

Principle Other Vehicle Warning



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Preface

Principle Other Vehicle Warning is a collaborative project between the Swedish National Road and Transport Research Institute (VTI) and Volvo Car Corporation (VCC) within the competence centre *Virtual Prototyping and Assessment by Simulation* (ViP).

The project has five parts. The first part is a literature survey to find guidelines for how to design automated warning signals for critical situations. The second part includes field tests to measure realistic sound and luminance levels to be used for the warnings. The third part is implementation of the sound and light warnings in one of the advanced simulators at VTI. The fourth part includes evaluation of these automated warning types through a simulator study at VTI. Finally, the fifth part involves analysis of required sensor performance to enable issuing of timely warnings.

Project participants from VTI were Birgitta Thorslund (project manager, research engineer), Jonas Jansson (research director), Björn Peters (senior researcher), Anne Bolling (investigator), Anders Genell (researcher), Jonas Andersson Hultgren (research engineer), Anders Andersson (research engineer), Katja Kircher (researcher), Christer Ahlström (researcher) and Sven-Olof Lundkvist (researcher).

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Birgitta Thorslund

Quality review

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Abbreviations

HL	Hearing Loss
LP	Lateral Position
NH	Normal Hearing
POV	Principle Other Vehicle, i.e. the vehicle that has the warning system and warns the driver in the Subject Vehicle (SV below)
POVW	Principle Other Vehicle Warning
SDLP	Standard Deviation Lateral Position
SV	Subject Vehicle, i.e. the vehicle driven by the test participant
SWRR	Steering Wheel Reversal Rate
TLC	Time to Line Crossing
TTC	Time to Collision

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Principle Other Vehicle Warning

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Executive summary

In some cases, the only possibility for a driver to avoid a collision may be to issue a warning to another driver, so that s/he may take evasive actions. Connecting the horn and the headlight to an already existing sensor system used for automatic warning activation is a cost effective means of providing such a warning system. This report covers the implementation and evaluation of such an automated warning system in a driving simulator at VTI.

Drivers, 24 with normal hearing and 24 with moderate hearing loss, experienced five critical events in which four different warning modalities were evaluated using both performance indicators and subjective measures. Additionally, all drivers experienced two non-critical events, representing “greetings”, to examine possible side effects of the implemented new warning system.

A visual distraction task, presented on a display at a low down angle from the driver’s forward gaze direction, was used to distract the driver and create critical situations. This task was present during the complete driving session and announced twice per minute.

After the experiment the drivers filled in a questionnaire regarding driving performance, experience of the warning system, preferred warning type, perceived task difficulty and driving realism.

The results were consistent. A combined sound and light warning significantly increased cautious behaviour and also lead to the highest perceived criticality of the situations. The combined warning was also associated with the worst performance on the visual distraction task, meaning that the driver’s attention was effectively drawn from the visual distraction task. Drivers were generally positive towards the warning system, and most positive towards the combined warning presenting light and sound signals.

The possibility to produce a correct autonomous activation of the warning signals depends on the capabilities of the vehicle’s proximity sensors and data processing. Also, the effect may be degraded at higher relative velocities because of the increased distance at which a warning needs to be issued.

Drivers were able to distinguish between warnings (at critical events) and greetings (at non-critical events) suggesting that the tested additional use of horn and headlight would not affect reactions to non-critical warnings or greetings.

Hearing loss was associated with worse performance on the visual distraction task and less perceived realism of the driving simulator. But it was not associated with effects on any driving behaviour measures or of warning modalities. This result suggests that the evaluated system should work also for drivers with moderate hearing loss.

1 Introduction

Systems for automatic activation of brakes and steering are currently entering the market. Such systems use proximity sensors to monitor the state of surrounding actors. Depending on the specific situation, the effort or possibility to avoid or mitigate an accident may differ significantly between the principle actors of a pending collision. For example, one Actor (1) may easily avoid a collision by making a velocity or directional change, while the other Actor (2) may be unable to do so. In this case, the only possibility for Actor 2 to avoid the collision may be to issue a warning to Actor 1, so that s/he may take evasive actions. Connecting the horn and the headlight to an already existing sensor system used for automatic warning activation is a cost effective means of providing such a warning system. Such a warning could of course also be triggered manually by the driver. One aim of the current project was to evaluate the effectiveness of such a warning by implementing the warning signals in a driving simulator and validating if the communication between the actors is experienced as intended. A second aim was to examine the effects of hearing loss on driving performance and the implications of this on the warning system. The issue of hearing impairment is of special interest because currently, hearing ability is not assessed as part of the licensing procedure for passenger vehicles, and therefore warning and support systems should be available also for drivers with hearing loss.

The field of transportation and hearing loss has received relatively little attention in the literature and the level of knowledge is thus rather low. Hearing loss is not an impediment for obtaining a driving license for passenger cars because individuals with hearing loss are not considered as an increased traffic safety risk (Englund, 2001). For commercial driving there is a requirement that the minimum hearing ability, with or without hearing devices, is to hear normal speech from a distance of four meters (Widman, 2008). However, field studies have revealed that hearing loss in older drivers is associated with poorer driving performance in the presence of visual or auditory distractors (Hickson, Wood, Chaparro, Lacherez, & Marszalek, 2010).

The prevalence of hearing loss in Europe is roughly 30% for men and 20% for women at the age of 70 years, and 55% for men and 45% for women at the age of 80 years (Roth, Hanebuth, & Probst, 2001). This number is increasing due to both longer life and increasingly noisy environments. The prevalence of hearing loss is increasing for all ages, although the most common category of hearing loss is presbycusis, which is related to age (HRF, 2009). The older part of the population is increasing and thus the number of road users with hearing loss will also increase.

The use of innovative driver support systems in vehicles (e.g., collision warning, parking aid, and lane keeping systems) is increasing rapidly and the systems are becoming more and more advanced. Additionally, due to an increased availability of systems for infotainment (e.g. navigation systems and mobile phones), there is an increased risk of distracting the driver from the driving task. Existing driver support systems frequently utilize auditory information and may thus exclude drivers with hearing loss.

With the knowledge of the increase of drivers with hearing loss it is reasonable to consider this group when designing support systems for cars. Thus, the study conducted included drivers with hearing loss, and the effect of different warning modalities was evaluated using two driver groups (drivers with hearing loss and drivers with normal hearing).

For creating critical events required for the evaluation of an effective warning in near collision situations distracting the driver is essential. Also, when cognitively processing information, for example from a warning system, the working memory plays a central role. In Baddeley's multi-component model of the working memory (Baddeley, 2012; Repovs & Baddeley, 2006) the phonological loop is one component. Within this loop, a phonological store holds memory traces in phonological form, and an articulatory rehearsal process recodes information from other modalities (Baddeley, 1983; Repovs & Baddeley, 2006). Andersson (2002) demonstrated that specific aspects of the phonological system deteriorate as a function of poor auditory stimulation in individuals with hearing loss. Specifically, the phonological representations are deteriorating and this deterioration also affects the ability to rapidly perform phonological operations, i.e. to analyse and compare letters (Andersson, 2002). Thus, it is reasonable to assume that a visual distraction task, which includes performing phonological operations and is performed during driving, would affect drivers with hearing loss more than normal hearing drivers. This assumed effect of hearing loss was also evaluated in the study.

2 Approach and objectives

The reported work addresses the evaluation of a system intended to warn a driver (by means of headlight and/or horn signals) of a Principle Other Vehicle approaching in the opposite direction in the same lane.

2.1 Objectives

One objective of the current project was to develop simulation technology for the realistic sensation of headlight glare and horn sound of an encountering vehicle. These features had not previously been implemented in a simulator and the results obtained in the project are expected to be valuable for other partners working with simulator technology.

A second objective of the project was to study the effect of using an automated warning system (with the implemented light and sound features) in a critical situation in a driving simulator. The aim of this specific study was to find a suitable external warning signal, coming from an encountering vehicle, which makes the driver react fast and try to avoid a collision. It is important that the driver understands the message of the signal to be able to distinguish between “normal” horn and blink signals, which are not time critical, and this time critical warning. To be able to compare changes in driving behaviour associated with cognitive workload an additional cognitive task was added. This task also served as a distractor in order to put the drivers into critical events.

Since a feasible warning system should be accessible for all drivers an additional objective was to examine if there was a difference in driving behaviour of individuals with and without hearing loss. Therefore both drivers with and without hearing loss were included in the simulator study.

