgan, J. L.(2016). *Human factors design guidance for driver-vehicle interfaces* (Report No. DOT HS 812 360). Washington, DC: National Highway Traffic Safety Administration. Dec. 2016.

Carsten, O., Ezenwa, A., Tomlinson, A., Horrobin, A. (2020*). ISA Interface Study*. Institute for Transport Studies, University of Leeds.

Crozier, R., Ranyard, R., & Svenson, O. (Eds.). (1997). *Decision making: Cognitive models and explanations.* Retrieved from https://ebookcentral.proquest.com

Daniels, A. (2000*). Bringing out the best in people, how to apply the astonishing power of positive reinforcement*. New York: McGraw-Hill Companies, Inc.

De Craen. S. et al. (2019). *Report on effective feedback* (Deliverable 4.5). Retrieved from MeBeSafewebsite: https://www.mebesafe.eu/results/.

Department for Transport. (2019). *Vehicle Speed Compliance Statistics, Great Britain: 2018*. Retrieved from: https://www.gov.uk/government/statistics/vehicle-speed-compliance-statistics-for-great-britain-2018

Elliott, M. A., & Thomson, J. A. (2010). *The social cognitive determinants of offending drivers' speeding behaviour.* Accident Analysis & Prevention, 42(6), 1595–1605. DOI: 10.1016/j.aap.2010.03.018

ETSC. (2017). *Briefing: Intelligent Speed Assistance (ISA).* Retrieved May 29, 2020, from https://etsc.eu/briefing-intelligent-speed-assistance-isa/

ETSC. (2019). *Reduce Speeding In Europe.* PIN Flash Report 36. Retrieved May 29, 2020, from:https://etsc.eu/reducing-speeding-in-europe-pin-flash-36/

European Comission. (2013*). Evaluation study on Speed Limitation Devices*. Brussels: European Commission: Directorate-general for Mobility and Transport.

European Commission. (2016a) *Advanced driver assistance systems*. European Commission, Directorate General for Transport. Retrieved January 28, 2020, from: https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/ersosynthesis2016-adas15_en.pdf

European Commission. (2016b). *Speed choice: why do drivers exceed the speed limit?* European Commission, Directorate General for Transport. Retrieved January 28, 2020, from https://ec.europa.eu/transport/road_safety/specialist/knowledge/speed/many_drivers_exceed_the_speed_limit/speed_choice_why_do_drivers_exceed_the_speed_limit_en

Fleiter, J. & Watson, B., (2005*). The speed paradox: the misalignment between driver attitudes and speeding behaviour*. Journal of the Australasian College of Road Safety.

Fogg, B. (2009*). A behavior model for persuasive design*. Proceedings of the 4th International Conference on Persuasive Technology - Persuasive '09. DOI:10.1145/1541948.1541999

Garvill, J., Marell, A., & Westin, K. (2003). *Factors influencing drivers' decision to install an electronic speed checker in the car.* Transportation Research Part F, 6(1), 37–43.

Green, P., Sullivan, J., Tsimhoni, O., Oberholtzer, J., Buonarosa, M.L., Devonshire, J., Schweizer, J.,Baragar, E., & Sayer, J. (2008*). Integrated Vehicle-Based Safety Systems (IVBSS): Human Factors AndDriver-Vehicle Interface (DVI).* (Report No. DOT HS 810 905) Summary Report. U.S. Department of Transportation. National Highway Traffic Safety Administration. Feb. 2008.

Hamill, S. (2008). *To Slow Speeders, Philadelphia Tries Make-Believe*. The New York Times. Retrieved from https://www.nytimes.com

Hanington, B., & Martin, B. (2012). *Universal methods of design : 100 ways to explore complex problems, develop innovative strategies, and deliver effective design so*. Retrieved fromhttps://ebookcentral.proquest.com

Hansen, P. G. (2020). *Nudging Traffic Safety By Visual Illusions*. Retrieved May 19, 2020, from https://inudgeyou.com/en/nudging-traffic-safety-by-visual-illusions/

Harms, L., Klarborg, B., Lahrmann, H., Agerholm, N., Jensen, E., & Tradisauskas, N. (2008). *Controlled study of ISA effects: Comparing speed attitudes between young volunteers and external controls, and the effect of different ISA treatments on the speeding of volunteers*. IET Intelligent Transport Systems, 2(2), 154-160. https://doi.org/10.1049/iet-its:20070043

Hart, S. G., & Staveland, L. E. (1988*). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research*. In P. A. Hancock & N. Meshkati (Eds.), *Advances in psychology, 52. Human mental workload* (p. 139–183). North-Holland. https://doi.org/10.1016/S0166-4115(08)62386-9

Heino, A. (1996). *Risk taking in car driving; perceptions, individual differences and effects of safety incentives*. s.n, 144.

Horberry, T., Regan, M. A., & Stevens, A. (Eds.). (2014). *Driver acceptance of new technology: Theory, measurement and optimisation.* Retrieved from https://ebookcentral.proquest.com

ISO International Organization for Standardization. (2005). *Road vehicles - Ergonomic aspects of in-vehicle presentation for transport information and control systems - Warning systems.* (Standard No. TR 16352). Switzerland.

Jamson, S., Chorlton, K., & Carsten, O. (2012). *Could intelligent speed adaptation make overtaking unsafe?* Accident Analysis and Prevention, 48(1), 29–36.

Javid, M.A., & Ahmad Al-Roushdi, A.F.A. (2019). *Causal Factors of Driver's Speeding Behaviour, a Case Study in Oman: Role of Norms, Personality, and Exposure Aspects*. International Journal of Civil Engineering, 17, 1409–1419. DOI: 10.1007/s40999-019-00403-8

Klein, G. (1998). *The recognition-primed decision model.* In G. Klein (Ed.), Sources of Power: How People Make Decisions (pp. 15-30). Mass: MIT Press, Cambridge, Mass.

Lee, J.D., McGehee, D.V., Brown, T.L., Reyes, M.L., 2002. *Collision warning timing, driver distraction, and driver response to imminent rear-end collisions in a high-fidelity driving simulator*. Hum. Factors 44 (2), 314–334.

Nadkarni, I. T. (2019, April 19). *Parliament approves EU rules requiring life-saving technologies in vehicles.* European Parlament News. Retrieved from: https://www.europarl.europa.eu/news/en/press-room/20190410IPR37528/parliament-approves-eu-rules-requiring-life-saving-technologies-in-vehicles

Nilsson Wikberg, Å. Ericson, Å., & Törlind Peter. (2015). *Design: process och metod* (1st ed., Vol. 1).Poland: Interak.

Pugh, S. (1990). *Total Design - Integrated Methods for Successful Product Engineering*. Wokingham: Addison-Wesley Publishing Company.

Reagan, I. J., Bliss, J. P., Houten, R. V., & Hilton, B. W. (2012*). The Effects of External Motivation and Real-Time Automated Feedback on Speeding Behavior in a Naturalistic Setting*. Human Factors: The Journal of the Human Factors and Ergonomics Society, 55(1), 218–230. doi: 10.1177/0018720812447812

SafetyNet. (2009). *Speeding*, Retrieved 29 January, 2020, from: https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/specialist/knowledge/pdf/speeding.pdf

Sleeswijk Visser, F., Stappers, P. J., van der Lugt, R., and Sanders, E. B. N. (2005). *Contextmapping: experiences from practice.* CoDesign 1:2, 119-149, doi: 10.1080/15710880500135987

Stanton, N. A., Walker, G. H., Young, M. S., Kazi, T. M., & Salmon, P. (2007). *Changing driversminds: the evaluation of an advanced driver coaching system.* Ergonomics, 50(8), 1209–1234. doi:10.1080/00140130701322592