The project included:

1. A literature survey on the design of warning systems, especially collision warnings.
2. Field measurements of sound and light levels for the implementation of these features in a driving simulator.
3. A simulator study to evaluate:
 - a. Driver reactions to an external warning signal in critical situations.
 - b. Changes in driving behaviour due to cognitive workload.
 - c. Effect of hearing loss on driving behaviour.
4. Analysis of required sensor performance to be able to issue timely warnings.

3 Literature survey

The aim of the literature survey was to examine the state of the art of how to design a warning system, in general and specifically for collisions. There is limited research on how to design warning signals to effectively warn the driver and ultimately avoid a collision. In a simulator study, auditory collision warnings with increasing intensity were shown to be more effective than other types of auditory warnings at changing driving behaviour (Gray, 2011).

Similarly, other studies have shown that looming, i.e. when an approaching object becomes increasingly large on the perceiver's retina, plays an important role when drivers make decisions on when to act (Edworthy, 1995b; Terry HR & Perrone, 2008). In the current study, the headlights of the encountering vehicle had a looming effect as the vehicles approached each other.

According to research regarding warning signals in general, auditory warnings should, if possible inform about the nature of the events to the user (Edworthy, 1995a). Research has also shown that; the frequency at which people respond to alarms is matched with the false alarm rate, increasing the perceived urgency of an alarm decreases reaction time, and increasing the number of modalities in which a warning is presented decreases reaction time (Edworthy, 1995b).

According to Lewkowicz and Ghazanfar (2009) coherent representation of objects combining modalities enables us to have meaningful perceptual experiences. Multi-sensory integration is central to adaptive behaviour because it allows us to perceive a world of intelligible perceptual objects (Haustein, Sirén, Franke, Pokrieke et al., 2013).

Warnings need to command attention without causing startle and annoyance (Lyxell, Andersson, Borg, & Ohlsson, 2003). Research has shown that hearing is our primary warning sense, i.e. a sound which is loud enough will be heard, and we can do nothing about blocking out that sound. For vision, the obvious alternative, we need to be looking at the right place at the right time and we can more easily ignore visual stimulation. Several research studies (Andersson, 2002; Rimmer, 2006) have shown that when visual and auditory warnings are directly compared, compliance rates are much higher to auditory warnings.

There are four attributes of a stimulus: type, intensity, location, and duration. The localizability of auditory warnings is an important issue, which in general, will be improved by having several audible components in the warning sound, preferably with a fairly low fundamental frequency (Lyxell et al., 2003). According to Edworthy and Hellier (2000) it is of some concern that the most universal type of warning sound is the continuous tone, often a sinusoid which, as well as all the other disadvantages associated with such a tone, is very hard to localise. Such sounds are simply inappropriate acoustically as warning sounds (Lyxell et al., 2003).

4 Sound and light signals – measurements and implementation

In the conducted simulator study, an automated warning system was “placed” in the encountering vehicle and the warning signal presented in the simulator car was amplified as the distance between cars decreased. The warning type was sound and/or light and the signals were pulsed to avoid continuity leading to difficulty in localization. To avoid a decrease in frequency of response, there were no false alarms.

Measurements were performed to collect sound and light information for the implementation of warning signals in the simulator. This implementation was required because flashing lights and a honking horn are new features that have not previously been implemented in the simulator.

4.1 Light

Photos of an encountering car were taken (Canon 5D Mark II) and luminance levels were measured simultaneously on a cloudy day to meet light conditions of daylight in the simulator. This was done every tenth meter from 100 meters distance between the cars, using both full beam and half beam (see Figure 1). The luminance measures showed no difference between full beam and half beam due to the bright background light (53000 lux). Thus, the implementation of light had to rely on the photos.

At the implementation in the simulator, the size of the light beam was enlarged to make the full beam more distinct. Light blinks were accomplished by activating and deactivating the full beam of the encountering vehicle. At critical events a pulsed warning signal, of 0.3 seconds full beam presented 5 times with 0.04-second pauses between, was presented. At non-critical events (i.e. at greetings) two blinks, of 0.15 seconds with a 0.10-second pause between, were presented.

4.2 Sound

The horn signal from a Volvo V70 was recorded in field condition at a distance of 1.7 meters using a Svantek 955 Class 1 device with a signal to noise ratio of 55 dB(A). The recording was adjusted according to an airborne sound transmission in a SAAB 9-3 cabin (the car cabin in the simulator used).

At critical events, the sound warning was implemented as a pulsed sound signal analogous to the light warning. Horn signals of 0.3 seconds were presented 5 times with 0.05-second pauses between. The warning signals were increasing in intensity as the encountering vehicle came closer. At non-critical events (i.e. greetings) two 0.1-second signals separated by a pause of 0.15 seconds were presented. Figure 2 shows the appearance of the sound signals.

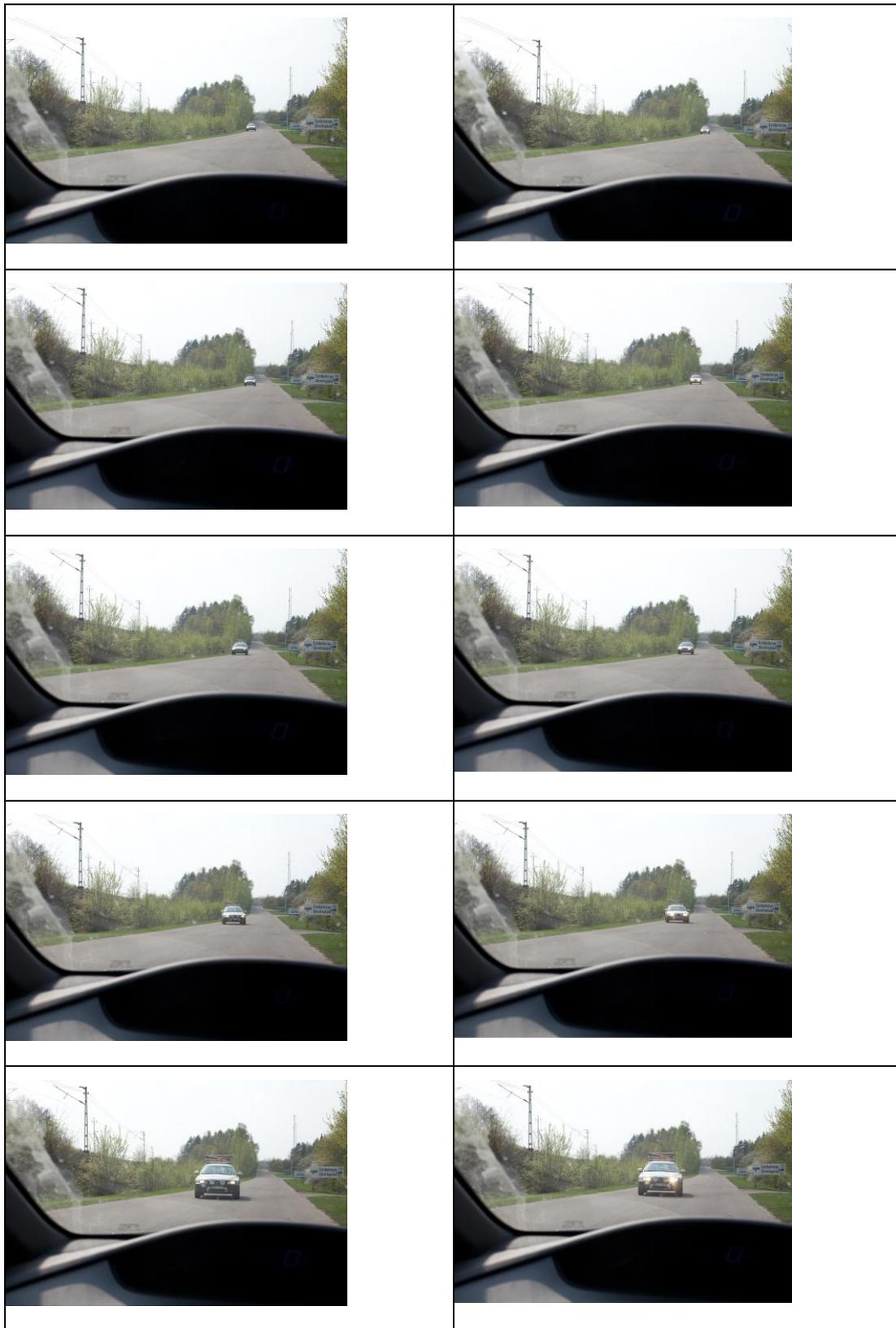


Figure 1: Photos of encountering car with half beam (left) and full beam (right), displayed for 100, 80, 60, 40 and 20 meters distance, respectively.

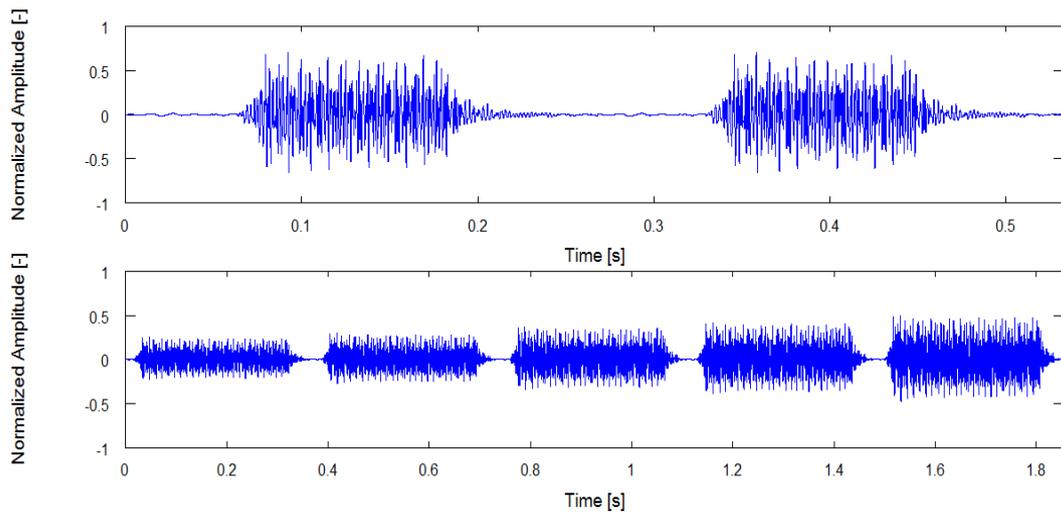


Figure 2: Sound signals presented at non-critical events (top) and at critical events (bottom).

5 Simulator study

A simulator study was conducted in the advanced moving base driving simulator III at VTI (Nordmark, Jansson, Palmkvist, & Sehammar, 2004).

The purpose of this part of the project was to answer the following questions:

1. How useful are horn and headlight as a warning in a critical situation?
2. Can additional safety be gained by connecting sensors to existing warning systems (headlight and horn)?
3. Does the use of combined horn and headlight as critical warnings affect reactions to non-critical warnings/greetings?
4. What do drivers think about these warnings?
5. Are there any effects due to hearing loss?



Figure 3: VTI driving simulator III.

5.1 Intended effects and hypotheses

The main intended effect of the warning system implemented and evaluated in the simulator is to prevent head-on collisions, by alerting the driver of the Subject Vehicle (SV) on the impending hazard, and thereby eliciting an earlier avoidance reaction. However, getting an effect may depend on factors such as warning type, hearing loss and the general usefulness of the system.

The key hypothesis is thus that the warning leads to a faster avoidance response compared to a condition without warning. Other relevant hypotheses concern the effect of warning type, hearing loss, system usefulness etc. Thus, while driving and performing a visual distraction task all participants (with and without hearing loss) experienced a critical event several times receiving warnings of different modalities.

This was to test the hypotheses:

- A warning leads to shorter reaction time than no warning.
- Different warning modalities have different effects on reaction time, such that an auditory or combined warning will be more effective than a visual.

- Warnings will increase cautious driving behaviour by:
 - Increased distance to encountering vehicles.
 - Decreased variation in lateral position.
 - Increased steering activity.
 - Increased time to line crossing.
 - Increased time to collision.
 - Shorter glances away from the road.
- Different warning modalities have different effects on ratings of criticality, such that a combined warning will be experienced as more critical compared to the others.
- The subjective judgment of the warnings will vary between the groups, such that the hearing loss group will experience the sound warnings less critical.
- Warnings (at critical events) will be experienced as more critical than greetings (at non-critical events).
- Warning type will affect the performance on the visual distraction task, such that a sound and a combined warning will interrupt the task and lead to worse task performance.
- The visual distraction task is more demanding for the group with hearing disorder, because they have a higher cognitive workload when using the phonological loop.
- Letters that are phonologically alike (for example BPDV) are harder to remember for both groups and especially hard for the hearing loss group.

5.2 Method

5.2.1 Participants

The number of participants in the simulator study was 48, 24 with normal hearing (NH) and 24 with a moderate hearing loss (HL) according to the WHO definition of a hearing threshold between 41 and 70 dB, which was measured by a PTA4 (Pure Tone Average of 500, 1000, 2000 and 4000 Hz) (Arlinger, 2007). The intention was to have 12 men and 12 women in each group, but after cancellations and rebooking the HL group included 13 men and 11 women. On average the women drove 3000-5000 km per year and the men drove 5000-10000 km per year, with no difference between groups. The mean age was 60 years (SD = 5.8) in the NH group and 64 years (SD = 7.7) in the HL group. This is the age span where it is most likely to find individuals with hearing loss who are still driving.

5.2.2 Design

The experimental design was mixed and the participants were subjected to repeated measures with four treatment levels. Warning type (4 levels) and visual distraction (2 levels) were within-subject variables, while hearing status (2 levels) and gender (2 levels) were between-subjects variables. The four experimental warning conditions were used to evaluate the efficiency of different warning signals. Differences between individuals with and without hearing loss were evaluated on a group level. See Table 1.

Table 1: Experimental design.

	Warning modalities			
	Visual	Auditory	Visual+Auditory	No warning
Normal Hearing	24	24	24	24
Hearing Loss	24	24	24	24

Non-critical events with sound and light signals from an encountering vehicle, the Principal Other Vehicle (POV), were presented between the critical events. These non-critical signals should represent a greeting or a wish to make the driver aware of the headlight. Compared to the warning signals at the critical events, these are shorter and meant to be experienced as friendly (see chapter 4 for descriptions of the sound and light signals). The purpose of the non-critical signals was to evaluate if drivers understand the difference between a critical and a non-critical signal and how their reactions are affected by the experience of the POV.

5.2.3 Driving scenario

The driving scenario was a simulated two-lane rural road with 70 km/h speed limit, daylight conditions and dry road surface. There was a moderate density of ambient traffic (2-3 vehicles per minute) travelling in the opposite direction to the participants. While driving the participants were distracted by means of a visual distraction task, i.e. by reading and repeating letters displayed on a screen placed at a relatively large downward angle (40-45 degrees). The vehicle driven by the participants was then “pushed” across the centre line towards an encountering vehicle by introducing a steering angle in the simulated vehicle without submitting that information to the motion platform. Using a terminology analogous to that in the ViP project SPASS (Fisher, in preparation), the SV (Subject Vehicle) is the vehicle with the participant and the POV (Principle Other Vehicle) is the encountering vehicle in the simulator, see Figure 4 below. The critical event with light warning implemented in the simulator is shown in Figure 5.

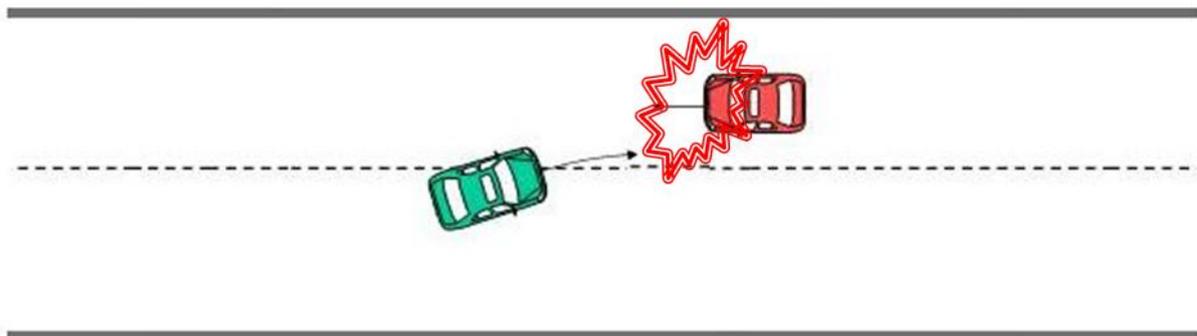


Figure 4: The critical event where the Subject Vehicle (SV; green) crosses the centre line and the encountering Principal Other Vehicle (POV; red) has the warning system implemented.



Figure 5: A critical event where a light warning, through a pulsed headlight, is presented by the POV.