Steinberger, F., Schroeter, R., & Watling, C. N. (2017*). From road distraction to safe driving: Evaluating the effects of boredom and gamification on driving behaviour, physiological arousal, and subjective experience.* Computers in Human Behavior, *75*, 714–726. DOI: 10.1016/j.chb.2017.06.019

Spyropoulou, I. K., Karlaftis, M. G., & Reed, N. (2014*). Intelligent Speed Adaptation and driving speed: Effects of different system HMI functionalities*. Transportation Research Part F: Traffic Psychology and Behaviour, 24, 39-49. DOI:10.1016/j.trf.2014.02.008

Thaler, R. H., & Sunstein, C. R. (2009). *Nudge: Improving decisions about health, wealth, and happiness. (2nd. ed.)* New York: Penguin Books.

Trafikverket. (2019). *Analys av trafiksäkerhets utvecklingen 2018.* Målstyrning av trafiksäkerhetsarbetet mot etappmålen 2020. Publication 2019:090. Borlänge: Trafikverket.

Trafikverket. (2019). *Hastighetsgränser på väg*. Retrieved from Trafikverket.se: https://www.trafikverket.se/contentassets/db8c1dc03f454453b623da180cd424cb/folder_hastighet_190125.pdf

Transport Canada. (2005*). Driver Attitude to Speeding and Speed Management: A Quantitative and Qualitative Study.* Transport Canada Publication No. TP 14756 E. Ottawa: Transport Canada.

Transportstyrelsen. (2020a). *Personbil och lätt lastbil.* Retrieved May 29, 2020, from: https://www.transportstyrelsen.se/sv/vagtrafik/Korkort/ta-korkort/personbil-och-latt-lastbil/

Transportstyrelsen. (2020b). *Statistik över vägtrafikolyckor*. Retrieved May 18, 2020, from: tyrelsen.se/sv/vagtrafik/statistik/olycksstatistik/statistik-over-vagtrafikolyckor/

Truelove, V., Freeman, J., Szogi, E., Kaye, S., Davey, J., & Armstrong, K. (2017*). Beyond the threat of legal sanctions: What deters speeding behaviours?* Transportation Research Part F: Traffic Psychology and Behaviour, 50, 128–136. DOI: 10.1016/j.trf.2017.08.008

United Nations. (2015). *Transforming Our World*. The 2030 Agenda For Sustainable Development, pp. 1-21.

Várhelyi, A., & Mäkinen, T. (2001). *The effects of in-car speed limiters: Field studies.* Transportation Research Part C: Emerging Technologies, 9(3), 191-211. https://doi.org/10.1016/S0968-090X(00)00025-5

Van der Laan, J.D., Heino, A., & De Waard, D. (1997*). A simple procedure for the assessment of acceptance of advanced transport telematics.* Transportation Research - Part C: Emerging Technologies, 5, 1-10.

Volvo Cars. (2020). [Manual*] Instrument panel: Displays and voice control: XC90 2021: Volvo Support.* Retrieved May 29, 2020, from https://www.volvocars.com/enca/support/manuals/xc90/2021/displays-and-voice-control/instrument-panel/instrument-panel

Wallén Warner, H. (2006). *Factors Influencing Drivers' Speeding Behaviour*. Acta Universitatis Upsaliensis.Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Social Science 21. 93 pp. Uppsala. ISBN 91-554-6724-5

Wickens, C. D. (2008). *Multiple Resources and Mental Workload*. Human Factors: The Journal of the Human Factors and Ergonomics Society, 50(3), 449–455. DOI: 10.1518/001872008x288394

Wijers, P. (2017*). Speed reduction methods to save lives and promote road safety and quality of life.* Retrieved May 20, 2020, from: https://making-traffic-safer.com/speed-reduction-methods-promote-road-safety-save-lives/

Wilson, C. 2014*. Interview Techniques for UX Practitioners: A User-Centered Design Method*. Waltham: Elsevier Inc. E-book.