Detailed description of the critical event

The critical event is illustrated in Figure 6 and the parameters are described in Table 2.

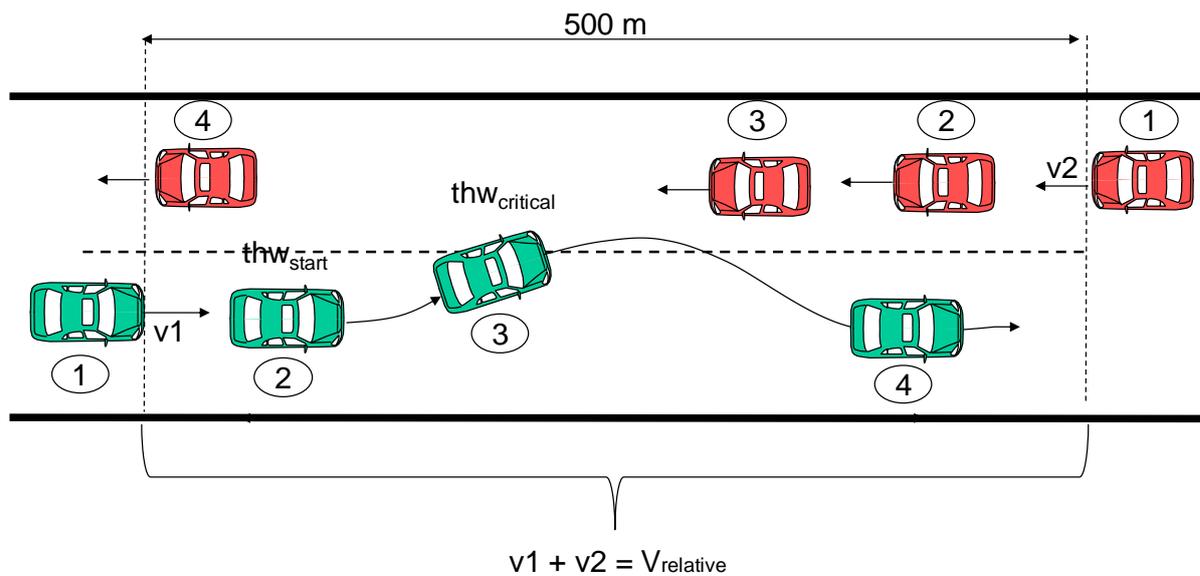


Figure 6: Critical event overview. SV in green and POV in red. Parameter list in Table 2.

Initially the SV travelled in the right lane at speed v_1 , paced by the driver. When initiating the critical event at t_1 , POV was instantiated at a distance of 500 m from the SV in the opposite lane. POV travelled towards SV with a speed that was coupled to the SV speed so their combined relative speed (v_{relative}) became 140 km/h. Until the vehicles reached t_3 , the POV speed was continuously adjusted to maintain v_{relative} . In a similar way, the lateral position of the POV was controlled in relation to SV's lateral position, such that their relative lateral distance (lateral clearance) remained exactly equal to the lane width. At t_2 , when the distance between SV and POV was Δ_{start} , the visual distraction task was initiated. At the time t_{yaw} the yaw deviation necessary to move the SV across the centre line was initiated, such that the heading angle, as well as the

relative lateral and longitudinal distances between SV and POV, were the same at t_3 for all repetitions of the critical event.

The warning was activated at time t_{warning} , which is the starting point for the reaction time measures. At t_3 the POV's speed and lateral position were decoupled from the SV, i.e. set to be constant from that time onwards.

Table 2: Parameters of the critical events.

Parameter	Value	Comments
ΔS_{start}	200 / 180 m	Shorter for non-critical events.
V_{relative}	140 km/h	
t_{yaw}	$t_2 + 0.9$ s	
t_{warning}	$t_{\text{yaw}} + 1.5$ s	
t_{distract}	2.8 s	Time period for yaw deviation.
ϕ_{crit}	3 degrees	Maximum yaw deviation.
t_3	$t_{\text{yaw}} + t_{\text{distract}}$	

5.2.4 Driving task

The participants drove the subject vehicle (SV) and their driving task was to drive as they usually do, given the instruction that they had an appointment to meet a friend in 30 minutes in a city located 35 km further down the road. The participants were not told about the critical events appearing along the road. During the drive the participants experienced the critical event five times in total. Three different warning signals were presented, at one critical event each. The warning signal presented at the first critical event was repeated at the fifth critical event. The warnings came from the encountering vehicle (POV) and were given through an automatic system triggering the horn and/or the headlights of the POV. There was also a baseline critical event when no warning was given. The warning signals used are listed in Table 3 and are described in more detail in chapter 4.

Table 3: Warning signals.

	Signal
1	Auditory (horn)
2	Visual (headlights)
3	Auditory + visual (horn + headlights)
4	No signal (baseline)

The warning signals were presented in varying and balanced order between the participants to avoid order effects. Presenting the same warning at the first and last (fifth) critical event was done in order to investigate the learning effect. Non-critical events (light “greeting” and sound “greeting”) occurred in the gaps between two critical events. After each event (critical as well as non-critical) the participants were prompted by a question on the screen to rate how critical the situation was. The timeline of the driving session is shown in Figure 7.

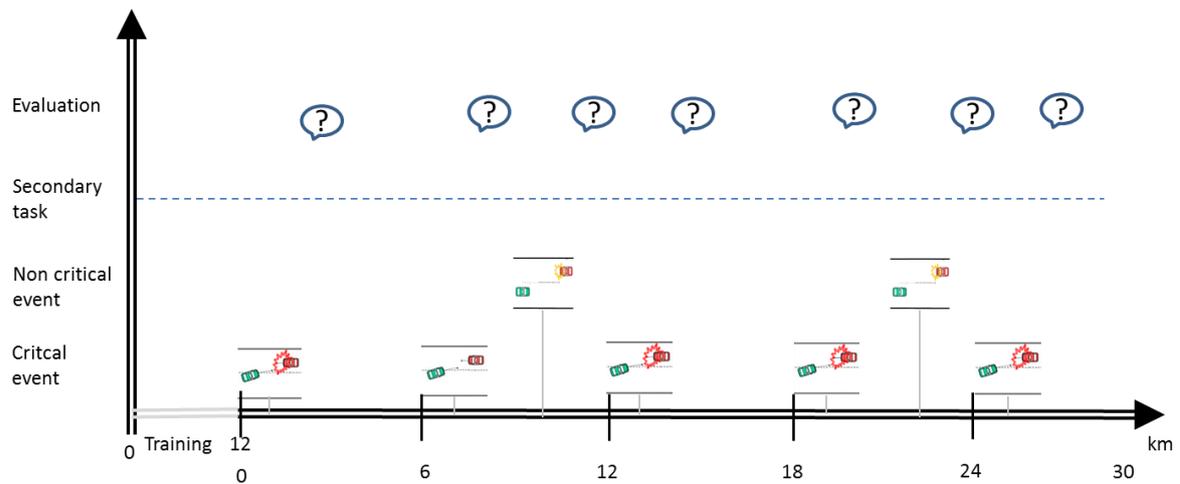


Figure 7: Timeline of the driving session. Critical events were presented with approximately 10-minute intervals. Non-critical events were presented in two of the gaps between critical events. The visual distraction task occurred once every 30 seconds. After each event the participants were asked to evaluate how critical the situation was.

5.2.5 Visual distraction task

To make the participants visually distracted from the forward roadway a visual distraction task was displayed sufficiently far down and to the right of their forward gaze direction, see Figure 8.



Figure 8: Position of the visual distraction task display.

The participants were prompted by a vibration in the seat to first look at the display and then read back a complete sequence of 4 letters appearing on the display. To create two levels of cognitive workload, the phonological similarity effect was used (Conrad & Hull, 1964). Thus, two sequences consisting of randomized letters that were either phonologically alike (e.g. BDPT) or not phonologically alike (e.g. RKNJ) were used. Each letter was displayed for 0.7 seconds, with no pause between letters, creating a total task duration of 2.8 s. This is an adaptation from Sternberg's scanning paradigm (Sternberg, 1966), where a set of 1 to 6 digits were presented sequentially to the subject

at the rate of one digit every 1.2 seconds, which was pragmatically tested. The total length of the distraction task used corresponds to the necessity of creating a critical situation while drivers take their eyes off the road. The instruction was to look at all four letters and then repeat the whole sequence. To motivate the participants to complete the task, they were told that the task was important and that their responses would be checked for correctness. The visual distraction task occurred on average once every 30 seconds of the drive. At the critical event, initiation of the visual distraction task was automatically triggered based on POV position, to ensure the distraction task overlapped the SV lane departure.