World Health Organization. (2017). *Managing speed*. Retrieved from: https://www.who.int/publications-detail/managing-speed

World Health Organization. (2018). *Road traffic injuries.* Retrieved January 23, 2020, from: https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries

Yannis, G., Louca, G., Vardaki, S., & Kanellaidis, G. (2013). *Why do drivers exceed speed limits.* European Transport Research Review, *5*(3), 165–177. DOI: 10.1007/s12544-013-0097-x

Åberg, L., Larsen, L., Glad, A., & Beilinsson, L. (1997*). Observed vehicle speed and drivers' perceived speed of others.* Applied Psychology, 46(3), 287–302.

Åklagarmyndigheten. (n.d.). *Brott mot trafikförordningen (1998:1276).* Retrieved from: https://www.aklagare.se/globalassets/dokument/ordningsbotskatalog/ordningsbot-bilaga-01-trafikforordningen

14 APPENDICES

I. Interview template for empirical study 1

II. Sensitizing assignment for empirical study 2

III. Mediating toolkit for empirical study 2

IV. Interview template for empirical study 2

V. Focus group structure for empirical study 3

VI. Interview template for empirical study 4

VII. Questionnaire template for empirical study 4

VIII. Interview template for empirical study 5

I. INTERVIEW TEMPLATE FOR EMPIRICAL STUDY 1

Markera åldersspann: 25-35 36-50

Markera kön: Kvinna / Man

Vardagligt körbeteende:

1. Hur ofta brukar du köra bil?
   a. Varje dag
      Några ggr vecka
      Några ggr månad
      Några ggr år
2. I vilket syfte kör du oftast bil?
3. Vad är viktigt för dig för att det ska kännas bra att köra bil?
4. Vad gör dig frustrerad i trafiken?
5. Vilka ord passar bäst in på dig som bilförare:
   a. Säker
      Medveten
      Ansvarstagande
      Risktagande
      Aggressiv
      Spänningssökande
      Följer strömmen
      Försiktig
      Osäker
      Annat:________
   b. Be deltageren utveckla varför hen vart att (ordet) passar in på hen som förare.

Överträdelser:

6. Vad är fortkörning enligt dig?

   Läs ej upp: låt svara fritt och markera det som passar bäst.

   Allt över tillåten (ex. 51 på 50km/h väg)
   Olämpligt med hänsyn till situation (väder, trafik osv)
   Viss andel över (ex. 5-10 km/h över tillåten)

7. Vilket passar bäst på dig:
   a. Överträder aldrig hastighetsbegränsningarna
   b. Överträder sällan hastighetsbegränsningarna
   c. Överträder oftast hastighetsbegränsningarna
   d. Överträder alltid hastighetsbegränsningarna

8. Skulle du säga att ditt generella fortkörningsbeteende är medvetet eller omedvetet?
   a. Om medvetet: Vad är den främsta orsaken?
   b. Om omedvetet: Vad tror du är den främsta orsaken?

9. Kan du berätta om det senaste tillfället som du kan minnas där du överträdde hastighetsbegränsningen och vad det berodde på?

(Om de inte minns) Kan du berätta om en typisk situation då du brukar köra över hastighetsbegränsningar?

10. Vilka faktorer avgör vilken hastighet du kör i?

11. Vad tycker du är positivt med att hålla hastighetsgränsen?

12. Vad tycker du är negativt med att hålla hastighetsgränsen?

13. Skulle du säga att det är svårt att hålla hastighetsgränsen?
    a. Om ja: Varför anser du att det är svårt?
    b. Om nej: Vad är det som gör att det inte är svårt enligt dig?

14. Kan du berätta om ett tillfälle då du själv känt att du har kört för fort?
    a. Vad var det för typ av väg? Vägförhållanden?
    b. Hur fort körde du då?
    c. I vilken situation va det?
    d. Varför tycker de att det va en betydande överträdelse enligt dig?
    e. Hur upplevde du den här situationen?