5.2.6 Measures and performance indicators

Driving behaviour was measured before and after each critical event to be able to compare the effect of the different warning signals. The measures included, for example, Lateral Position and Time to Line Crossing. Other measures focused on reaction times from the moment the warning was given to a response by the participant, for example reaction times for Steering Wheel Correction and Brake Response. The measures of driving behaviour (the performance indicators) were accompanied by subjective ratings during and after the test drive.

Subjective ratings were used to evaluate the realism of the simulated events, both critical and non-critical, and the usefulness of the warnings provided by the POV.

The subjective ratings of the usefulness of the warnings was an important measure. Therefore, the participants evaluated the warnings during the drive, to avoid that they failed to recall all warnings and situations after completion of the whole drive. Thus, after each event, both critical and non-critical, the question “How critical?” appeared on the screen, and the participants rated how critical they had experienced the situation on a scale from 1 (not critical at all) to 7 (extremely critical). The purpose of this question was also to evaluate the experience of non-critical warnings.

Gaze behaviour was measured with an eye tracking system from Smart Eye AB (Smart Eye Pro 5.6). The system uses three cameras, which in most cases give a higher performance (more data and higher accuracy) than a one-camera system (Ahlstrom & Dukic, 2010). The eye tracking measures included, for example, Percent Road Centre, which is the amount of gazes within the area around the road centre (Victor, Harbluk, & Engström, 2005), and Glances Away From the Road. These data could be of interest for an analysis of different driving behaviour and strategies for individuals with and without hearing loss.

The performance indicators and other measures that were used in the simulator study are listed Table 4. Performance indicators were measured during 16 seconds before the event (critical as well as non-critical) and during 16 seconds after the event, to compare the effect of different warnings and greetings on driving behaviour. The reason for not measuring them during the event was that many of these measures are affected by the manoeuvre creating the critical event.

Table 4: Measures and performance indicators.

Measures/performance indicator	Unit	Measured
Steering Wheel Reaction Time	s	From warning to steering wheel correction
Brake Response Reaction Time	s	From warning to brake pedal activation
Look Up Reaction Time	s	From warning to looking up
Mean Lateral Position (Mean LP)	m	Before and after critical event (16 s)
SD Lateral Position (SDLP)	m	Before and after critical event (16 s)
Min Time to Line Crossing (Min TLC)	s	Before and after critical event (16 s)
Min Time to Collision (Min TTC)	s	Before and after critical event (16 s)
Steering Wheel Reversal Rate (SWRR)	n	Before and after critical event (16 s)
Lateral Clearance	m	0-5 s before the SV pass the POV
Eyes Off Road Time	s	Before and after critical event (16 s)
Eyes Off Goad Glances	n	Before and after critical event (16 s)
Eyes Off Road Longest Glance	s	Before and after critical event (16 s)
Subjective rating of criticality		Rating of criticality on a 1-7 scale

5.2.7 Procedure

Before the test drive the participants were given written and spoken instructions about the experimental session, and asked to sign an informed consent. The visual distraction task (see chapter 5.2.5) was practiced and the importance of performing it was stressed. There was a short (5 minutes) training session in the simulator in order to get the participants familiar with the driving situation and the visual distraction task. During the training session there were two non-critical events when an encountering POV was “greeting” the participant in the SV, once with the horn and once with the headlight. The test leader introduced these non-critical signals as greetings. The subjective rating of how critical the situation felt (chapter 5.2.6) was also practiced. During the test drive there was no communication between the participant and the test leader. After the test drive was completed the participants filled in a questionnaire regarding, for example, situation realism, experiences and usefulness of the warnings (see Appendix: Questionnaire after driving).

5.2.8 Analysis

Correlated data from the repeated measures design for performance indicators and measures were modelled using General Estimating Equations (GEEs) in SPSS. Predictor variables were warning type (within subject), hearing status and gender (between subjects). Both main effects and interaction effects were examined for all variables. Working correlation matrix was set to exchangeable since symmetry was assumed. Outputs are Wald statistics (χ^2), showing the significance, and a regression coefficient (B) presenting the relation between the groups (hearing status and gender).

The same method was used for analysing the performance on the visual distraction task with the predictors; warning type and difficulty level (within subject), hearing status and gender (between groups), and order of warning set as a covariate. Measures of the visual distraction task performance were Amount Correct (number of correct letters in correct order), Amount Skipped (number of skipped letters), and Amount Correct Ignoring Order (number of correct letters regardless of order), which will all be numbers between 0 and 4. See Table 5 for examples of these measures.

Table 5: Visual distraction task performance measures; Amount Correct, Amount Skipped and Amount Correct Ignoring Order.

Letter sequence	Response (example)	Amount Correct	Amount Skipped	Amount Correct Ignoring Order
BDPT	BDTP	2	0	4
RQGH	RQ_H	3	1	3

Throughout both described analyses above, the first critical event was separated from the following, to control for expected learning effects and realism. The participants were expected to be more surprised by the first critical event because it was not what they had expected. This critical event was also more realistic since such situations are not very likely to happen often.

The questionnaire (see Appendix: Questionnaire after driving) was analysed using SPSS with an ordinal logistic regression, since this method is appropriate for non-equidistant alternatives. All variables were entered simultaneously since neither the effect of gender nor the effect of hearing status group was expected to be larger. Main effects of gender and hearing status were examined as well as interaction effects. The outcome is Odds Ratio (*OR*) describing a measure of the influence of the factor on the dependent variable. *OR* = 1 means no influence, *OR* > 1 means an increasing influence and *OR* < 1 means a decreasing influence.

The statistical analyses were made with a significance level of 5% ($p < 0.05$).

5.3 Results

Although the instruction was to consider the visual distraction task as important, several participants were not comfortable with looking away from the roadway during the meeting event. Thus, 12% of the visual distraction tasks during meeting events were skipped and there was no effect of order of warning type. Further analysis was carried out only on events (critical as well as non-critical) where the visual distraction task was actually performed. Only 88% performed the first task and again there was no effect of order of warning type, showing the unwillingness to look away although this was the first critical event. The first critical event was treated separately throughout the analysis, due to possible learning effects, and results related to this event are presented separately below.

5.3.1 TTC and reaction times

In the current simulator study the majority of all critical events did not lead to an incident or near crash situation, defined by $TTC < 1$ s with a Lateral Clearance < 0.5 m,

see Figure 9. A warning was triggered at $TTC = 2.8$ s, equivalent to a distance of about 110 m between the vehicles. At this stage, the SV was still positioned in its original lane and had a lateral velocity less than 0.5 m/s.

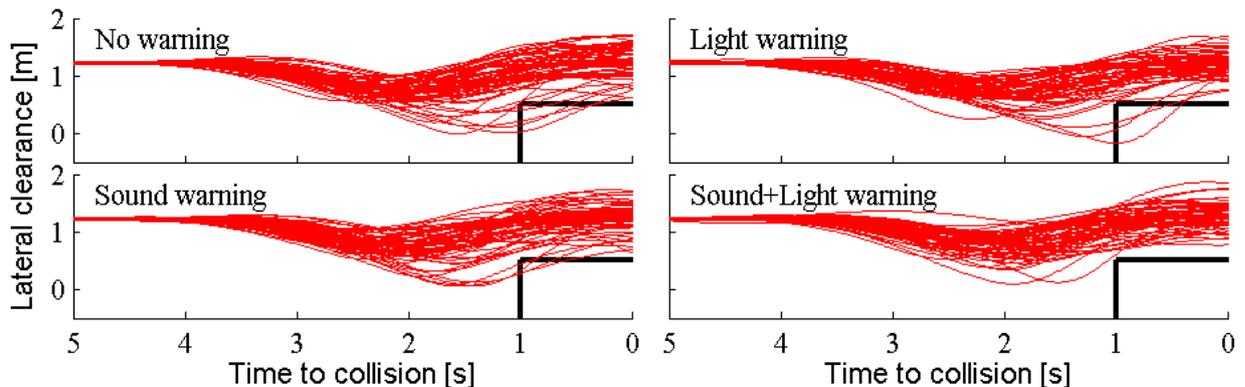


Figure 9: Lateral Clearance (m) and TTC (s) (if no evasive action was taken) for the four warning types, respectively. Trajectories that pass through the rectangular area (thick solid line; $TTC < 1$ s and Lateral Clearance < 0.5 m) are defined as incidents. Detected numbers of incidents were: No warning = 5, Light warning = 3, Sound warning = 4, and Sound + Light warning = 0.