15. Finns de tillfallen du tycker det är okej att köra över hastighetsbegränsningar?

16. Finns de tillfallen du inte tycker det är okej att köra över hastighetsbegränsningar?

17. Vilket påstående passar bäst:
    a. Jag tycker oftast hastighetsbegränsningarna är för låga
    b. Jag tycker oftast hastighetsbegränsningarna är lämpliga
    c. Jag tycker oftast hastighetsbegränsningarna är för höga

<u>Påverka hastighet:</u>

18. Finns det något du kan tänka på som hade kunnat motiverat dig att hålla hastigheten?

19. Finns det situationer då du tror att du hade upplevt det som positivt att bli uppmanad att hålla hastigheten?

20. Finns det situationer då du tror att du hade upplevt det som negativt att bli uppmanad att hålla hastigheten?

21. Hur tror du att din upplevelse hade varit av att få feedback hur du hållit hastigheterna?

22. Övriga kommentarer eller funderingar?

II. SENSITIZING ASSIGNMENT FOR EMPIRICAL STUDY 2

(Skickas ut som digital enkät 1 vecka före empiriska studie 2)

Tack för att du vill delta i vår studie!

Innan det är dags att träffas så fundera över vad som hade kunnat motivera dig att hålla hastighetsbegränsningarna i framtiden. **Vi vill att du i samband med en körning reflekterar över följande frågor nedan. Om du inte kommer köra bil innan vi träffas så fundera istället över en typisk sträcka som du kört och kan återkalla tillräckligt för att svara på frågorna nedan.** Det finns inga rätt eller fel och svaren behöver inte vara realistiska eller implementerbara. Vi är bara intresserade över vad du tror hade kunnat motivera just dig i framtiden. **Skriv ner vad du tänker i text eller stödord innan vi ses så kommer vi gå in mer på det då.**

Alla frågor berör just den sträcka du kört/valt som en typisk sträcka.

1. Vad hade kunnat motivera dig att hålla hastighetsbegränsningen under den sträckan du kört?

Reflektera över hur du hade upplevt att bli påverkad att hålla hastigheterna under sträckan genom att bli:

2. Informerad (Du avgör själv vad du anser är information I det här fallet)
3. Varnad (Du avgör själv vad du anser är en varning I det här fallet)
4. Begränsad (Du avgör själv vad du anser är en begränsning I det här fallet)

III. MEDIATING TOOLKIT FOR EMPIRICAL STUDY 2

IV. INTERVIEW TEMPLATE FOR EMPIRICAL STUDY 2

Scenarion:

I. En bild med mycket trafik omgivande trafik. Hastighetsbegränsningen är 50 km/h.
II. En bild med gångtrafikanter på trottoar i övrigt ingen trafik. Hastighetsbegränsningen är 50 km/h.
III. En bild på en tom väg med hastighetsbegränsning 30 km/h.
IV. Samma bild på tom väg men med hastighetsbegränsningen 50 km/h.
V. En bild på en tom väg utanför en skola (markerat att det är skolområde). Hastighetsbegränsning 30 km/h.
VI. En bild på en tom snö/isbeklädd väg med hastighetsbegränsning 50 km/h.
VII. Samma bild som tidigare men nu istället kvälls/mörkt. Hastighetsbegränsning 50 km/h.

Inledande Intervju :

1. Hur ofta brukar du köra bil?
    a. Varje dag
       Några ggr vecka
       Några ggr månad
       Några ggr år

2. Hur skulle du beskriva dig själv som förare?

3. Vad är fortkörning enligt dig?

   Läs ej upp: låt svara fritt och markera det som passar bäst.

   Allt över tillåten (ex. 51 på 50km/h väg)
   Olämpligt med hänsyn till situation (väder, trafik osv)
   Viss andel över (ex. 5-10 km/h över tillåten)

4. Vilka faktorer avgör vilken hastighet du kör i?

5. Vi bad dig att fundera över några frågor innan du kom hit idag och vi tänkte gå in på dem lite.

    a. Motivation att bli påverkad – Individuella förberedda följdfrågor
    b. Information – Individuella förberedda följdfrågor
    c. Varningar – Individuella förberedda följdfrågor
    d. Begränsningar/ingripande - Individuella förberedda följdfrågor

Scenario Enactment:

Ge deltagaren Toolkitet
Visa upp bild för scenario och låt deltageren själv berätta vad hen ser i bilden. Använd nedan beskriven procedur och upprepa för varje scenario.

Du kör enligt bilden (I-VII) och har precis kört över hastighetsbegränsningen.

6. Hur resonerar du kring hur du skulle föredra att bli påverkad till att hålla hastighetsgränsen i den här situationen?

7. Potentiella följdfrågor om det inte framkomemr i deras egna resonemang:
   a. Vad är information för dig?
   b. Vad är varningar för dig?
   c. Vad är att bli begränsad för dig?
   d. Hur hade du inte velat bli påverkad?
   e. Varför valde du som du gjorde? Vilka faktorer i denna trafiksituationen påverkade ditt val av metod?

2. I den situationen som du nu är i och så som du beskrivit en potentiell metod, tror du att du hade resonerat annorlunda om du vad **10 minuter sen** till en arbetsintervju?

3. I den situationen som du nu är i och så som du beskrivit en potentiell metod, tror du att du hade resonerat annorlunda om det var på en **sträcka du kör varje dag**?

4. (Scenario 1: Om all annan trafik hade kört över hastighetsgränsen, tror du att du hade resonerat annorlunda kring den beskriva metoden då? (Om de inte har nämnt något om **flowet**))

Återställ toolkitet efter varje scenario!

V. FOCUS GROUP STRUCTURE FOR EMPIRICAL STUDY 3

Uppvärmingsaktivitet:

1. Ta 2 minuter och fundera på ett säkerhetssystem som ni själva har i er bil eller som ni vet om och uppskattar. (Det kan exempelvis vara något som Cruise Control, Lane Departure system, Backkamera, avstånds varningar etc.)
    a. Fundera på vad med det stemet är det du uppskattar?
    b. Finns det något med det systemet som hade kunnats göra bättre

Låt dem berätta en och en och diskutera i 10 min.

Introducera de olika katerogrierna av koncept för deltagarna genom att visa upp skisserna och berätta kort vad ideerna innebär.

Diskutera varje kategori utifrån följande teman:

2. Vad är er initiala tanke om denna idé?
3. Under vilka förutsättningar skulle den iden fungera bra?
4. Under vilka förutsättningar skulle det iden mindre bra?
5. Vad skulle acceptansen vara för ett sådan ide implementerad i deltagarnas bil?
    a. Vilka förutsättningar skulle krävas för acceptans

Upprepa fråga 2-5 för varje kategori av ideer. 5 minuter för varje kategori.

VI. INTERVIEW TEMPLATE FOR EMPIRICAL STUDY 4

1. Hur ofta kör du bil?

2. Hur skulle du beskriva dig själv som förare?

3. Har du använt någon typ av speed assistance system innan? (ISA, blinkande HB skylt, varningar, cruise control, speed limiter osv)
    a. Vad tyckte du om det?

<u>Introducera de olika prototyperna för deltageren:</u>

Orange:
(35 km/h) De varningar som du kommer få är dels att instrumentklustret kommer att ändra färg, positionering samt blinka.
(40 km/h) I nästa steg kommer ratten börja lysa kort.
Rött:
(55 km/h) Rött cluster.
(65 km/h) ratten blir röd
(75 km/h) Säkerhetsbältet

4. Vad är din initiala tanke om de olika prototyperna?
    a. Instrumentpanel
    b. Ratt
    c. Säkerhetsbälte

<u>Körning:</u>

Så nu tänkte vi åka ut och kör så du får testa dessa I trafiken också.Vi tänker att vi ska köra den här vägen (visa karta) men vi kommer vägleda dig också och det är ju ingen fara om vi missar en avfart. Vi kommer
ställa lite frågor under tiden men fokuser på körningen och det är helt ok att bara strunta I att svara o ch vi bedömmer absolut inte hur du kör.