First critical event

Reaction times from warning to Steering Wheel Correction, Brake Response and Look Up were compared for the different warning types. Including only the first critical event revealed a significant effect of warning type on Steering Wheel Correction ($n = 17$), such that the light + sound warning led to a decrease in reaction time compared to no warning ($\chi^2 = 10.31$, $p < 0.05$, $B = -0.24$) and compared to the light warning ($\chi^2 = 10.31$, $p < 0.05$, $B = -0.20$). There was also a significant effect of warning type on Time to Look Up ($n = 7$), such that the sound warning led to a decrease in Look Up Reaction Time compared to no warning ($\chi^2 = 18.00$, $p < 0.05$, $B = -0.30$). There was no effect of warning type on Brake Response Reaction Time, and no effect of hearing loss or gender on any reaction times.

Following critical events (events 2-5)

Excluding the first critical event, there was a significant effect of warning type on time from warning to Steering Wheel Correction ($n = 27$), such that all warnings led to approximately 2 s shorter reaction times compared to no warning; light warning ($\chi^2 = 13.12$, $p < 0.05$, $B = -0.21$), sound warning ($\chi^2 = 13.12$, $p < 0.05$, $B = -0.17$) and light + sound warning ($\chi^2 = 13.12$, $p < 0.05$, $B = -0.23$). There was also a significant effect of warning type on Time to Look Up ($n = 19$), such that the light + sound warning led to 0.2 s decrease in reaction time compared to no warning ($\chi^2 = 13.64$, $p < 0.05$, $B = -0.21$). There was no effect of warning type on Brake Reaction Time, and no effect of hearing loss, gender or order of warning on any reaction times.

5.3.2 Driving behaviour

The effects of warning type on driving behaviour were identified by comparing the performance indicators and measures from time windows of 16 seconds before and after

the critical event, respectively. The reason for this before and after comparison was that all these measures are affected by the manipulation creating the critical event, and thus at that particular moment not controlled by the participant. The results presented are thus the effects of the critical event, and when an effect of warning type is significant, a difference in that particular measure was affected by warning type.

First critical event

A significant effect of warning type appeared in SDLP, such that the light + sound warning reduced the Variation in Lateral Position with 0.05 m more from before to after critical event compared to no warning ($\chi^2 = 7.82, p < 0.05, B = 0.05$). The reductions were 0.06 m and 0.01 m, respectively.

The eye tracking data revealed that the Longest Glance Away from Road was significantly affected by warning type. For the light + sound warning the Longest Glance decreased significantly compared to no warning for which the Longest Glance increased ($\chi^2 = 6.91, p < 0.05, B = 0.38$). The changes from before to after the critical event were 0.26 s decrease and 0.13 s increase, respectively.

At the first critical event there was no effect of warning type on changes in Lateral Position, TLC, SWRR, TTC, Eyes Off Road Time, or Number of Glances Away from Road. There was no effect of hearing status or gender on the change in any performance indicators or measures at the first critical event.

Following critical events (events 2-5)

The data from the following critical events revealed a significant effect of warning type on SWRR, such that the light + sound warning led to a larger increase (one more reversal per minute) compared to no warning ($\chi^2 = 7.23, p < 0.05, B = 0.90$). The changes were 1.46 reversals per minute and 0.47 reversals per minute, respectively.

On the other measures; Lateral Position, SDLP, TLC, TTC, Eyes Off Road Time, Number of Glances Away from Road, and Longest Glance Away from Road no effects of warning type were found. There was no effect of hearing loss or order of warning on the change in any performance indicators at the following critical events.

5.3.3 Criticality rating

First critical event

At the first critical event there was a significant effect of warning type on criticality rating, with higher ratings for the light + sound warning compared to all other modalities; no warning ($\chi^2 = 10.09, p < 0.05, B = 1.24$), light warning ($\chi^2 = 7.23, p < 0.05, B = 1.40$) and sound warning ($\chi^2 = 7.23, p < 0.05, B = 1.09$).

Also a significant effect of gender emerged, such that women rated the first critical event as more critical than men did ($\chi^2 = 3.95, p < 0.05, B = 1.00$). No effect of hearing loss and no interaction effect of warning type and gender was found.

Events following after the first critical

A significant effect emerged in the subjective ratings of criticality, such that criticality was rated significantly lower for non-critical events, i.e. both for sound and light

“greetings”, compared to warnings at critical events ($\chi^2 = 355.25, p < 0.05, B = -1.35/-1.99$). There was no significant effect of warning type in the ratings of critical events, see Figure 10.

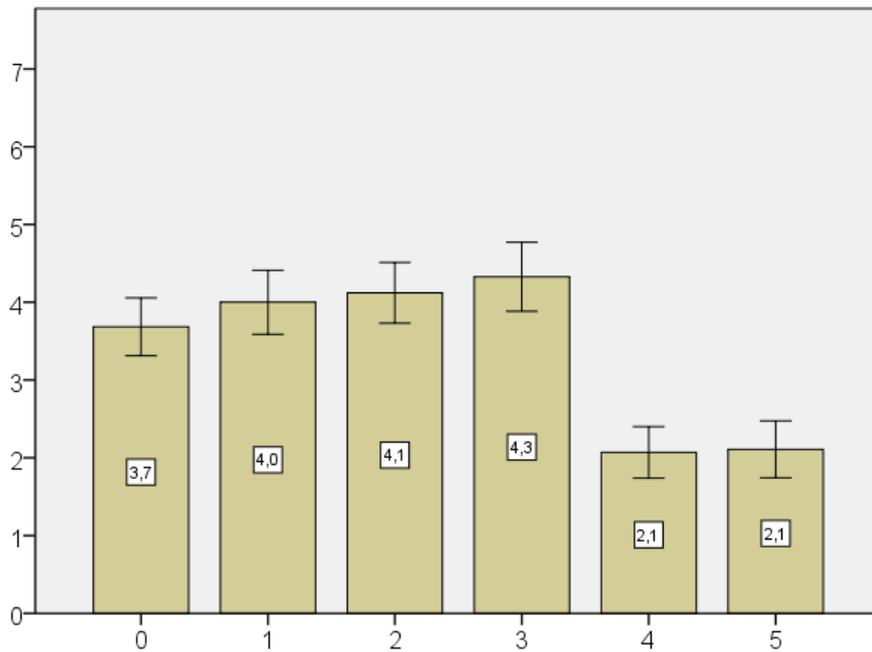


Figure 10: Mean ratings of criticality of the events following after the first critical, on a scale from 1 (not critical at all) to 7 (extremely critical). 0 = No warning, 1 = Light warning, 2 = Sound warning, 3 = Sound + light warning, 4 = Light greeting, 5 = Sound greeting. Error bars represent 95% CI.

There was a trend of order of critical event on criticality rating, with criticality rated lower with increasing order, Figure 11. No effect of gender or hearing status was found.

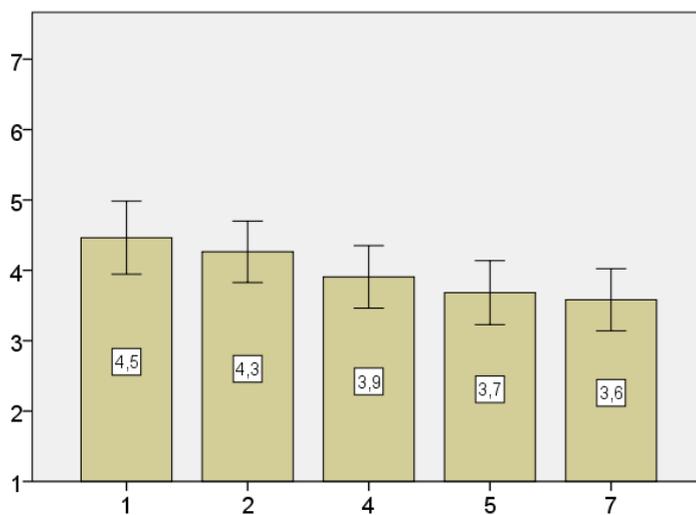


Figure 11: Trend of order of event on experienced criticality. Only critical events, i.e. events 1, 2, 4, 5 and 7 in Figure 7. Error bars represent 95% CI.

5.3.4 Visual distraction task

Amount Correct

For the Amount Correct, there was a significant main effect of difficulty level, such that the higher difficulty level, not phonologically alike letters, led to on average 0.2 fewer correctly read back letters compared to the lower difficulty level, phonologically alike letters ($\chi^2 = 7.94, p < 0.05, B = -0.19$).