Följdfrågor under tiden:

5. Vad är din upplevelse/åsikt om denna metoden? I denna situationen
6. Hur tror du att det hade varit att ha detta I din bil som du kör varje dag?
7. Finns det situationer du tror att du hade upplevt den som användbar?

<u>Efter test:</u>

Först kommer du få uppleva varningen I instrumentklustret, efter det kommer du få kolla på den här (visa upp Van der Laan skalan). Du ska få
skatta prototypen utefter dessa påståendena där du gärna får resonera hur du tänker när du fyller I dom.

1 Användbart	|__|__|__|__|__|	Meningslöst
2 Trevligt	|__|__|__|__|__|	Otrevlitg
3 Dåligt	|__|__|__|__|__|	Bra
4 Roligt	|__|__|__|__|__|	Tråkigt
5 Effektivt	|__|__|__|__|__|	Ineffektivt
6 Irriterande	|__|__|__|__|__|	Angenämt
7 Behjälpligt	|__|__|__|__|__|	Uselt
8 Oönskat	|__|__|__|__|__|	Önskat
9 Uppmärksamhetshöjande	|__|__|__|__|__|	Sövande

Van der Laan, J.D., Heino, A., & De Waard, D. (1997). A simple procedure for the assessment of acceptance of advanced transport telematics. Transportation Research - Part C: Emerging Technologies, 5, 1-10.

6. Sen vill vi att du väljer ut en fördel och en nackdel med instrumentclustret
    a. Finns det situationer där du tror att det hade varit användbart för dig?

7. Sen vill vi att du väljer ut en fördel och en nackdel med ljuset på ratten?
    a. Finns det situationer där du tror att det hade varit användbart för dig?

8. Sen vill vi att du väljer ut en fördel och en nackdel med det vibrerande säkerhetsbältet?
    a. Finns det situationer där du tror att det hade varit användbart för dig?

VII. QUESTIONNAIRE TEMPLATE FOR EMPIRICAL STUDY 4

1. Hur ofta brukar du köra bil?
    a. Varje dag
       Några ggr vecka
       Några ggr månad
       Några ggr år

2. Vilka ord passar bäst in på dig som bilförare:
    - Säker
    - Medveten
    - Ansvarstagande
    - Risktagande
    - Aggressiv
    - Spänningssökande
    - Följer strömmen
    - Försiktig
    - Osäker
    - Annat:_______

3. Vilket passar bäst på dig:
    - Överträder aldrig hastighetsbegränsningarna
    - Överträder sällan hastighetsbegränsningarna
    - Överträder oftast hastighetsbegränsningarna
    - Överträder alltid hastighetsbegränsningarna

4. Skulle du säga att ditt generella fortkörningsbeteende är medvetet eller omedvetet?
    - Medvetet
    - Omedvetet

Följande procedur upprepas tre gånger för varje video:

Kolla på videon svara sedan på frågorna och använd skalorna för att utvärdera det som sker i videon för att få föraren att sänka hastigheten.

5. Vad är din initiala tanke om att bli påverkad enligt videon före en överträdelse?

6. Fyll i följande skalor baserat på vad som passar bäst in på din upplevelse av det om visades på videon?

Användbart |__|__|__|__|__| Meningslöst

Trevligt |__|__|__|__|__| Otrevlitg

Dåligt |__|__|__|__|__| Bra

Roligt |__|__|__|__|__| Tråkigt

Effektivt |__|__|__|__|__| Ineffektivt

Irriterande |__|__|__|__|__| Angenämt

Behjälpligt |__|__|__|__|__| Uselt

Oönskat |__|__|__|__|__| Önskat

Uppmärksamhetshöjande |__|__|__|__|__| Sövande

Van der Laan, J.D., Heino, A., & De Waard, D. (1997). A simple procedure for the assessment of acceptance of advanced transport telematics. Transportation Research - Part C: Emerging Technologies, 5, 1-10.