A significant effect of warning type emerged, such that all warnings containing sound signals led to fewer correct letters compared to no warning; sound greeting on average 0.6 fewer ($\chi^2 = 17.40, p < 0.05, B = -0.56$), sound warning on average 0.6 fewer ($\chi^2 = 17.40, p < 0.05, B = -0.58$), and light + sound warning on average 0.8 fewer ($\chi^2 = 17.40, p < 0.05, B = -0.75$).

There was also a significant main effect of gender, such that men reported on average 0.8 more correct letters compared to women ($\chi^2 = 4.18, p < 0.05, B = 0.76$).

No main effect of hearing loss, and no interaction effects of hearing loss and gender, hearing loss and warning type, hearing loss and difficulty level, or gender and difficulty level appeared on the Amount Correct.

Amount Skipped

Looking at the Amount Skipped letters revealed, again, a significant main effect of difficulty level with on average one more skipped letter at the higher difficulty level ($\chi^2 = 5.37, p < 0.05, B = 1.02$).

A significant main effect of warning type emerged, such that the three critical warnings all led to more skipped letters compared to no warning; light warning on average 0.6 more ($\chi^2 = 29.72, p < 0.05, B = 0.56$), sound warning on average 0.6 more ($\chi^2 = 29.72, p < 0.05, B = 0.63$), and light + sound warning on average 0.9 more ($\chi^2 = 29.72, p < 0.05, B = 0.88$).

There was also a significant main effect of hearing status, such that participants with hearing loss skipped on average 0.7 more letters than normal hearing participants ($\chi^2 = 5.35, p < 0.05, B = 0.66$).

A significant interaction effect of gender and difficulty level emerged, such that women skipped approximately one more letter in the higher difficulty level compared to in the lower difficulty level, whereas for men there was no difference ($\chi^2 = 9.22, p < 0.05, B = 0.87$).

No main effect of gender, and no interaction effects of hearing loss and gender, hearing loss and warning type, or hearing loss and difficulty level appeared on the Amount Skipped.

Amount Correct Ignoring Order

Also for Amount Correct Ignoring Order there was a significant main effect of difficulty level, such that the higher level led to on average one fewer correct letter ($\chi^2 = 3.98, p < 0.05, B = -1.03$).

A significant main effect of warning type emerged, with sound warning ($\chi^2 = 31.02, p < 0.05, B = -0.67$) and light + sound warning ($\chi^2 = 31.02, p < 0.05, B = -0.77$) leading to less correct letters (regardless of order) compared to no warning, while sound greeting led to more correct letters compared to no warning ($\chi^2 = 31.02, p < 0.05, B = 0.50$).

Again a significant interaction effect of gender and difficulty level emerged, such that women reported on average one correct letter less in the higher difficulty level compared to the lower difficulty level, whereas for men there was no difference ($\chi^2 = 9.04, p < 0.05, B = -1.01$).

There was no significant main effect of hearing status or gender, and no interaction effects of hearing status and difficulty, hearing status and warning type, gender and warning type, or hearing status and gender.

5.3.5 Questionnaire after driving

Almost all participants, 94% ($n = 45$), reported that they had experienced warnings during the drive. Among those, 98% had experienced sound warnings, 87% light warnings and 71% combined warnings (sound + light). Only one third, 31%, had experienced greetings. Among those, 21% had noticed light greetings, 31% sound greetings and 8% combined greetings (sound + light, which did not exist). No significant effects of gender or hearing loss emerged, neither for experiencing warnings nor for noticing greetings.

Driving performance was rated slightly above average ($M = 3.3; SD = 0.6$; on a scale from 1 = very poor to 5 = very good). There were no main effects, neither of gender nor of hearing loss, and no interaction effect of gender and hearing loss on the rated driving performance.

The general realism in the simulator was rated high ($M = 3.7; SD = 0.7$; on a scale from 1 = not at all realistic to 5 = very realistic). Men experienced the simulator as significantly more realistic ($OR = 17$). A significant effect of hearing loss emerged, such that participants with normal hearing experienced the simulator as more realistic ($OR = 6.30$). There was no significant interaction effect of hearing loss and gender.

The usefulness of warning was rated slightly above average ($M = 3.2; SD = 1.2$; on a scale from 1 = not at all useful to 5 = very useful). No effect of hearing loss or gender emerged.

Of 15 participants (31%) reporting that they had perceived greetings 9 belonged to the NH group and 6 to the HL group. Realism of greetings was rated higher, although not significantly, by the HL group ($M = 4.0; SD = 0.9$) than by the NH group ($M = 3.2; SD = 1.1$).

Regarding simulator sickness, significant main effects emerged for hearing status and gender. Participants with hearing loss experienced more simulator sickness ($OR = 0.07$), and women experienced more simulator sickness ($OR = 0.09$). There was also an interaction effect, such that female participants with hearing loss experienced most simulator sickness. See Table 6 for mean values and standard deviations of experienced simulator sickness.

Table 6: Experienced simulator sickness (ratings on a scale from 1 = not at all to 5 = very much). NH = normal hearing, HL = hearing loss.

Group	Gender	n	Mean Value	
			M	SD
NH	Male	12	1.75	1.05
	Female	12	1.25	0.45
HL	Male	13	1.38	0.87
	Female	11	2.91	1.57

No significant effects of hearing loss or gender on experienced realism of simulator sound emerged (M = 3.3; SD = 1.0; on a scale from 1 = not realistic at all to 5 = very realistic). For the realism of simulator vibrations a significant main effect of gender emerged, such that men experience the vibrations as more realistic (OR = 5.68).

The participants were positive towards the way of announcing the visual distraction task through seat vibration (M = 4.6; SD = 0.7; on a scale from 1 = very poor to 5 = very good). No effects of hearing loss or gender emerged.

The difficulty of the visual distraction task was rated slightly above average (M = 3.3; SD = 0.8; on a scale from 1 = not at all difficult to 5 = very difficult). A significant main effect of gender emerged, such that men experienced the visual distraction task as significantly less difficult (OR = 0.20).

The participants were generally positive to the warning system, and the warning modalities. In total, 75% were positive to the visual warning, 65% to the auditory warning, and 85% to the combined warning (sound + light). Figure 12 shows the participants' interest in warning system modalities divided by hearing status and gender.

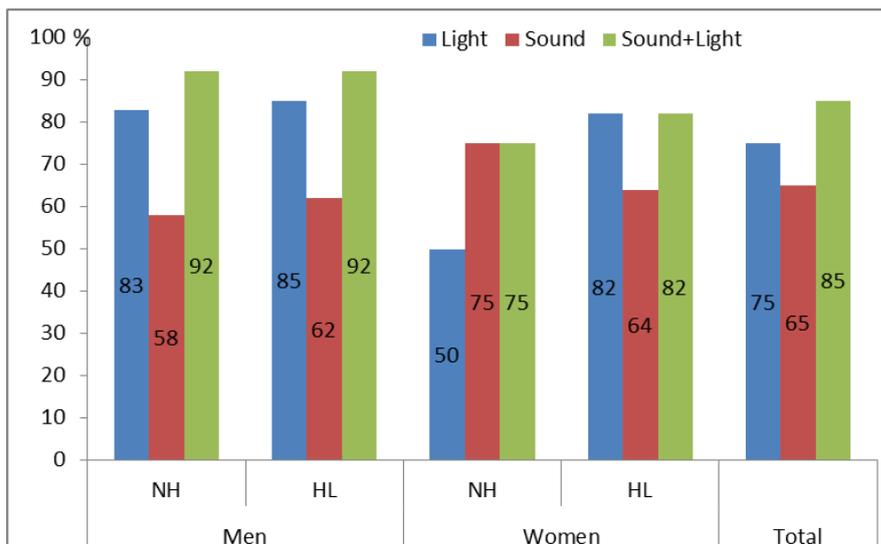


Figure 12: Participant shares (%) interested in automated warnings from encountering vehicle; divided by warning type, hearing status (NL = normal hearing, HL = hearing loss) and gender.

5.4 Discussion

5.4.1 Discussion of hypotheses and results

The main intended effect of the warning system implemented and tested in the reported project is to prevent head-on collisions by alerting the driver in the Subject Vehicle of an impending hazard. The key hypothesis is thus that the warning leads to a faster avoidance response compared to a condition without warning. Other relevant hypotheses concern effects of warning type, hearing loss, usefulness of system etc.

A warning was expected to lead to shorter reaction time compared to no warning. This expectation was supported by the reaction time measures Time to Steering Wheel Correction and Time to Look Up, both at the first critical event and the following events. The reaction time results showed a consistent pattern; warnings led to shorter reaction times than no warning, and light + sound warning led to shorter reaction times than the other warning modalities (all reaction time effects about 0.2-0.3 seconds). Thus, the assumption of an auditory or combined warning being more effective was supported as well, which is in line with previous research (Andersson & Lyxell, 1999; Hausteijn et al., 2013; Lewkowicz & Ghazanfar, 2009; Rimmer, 2006).

The warnings were expected to increase cautious driving behaviour. This expectation was supported by the light + sound warning, which at the first critical event led to a decrease in Lateral Position Variation and a decrease in Longest Glance Away from Road compared to no warning. There was also an increase in Steering Activity at the critical events following after the first. According to previous research this indicates an increased level of attention (Macdonald & Hoffman, 1980; Nakayama, Futami, Nakamura, & Boer, 1999) and is again supporting the expected increase in cautious behaviour. However, on the other behaviour measures expected increase or decrease did not emerge in the results.

Different warning modalities were expected to have different effects on ratings of criticality, especially the combined warning was expected to be experienced as more critical than the others. This expectation was supported by the results at the first critical event, where the light + sound warning led to higher criticality ratings than the other warning types. However at the following critical events no significant difference appeared. The expected difference in criticality ratings associated with hearing loss did not emerge but a significant effect of gender was found, women rated the first critical event as more critical than men did. This effect was not expected, but might be explained by the lower annual mileage associated with the female drivers.

As expected, the subjective ratings of criticality were significantly lower for non-critical events as compared to critical events. This result points to a distinction between the warning and greeting signals and that drivers are capable to distinguish between them, indicating that the suggested new use of horn and headlight for warning purposes would not affect traditional reactions to non-critical warnings or greetings.

Warning type was expected to affect performance on the visual distraction task, such that sound and combined warnings would interrupt the task and lead to fewer correct letters. This hypothesis was confirmed by results showing that all signals containing sound led to fewer correct letters compared to when no warning was given. In line with this is also the fact that the three critical warnings all led to a higher Amount Skipped letters compared to no warning.

The worse performance on the visual distraction task expected in the hearing loss group was not confirmed by a lower Amount Correct letters, but by a higher Amount Skipped letters. The expected effect of task difficulty was confirmed in both groups NH and HL by results showing fewer correct letters and more skipped letters for the higher difficulty level.

There was a significant main effect of gender on visual distraction task performance, men reported more correct letters compared to women, and also a significant interaction effect of gender and difficulty level showing that women skip more letters in the higher difficulty level compared to the lower difficulty level, whereas for men there was no difference. This result was further confirmed by men rating the visual distraction task as less complicated, and might also have to do with women reporting more experienced simulator sickness.

5.4.2 General discussion

Many drivers (12%) skipped the visual distraction task in a situation with an encountering vehicle. Also, there was no effect of order of events, which means that even though the drivers were not prepared for any critical events they were unwilling to take their eyes off the road. This is probably related to the high ratings of reality in the simulator making the drivers experience a risk with performing the visual distraction task.

The number of reactions (Steering Wheel Reaction, Brake Reaction, Time to Look Up) at the critical events were low, indicating that the critical event could possibly have been made more critical. However, this could also have led to a situation when even more drivers avoided the visual distraction task.

The first critical event was regarded as the most interesting and also most relevant, since the drivers were totally unprepared for the situation. This event was also the one where most significant results appeared. Although not overwhelmingly many significant results, the significant results were consistent. The combined sound and light warning increased cautious behaviour significantly, and also led to the highest perceived criticality of the situations. This warning was also associated with the worst performance on the visual distraction task, meaning that the drivers' attention was effectively drawn from the visual distraction task. Drivers were generally positive towards the evaluated warning system, and most positive towards the warning with combined light and sound.

Detecting that the vehicles are on collision course before the Subject Vehicle (SV) enters the Principle Other Vehicle's (POV's) lane (Lateral Clearance about 0.6 m) is highly challenging for the sensor system, which may, for example, be camera and radar based. Furthermore, providing warnings to a vehicle (i.e. the SV) that still has not entered the POV's lane, and possibly never will do so, may be disturbing for the driver of the SV. Realistic and suitable sensor systems may be able to detect if the SV enters the POV's lane at distances of up to 80 – 120 m, in this study equivalent to 2 – 3 s TTC. Camera based sensor systems may be able to do so by detecting the lane markings and detecting if any part of the SV is placed inside the POV's lane. Such actions by the driver of the SV may also motivate a warning, hence reducing the risk of triggering disturbing warnings during normal traffic conditions.

Hearing loss had a negative effect on the experienced realism of the simulator. This effect could possibly be explained by the fact that individuals with hearing loss experienced more motion sickness.

5.5 Conclusions

The results reveal that additional safety can be gained by connecting collision sensors to existing warning systems. Light and sound warnings using headlight and horn signals, and issued in a critical situation, are useful for warning an encountering driver, and may have an effect that increases safety. Both horn and headlight warnings have been shown effective in calling drivers' attention in critical situations, with a combination of the two modalities leading to higher perceived criticality and faster responses than horn or headlight warnings alone. Drivers were positive towards having automated warnings from encountering vehicles in critical situations and most positive towards the warning combining light and sound.

This type of countermeasure is the only feasible solution to avoid an accident in certain situations, e.g. when the own vehicle is standing still and is about to be struck by an encountering vehicle. Correct autonomous activation of the warning signals is dependent on the capabilities of the vehicles proximity sensors and data processing. The possible effect may be degraded at higher relative velocities because of the increased distance at which a warning needs to be issued.

Drivers were able to distinguish between warnings (at critical events) and greetings (at non-critical events) suggesting that the additional use of horn and headlight, for critical warnings, would not affect reactions to non-critical warnings or greetings.

Hearing loss was associated with worse performance on the visual distraction task and less perceived realism of the driving simulator. But it was not associated with effects on any driving behaviour measures or of warning modalities. This suggests that the evaluated system should work also for drivers with moderate hearing loss.

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Appendix: Questionnaire after driving

1. How would you assess your own driving performance?

1 Very poor 2 3 4 5 Very good

2. How would you describe the simulator driving?

1 Not realistic at 2 3 4 5 Very realistic
all

3. How would you describe the simulator sound?

1 Not realistic at 2 3 4 5 Very realistic
all

4. How would you describe the simulator vibrations? (not those from the seat)

1 Not realistic at 2 3 4 5 Very realistic
all

5. The letter task was announced by a vibration in the seat, how would you describe this manner of calling for your attention?

1 Very poor 2 3 4 5 Very good

6. How would you describe the letter task?

1 Not difficult at 2 3 4 5 Very difficult
all

7. Did you experience any motion sickness during the drive?

1 Not at all 2 3 4 5 Very much

8. Did you experience any warnings from encountering vehicles during the drive?

Yes No If no, proceed to question number 12.

9. What types of warnings did you experience?

	Yes	No	I don't know
Sound	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Light	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sound + Light	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

10. Did you think of the warning as initiated by the other vehicle (automatic) or by the driver (manual)?

Automatic Manual

11. How would you describe the warnings?

1 Not useful at all	2	3	4	5 Very useful
<input type="checkbox"/>				

12. If you should enter the wrong side of the road, how would you prefer to receive a warning from the encountering vehicle?

	Yes	No	I don't know
Sound	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Light	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sound + Light	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

13. Did you experience any greetings from encountering vehicles during the drive?

Yes No If no, you are done with this questionnaire.

14. What types of other signals did you experience?

	Yes	No	I don't know
Sound	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Light	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sound + Light	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

15. How did you experience the greeting?

1 Not realistic at all	2	3	4	5 Very realistic
<input type="checkbox"/>				

Any further comments?

Thank you for your participation!



ViP

Virtual Prototyping and Assessment by Simulation

ViP is a joint initiative for development and application of driving simulator methodology with a focus on the interaction between humans and technology (driver and vehicle and/or traffic environment). ViP aims at unifying the extended but distributed Swedish competence in the field of transport related real-time simulation by building and using a common simulator platform for extended co-operation, competence development and knowledge transfer. Thereby strengthen Swedish competitiveness and support prospective and efficient (costs, lead times) innovation and product development by enabling to explore and assess future vehicle and infrastructure solutions already today.



Virtual Prototyping and
Assessment by Simulation

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