7. Har du någon övrig kommentar eller reflektion kring att bli påverkad att hålla hastigheten före en överträdelse så använd detta fält.

VIII. INTERVIEW TEMPLATE FOR EMPIRICAL STUDY 5

1. Hur ofta brukar du köra bil?
    - Varje dag
      Några ggr vecka
      Några ggr månad
      Några ggr år

2. Vilka ord passar bäst in på dig som bilförare:
    - ○ Säker
    - ○ Medveten
    - ○ Ansvarstagande
    - ○ Risktagande
    - ○ Aggressiv
    - ○ Spänningssökande
    - ○ Följer strömmen
    - ○ Försiktig
    - ○ Osäker
    - ○ Annat:________

3. Vilket passar bäst på dig:
    - ○ Överträder aldrig hastighetsbegränsningarna
    - ○ Överträder sällan hastighetsbegränsningarna
    - ○ Överträder oftast hastighetsbegränsningarna
    - ○ Överträder alltid hastighetsbegränsningarna

4. Skulle du säga att ditt generella fortkörningsbeteende är medvetet eller omedvetet?
    a. Om medvetet: Vad är den främsta orsaken?
    b. Om omedvetet: Vad tror du är den främsta orsaken?

<u>Följande procedur upprepas tre gånger för varje video:</u>

Vi börjaar med att kolla på videon innan du svarar på följande frågor och fyller i skalorna.

5. Vad är din initiala upplevelse av konceptet?

6. Hur hade du reagerat om detta hade hänt när du gick över hastighetsgränsen?

7. Hade du kunnat tänka dig att ha det i din bil?

8. Fyll i följande skalor för att beskriva vad du anser om konceptet

Användbart	|__|__|__|__|__|	Meningslöst
Trevligt	|__|__|__|__|__|	Otrevlitg
Dåligt	|__|__|__|__|__|	Bra
Roligt	|__|__|__|__|__|	Tråkigt
Effektivt	|__|__|__|__|__|	Ineffektivt
Irriterande	|__|__|__|__|__|	Angenämt
Behjälpligt	|__|__|__|__|__|	Uselt
Oönskat	|__|__|__|__|__|	Önskat
Uppmärksamhetshöjande	|__|__|__|__|__|	Sövande

Van der Laan, J.D., Heino, A., & De Waard, D. (1997). A simple procedure for the assessment of acceptance of advanced transport telematics. Transportation Research - Part C: Emerging Technologies, 5, 1-10.

9. Kan du se någon fördel med detta konceptet?

10. Kan du se någon nackdel med detta konceptet

11. Har du någon övrig kommentar eller reflektion kring att bli påverkad att hålla hastigheten enligt konceptet?

(Upprepa 5-11 för varje koncept)

Avslutande intervju:

12. I alla koncepten användes en dynamisk hastighetsmätare i vindrutan som med färg indikerade på överträdelser. Vad tyker du om en sådan typ av varnare?

13. I alla koncept användes ratten för att signalera fortkörning vid 55 km/h på en 50 km/h väg. Vad tycker du om den typen av varning?

14. I alla koncept användes Säkerhetsbältet för att signalera fortkörning vid 60 km/h på en 50 km/h väg. Vad tycker du om den typen av varning?

15. Är det något koncept som stack ut som bättre eller sämre för dig i din körning?

16. Ranka koncepten utifrån vilket du helst hade velat använda
    Social proof
    Gas consumption
    Situational factors
    Illusions

17. Hur resonerade du kring rankningen av de olika koncepten?

18. Har du någon övrig kommentar eller reflektion kring att bli påverkad att hålla hastigheten enligt konceptet?